WE
ARE
THERE

2018/**2019**/2020
Corporate Report

DASSAULT SYSTEMES | The **3D**EXPERIENCE® Company

Because experience is human, experience is about enjoying art, science and technology to imagine and create a better world for all. And this world must be sustainable.

Dassault Systèmes builds on imagination, knowledge and know-how to make a lasting contribution for the benefit of all. To achieve this strategy, we will focus on developing our leadership in Life Sciences & Healthcare alongside two other strategic sectors of the economy: Manufacturing Industries and Infrastructure & Cities.

We stand at the threshold of a new world, where industry will need to create new landscapes in terms of what we offer, decide between use case scenarios and transform the art of production. We'll only be able to tackle these challenges by balancing all the dimensions of what it means to be human at once: an industrial being, a social being and a living being. The ability to imagine, the passion to learn, the willingness to dare, and the art of how we make it happen will be crucial.

In this brave new paradigm, virtual will be the vital link between the imagination, the useful and the sustainable.

WE ARE WHERE
CITIES BECOME HUMAN,
HEALTH BECOMES PERSONALIZED,
HORIZONS EXPAND,
SUSTAINABILITY TAKES ROOT,
EMOTIONS ARE CREATED.

WE WILL BE THERE TOMORROW.

" Delivering on our financial
objectives, setting the stage
for multi-decade expansion. **"**

CONVERSATION

BERNARD CHARLÈS
Vice Chairman of the Board of Directors
and Chief Executive Officer

CHARLES EDELSTENNE
Chairman of the Board of Directors

2019 has been a year of intense activities for Dassault Systèmes, during which we achieved all our objectives thanks to the adoption of the **3D**EXPERIENCE by our customers, and over achieved those announced in 2014 as part of our five-year strategic plan. We also, and above all, have further deepened our strategy and expanded our addressable market, completed a major acquisition in the Healthcare sector with Medidata, reinforced and renewed our executive committee, setting a path for growth for the coming decades.

2019 strong performance: satisfactory revenue and EPS growth
Non-IFRS 2019 total revenue increased 13% inconstant currencies, reaching €4,056 million. This growth was driven by an increase of 15% of non-IFRS recurring revenue (representing 72% of our total software revenue), non-IFRS license revenue growth of 6%, and acquisitions.

The **3D**EXPERIENCE recorded a good performance on large clients' deployment, with a 22% increase in non-IFRS software revenue and represented 29% of non-IFRS software revenue. As for our Diversification Industries, they represented 34% of non-IFRS software revenue.

At 32%, non-IFRS operating margin improved 10 basis points, driven by strong organic improvement and favorable currency effects, more than offsetting the dilutive effect of 120 basis points of acquisitions. Finally, non-IFRS EPS growth was 17%, reaching €3.65, €0.06 resulting from the acquisition of Medidata.

2014-2019 plan achieved
Benefiting from our sustainable growth drivers, the **3D**EXPERIENCE adoption dynamic, diversification, and our strong execution capacities, we delivered our results according to our commitments. Reaching in 2019 a €3.65 EPS, we over delivered on our objective established in 2014 to double our EPS

to reach €3.50. The increase was principally driven over the five-year period by top-line growth. We expanded into more economic sectors and the share of our diversification industries representing over one-third of our revenue, bolstered our growth.

Wide customer adoption and numerous deployments of the 3DEXPERIENCE
Our strategy is primarily dedicated to serve our clients and help them navigate the major transformations and challenges their industries are facing. Among many others, two major contracts highlight 2019. Toyota has decided to adopt **3D**EXPERIENCE POWER'BY in a global deployment, including suppliers, for more than 40,000 users, to prepare the advent of electrified, smart and connected cars. In Aerospace, Lockheed Martin will deploy **3D**EXPERIENCE platform to become the standard engineering and manufacturing software for all new developments.

Successful 2012 vision, need to go beyond our current strategy
In 2012, we introduced our purpose, unveiled the **3D**EXPERIENCE concept and the **3D**EXPERIENCE platform. At the time, we shared our belief, while providing to business and people **3D**EXPERIENCE universes to imagine sustainable innovations capable of harmonizing product, nature and life, that the 21st century would be a time of unprecedented invention and creation.

In 2012, we were largely focused on products, but through the implementation of our mission, we decided that we can go further, extending our scope from things to life. We also considered that while the "Social Industry Experience" made sense, we had to go beyond this concept.

Experiences are, first and foremost, human and that is the reason why we now prefer to speak about "Human Industry Experiences". Henceforth, we have the ambition to become the world leader in three strategic sectors of the economy: Manufacturing Industries, Life Sciences and Healthcare, Infrastructure and Cities.

Medidata acquisition, strengthening of our strategy in life sciences and new ambition
By identifying Life Sciences and Healthcare as a major axis of development, we executed this strategy with the acquisition of Medidata, which is for Dassault Systèmes, a landmark. This acquisition was, by its size, the largest in Dassault Systèmes' history, with a total purchase price of $5.8 billion. It was funded by our cash flow from operations, which reported an excellent performance in 2019, increasing by 32% to €1,186 million, and by Dassault Systèmes' first bond issuance of €3.65 billion. This inaugural issuance received strong interest and was largely oversubscribed. At the end of 2019, our ratio of net financial debt plus lease of €3.4 billion on EBITDAO of €1.3 billion, stands at 2.5.

With this acquisition, we reinforce our business experience platform with an end-to-end approach from research and discovery, to development, clinical testing, manufacturing and commercialization of new therapies and health technologies. We believe this can be instrumental to our contribution to a sustainable world.

Similar to the revolution in industry we initiated in 1989, with the creation of the first virtual twin of the Boeing 777 and the major decision we announced on February 9, 2012, to shift our center of gravity from product to experience, we now have the ambition to create the virtual twin of the human, to offer solutions enabling the development of personalized, therefore more effective, treatments. We have started to work in this direction with our Living Heart program, certified by the United States FDA, and through the research

we are currently conducting on the human brain. We are aware that carrying out such an undertaking takes time, but we are highly motivated by this exciting perspective.

Business outlook
To ensure that all operational decisions are taken in a very consistent manner and in line with our corporate strategy, we are extending the scope of responsibility of key executives and establishing a new multi-generation leadership, led by Pascal Daloz as Chief Operating Officer. As these lines are being written, we presented for the first quarter 2020 our total non-IFRS revenue below our initial targets by 2.5%, due to services and new licenses weakness. On the other hand, non-IFRS recurring revenue, growing 30% and non-IFRS EPS improving 9% at €0.95 are in line with our objectives.

Prior to the crisis generated by the COVID-19 pandemic, we had set an objective of 21% to 23% growth of our total non-IFRS revenue at constant currency, with non-IFRS recurring revenue as the main driver, and a non-IFRS EPS target of €4.15 to €4.20, up 14% to 15%.

The new objectives taking into account the possible evolution of the crisis during the year are the following: 12% to 13% growth of our total non-IFRS revenue at constant currency, on a solid non-IFRS recurring revenue growth and a non-IFRS EPS target of €3.65 to €3.72, stable to slightly growing compared to the 2019 non-IFRS EPS. We remain fully committed to serving our customers and are attentive to our staff during this crisis, which brings to light the benefits of our **3D**EXPERIENCE platform, our remote and Cloud solutions.

We are also particularly active in the Life Sciences sector to ensure the success of the large number of ongoing clinical trials and development of medical devices. Considering new horizons, setting a path for growth for the coming decades, is only possible with the support and trust of our clients, the motivation and sense of community of all of Dassault Systèmes' collaborators, energized by a purpose giving strong meaning to their daily experiences as employees, citizens and human beings.

Finally, because experience is human, it is all about making the most of art, science and technology to imagine and create a more sustainable world. This ambition is at the very heart of the mission we embraced in 2012. It consists in, thanks to virtual universes, helping our customers harmonize nature, product and life. Such a mission inspires all of our collaborators to always embrace learning, question certainty and be curious and imaginative to remain innovative.

Because experience is human, it is all about making the most of art, science and technology to imagine and create a more sustainable world.

GOVERNANCE

BERNARD CHARLÈS
Vice Chairman of the Board of Directors
and Chief Executive Officer

DOMINIQUE FLORACK
President

Around **PASCAL DALOZ,** the Operations Executive Committee, from left to right:

ELISA PRISNER, Vice President Business Platform Experience
SAMSON KHAOU, Executive Vice President, Asia-Pacific
PHILIPPE LAUFER, Executive Vice President, 3DS Global Brands
THIBAULT DE TERSANT, Senior Executive Vice President, General Secretary
FLORENCE VERZELEN, Executive Vice President, Industry, Marketing, Global Affairs, Workforce of the Future
PASCAL DALOZ, Chief Operating Officer & Chief Financial Officer
ERIK SWEDBERG, North America Managing Director
FLORENCE HU-AUBIGNY, Executive Vice President, Research & Development
LAURENCE BARTHÈS, Executive Vice President, Chief People & Information Officer
OLIVIER RIBET, Executive Vice President, Europe, Middle East, Africa, Russia (EMEAR)
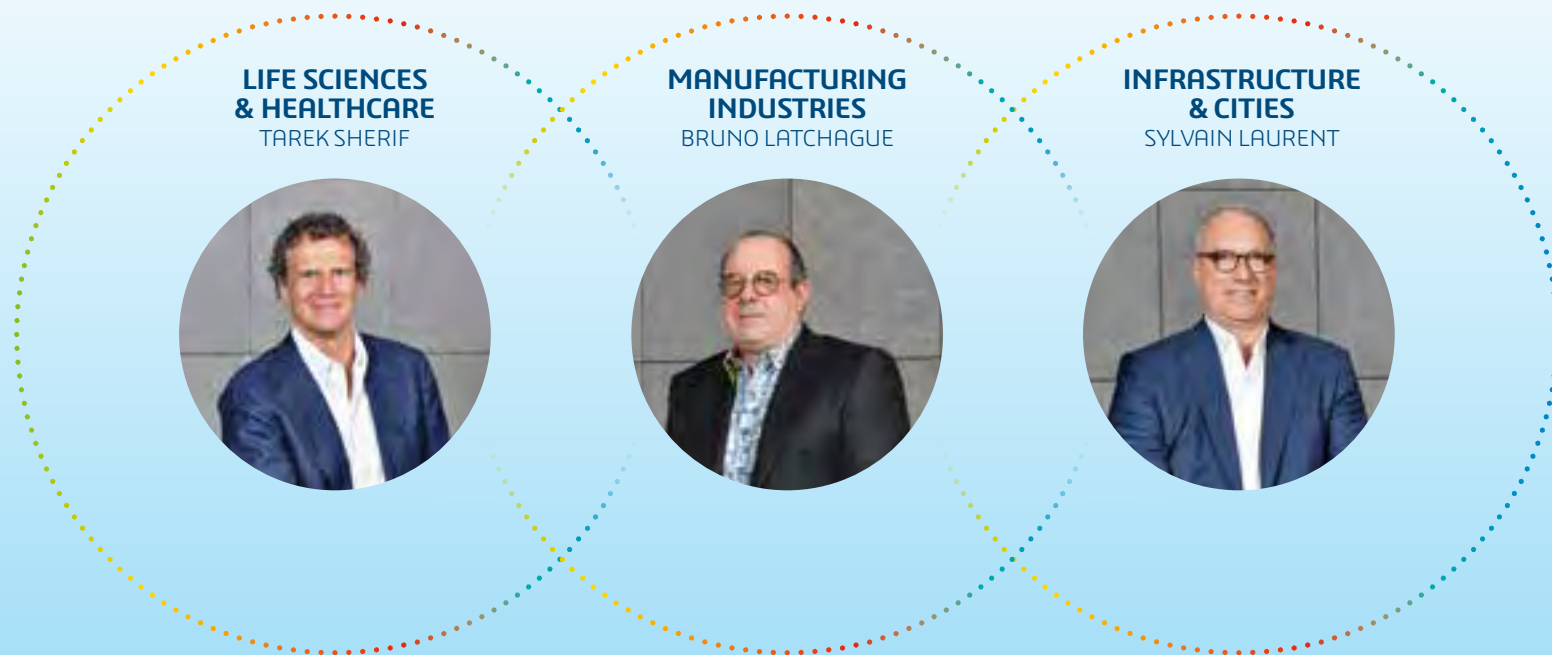**VICTOIRE DE MARGERIE,** Vice President Corporate Equity & Communications

PROFILE

We roll out our strategy by calling on our Strategic Operational Elements: Brands, Industries and Geos. Dassault Systèmes' Brands create great user experiences and build vibrant user communities and develop the apps that power the **3D**EXPERIENCE platform.

Our Industries develop Solution Experiences, which are industry-focused offerings that deliver specific value to companies and users in a particular industry.
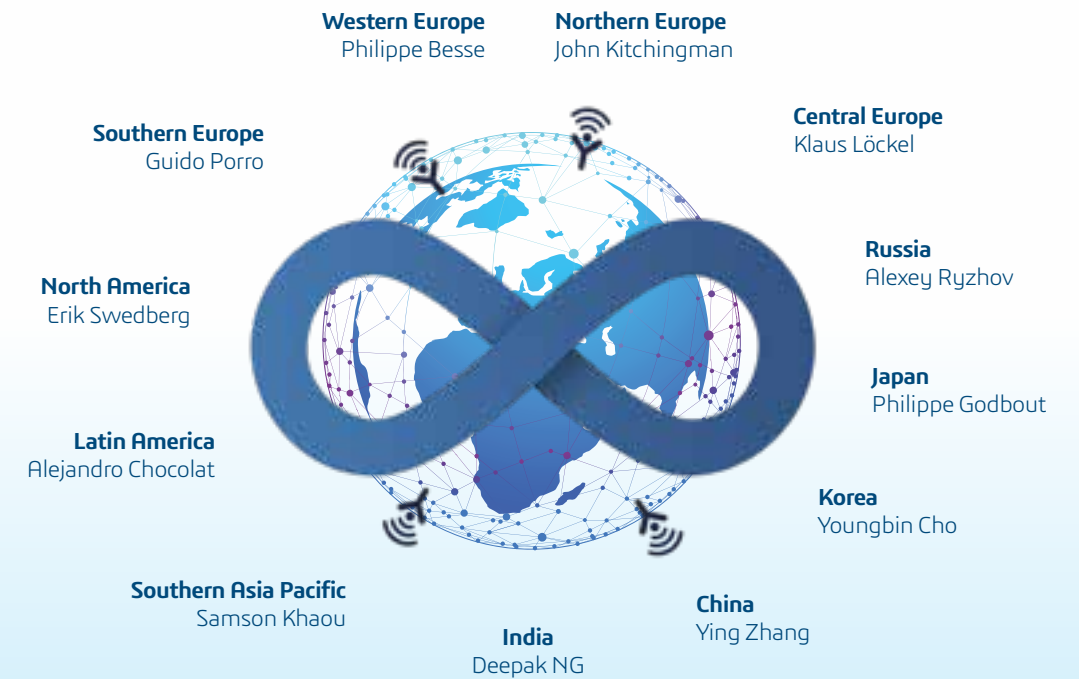
Our twelve GEOs are responsible for making GEOs the driving force for the development of our business and drive the implementation of our customer-centric engagement model.

Western Europe
Philippe Besse

Northern Europe
John Kitchingman

Southern Europe
Guido Porro

Central Europe
Klaus Löckel

Russia
Alexey Ryzhov

North America
Erik Swedberg

Japan
Philippe Godbout

Latin America
Alejandro Chocolat

Korea
Youngbin Cho

Southern Asia Pacific
Samson Khaou

China
Ying Zhang

India
Deepak NG

LIFE SCIENCES & HEALTHCARE
TAREK SHERIF

MANUFACTURING INDUSTRIES
BRUNO LATCHAGUE

INFRASTRUCTURE & CITIES
SYLVAIN LAURENT

TRANSPORTATION & MOBILITY
Laurence Montanari

AEROSPACE & DEFENSE
David Ziegler

MARINE & OFFSHORE
Alexandre Tew Kai

INDUSTRIAL EQUIPMENT
Philippe Bartissol

HIGH-TECH
Olivier de Percin

HOME & LIFESTYLE
Philippe Loeb

CONSUMER PACKAGED GOODS & RETAIL
Philippe Loeb

LIFE SCIENCES
Claire Biot

ENERGY & MATERIALS
Thomas Grand

CONSTRUCTION, CITIES & TERRITORIES
Simon Huffeteau

BUSINESS SERVICES
Taherah Kuhl

3DEXCITE
Dominic Kurtaz

CENTRIC PLM
Christopher Groves

ENOVIA
Stéphane Declée

SOLIDWORKS
Gian Paolo Bassi

EXALEAD
Morgan Zimmermann

CATIA
Olivier Sappin

NETVIBES
Morgan Zimmermann

GEOVIA
Michelle Ash

MEDIDATA
Tarek Sherif
Glen de Vries

BIOVIA
Jason Benedict

Social & Collaborative Apps
Information Intelligence Apps
3D Modeling Apps
Simulation Apps
3D
V+R

SIMULIA
Bruno Latchague

DELMIA
Guillaume Vendroux

3DVIA
Vincent Picou
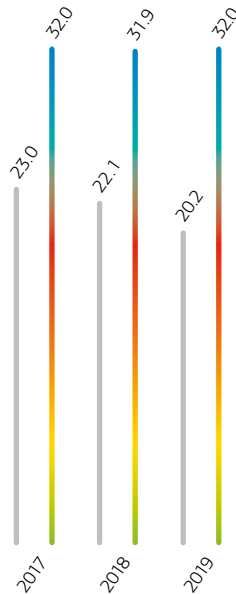
SUCCESS OF OUR 2014-2019 PLAN: OPENING A NEW HORIZON

DOUBLING EPS IN 5 YEARS

Target set in 2014 for 2019

€3.50 EPS[1]

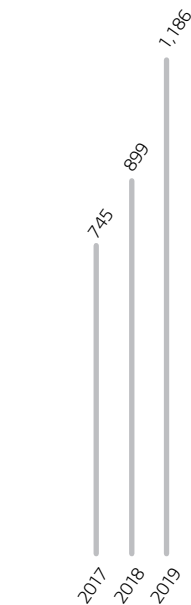Target overachieved in 2019

€3.65 EPS[1]

ORGANIC AND ACQUISITIONS-RELATED GROWTH OF +13%[2] IN REVENUE
(€M)

3,228 3,242 3,477 3,491 4,018 4,056

2017 2018 2019

DILUTION IMPACT OF ACQUISITIONS ENTIRELY OFFSET AND STABLE OPERATING MARGIN
(%)

23.0 32.0 22.1 31.9 20.2 32.0

2017 2018 2019
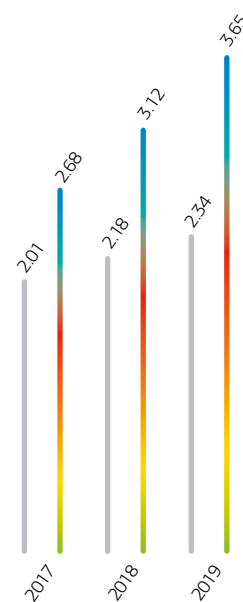
DILUTED EPS[1] (€) UP +17% IN 2019 (€)

2.01 2.68 2.18 3.12 2.34 3.65

2017 2018 2019
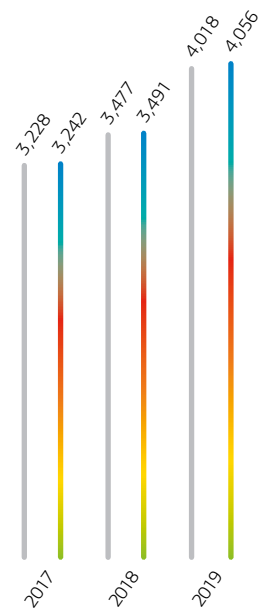
NET CASH PROVIDED BY OPERATIONS[3] INCREASED IN 2019
(€M)

745 899 1,186

2017 2018 2019

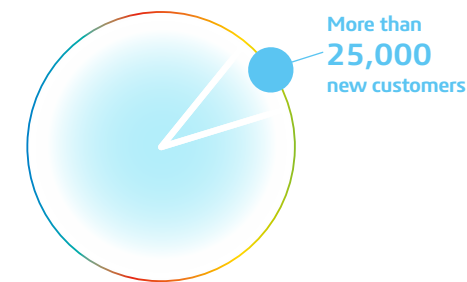IFRS   NON-IFRS[2]
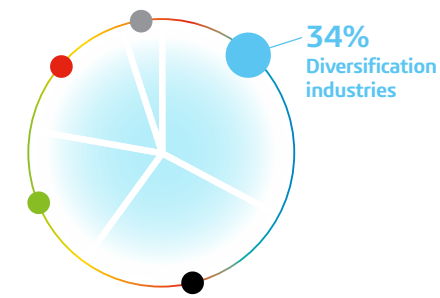
Industry diversification[1]

34% Diversification industries

- 34% Diversification industries
- 29% Transportation & Mobility
- 16% Industrial Equipment
- 14% Aerospace & Defense
- 7% Business Services
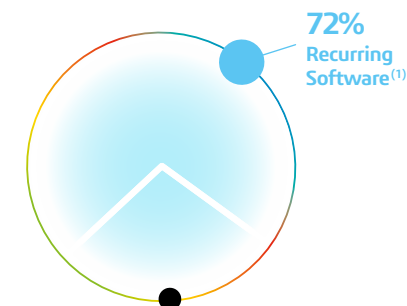
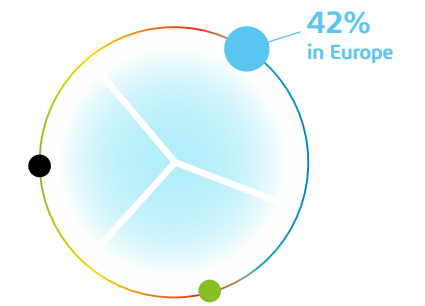**Large proportion of recurring revenue**

72% Recurring Software[1]

- 72% Recurring Software[1]
- 28% Licenses and Product Development[1]

A large installed base with 270,000 customers

More than **25,000** new customers

Excellent performance in Americas, Europe and Asia progressing well

42% in Europe

- 42% Europe[3]
- 31% Americas[3]
- 27% Asia[3]

Leading brands serving our users[2]

- 27% CATIA
- 20% SOLIDWORKS
- 10% ENOVIA
- 31% Other software
- 12% Services and other

PUSHING THE BOUNDARIES OF POSSIBILITIES IN 21st CENTURY HEALTHCARE

Life Sciences & Healthcare is now our second largest core sector. Our idea is simple. We want to help health innovators power smarter therapeutics for healthier people. In the age of precision medicine and patient experiences, it is clear that the future of healthcare will be shaped by inclusive and multi-discipline platforms enabling virtual twin experiences for healthcare. We made virtual twins of cars and airplanes possible. We will do the same for the human body. The **3D**EXPERIENCE platform combines modeling, simulation, data science, AI, and collaboration in a new, unified, end-to-end approach. This ushers in a revolution for the 4,500 pharmaceutical and biotech companies and 50,000-plus medical device manufacturers that make up the health ecosystem, empowering them to develop sustainable solutions by connecting the dots from research to commercial deployment of new therapies and health technologies.

Bernard Charlès
Vice Chairman
of the Board of Directors
and Chief Executive Officer

KEY DATES

April 29, 2014
Acquisition of Accelrys

October 29, 2019
Acquisition of Medidata

November 13, 2019
Life Sciences Day

OPENING UP A NEW WORLD OF VIRTUAL TWIN EXPERIENCES FOR HEALTHCARE

MEDIDATA,
to operate as a new expertise

Life Sciences,
as a New Core Sector

A UNIFIED AND END-TO-END OFFER

COMMERCIALIZATION
Launched to Cure

MANUFACTURING
Made to Cure

COMPLIANCE
License to Cure

RESEARCH & DISCOVERY
Design to Cure

CLINICAL TESTING
Clinically Approved

PRECLINICAL DEVELOPMENT
ONE Lab

Dassault Systèmes

Medidata Solutions

A PURPOSE-DRIVEN COMPANY

POSITIVE OUTCOME FOR CLIENTS' HANDPRINT

Dassault Systèmes can enable sectors, such as the global automotive sector, to create handprints which are around 10,000 times greater than its own footprint. Clearly, this is where its sustainability efforts should be focused, for the good of humanity and the planet. http://hwpi.harvard.edu/files/chge/files/handprints_of_product_innovation.pdf

1
Footprint

VS

10,000
Handprints

Negative impact for the planet

Positive impact for the planet

Dassault Systèmes provides business & people with **3D**EXPERIENCE universes to imagine sustainable innovations capable of harmonizing product, nature and life.

WELL POSITIONED IN SRI INDEXES AND RANKINGS, DASSAULT SYSTÈMES IS:

1
Corporate Knights Most Sustainable Corporations (2018)
"the most sustainable companies in the world"

2
Fortune Future 50 Sustainability All Stars (2019)
"companies focused on environmental innovation, the rational use of resources and efforts to limit emissions among other factors"

20
Fortune Future 50 (2019)
"companies with the strongest long-term growth potential"

AA
MSCI ESG indexes (2019)
"to measure a company's resilience to long-term, financially relevant ESG risks"

DASSAULT SYSTÈMES' ENGAGEMENT

Moderate CO_2 emissions
in 2018
11.5 tCO_2-eq per employee

in 2019
-6% to 10.8 tCO_2-eq per employee

Setting a target to reduce emissions by 2030
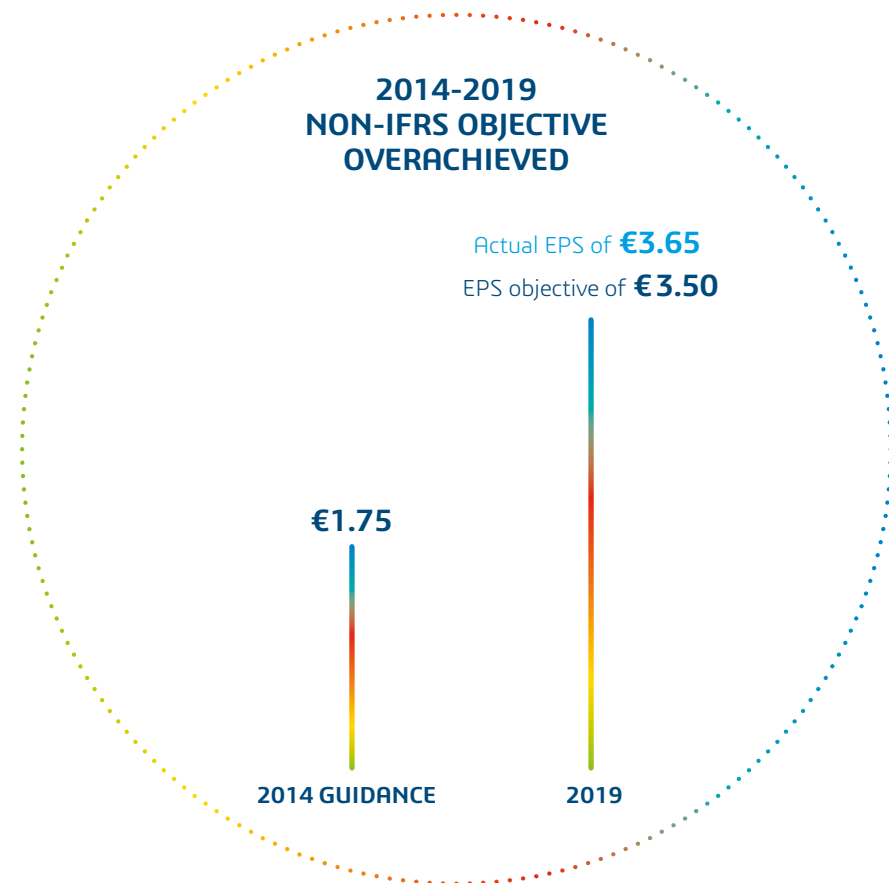
REACHING ALL OUR 2019 OBJECTIVES

Looking at our top-line financial performance and before including our recent Medidata acquisition, we delivered for 2019 total non-IFRS revenue growth in line with our objectives. Driving these results was our non-IFRS recurring software revenue, which increased 8% on an organic basis at constant currency, 200 basis points above 2018, and at the high end of the goal we had shared.

From an earnings perspective, 2019 represents the successful completion of our five-year plan to double our non-IFRS EPS to €3.50. We achieved this commitment thanks to the strength and sustainability of our strategic growth drivers. **3D**EXPERIENCE non-IFRS software revenue grew between 2014 and 2019 at a CAGR exceeding 20%. Diversified industries contribution to our software sales mix improved and global geo expansion broadened our market footprint over this timeframe.
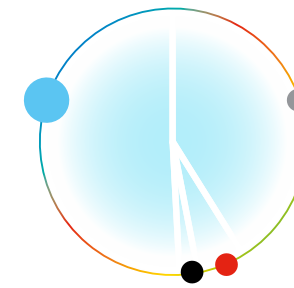
Pascal Daloz
Chief Operating Officer
and Chief Financial Officer

2014-2019 NON-IFRS OBJECTIVE OVERACHIEVED

Actual EPS of **€3.65**
EPS objective of **€3.50**

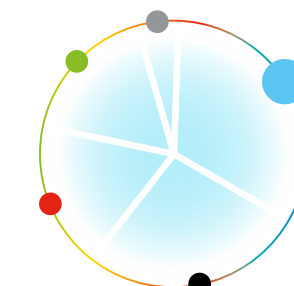**€1.75**

2014 GUIDANCE   2019

SHAREHOLDERS' INFORMATION

Shareholders' composition (controlled capital)

- 51% Free float
- 41% Groupe Industriel Marcel Dassault
- 6% Charles Edelstenne
- 2% Bernard Charlès

Shareholders' composition (free float)

- 33% North America
- 27% France
- 18% Continental Europe (excluding France)
- 17% UK & Ireland
- 5% Rest of world

SHAREHOLDERS' CONTACT

Tel.: +33 (0)1 6162 6924
Fax: +33 (0)1 7073 4359
E-mail: investors@3ds.com
www.3ds.com/investors

DASSAULT SYSTÈMES STOCK DATA

Listed on NYSE, Euronext Paris and traded on the American OTC market

Member of CAC 40

Share price 31/12/2019
● €146.55 ● $164.5

Market capitalization
● €38.01 MD ● $42.72 MD

Comparison of the 1-year stock performance
● DASSAULT SYSTÈMES +41%
● CAC 40 +26%
● NASDAQ +35%

Daily volume of stock traded on Euronext Paris
● 324,666 shares

STEADY NON-IFRS GROWTH (€)

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
0.52	0.59	0.62	0.64	0.63	0.68	0.80	0.92	0.95	1.01	0.93	1.25	1.46	1.69	1.75	1.82	2.25	2.49	2.68	3.11	3.65
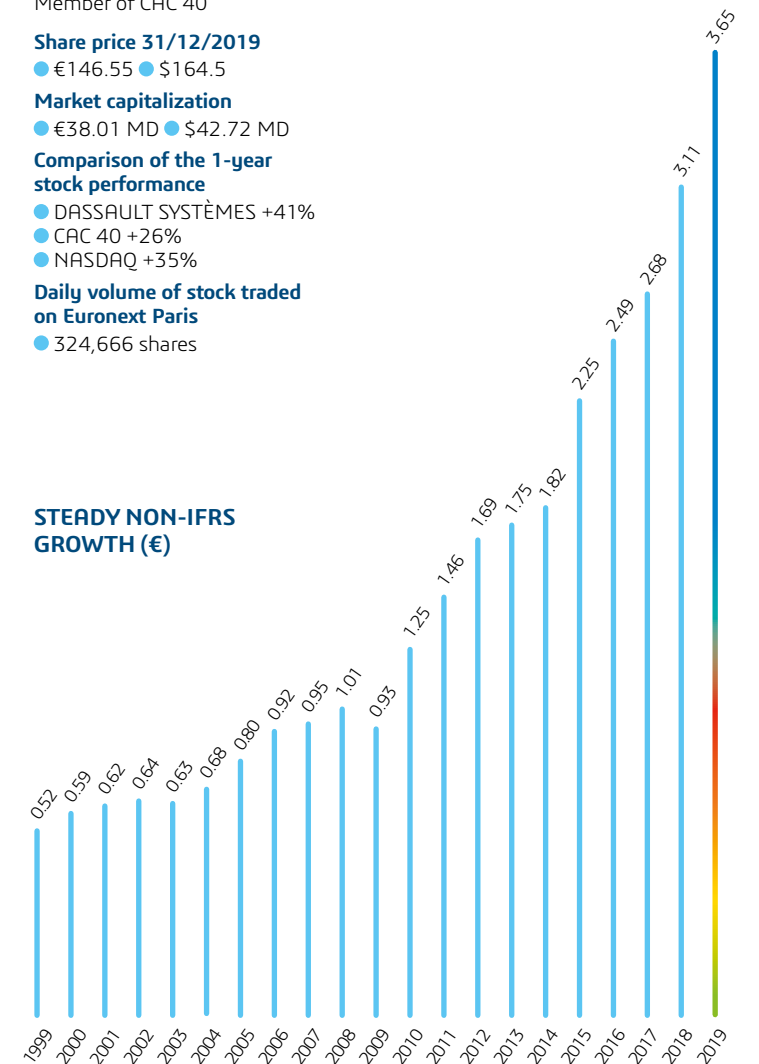
KEY 2019 SHAREHOLDERS' EVENTS

Thursday, April 23, 2020 Release of first quarter earnings
Tuesday, May 26, 2020 Annual shareholders' meeting
Thursday, July 23, 2020 Release of second quarter earnings
Thursday, October 22, 2020 Release of third quarter earnings
Tuesday, November 17, 2020 CAPITAL MARKETS DAY
Thursday, February 4, 2021 Release of fourth quarter earnings

THE ONLY PROGRESS IS HUMAN

Today, society faces a number of challenges in major areas such as healthcare, cities and the environment. To meet those challenges as a community, we need to find bold answers to these questions, while respecting the world that surrounds us. Through concrete actions, the initiative from Dassault Systèmes – named "The Only Progress is Human" – aims to enable sustainable innovation through virtual universes.

Because virtual universes offer an infinite space for creativity, they allow us to put imagination and human experience at the core of the creative process. With a virtual experience twin of the real world, Dassault Systèmes enables innovators to work more efficiently and more sustainably by proactively thinking about the product's impact on the environment and society, and to better understand how it can interact harmoniously with nature and our lives.

The initiative consists of 10 Acts, inspired by the expectations of younger generations regarding our future world, and by Dassault Systèmes' ability to deliver solutions to answer their questions. Each Act addresses one theme and one major challenge for society.

For the first time, Dassault Systèmes is addressing the public to show how it offers the possibility to create innovations that contribute to human progress, and in particular, how its solutions enable governments, companies and individuals to better understand the challenges they face and how to sustainably innovate. Each Act will illustrate how virtual twins are used in the real world to create human-centric experiences that rise to the challenge posed by each theme. Formats will vary between Acts, and will involve a range of events, partnerships and unique experiences. All Acts will incorporate virtual worlds and engage the public in order to encourage innovation using Dassault Systèmes solutions.

Victoire de Margerie
Vice President Corporate Equity & Communications

VIRTUAL HARMONY

Act I
EMOTION
How can virtual worlds change the way we experience emotions?

The first Act focused on emotion – a powerful catalyst for positive action and innovation – at the Virtual Harmony event that took place at the Jardin des Plantes in Paris on February 26, 2020. This unique musical and visual experience showed how the virtual world can engage both intellect and emotion. The music featured violinist Renaud Capuçon and focused on the 3Dvarius, a futuristic, 3D-printed electric violin designed with CATIA by Laurent Bernadac, an engineer specializing in mechanical design and energy, and also a professional violinist.

Act II
HEALTH
How can we control our health better in the future?

Act III
CITIES
How can cities adapt to our ever-growing needs?

Act IV
NATURE
Can we imagine a 100% sustainable industry?

Act V
CONSUMPTION
How can we consume goods sustainably in the future?

Act VI
MOBILITY
How can we move freely around the world without impacting the environment?

Act VII
ENERGY
How can we create an energy-positive world?
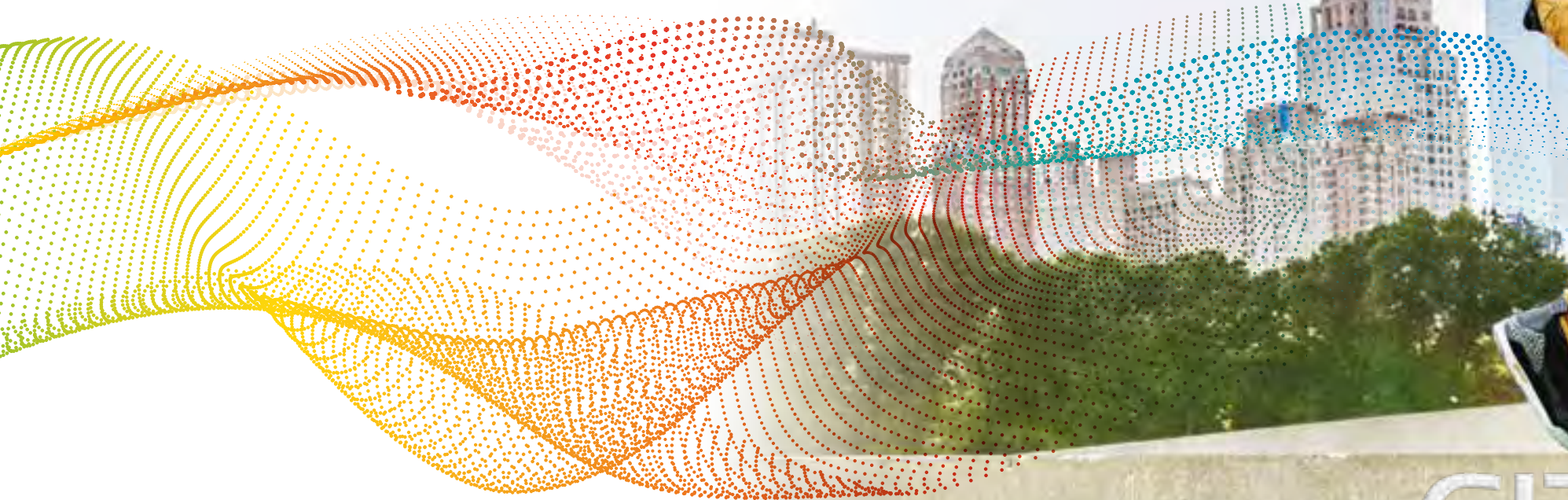
Act VIII
WATER
How can we safeguard our most precious resource?

Act IX
HERITAGE
How can we better navigate the future by understanding the past?

Act X
FUTURE
How can we build a better world for the next 40 years?

WE
ARE
WHERE...

CITIES BECOME
HUMAN

Because the best way
of meeting the challenges
of urbanization is to make
sure that city renewal
projects focus on the people
who live there, because the
ways in which we consume
and travel need to change,
we are there.

Urban transformation projects – whether they involve transportation infrastructure, real estate developments or architectural projects – require teams to communicate effectively. Project managers, project owners, contractors and architects need a collaborative environment and a single set of reference data to make sure they are speaking the same language.

That communication now extends to residents, because a city's planning only makes sense if it enhances the quality of life and experience of the people who live there. These requirements also arise in a context in which data of all kinds are increasingly widely available and can be harnessed to drive a city's transformation. Data make it possible not only to manage, regulate and plan the way cities work, but also to invent new types of services. This is one of the major developments over the last few years, and the movement is only just beginning.

Simon Huffeteau
Vice President Construction,
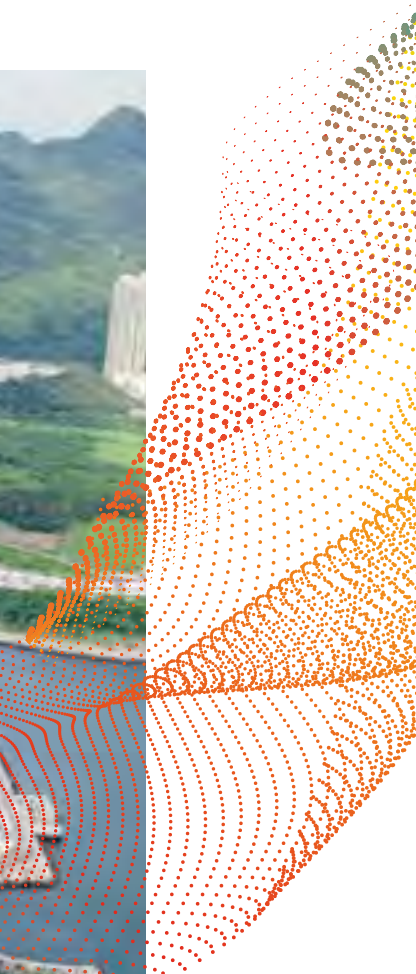Cities & Territories, Dassault Systèmes

A sustainable, resilient and inclusive city

The first challenge that urban planners must meet is to ensure that cities are sustainable and, beyond that, resilient. This can involve much more short-term issues, such as how well will the urban system cope with a strike by refuse collectors, an extreme weather event, a flood or a major fire? Will it survive a crisis? Another challenge, which also relates to a city's sustainability, is to ensure that it is inclusive: this should be understood not only in social terms but also from the human point of view, because a city is inhabited and experienced by human beings. For example, it is imperative that real estate development is coherent with transportation system development.

Another challenge relates to a city's governance, and the quality of relationships between the municipal authorities, the city's local economic ecosystem and its citizens, in a context in which many private-sector entities now act as middlemen, using digital technology to offer a city's inhabitants various goods and services, such as transportation. To make a city sustainable, resilient and inclusive, digital platforms have a key role to play. Dassault Systèmes adds value in precisely this area: it supports development, oversight and execution of public policy and projects, helping the city authority become the entity driving the transformation of the city and its context. Today, when a major real estate developer builds a tall building, its square footage is less important than the experience provided to its occupants and the city authority's ability to understand the overall impact. The **3D**EXPERIENCE platform gives municipal authorities a way to regain control of their cities and allow project owners to take into account the city context when making their decisions. Having previously been organized around Architecture, Engineering and Construction, the platform's focus is now on Construction, Cities and Territories, showing the role that Dassault Systèmes intends to play with respect to cities and, particularly, the people who live in them.

Hong Kong, China

Sustainable cities: key issues

Morphosis Architects has always been interested in how cutting-edge tools can expand and augment the design process. Founded by Thom Mayne, Morphosis' architecture and planning projects are recognized the world over, and feature major innovations in terms of form, constructability and sustainability.

Morphosis was one of the first architecture firms to adopt CATIA and parametric modeling, and it uses the **3D**EXPERIENCE platform at all stages from design to completion, from immersive visualization of the concept to optimization of energy-efficient façade systems.

A building's architecture is an increasingly complex system that requires tools and innovations that are themselves increasingly sophisticated in terms of design and construction. This growing complexity reflects the increasing demands that architecture must address in terms of functionality, environmental sustainability, and performance, which now also overlap with issues relating to sustainable cities. For example, urban growth is creating traffic congestion problems all over the world.

A new, integrated travel system

With limited space available on the ground, it will be hard for current traffic routes to cope with increasing volumes of travel. This is why Urban Air Mobility (UAM) is such an active area of development. Fifty companies, from established aerospace and automotive groups to technology startups, are currently working in this field. Hybrid propulsion systems are being developed for the near term, but all-electric airborne vehicles that can take off and land vertically are the future: their low emissions and noise levels are a winning combination for our cities. Unmanned Aerial Vehicles (UAVs) also are a major application of UAM technology. Designing these vehicles and showing that they can operate reliably in a complex urban environment are major challenges. Multidisciplinary analyses must be carried out within a tightly defined regulatory framework. The large amount of data involved requires integrated project management that combines virtual prototyping and physical simulation within a collaborative platform. The most advanced aerodynamic and aeroacoustics simulation techniques are integrated within the SIMULIA solution, allowing users to understand and resolve highly complex issues, starting with noise, which is mainly produced when the blades of the main rotor hit the turbulence generated by the other blades. Vehicles often have a number of rotors, some of which can be coaxial and contra-rotating, with variable angles and speeds, resulting in a level of complexity that goes beyond the capabilities of traditional fluid dynamics simulations.

To maximize the range of these vehicles, simulation also is vital in battery design, and the constant quest to make vehicles lighter and more robust means that components and assemblies, subject to multiple nonlinear loads, must be optimized. Finally, all of these low-flying aircraft must communicate and coordinate

❝ Developing a quiet, optimized and certified vehicle for Urban Air Mobility (UAM), within the target compressed timeframes, can only be accomplished with the range of multiphysics simulation capabilities provided by SIMULIA.

Our high-fidelity computational fluid dynamics (CFD) uniquely predicts noise signatures of these vehicles, and our electromagnetics capabilities ensure communication system functionality in all adverse conditions. Additionally, with a long history in aerospace certification for structures and composites, our customers can be certain that regulatory requirements will be met, even in the early design phase.

Rachel Fu
Senior Manager,
SIMULIA Aerospace
& Defense Initiatives

THOM MAYNE
Born in the United States in 1944, architect Thom Mayne is part of the deconstructivist movement and co-founder of design and architecture firm Morphosis. His designs can be found all over the world, and he won the Pritzker Prize in 2005.

❝ By modeling our projects in 3D, we can progress very quickly, considerably increase the amount of time we spend thinking and reduce the time spent on manual work.

with each other reliably so that they can safely operate as part of an urban transportation system, and this requires integrated multi-scale electromagnetic simulations. The technologies integrated into the SIMULIA and CATIA suites allow users to move away from traditional design paths, which are required to achieve a viable concept vehicle quickly and efficiently, in this competitive emerging market.

Last-mile logistics
Public transport and shared two-wheeled vehicles also are key parts of a transportation system, as are delivery vehicles, which represent a rapidly changing industry. The explosion of e-commerce, traffic congestion, the environmental impact of transportation, pedestrianization and the banning of certain vehicles from city centers all mean that urban logistics need a thorough overhaul. Whether a package has come from halfway around the world or the next city, the last mile is a major headache for logistics companies.

Generally, they deliver packages using large vans, which are unsuited for small volumes and urgent deliveries. Today, many companies understand that these urban vehicles need to be rethought, while also reducing their environmental footprint. Both major international automotive groups and specialist startups are working on the issue. For example, they are looking at electric propulsion methods, cockpit ergonomics, the driving position, the interface with the driver, the way in which vehicles are unloaded, ease of maintenance and upgradability. Whatever their size, those companies are adopting an agile approach, using collaborative platforms that include users in the process of defining product specifications. This approach helps them speed up the development of their first vehicles, which they then can rapidly adjust based on customer feedback.

PIXEL

XYT: VEHICLES DESIGNED BY AND FOR DELIVERY DRIVERS

XYT is a next-generation vehicle manufacturer that has developed the PIXEL, a modular electric utility vehicle specifically designed for urban logistics to make the last kilometers of a delivery. Its chassis and its various container models allow the user to configure the ideal vehicle for the activity, to enhance it, and to optimize it as needed. Designed alongside industry professionals, the vehicle improves working conditions, profits and performance for tradesmen, retailers and e-commerce companies. Light and eco-designed, these vehicles offer good durability and autonomy, thereby reducing their environmental footprint for sustainable mobility.

EZ-FLEX

TESTED WITH CUSTOMERS

The Renault EZ-Flex is an experimental electric smart utility vehicle, designed for urban deliveries. It was designed by the Renault group's LCI (collaborative innovation lab) and represents a novel collaborative and innovative approach.

Across Europe, customers will test a dozen of these vehicles and suggest changes to help address future uses more effectively. The LCI is a multidiscipline team of engineers and architects specializing in mechanics, platforms, bodywork and product architecture; designers specializing in vehicle exteriors, interiors and user interfaces; and marketing experts. The cloud-based **3D**EXPERIENCE platform ensures that all disciplines can work together, speeding up the validation of concepts and making them more robust through digital modeling and a single-design approach.

Interacting with city residents
Another way our cities are being transformed is by identifying and harnessing data, a central part of the smart cities approach. More than 90% of the world's data have been generated over the past two years, and this trend will continue: data from mobile computing, artificial intelligence and augmented reality create artificial landscapes that form part of the urban fabric. The combination of the virtual and physical worlds offers new opportunities to designers as they seek to address social and sustainability issues.

In April 2019, five international teams took part in the DATAVIRONMENT Hackathon Challenge in Milan, bringing together the most cutting-edge architecture and design practices.

They had 48 hours to design the Milan of the future, using data and the CATIA and SOLIDWORKS design solutions integrated in **3D**EXPERIENCity.

Their experiments included the location between the ancient Parco Sempione – Milan's largest park – and CityLife, Milan's new business, residential and retail district. The first team created a covered walkway, with canopies that move in response to heat, light and interactions with people. The second proposed turning car-parking spaces into modular farms to promote local food production. Another team designed a data center that is visibly integrated within the city, clearly showing the increasing use of data in urban management, whereas data centers are usually relegated to unpopulated areas. The fourth team designed an automatic generator of restaurant extensions, and the winning team designed a holistic, automated urban planning and construction tool, using data related to the distance from the city's historic and modern centers and each building's use (retail, residential, cultural, etc.). The tool not only simulated proposed buildings, but also future changes to the urban fabric. It showed the extent to which urban planning is a dynamic discipline that combines both the past and the future.

24
people involved in the first DATAVIRONMENT Hackathon, divided into five teams

90%
of the world's data have been generated in the last two years

❞ Harmonizing all elements of city life into healthy, pleasant human experiences requires a sense of responsibility and exposure to the urban context in all its complexity. Ethical design requires the ability to respond immediately and intelligently to the global standards that a city must meet.
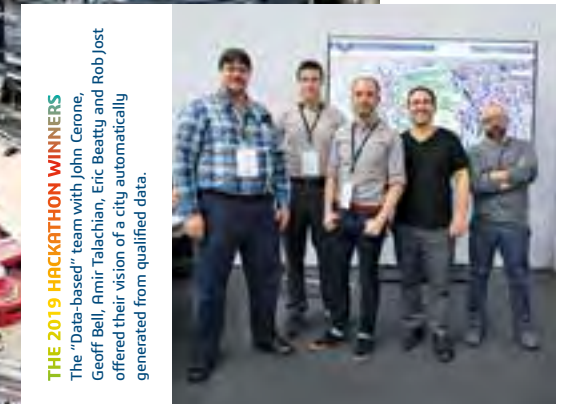
HONG KONG
AND ITS VIRTUAL TWIN

Arup is a global firm of designers, engineers, architects, planners, consultants and technical specialists, leading the study of cities. It has operations in more than 140 countries and its teams combine knowledge of the built environment with new technologies in order to design a better world in the digital era. Its Smart Green Resilient strategy aims to reduce demand for resources, promote a low-carbon economy, make business more productive, improve the quality of urban life and increase climate resilience. In October 2019, Arup and Dassault Systèmes formed a strategic partnership: the **3D**EXPERIENCE platform is giving Arup the benefit of virtual twin technology, and now offers a collaborative solution that is enhanced by Arup's experience. The two partners are taking part in Hong Kong's plan to unify data representations and systems in order to improve the way the city functions and, therefore, the quality of life of its inhabitants. Hong Kong's government is encouraging the creation of shared infrastructure consisting of spatial data, with innovation and technology being used to meet urban challenges and improve quality of life, sustainability and efficiency, with the ultimate goal of increasing Hong Kong's appeal. The project has two phases: the first focuses on devising a global framework, including targets and a roadmap with the aim of creating a smart city.

The second showcases several applications in four areas: urban planning and the use of space on the ground, through pedestrianization and urban design, for example; infrastructure and engineering, such as the visualization of underground spaces and water, electricity and wastewater services; the landscape, the environment and their conservation; and the combination of working processes. The platform has already shown its great potential in fostering collaboration between the public sector, private sector and academia.

A SMART **CONSTRUCTION INDUSTRY**

Pacific Consultants is a construction consultancy founded in 1951 to support the nation's development of post-war reconstruction in Japan. They have been involved in urban development in Japan and overseas, like transportation infrastructure such as roads, railways, ports and others. The civil engineering industry in Japan possesses world-class technical capabilities of earthquake resistance technology and seismic technology against tsunamis and heavy rain, and the professionalism of engineers involved in the projects is very high. However, because competent technology often depends on personal skills, there are problems that skills are not handed down if engineers retire. Therefore, it will be necessary in the future to digitalize processes and share knowledge. Pacific Consultants has adopted the **3D**EXPERIENCE platform with the aim of improving productivity and reforming work styles on projects like bridges and sand control dams. In order to determine effective positions and structure, calculation and trial and error are repeated, but quick design is possible by changing conditions and positioning using CATIA design templates. Since design templates can be reused, projects can be continuously improved.

In the future, with the aging of structures, the issue will be how to maintain and manage them efficiently. In addition to the structures that will be built in the future, 3D-enhanced maintenance and centralized management of structures in the cloud environment will open up a smart construction industry.

Tama Ôhashi Bridge

WE
ARE
WHERE...

HEALTH BECOMES PERSONALIZED

Because the healthcare
industry produces
a huge amount
of raw data that can
be harnessed; because
simulation can help train
doctors and educate
patients; because digital
technologies offer a way
of developing a more
open, collaborative
and inclusive kind of
medicine, we are there.

Since Dassault Systèmes was created, the leading role we play in sustainable innovation has led us to adopt the ambition of achieving harmony between product, nature and life. We are now applying the knowledge and know-how we have developed in the world of products to the world of life. The aim of using virtual worlds to cure people and help them lead a better life has been driving us for many years. We firmly believe that this requires the virtual twin of the human body – created on our **3DEXPERIENCE** platform with its modeling, simulation, data intelligence and collaboration capacities. By joining forces with Medidata, we now have an unrivaled set of assets with which to pursue our vision and develop our scientific culture. By combining data intelligence and simulation, we can offer more intelligent therapies and contribute to life sciences what we have been contributing to manufacturing since we created the first digital mock-up.

Bernard Charlès
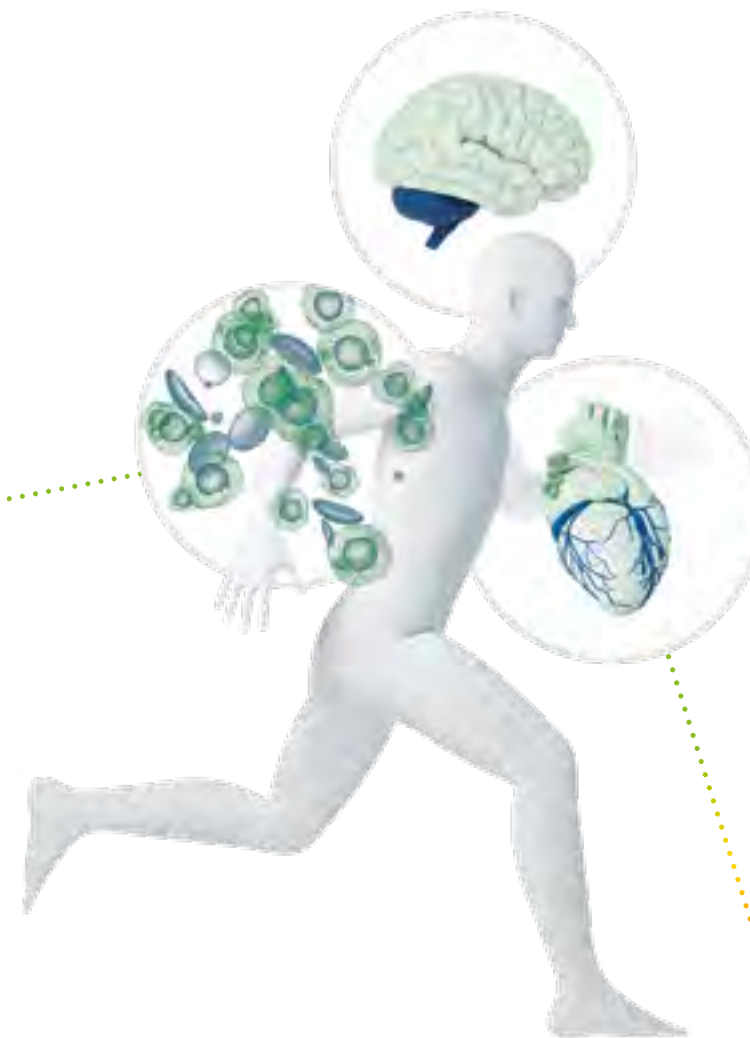Vice Chairman of the Board of Directors and Chief Executive Officer

MEDIDATA WAS FOUNDED 20 YEARS AGO WITH THE GOAL OF CREATING TECHNOLOGY AND SERVICES THAT WOULD POSITIVELY IMPACT THE LIFE SCIENCES INDUSTRY AND, ULTIMATELY, PATIENTS' LIVES.

Our mission then, as it is now, was to power smarter treatments and healthier people.

The internet was developing rapidly back then, and we saw a better way to collect and manage clinical trial data, which were largely manual processes at the time. Innovative data and technology were central to our business plan and, as our success and reputation grew, our electronic data capture (EDC) solution became a *de facto* standard for running clinical trials. Today, more than half of all clinical trials use one of our solutions. There's an excellent chance that a medicine you or a loved one has taken was developed with Medidata's help.

As part of Medidata's evolution, around 10 years ago, we asked our customers for the right to use the huge volume of data we were collecting. This was highly strategic from a business perspective and transformative from a scientific standpoint. We now have billions of data points to analyze for strategic insights and to generate evidence for our life science customers and partners; it represents a tremendous competitive advantage.

Our creative approach to problem-solving and purpose-driven mission is what made us an attractive company for Dassault Systèmes to acquire. Our companies share similar cultures and values.

For several years, Dassault Systèmes has been applying its expertise, developed in the aerospace and automotive sectors, to life sciences under its BIOVIA brand. Joining forces with Dassault Systèmes creates a fabulous opportunity to drive even more rapid, transformative progress in the life sciences industry. Today, a new wave of innovation is taking place, based on creating targeted therapies and treatments that are tailored to the patient. Yet, there are still decades of traditional clinical practices fraught with inefficiencies to overcome. I have no doubt, though, that there is growing recognition that the life sciences industry needs to digitally disrupt its R&D operating model. The realization that precision medicine has benefits for both the patient and the business is gaining momentum. This is the kind of transformation that took place in the aerospace industry several decades ago, when Dassault Systèmes started to visualize how to create a digital mock-up of an aircraft and then a virtual twin.

The same thing is going to happen in life sciences, and then in healthcare more broadly. The way in which care is delivered is changing, too, with patients becoming more proactive in tracking

their own data and using it in discussions with their doctor to manage their health. In precision medicine, we are working on solutions – therapeutic and care-based – that are tailored to the individual patient.

To achieve that target, we need to know about the patient's genome and phenotype, lifestyle and environment, and other clinical data points to develop a working model. To that end, the patient experience will guide us. A life, from cradle to grave, is a set of experiences, and what's important is not the destination, but the journey. I like to think that what we're doing improves that journey. And, in partnership with Dassault Systèmes, we will have a positive impact on the world. People are proud to be associated with a company like ours.

Tarek Sherif
Co-Founder and Co-CEO of Medidata, head of Life Sciences & Healthcare sector, Dassault Systèmes

DIGITAL TRANSFORMATION IS CHANGING THE BUSINESS OF HEALTHCARE AT BREAKNECK SPEED.

Across the industry, from biopharmaceutical and medical device companies to hospital systems and regulators, everyone is seeking the next big technological innovation. But our eyes are on the ultimate prize: to help develop new treatments, enhance care, improve outcomes, maximize efficiency and increase value in our data-powered world. Medidata is helping to combine and amplify breakthroughs in medical science and artificial intelligence to realize the promise of precision medicine. The ability to provide the right treatment to the right patient at the right time will be transformative in the way we diagnose and deploy medicines. Precision medicine is only made possible by collecting and analyzing massive amounts of data. And that demands that we adopt a new mindset. To be specific, three new mindsets.

First is that more and different types of data will need to be collected to realize the potential for personalized prescriptions. Rather than learn all we can about a specific organ or disease state, we need to take a holistic approach. After all, we are the sum of our genetics and biomarkers, plus our medical and family history, our activities of daily life, and our ability to move, remember and engage with others. This is what drives Medidata. Our people, experience, expertise and our next generation of tools will help provide the evidence and insights to demonstrate the value of new therapies and devices to regulatory authorities, medical professionals, patients and insurers.

The second shift in thinking involves the current R&D model – in place for about 80 years – of attempting to find the most effective treatment for the greatest number of patients. But, as we learn more about the individual both biologically and behaviorally, the more likely it is that a particular therapy will not be the most appropriate choice. Our work in Idiopathic Multicentric Castleman Disease (iMCD), a rare, difficult to diagnose, life-threatening disorder, illustrates this point. Early testing to predict treatment response to siltuximab (the only FDA-approved drug for iMCD) is urgently needed

to inform clinicians about the likelihood of patient response to therapy, adjust treatments if needed and identify novel therapeutic targets for siltuximab non-responders. Medidata partnered with the Castleman Disease Collaborative Network and used our proprietary machine-learning algorithms to identify a protein biomarker that could be used to measure the likelihood of response soon after beginning therapy. Starting from an efficacy rate of 19% for siltuximab, we identified a subset of patients where the efficacy rate was almost 70%. We helped to create a real source of hope for patients.

Patients are where we see the third needed change in mindset: we must place the patient at the center of our efforts. The patient is as much a partner in transforming healthcare as drug developers and medical professionals. That is why Medidata pays special attention to patient needs and works to ensure clinical trials are as targeted, efficient and accessible as possible. With this imperative, Medidata is pioneering "virtual" trials and "synthetic" controls to speed the development of new therapeutics and minimize patient exposure to potentially harmful agents. Traditionally, clinical trials have required at least two groups to prove that a treatment is effective. Each time a patient took the new treatment, another patient, taking either a placebo or the standard treatment, was required as the control group.

Today, we are able to compare patients receiving new treatments with a much smaller control group by reusing patient data from previous studies. This predictive modeling is made possible by the industry's largest structured, standardized clinical trial data repository, connected with real world, translational and other datasets. The ever-growing Medidata solutions are built upon more than 20,000 trials and nearly 6 million patients. Medidata's end-to-end solution for clinical development is powering the digital transformation of the life sciences industry, enabling our partners and customers to turn ideas into new scientific realities.

Glen de Vries
Co-Founder and Co-CEO of Medidata
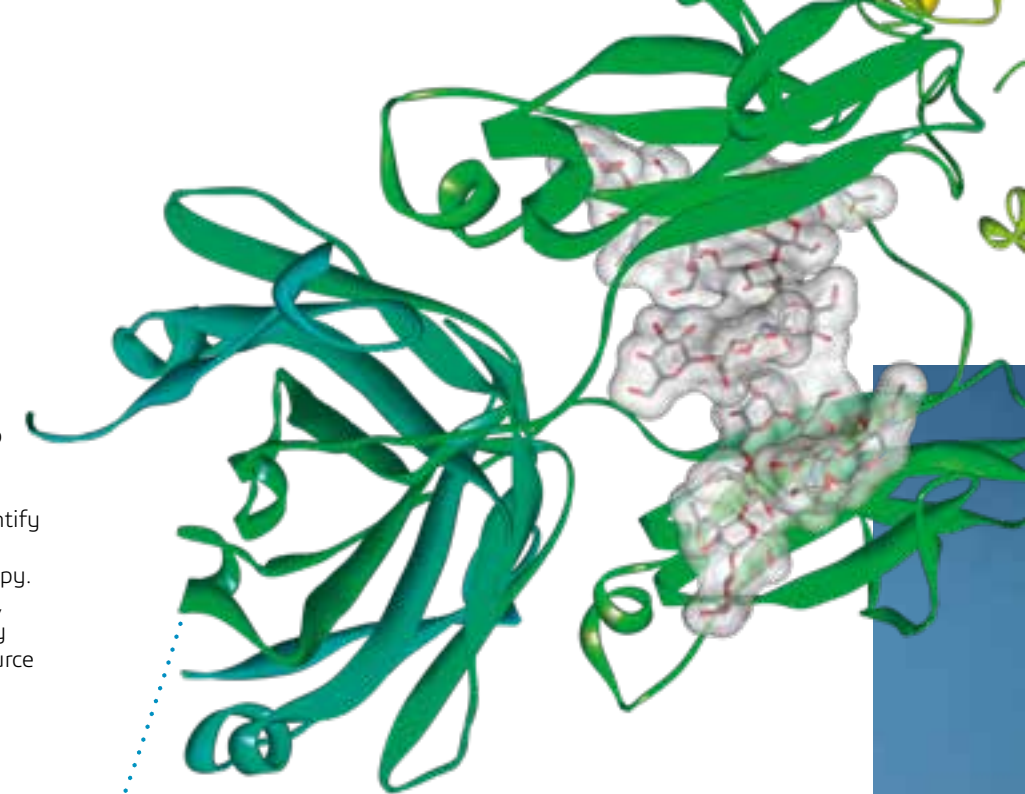
THE PATIENT EQUATION, THE DATA-DRIVEN FUTURE OF PRECISION MEDICINE AND THE BUSINESS OF HEALTHCARE[1]

In *The Patient Equation*, Glen de Vries sets out his ideas and strategies for helping scientists, medical professionals, policymakers and patients advance and accelerate the digital transformation of the life sciences. He explains how biotech, pharmaceutical and medical device companies can embrace the data revolution to deliver faster, cheaper and more effective solutions for patients. With more and diverse forms of data, precision medicine can become a reality where scientific and medical decisions are enhanced by algorithms – our individualized patient equations – to deliver the right treatment at the right time.

(1) Available in Summer 2020

IMPROVING HEALTHCARE BY COLLABORATING, LEARNING AND PRACTICING

Although medical innovations have considerably improved people's health overall, chronic diseases have never affected so many people. Epidemic crises are becoming more frequent and brutal. This is why people working in the healthcare sector need to adopt virtual platforms to connect, link and share data. By doing so, they will be able to provide new therapies that take into account the social and environmental factors that affect a person's health. Such platforms will make it possible to share information between patients, caregivers' practices, funding organizations and regulatory bodies to increase global knowledge in the life sciences field. They also will have a role to play in preventing disease and will make patients more independent by facilitating treatment at home. The quality, reliability and extent of a city's healthcare infrastructure are central to that city's appeal. Smart cities are connecting the virtual and real worlds and developing sustainable urban solutions to protect the health of their growing, aging populations, while also offering a better experience to their citizens. Currently, a patient's care pathway is fragmented between various specialists, resulting in a jumble of disconnected health services. Participants in the medical sector will increasingly need to pool their data to achieve genuine collaborative intelligence. The experience economy, by putting patients at the center of value creation, offers a holistic care model that favors innovation. Since patients are central to their own care pathways, the right to access and control their personal data is becoming more vital than ever. The security and confidentiality of those data are a priority, and regulations relating to personal healthcare data will be gradually harmonized throughout the world. Data anonymization is essential.

The technology will result in new approaches for pre-symptomatic prevention and early diagnosis: recent progress in machine learning, combined with solid scientific knowledge, has resulted in prediction models that make use of imaging and genomics techniques. These new models can produce personalized recommendations for patients, taking into account their individual chances of developing specific diseases.

High-definition technologies are adding value in neurosurgery, where brain imaging is being combined with functional electrophysiology and perioperative assessments in the operating theater. In orthopedics, the patient's virtual twin can be used to guide surgical planning by predicting the result of the operation. By 2030, 3D printing could be used to make prescription drugs or new tissue based on a 3D model of the patient's organs. Finally, home care can reduce the risk of complications arising from hospitalization, but requires complex infrastructure and a network that relies on new platforms capable of collecting patient data, producing diagnoses, connecting patients with healthcare professionals and checking the efficacy of treatments. The Living Heart project is an excellent example of how virtual universes will radically improve the healthcare experience and the major contribution of virtual twins for monitoring, understanding, preventing, diagnosing and maintaining health.

Claire Biot,
Vice President, Life Sciences Industry

Patrick Johnson
Vice President, Research & Technology strategy

Sébastien Massart
Head of Corporate Strategy

Nicolas Pécuchet
Healthcare & Life Sciences Research Manager

INNOVATIVE PROCESSES WITHIN A STRICT REGULATORY FRAMEWORK

German company B. Braun is one of the world's largest suppliers to the healthcare sector. It offers a comprehensive array of products and services in the fields of anesthesia, intensive care, cardiology, surgery and dialysis, serving healthcare establishments, pharmacies and home-care providers. In 2019, B. Braun decided to invest in digital solutions to round out its product range, as well as improving efficiency, quality and collaboration in its supply chain, by adopting the License to Cure solution based on the **3D**EXPERIENCE platform. Dassault Systèmes is working in close collaboration with TECHNIA, one of the largest Life Sciences system integrators worldwide, to deliver business transformation to B. Braun. The solution is allowing the company to streamline its scientific and operational processes, from modeling and simulation to production, while meeting exacting quality and regulatory compliance standards. The result is to increase the benefits for patients and medics while also reducing costs.

10%
of global GDP: healthcare expenditures in 2022
(Source: Deloitte, 2019)

6%
Average annual growth in healthcare expenditures in low-income countries
(Source: WHO, 2018)

71%
People who expect 3D-printed-to-order organs to have a direct impact on their health
(Source: Frost & Sullivan, 2014)

PKVITALITY

## AN ATTRACTIVE AND SMART DIABETES MONITORING DEVICE

PKvitality is a French manufacturer specializing in wearable medical devices. For diabetes sufferers, it is developing a smartwatch that measures their glucose levels constantly and in a non-invasive way, and alerts wearers and their loved ones in the event of a hypo- or hyperglycemic episode. A patch applied to the skin every week measures glucose levels in interstitial fluid using microneedles. The smartwatch interprets the signal sent by the patch, stores and displays information, and synchronizes information in the cloud. Alerts are sent to the patient using vibrations. This bio-wearable device, developed and honed using the **3D**EXPERIENCE platform, is a more practical and totally discreet way for patients to check their health status.

FEOPS

FEOPS: PLANNING AND CUSTOMIZING HEART INTERVENTIONS

FEops is a Belgian company that has developed, with the support of the **3D**EXPERIENCE Lab, the first and only patient-specific simulation technology for structural heart interventions. The solution accurately predicts how heart devices and implants will interact with a given patient. FEops also offers a unique pre-operative planning platform for structural heart interventions. This accessible, upgradable and automated platform uses artificial intelligence to help deliver better clinical results and make procedures more effective. Anatomical information about hundreds of real patients is accessible in the cloud; this eventually will provide a way of training medics and create an environment for clinical trials, along with a tool for modeling devices and implants using a diversified patient group.
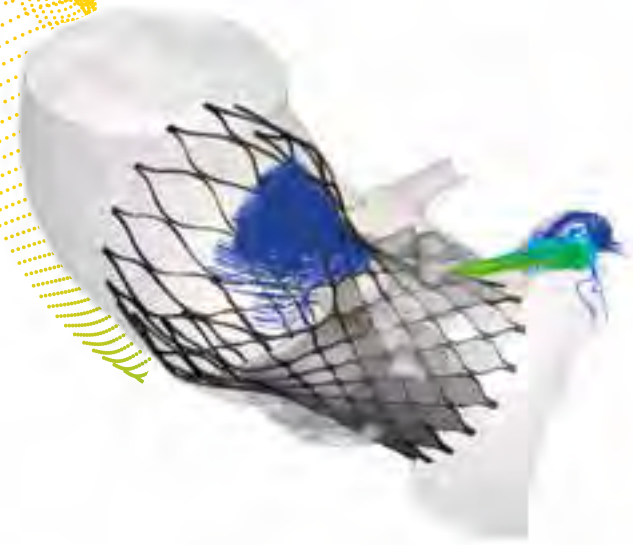
BIOSERENITY

A BETTER QUALITY OF LIFE

In June 2019, Dassault Systèmes strengthened its partnership with BioSerenity by taking an equity stake in the company. BioSerenity, founded in France in 2014 and already supported by the **3D**EXPERIENCE Lab, specializes in personalized healthcare. It is developing wearable devices comprising textile elements and discrete sensors that allow constant heart, epilepsy, urinary and sleep monitoring. As well as its medtech business, BioSerenity also analyzes signals, particularly biomarkers. Using science data, the company achieves an in-depth understanding of patients to devise a more customized care pathway through careful, responsible management of the data. BioSerenity also operates in the medical field as a provider of Healthcare as a Service (HaaS). Through its efforts, pathologies can be understood and treated on a more personal level, with unprecedented efficiency and at a reasonable cost. Dassault Systèmes is working in partnership with BioSerenity as it addresses all its challenges, particularly in terms of expanding its presence and adopting virtual twin technology to design the most effective and least invasive devices, to ensure that care pathways reflect the full diversity of their patients, and to personalize care in an affordable way.

A PROJECT TO SET A NEW STANDARD FOR INNOVATION

The Living Heart Project, which aims to simulate the human heart in 3D, was launched by Dassault Systèmes, in partnership with the US Food and Drug Administration, in 2014. The goal is to develop new testing paradigms for the insertion, placement and performance of cardiovascular devices. The five-year collaboration delivered on that goal and was extended for an additional five years in 2019, with a new target of using the Living Heart as a partial replacement for animal and human testing in clinical trials.

The project is supported by a global ecosystem, which has expanded to include more than 130 different organizations in 24 countries, representing pharmaceutical and medical device manufacturers, cardiologists, teachers, research organizations and regulatory agencies. Together, they are developing and validating high-precision, customized digital twins of the human heart, or "virtual clinics." They serve as a basis for *in silico* cardiovascular medicine,

teaching and training, medical device and drug design, clinical diagnostics and regulatory science, speeding up the translation of scientific innovation into improved care for patients. Conducting virtual clinical trials will not only make it possible to identify risks at an early stage, they also can define the effective patient population and provide synthetic control arms to reduce the need to recruit large groups of patients.

The same methodology is now being used for diagnosing and treating brain disorders and personalized orthopedic implants. Applying artificial intelligence and virtual reality technologies, the mysteries of the human body are becoming clearer. The world of medical innovation is changing forever.

HUGH HERR, BIONIC CLIMBER AND MIT PROFESSOR [1]

Expert climber Hugh Herr had both legs amputated at the knee after suffering severe frostbite following a winter climbing accident. He couldn't imagine life without climbing, and so he designed prosthetic legs that would allow him to pursue his passion. Each leg contains three miniature computers, 12 sensors and an actuator in the shape of a tendon, allowing him to dance, jump and, above all, climb again to the highest standard.

The system was designed with the help of SOLIDWORKS. But Hugh Herr wanted to go even further, from prosthetic to bionic limbs. A biophysicist by training, he is joint head of the Center for Extreme Bionics at MIT Media Lab, whose teams invented the AMI (Agonist-Antagonist Myoneural Interface). The principle consists of surgically stitching muscles together. When the agonist muscle is electrically stimulated, it contracts and pulls on its partner, the antagonist muscle. The muscle naturally contains biological sensors that detect this interplay and send a host of information to the central nervous system, and so the connection between the brain and the prosthetic limb is made. The system employs a pair of AMIs for each robotic joint. Synthetic proprioceptive sensors on each muscle measure their properties and send that information to the computers controlling the bionic limb. When users guide their phantom limbs using their brains, their muscles move dynamically and give the robot the order to move. The brain therefore controls the robot, and the muscles send information about the bionic limb's movements back to the brain. In this way, mechatronics and the nervous system become very deeply integrated.

Herr believes that this represents a major inflection point in history, in which designed objects can become an integral part of a human being's physical identity.

(1) Massachusetts Institute of Technology

> ❝ This represents a major inflection point in history, in which designed objects can become an integral part of a human being's physical identity. ❞

WE
ARE
WHERE...

HORIZONS
EXPAND

Because the future
of mobility lies
in designing and
developing new, more
energy efficient and
environmentally friendly
vehicles, because
we must invent new
ways of using transport,
we are there.

For decades, people saw cars as a way of adding a touch of glamor, liberty, chic and pizzazz to their everyday lives. Today, some people may be less enamored, and more likely to associate the automobile with particulate pollution, greenhouse gas emissions, traffic congestion and noise. To get back its mojo, the automotive industry needs to reinvent itself. The future will belong to greener mobility, hybrid and electric cars powered by smart technologies and delivering connected services. These faster, more precisely guided and safer vehicles need integrated platforms throughout the development cycle for design, testing and assessment of autonomous driving. At the same time, business models are shifting away from vehicle ownership, towards a pay-as-you-go approach. This highly disruptive change will save raw materials, energy and money, but change the industry. A whole new mobility ecosystem is taking shape, one that will transform the experience for drivers and passengers alike.

A car that likes people

Picking up the gauntlet of sustainable mobility, Canoo, a two-year-old company based in Los Angeles, has taken a different approach with its next-generation electric vehicles. Canoo's value proposition is built around users: design a car that likes people, rather than a car that people like. Using a common integrated platform (encompassing the chassis, the battery and its management system, the motor, brakes and shock absorbers) that is shared by all its vehicles, the company plans to develop a post-SUV vehicle specially designed for last-mile logistics and a self-driving shuttle.

Not only is Canoo's product revolutionary, its overall business model is, too. Canoo vehicles will not be sold, but rented using a highly flexible subscription plan that includes mileage, insurance and servicing and can be canceled at any time. With this pay-as-you-use concept, rather than full ownership, the business model shifts towards vehicle sharing and the car-as-a-service. The software industry has already shown that this approach can be successful: embracing the SaaS (Software as a Service) model increases value for both developers and users.

To achieve its goals, Canoo needs a unified data model, and the cloud-based **3D**EXPERIENCE platform provides it, with low entry costs and very rapid deployment times. The platform is always available and accessible by all of Canoo's business partners around the world. That includes designers, product analysts and supply chain managers. The user experience can be tested using virtual reality, creating a highly realistic environment.

What's more, the model can be used across the enterprise's entire ecosystem. And since the various vehicle components are manufactured in suppliers' factories, the cloud infrastructure is even more crucial.

A complete development process

Autonomy and electricity are the two major complementary trends that will shape the cars of the future. NIO, a global enterprise, has been designing and building a new generation of electric road cars that have been delivering superior performance and unique user experiences since the company was founded in 2014. The company's mission is that electric vehicles will simply become the natural choice for everyone, leading to a more sustainable tomorrow.

Right from the start, NIO was committed to expanding its global reach and needed a strong technology platform to support its growth and to orchestrate more than 10 development and manufacturing

FIA ADOPTS 3DEXPERIENCE

The FIA, the governing body for world motor sport, has decided to use the **3D**EXPERIENCE platform in the cloud so that it can interact more seamlessly with constructors competing in one of its World Championship. To improve and facilitate compliance checks on vehicles taking part in its events, the FIA's goal was to carry them out using CAD data. Since carmakers use different design systems, the data are provided in a neutral format that the **3D**EXPERIENCE platform can interpret.

## SPARKCHARGE, THE SOLUTION TO OVERCOME BATTERY FAILURE

Most regions of the world have good coverage with gas stations, reducing the risk of running out of gas. But it's a whole different ball game for electric vehicles. Rather than towing away an electric vehicle with a low battery, a roadside assistance service provider can now use SparkCharge's mobile charging unit. In less than 20 minutes, SparkCharge can recharge an electric vehicle that has run out of power sufficiently to get it back on the road and drive the last few kilometers to its destination. For this ground-breaking product, SparkCharge relied on Dassault Systèmes solutions to optimize every stage of design, engineering, prototyping, manufacturing and marketing.

GLOBAL CONNECTED CAR MARKET

17%
annual growth rate

US$63
billion in 2017

US$225
billion by 2025*
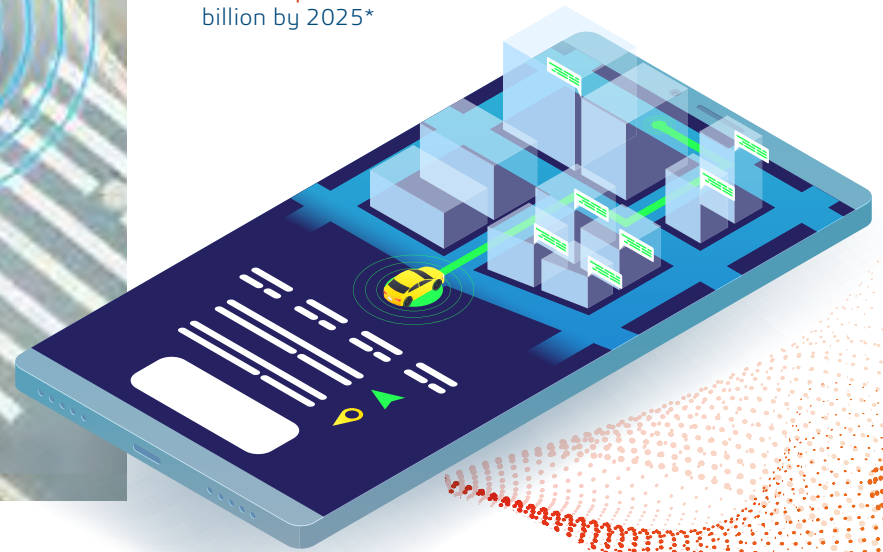
* Source: Allied Market Research.
The figures include technology (2G, 3G and 4G/LTE), connectivity solutions and services, such as driver assistance.

facilities, including in Shanghai, Beijing, San Jose (California), Munich and London. NIO selected **3D**EXPERIENCE as its enterprise R&D platform. Its engineers in China, Germany and the United States can perform development tasks collaboratively, despite the distance between them. They also gain rapid access to all vehicle data at any time, while checking integration and changes proposed by teams working on other sub-systems. Business partners and suppliers located in Sweden and India can also access the same data. What matters most to NIO is time to move from concept to product launch, staying ahead of the competition. With the ability for many teams to collaborate on the platform to quickly iterate product designs, NIO speeds up the entire development cycle; it only took NIO three years to develop a car from scratch in these conditions. NIO uses the platform to manage the entire product development process: definition, specifications, initial nomenclature, technical design in 3D and 2D, technical adjustments and shared functionality, as well as the interface with the downstream ERP information system. The continuous information flow carries through into manufacturing operations, including final assembly and logistics, via the virtual factory managed by the DELMIA solution.

Learning machines

Semi-autonomous vehicles have a bright future, and modeling their performance at every stage is crucial when engineering their cyber-systems, which will determine decision-making and interactions with their environment. Cars need to travel billions of kilometers *virtually* before they can be considered safe.

Autonomous connected vehicles are machines that can learn. They learn about their passengers and their environment – like roads, traffic systems and other vehicles – by using their sensors and software. Intelligent systems connected by the cloud enable new services such as journey sharing, giving the mobility ecosystem the chance to grow and diversify its business. Smart mobility requires a great deal of data to fuel new services, all of them powered by high-performance computing. 5G technology can potentially deliver the coverage, speed and latency that mobility systems require to achieve appropriate levels of responsiveness and, thus, safety.

Semiconductor companies have a key role to play in this value chain and are now working hand in hand with carmakers to produce reliable vehicles. As systems become more complex, innovation platforms help systems architects simplify project management, while ensuring end-to-end traceability and reducing development risk, time and costs.

Each stage in a project can now be effectively evaluated, from the original system requirements through to the detailed hardware and software delivered in the vehicle. Manufacturers are using virtual models and simulation to run hundreds of virtual tests. These virtual prototypes are capable of replacing costly physical testing and enabling design and engineering teams to analyze all of the electromagnetic, fluids and structural physics to achieve the overall optimal design, faster. A shared platform helps all stakeholders to detect and remedy inconsistencies and issues, and meet required quality and safety standards.

With vehicles providing growing levels of autonomy, quality and compliance are key challenges that the **3D**EXPERIENCE platform helps to meet.

The **3D**EXPERIENCE platform of Dassault Systèmes, and the integration of CST Studio Suite electromagnetic simulation technology on the platform, is a huge step toward improving communication between design and engineering teams. Modeling and simulation on the platform facilitate true multiphysics-based design. When you have up-to-date information, a single model and access to the right combination of tools, you can collaboratively perform virtual testing to optimize antennas for mechanical, thermal and, yes, even electromagnetic performance, simultaneously.

Marc Rutschlin
Strategic Planning Specialist, High-Tech Industry, SIMULIA brand of Dassault Systèmes

A new kind of flying machine

Helping people get around cities is a challenge for manufacturers interested in urban air mobility. Growing urban populations and the increasing size of cities around the world will inevitably cause traffic congestion problems. One solution is to develop safe, affordable, and accessible air travel in the urban context. Bell has developed the Nexus 4EX, a four-rotor all-electric air taxi with a range of around 100 km (60 miles), designed for use in cities. One of the challenges facing Bell is to gain regulatory authorization for this new type of urban flying machine, which needs to integrate and interconnect with a dense transport system.

Infrastructure is another issue: landing areas, for example on the rooftops of buildings, will also need to be certified for a specific category of aircraft.

As a result, manufacturers must work with politicians, local government teams and urban planners to help define the infrastructure required to develop urban air mobility. Gaining acceptance among the public will be another significant challenge. Although Bell's eventual aim is for the Nexus to be fully autonomous, a pilot will be required in the early days to gain the public's trust. Bell is more than just an aerospace company; it wants to be a provider of mobility services that form an integral part of a comprehensive, multimodal urban transport ecosystem.

By developing its Bell AerOS cloud-based solution, the company will be able to respond rapidly to the needs of city-dwellers by managing the maintenance, monitoring vehicle health, and scheduling the fleet. Bell is a long-standing user of Dassault Systèmes' solutions and technology, which play a key role when it is designing, developing and making its innovative products. As well as design solutions, simulation is now a vital tool for Bell; it is crucial for modeling the system of systems that is urban mobility, and for showing partners, urban planners and local politicians what it will look like in the future. It is an essential tool for communicating ideas and getting others to buy into them.

❝ As well as design solutions, simulation is now a vital tool for Bell; it is crucial for modeling the system of systems that is urban mobility, and for showing partners, urban planners and local politicians what it will look like in the future.

NEXUS 4EX
4 electrically powered rotors
Capacity: 5 passengers
(in autonomous flight mode)
Range: 97 km (60 miles)
Mass: 3,175 kg (7,000 lbs)
Cruising speed:
241 km/h (150 mph)
Maximum footprint:
12 m x 12 m (40 ft x 40 ft)

" The space industry has long remained a niche market, but is seeing an industrial renaissance similar to that of civil aviation, an industry in which Dassault Systèmes started, won its first customers and has undisputed credibility. In the space industry, as in aviation, product complexity must be managed over the long term: a satellite remains in orbit for around 15 years and cannot be brought back to Earth for modification. As a result, it's vital to define concepts in advance, and to be able to assess all design alternatives and then adjust the parameters of the initial brief. So we need to address the additional engineering requirements and adjust production systems at the same time. Since the satellite market is growing very rapidly, particularly for mega-constellations, we are moving from a cottage industry to mass production.

In 10 years' time there will be 50,000 satellites in orbit, 10 times the figure today. Earth itself, and all the journeys taking place on it, along with all connected objects, will be constantly monitored. Space will complement 5G technology. An autonomous car will use 5G in town, but will need satellites in areas with no 5G coverage. This is a major change that requires a new paradigm, and not just in the space industry. As well as the skills to develop and build a constellation of satellites, you now need to be able to model and simulate the behavior of an aircraft, car or boat within the ecosystem (a system of systems), particularly for communication purposes. You need to not only define the functional architecture of that system of systems, but also show that it works. Whether you're talking about air traffic control, autonomous driving or urban mobility, fundamental changes are happening. Our technology, particularly that which based on CATIA Cybersystems, is up to the challenge. "

David Ziegler
Vice President,
Aerospace & Defense Industry,
Dassault Systèmes
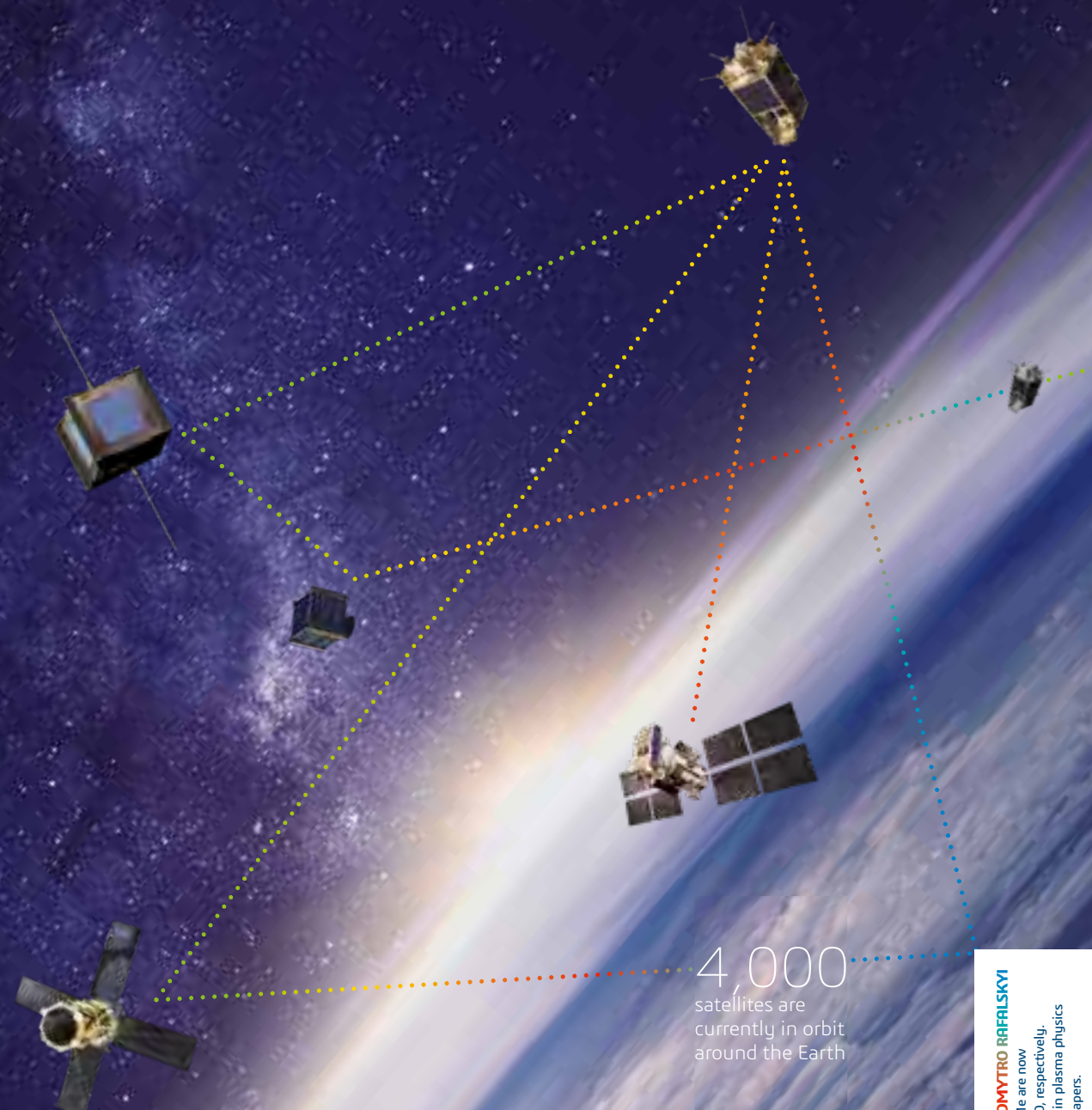
4,000
satellites are
currently in orbit
around the Earth

From 10,000 to
50,000
satellites are expected
to be launched
in the next 10 years

ANE AANESLAND AND DMYTRO RAFALSKYI
The co-founders of ThrustMe are now the company's CEO and CTO, respectively. Both have doctoral degrees in plasma physics and have published many papers.

Improving the life and capabilities of satellites
ThrustMe is once again going in an innovative direction compared to the rest of the space industry, and could be showing the way forward. Co-founded in France by Ane Aanesland – who obtained her doctoral degree in plasma physics from the Arctic University of Norway, the world's most northerly university – this startup now employs around 20 people of 14 nationalities, of whom 30% are women. ThrustMe's employees include specialists in diverse disciplines – from plasma physics and aerospace engineering to analog and digital electronics, chemistry, fluid dynamics – and they have solid simulation and experimentation skills, combining the two approaches in order to test prototype systems quickly in their laboratory. Particles in cell and fluid simulations, together with thermal, vibration and impact simulations, are carried out before and during experimental testing.

ThrustMe is a response to market demand for small satellites that can be organized into constellations ranging from the tens to the hundreds and even the thousands of units. The satellites, which have a low orbit just above 300 km (186 miles) above the Earth, last for only a few months before a natural decay. ThrustMe's aim is to extend their lifespan by giving them propulsive drag compensation; or, for those that have higher orbits, to ensure that they de-orbit after the mission.

More sophisticated missions require significant orbital changes, phasing or inclination changes. For any of these maneuvers in space, propulsion is primordial. ThrustMe's breakthrough innovations lay in the use of solid propellant for propulsion systems that classically use pressurized gases. It marries traditional space technologies with new, innovative solutions to address the market need for smaller, yet high-performing and safe, systems.

SIMULATION **IS PROPELLING INNOVATION**

Spacecraft, satellites and planetary exploration vehicles are complex systems in which there is no room for error. Since testing opportunities are limited, precise virtual simulations are needed to ensure that a product can do its job throughout its lifetime. To predict accurately how a system will respond, companies need to simulate interactions between various physical models using the principles of aerodynamics, electromagnetism and solid mechanics, combined with dynamic, thermo-structural, kinetic, noise, vibration and docking analyses. Dassault Systèmes brings this all together by integrating 3D modeling and SIMULIA multiphysics simulation on the **3D**EXPERIENCE platform, allowing the collaborative development of advanced space systems.

WE
ARE
WHERE…

SUSTAINABILITY TAKES ROOT

Because our planet is
sending distress signals,
because the idea of
a more sustainable form
of development is starting
to take hold, because
we need more imagination
and innovation in our
sciences, standard
practices and business
models, we are there.

Inventing new ways of producing and consuming is vitally important. Currently, manufacturers focus on efficiency, but their attention is shifting towards sustainability. Producers that fail to align themselves with sustainability objectives will find that their products and services fall below their customers' expectations, and they will struggle to find a market for them.

By testing ideas, products and experiences virtually before offering them in the real world, producers can find new, respectful ways of operating. In this way, virtual universes are catalysts for change, connecting and contextualizing the exponentially growing volume of data. Only the digital world provides a suitable platform for the observations and decisions needed to devise new methods of production. Therefore, using virtual technology increases efficiency in the real world.

Sustainable manufacturing Hackathon
To demonstrate the power of virtual worlds to make manufacturing more sustainable, 20 students from around the world and from various academic disciplines came together for the first-ever Dassault Systèmes Hackathon focused on sustainable manufacturing solutions.

Four teams with five students each used the **3D**EXPERIENCE platform; they worked, innovated and collaborated intensively over 48 hours before presenting and discussing the fruits of their labor. The yellow team focused on recycling plastic waste found in ocean gyres. Their concept was for autonomous boats to collect the plastic, which would be recycled to build houses using additive manufacturing. The recovered plastic also would be used to make water collection systems: plastic nets resembling spider webs would be used to condense morning mists into water droplets. The green team designed a "sunflower-factory" in which nature and technology would work in synergy.

This factory of the future would use biomimetics – using elements of nature to solve complex human problems – to adapt to its environment. Like a sunflower, the factory would absorb sunlight and blend in with nature, a self-sufficient ecosystem powered by its environment. The blue team's main goal was to create a healthy environment within a factory. With large windows and solar panels on the rooftop, the factory would contain green spaces in which employees could relax. Its second aim was intelligent resource synchronization: process sequencing, self-guided vehicles, automatic storage and retrieval systems, and robots that collaborate with humans. The red team, which won the Hackathon, proposed a way in which various companies in the same area could collaborate and share resources. Employee well-being would be improved through access to a nursery and fitness center, as part of a post-modern industrial complex. The approach would also enhance the manufacturing process itself through the sharing of skills and the pooling of certain technical services. By integrating the supply chain, carrying out joint operations, and sharing logistics facilities, storage costs could be reduced and production capacity increased.

Less waste for the planet and its inhabitants
Amcor has more than 35,000 employees across
200 production sites worldwide. This 150-year-old
company designs and manufactures a wide variety
of packaging for the food and beverage industry,
healthcare, homewares and personal care industries.
As one of the leading manufacturers of plastic
containers, Amcor is continually seeking ways to
reduce the amount of material used in bottles, while
keeping them strong and cost-effective to produce.

Throughout the process of designing a container,
engineers use simulation to identify areas of strain,
which indicate potential points of failure, helping
them create lightweight, optimized designs. Reducing
the amount of material by one gram or even half
a gram in each of the billions of containers that
Amcor and its customers produce annually represents
considerable cumulative savings. Amcor's customers
enjoy lower production and transportation costs and
reduced risk of product failure, while the planet
and its inhabitants benefit from less waste in landfills.
When designing its products, Amcor Rigid Plastic's
R&D teams use advanced digital engineering
techniques enabled with CATIA, SIMULIA Abaqus
and other Dassault Systèmes solutions, allowing them
to move from concept to production in the space of just
a few months.

Before

After
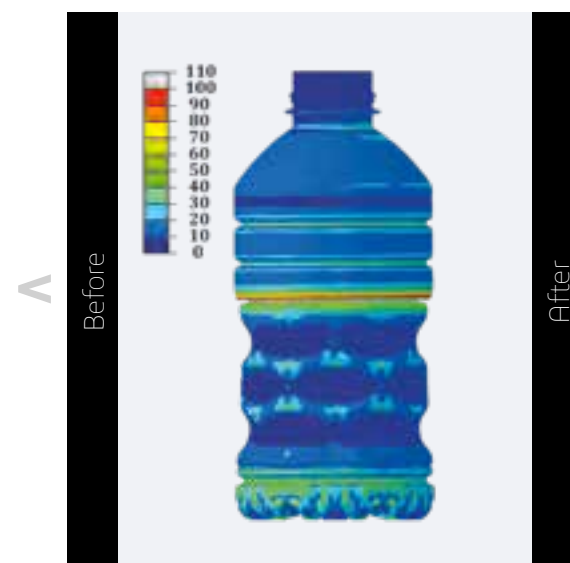
ARTIFICIAL INTELLIGENCE
SUPPORTING SUSTAINABLE MANUFACTURING

To help clients hit their sustainability targets by using AI
to transform their manufacturing activities, Dassault Systèmes
has adopted an approach based on the "three Ps" of sustainability:
people, planet and profit. Concerning people, to train future
generations, we need to transfer knowledge and expertise from
today's employees and devise technology to create experiences
that foster innovation, to build a more sustainable future.
Companies need to adapt to digital technology and make their
employees more autonomous. This goal can be achieved using
multidisciplinary lifelong learning approaches, combining
classroom study and practical work. With AI, augmented reality,
and virtual reality, knowledge can be imparted more quickly
and at the right time, making learning more intuitive.

Greater overall operational efficiency is good for the planet,
the second P. By implementing lean practices throughout a
product's lifecycle, companies can minimize their environmental
footprint. The aim is to assess, streamline and improve all
operations: product design, engineering, the production process
and the supply chain. Eliminating waste, unnecessary product
movements, overstocking, errors and quality problems requires AI
that is capable of learning. This technology is also proving its worth
by reducing energy consumption: for example, smart grids that
connect producers with consumers and predict consumption peaks
help to optimize operations in real time. The third P – profit –
involves replacing supply chains with global value networks
in which industrial partners join forces, redefining the way
they contribute to attaining common goals. AI-based collaborative
digital platforms allow companies to deliver sustainable, unique
and outstanding experiences. AI systems can process data
at lightning speed, assessing millions of potential scenarios.
They allow companies to coordinate all of their stakeholders
in a more efficient and agile way. Thus, companies can capture,
standardize and analyze data to assess the environmental
and social impacts of a given commercial activity, and define
the key issues to ensure informed decision-making.

Morgan Zimmermann
CEO of NETVIBES-EXALEAD,
a brand of Dassault Systèmes

18%
Reducing weight
from 44 grams
to 36 grams

US$15.7
billion (€14.7 billion):
the potential contribution
of AI by 2030,
according to PwC

Protecting fauna and flora

French startup XSun is designing and developing an energy-independent solar drone system that can make its own decisions. Its first product is revolutionary: a drone with double wings that are not stacked, as in a biplane, but arranged side by side to increase the surface area for photovoltaic cells and ensure optimal flight performance. Boosted by support from the **3D**EXPERIENCE Lab, XSun adopted the **3D**EXPERIENCE platform on the cloud, allowing its teams to collaborate effectively when designing, simulating and testing the drone. This flying machine has potential applications in numerous areas; land and sea observation, protection of fauna and flora, monitoring of atmospheric pollutants, defense and security applications as part of border and maritime surveillance, and checks on linear infrastructure, including roads and oil and gas pipelines.

XSun's main challenge is to optimize a complex system and find the best trade-offs in terms of structural requirements, footprint, position and internal volume.

Inevitably, assessing these constraints involves a large amount of cross-discipline work and requires digital collaboration, design and simulation tools. The platform makes it possible to analyze how the drone's aerodynamics are affected when one of its elements is adjusted. Because the **3D**EXPERIENCE platform enables XSun's engineers to perform the full set of simulations as soon as the overall design is ready, they can quickly see how different design options affect the whole in structural and spatial terms.
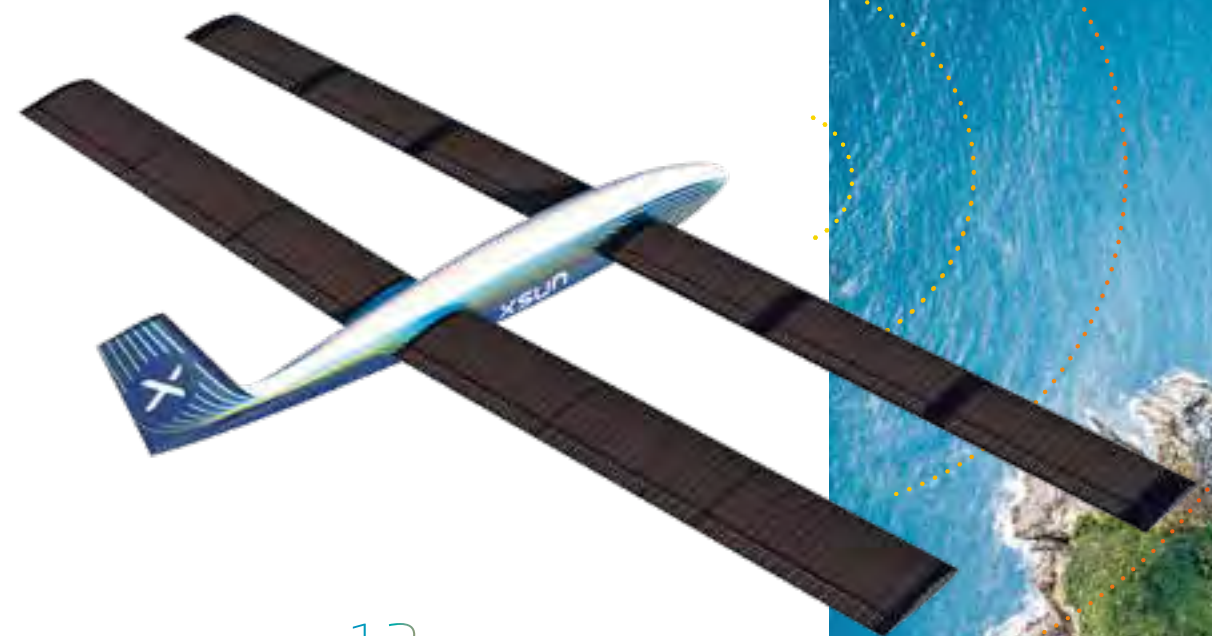
12
hour flight time for the SolarXOne drone, rising to 20 hours depending on the time of take-off

The changing role of engineers in the energy sector

Cross-discipline communication also is accelerating in the nuclear industry. To support the industry's transformation, Électricité de France (EDF) established the Switch program, to streamline and coordinate the design, construction, maintenance and decommissioning of a power plant.

Throughout a plant's lifecycle, the program allows millions of pieces of data to be organized, shared and used by all industry participants in a simple and safe way, optimizing, harmonizing and digitalizing all engineering processes. Virtual twins will exist alongside each power plant. Switch will also integrate data that is reliable, secure and available in real time.

With these new, digital capabilities, new, more dynamic work methods are appearing. The entire industry is in flux and reinventing itself around digital technology to become more efficient, competitive and collaborative. As a result, the role of the engineer is changing. To accelerate this transformation, EDF has chosen the **3D**EXPERIENCE platform as its operating model.

> Transforming our business involves interacting with our ecosystem, i.e. with all of the actors: industrialists, experts, and engineers… who work with us. We want to rethink our processes, the way we do things and the way we interact around the virtual twin of our equipment/plant.

Bruno Lièvre
Head of the Switch digital transformation program, EDF

Participants in the blue economy take action

In December 2019, as part of the 15th "Assises de l'économie de la mer" (economy of the sea conference), participants in the maritime industry launched a coalition in favor of ecological and energy transition, strongly encouraged by French President Emmanuel Macron and supported in his opening address to the conference. Frédéric Moncany de Saint-Aignan, chairman of the French Maritime Cluster behind the initiative – which is being led in partnership with ADEME (French environment and energy conservation agency) – formally announced the coalition, of which Dassault Systèmes is a founding partner: "Participants in the blue economy are today announcing a Coalition to speed up the maritime industry's ecological and energy transition. From 2020, a digital platform will allow partners to work together in order to develop solutions more quickly and deploy them widely […] making the French maritime industry a leading player in social responsibility and ecological transition."

The Coalition will initially produce an overview, which is currently lacking, of objectives, needs, technologies, participants and key data, and create an IT system to help with decision-making. This will allow the cluster's partners and all members of its ecosystem to work on maritime energy-use models, based on ambitious industrial projects and common R&D programs aimed at protecting human health and biodiversity and combating climate change. By involving the whole value chain and other sectors of the economy, these much-needed paradigm shifts and the solutions identified will transform the marine industry, ensuring that its products and activities are in harmony with nature and life. This ambition fits with that of Dassault Systèmes, which wants to contribute and put the **3D**EXPERIENCE platform at the heart of the work done by the Coalition, of which it is a member alongside many of its customers including Bureau Veritas, EDF and Naval Group.

Alexandre Tew Kaï, Vice President Marine & Offshore at Dassault Systèmes, said: "Improving collaboration between all industry players – from various sectors such as maritime, logistics, energy and insurance – is vital in enabling the Coalition to share the same view of existing data and to identify, validate and develop solutions together. Dassault Systèmes is working alongside the Coalition's members to accelerate those synergies by making the **3D**EXPERIENCE platform available to them. The platform allows users to organize working groups and deliverables, manage schedules efficiently and guide decisions using data and data analysis techniques based on a single, common database, along with virtual twins that will allow the Coalition to test its scenarios. Dassault Systèmes is also contributing its experience and ability to mobilize expertise and know-how in 11 different industries (including automotive and aerospace but also life sciences), allowing the Coalition to draw inspiration from current best practices in those industries. Finally, we want to raise France's international profile, particularly with respect to the United Nations, which is preparing a declaration on energy transition in the maritime industry, and in the work being jointly led by the Global Maritime Forum and the World Economic Forum through the "Getting to Zero Coalition", with which the Coalition has signed a partnership agreement."

LA FONDATION DASSAULT SYSTÈMES: COMMITTED TO THE OCEAN

La Fondation Dassault Systèmes is working with France's Ministry of Education, Onisep, Canopé and Ifremer (France's national institute for ocean science) on the Mission Océan project, an educational experience for high school students that uses 3D and virtual reality technology. The project was launched in 2019 in southern France, and will be rolled out across the country in 2021 to coincide with the start of the United Nations Decade for Ocean Sciences.

The aim is to enable students to discover the oceans, explore potential careers, use the expertise of industry and research professionals and devise projects that help protect the oceans.

Mission Océan will give students an alternative way of learning, using new methods made possible by 3D and virtual technology, that allows them to discover their own power to influence the environment and encourages them to think about their future education and careers.

LIST OF PARTNERS

Companies: Bureau Veritas | CMA CGM | Dassault Systèmes | EDF | Enedis | Engie | Naval Group | RTE | Soper | Total

Associations and federations: Association française pour l'hydrogène et les piles à combustible | Armateurs de France | Club Croisière de Marseille | Fédération française des pilotes maritimes | France Filière Pêche | Groupement des Industries de Construction et Activités navales | Association française du Gaz – Plateforme GNL | Union française de l'Électricité | Union nationale des industries de la manutention portuaire | Union des Ports de France

Research institutes: CEA | CNES | Ifremer | Météo France | Shom

Business clusters: Pôle Mer Bretagne Atlantique & Pôle Mer Méditerranée

Partner and joint leader of the project: Ecosys Group
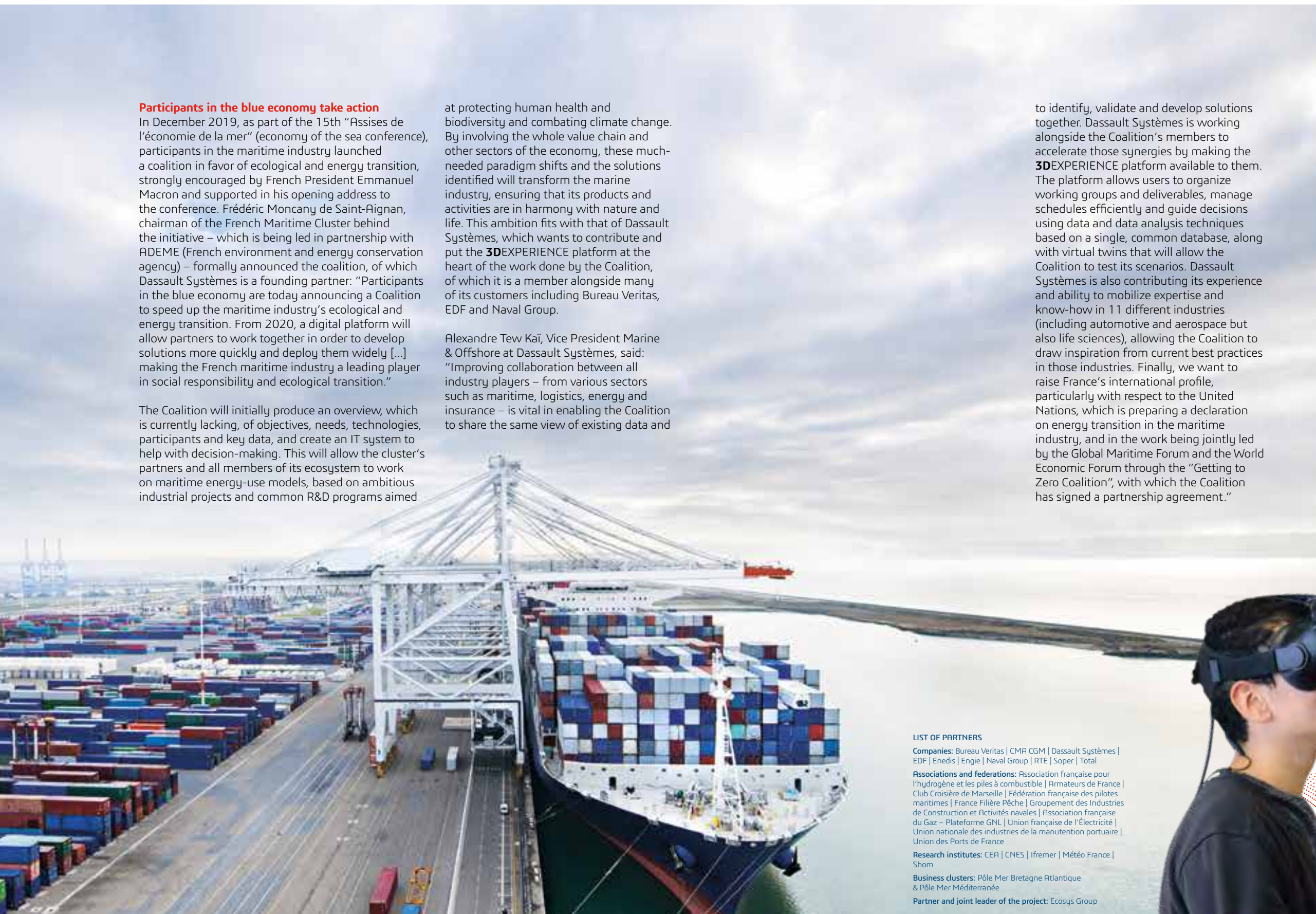
Industrial groups innovating with the first 3D classification process

Bureau Veritas, Naval Group and Dassault Systèmes have joined forces to invent 3D classification, based on the **3D**EXPERIENCE platform. The aim is to reduce the time and cost involved in reviewing new vessel designs and to improve data accuracy and traceability using digital continuity. To ensure that vessels comply with safety and environmental regulations before they take to the water, their designs and production facilities are tested, inspected and certified by independent classification companies such as Bureau Veritas, the world leader in this area.

To improve on the standard vessel classification process, which is based on 2D plans, Bureau Veritas, Naval Group and Dassault Systèmes decided to find innovative ways of collaborating in order to become more competitive in their respective areas. This resulted in them being the first to apply a 3D classification process to a top-level military vessel – a defense and intervention frigate – for the French Navy. The process was developed using the **3D**EXPERIENCE platform, and uses a single 3D model that allows digital information to be exchanged, improves collaboration and reduces the number of iterations needed in the design review process in order to achieve classification. All comments and iterations can be tracked, taken into account and revised in real time.

A major step forward

The collaborative project combines the expertise of Bureau Veritas in ship classification, of Naval Group in designing and building military vessels at the leading edge of technology, and of Dassault Systèmes in 3D design software, 3D digital mock-up solutions and lifecycle management. The 3D model integrates completely with the Bureau Veritas suite of modeling and calculation software. The collaboration represents a major step forward in modeling in relation to the ship classification calculations performed during naval defense design and construction, and in the marine industry's digital transformation.

THE PARTNERS

• **Naval Group** is a leading European player in naval defense. It designs, produces and maintains surface ships and submarines for the navies of France and other countries.
• **Bureau Veritas** is a world leader in testing, inspection and certification services, employing 77,000 people in more than 1,500 offices and laboratories across the globe. Bureau Veritas helps its clients improve their performance by offering innovative solutions to ensure that their assets, products, infrastructure and processes comply with standards and regulations.

EMOTIONS
ARE CREATED

Because we are going through a revolution that requires us to look beyond functional and technical aspects, because the virtual twin experience allows us to understand and take action more quickly, respectfully and collaboratively, we are there.

For Patrick Jouin, complex shapes suggested technology can produce a burst of emotion. The French designer has developed a new foldable chair concept, Tamu, that is light and 3D-printed. Anne Asensio, Vice President of Design Experience at Dassault Systèmes, interviews Jouin.

THE TAMU CHAIR, OR THE ART OF FOLDING

_ Anne Asensio: When faced with new technologies, designers are sometimes reluctant to change their habits, to "let go," and the idea of relearning everything they thought they knew is hard for them to accept. You're not one of them.

_ Patrick Jouin: That's right, because when I realized the possibilities of 3D printing, it opened up a world of opportunity for me. Once you start down that path, there's no going back. When we made our first 3D-modeled chair using SOLIDWORKS, we were amazed, even though there was no generative design at the time.

_ A. A.: When we first met, some time after you made that first chair, I suggested you try combining concept development, design and simulation within the **3D**EXPERIENCE platform, which includes generative design. How did it go for you?

_ P. J.: At the start of the Tamu project, there was just a sketch and the idea that the chair should fold, like a piece of origami. Next came the idea of a fabric or skin that we could fold so that it wouldn't take up space. At the same time, we had to ensure the chair's tensegrity so that it would stand up. The machine-driven process also factors in the weight of the person sitting on the chair.

_ A. A.: Actually, there is no machine, just people operating the software. This is another area in which you had to break away from your usual practices: accepting that others could come up with new solutions to meet your requirements, for example, by taking a scientific approach. That inclusive process, combining man and machine and adding a community component, is new. It's a form of collaboration that could herald a new era, a new style, a new language.

_ P. J.: The idea of combining form and function also seems key to me. By using a very light mesh, we made the chair highly ergonomic and comfortable to sit on, because it molds to the body. We used an optimization system so that the chair was as transparent and light as possible. We were able to generate a material that was impossible to model a few years ago. It used to be too complex; we could imagine it but not make it real. That's all changed now. We are also using all of this software-based intelligence to improve the way the chair is made, from selecting the material to 3D printing. The approach involves a complex triangular system. The result is an expression of the software's hidden beauty. When we devised the concept for this chair, we built on thousands of years of human intelligence. Every time I put my pencil on a sheet of paper, I'm perpetuating that intelligence, like all designers do.

We can now generate a material that was impossible to model a few years ago. It used to be too complex; we could imagine it but not make it real. That's all changed now.

During Milan Design Week 2019, Morphosis Architects created an immersive installation.

MORPHOSIS
MATERIAL
METAMORPHOSIS

The installation used projection and augmented reality to provide insight into how the firm approached design problems with advanced software platforms. One of the best opportunities for use of this technology is in the development of complex façade systems. The façade panels that Morphosis employs in many of its designs are perfectly controlled to conserve material costs, balance shading and views, and allow for easy constructability. In the installation, the firm also carefully designed the panels for the projections to create a unique viewing experience; the rotating panels produced random alignments, and people become key participants in the installation by interacting with it, giving it meaning and making it desirable.

Three projects and three geometric systems were presented: the modular pre-cast concrete façade of the Perot Museum of Nature and Science (Dallas), the fiber-reinforced polymer brise-soleil units of the Kolon One & Only Tower (Seoul), and the iridescent, robotically punched anodized façade of the Bloomberg Center (New York City). The installation as a whole aimed to help people understand the way that data, concept and technology work together at different levels to achieve the goals of a project.

Architecture is a discipline that is now shifting into a much more virtual space: when Morphosis designs a building, it spends several months developing a virtual model, virtual systems and virtual mockups that can be subject to tests and simulations to observe how the building will perform when built. Virtual and augmented reality are used to explore users' experience as they interact with the future space, not just on a screen but in a simulation of the space itself. The firm's model shows how digital tools can factor in the way in which people experience geometry, moving from the virtual to the physical. The installation also looks at how materials interact, how research can be used to address the constraints of a project and how the younger generation of architects is making a difference.

MORPHOSIS, PLAYING WITH GRAVITY

Morphosis Architects was founded by Thom Mayne in 1972. The firm's work is known as much for its highly sustainable buildings as for complex architectural forms – twisting, constraining, moving, shifting and disrupting components in a building in order to produce a kind of architecture that fights against gravity or plays with it, instead of simply submitting to it. Fractured spaces, oblique walls and architectural elements that appear suspended are common features of its work, which can be found in the Americas, Europe and Asia. Thom Mayne received the Pritzker Prize, the world's greatest distinction in architecture, in 2005.

Permanent dialogue
Morphosis Architects has a team of 70 people, including architects, designers and advanced technology specialists, as well as an in-house fabrication workshop called X-Tech that works with the Morphosis team to develop prototypes, test materials and undertake smaller-scale fabrication jobs. They operate a small manufacturing facility with both digital and analog production equipment, and they support all of the firm's design teams.

The research studio also is involved in prototyping and studying materials. It recently worked with a tile manufacturer to make a series of geometric tiles, designed using CATIA, which were then prototyped by a manufacturer in the United States. Morphosis is interested in pushing back the limitations of materials, working closely with its suppliers.

There is a permanent dialogue between designers and manufacturers. The process involves many iterations between digital design, modeling and simulation, and a continuous dialogue between design teams, researchers and suppliers. In the same way, virtual simulation and testing with a 3D printer – a technology that the firm first adopted in 1999 – are combined. The firm now is employing these innovations in the curving ceramic façade of the Orange County Museum of Art, currently under construction in Costa Mesa, California.

The next generation of architects
The Morphosis team consists of people from all over the world. The firm employs many interns and has a facility that provides training in both architecture and production, based on its view that the fabrication process cannot be separated from the design process. Many members of the team, including the firm's founder Thom Mayne, also hold teaching positions at nearby architecture colleges, and the firm as a whole is committed to working with universities to bring through the next generation of architects. In a recent one-day workshop led by Morphosis Director of Design Technology Kerenza Harris, students were tasked to design the first city on the planet Mars, using many CATIA tools including the Imagine & Shape solution. Students could play around with the city's design on various scales, and think about the city as a system of smaller components. They also created a narrative as well as virtual and augmented reality visualizations to share their ideas.

German household appliance group Miele's Design Center is in charge of the group's user and brand experience: it seeks to design the best experience and product design for its customers as well as enhance the way they interact with its products.

VIRTUAL DIAMONDS ARE FOREVER

Once cut, diamonds are the essence of purity. But getting them out of the ground involves the same noise, dust and risk of accidents as those found in any other mine, whether underground or open-pit.

This is why Debswana – a joint venture between De Beers and the government of Botswana, the world's largest diamond producer – wanted to offer visitors a realistic virtual tour of its Jwaneng mine and associated processing plant. Virtual tours avoid the issues that arise with real-world tours, which require adjusted safety rules in the presence of visitors, a one hour visitor safety briefing, attendance by engineers to provide explanations, 3-4 hours of walking in a hot, noisy and dusty environment and, although controlled, the real risks associated with any industrial site or mine. The 3DEXCITE solution, based on the **3D**EXPERIENCE platform, allows Debswana to design virtual tours, maintaining a sense of the mine's huge scale while also educating visitors about its processes and facilities.

The virtual 3D tour is an enhanced interactive experience: visitors can move around the mine and learn detailed information about the mining process. The 3D rendering produces a simplified visual presentation, making the process easier to understand by removing unimportant details.

The experience starts with a bird's-eye view of the processing plant in operation, and visitors then can explore each building in detail. By selecting a building, the visitor can zoom in and see what is happening inside, with a particular focus on the machinery. Visitors can find out contextual information about each machine, and sectional views are available for some machines. An immersive 360° video experience also gives an idea of the mine's sheer scale. During the tour, visitors can select various video sequences to make them feel like they are actually present within this world, with each scene – featuring spatial audio effects – depicting different situations. Huge vehicles, enormous machines and spectacular blasting operations give visitors a genuine feel for how a mine works, without the drawbacks or risks. Debswana also is planning to upgrade and reuse the initial model to train its staff and to carry out real-time supervision of the plant and mine.
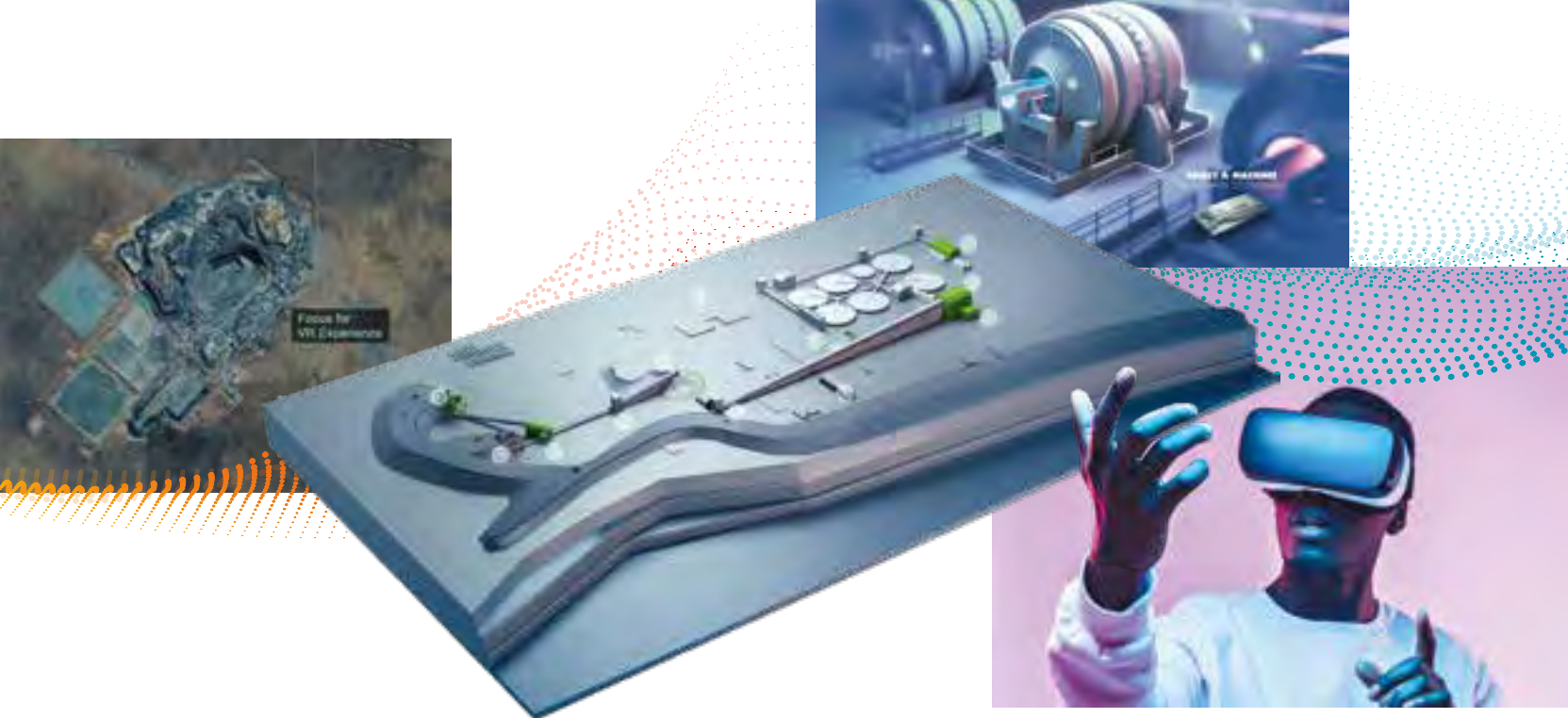
A BRIDGE BETWEEN SYSTEMS ENGINEERING AND CREATIVE DESIGN

When Miele, the manufacturer of premium domestic appliances, wanted to review and extend its traditional product design methods to incorporate experience design, it used Dassault Systèmes' Design Studio to transform the process of creating the Miele experience. Creating a brand experience consists of defining and developing the user's experience of the brand's products within their natural environment: the household itself. This could not be replaced by a laboratory or a test stand. Today, the desired experience and services are defined using a "design thinking" method. This involves producing usage scenarios taking various visual forms that can be shared with others, such as storyboards and animated films, to forge agreement among the project's stakeholders.

However, producing these media and adjusting them for each iteration of the project is very time-consuming. In addition, they are not interactive and so do not allow all usage variants to be tested during project reviews or user testing. The aim is to adopt new tools in the upstream discussion phase and to transform the process by designing the experience using virtual 3D systems like those used in product design.

A project to demonstrate this new approach to experience design focused on a Miele robot vacuum. Today, when developing a product, it is possible to define the product experience and create virtual prototypes, or digital twins, factoring in the product's services, behavior and interactions to limit the risk of errors, facilitate decision-making and reduce costs.

❝ That's the first time we bring things out of the virtual environment directly to the real user to interact with.

**Andreas Enslin**
Miele Design Center Director
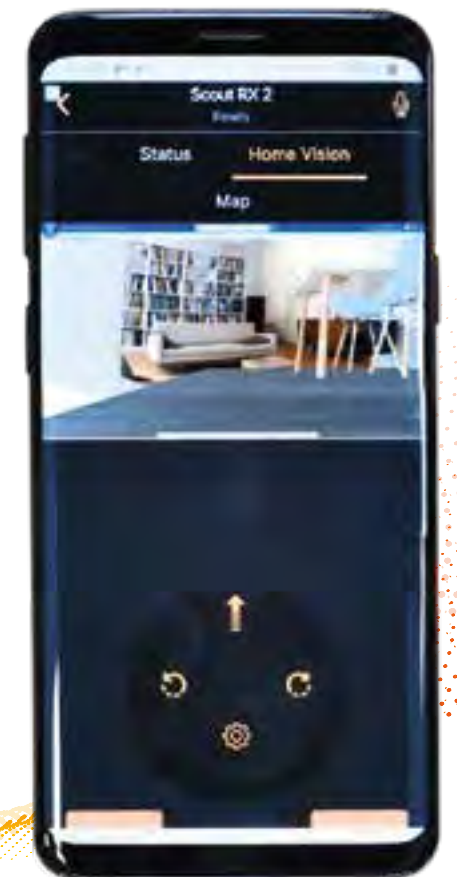
Sunreef Yachts' high-end catamarans are created for demanding clients who expect the highest standards of design, safety and luxury.

Its customized yachts combine bold design, energy efficiency, reliability and high performance. The company uses SOLIDWORKS to create the entire design and SIMULIA XFlow to simulate and check the boats' seaworthiness before the design is finalized. SIMULIA XFlow tests the yacht's aerodynamics and hydrodynamics, allowing the designers to calculate the power required to propel it at different speeds and in various sea conditions; this determines the engine, propeller and sail design.

New, unconventional shapes can be created and simulated, unleashing the marine architects' powers of innovation. They can test unusual hull designs and various stabilizing methods to generate a whole new aesthetic.
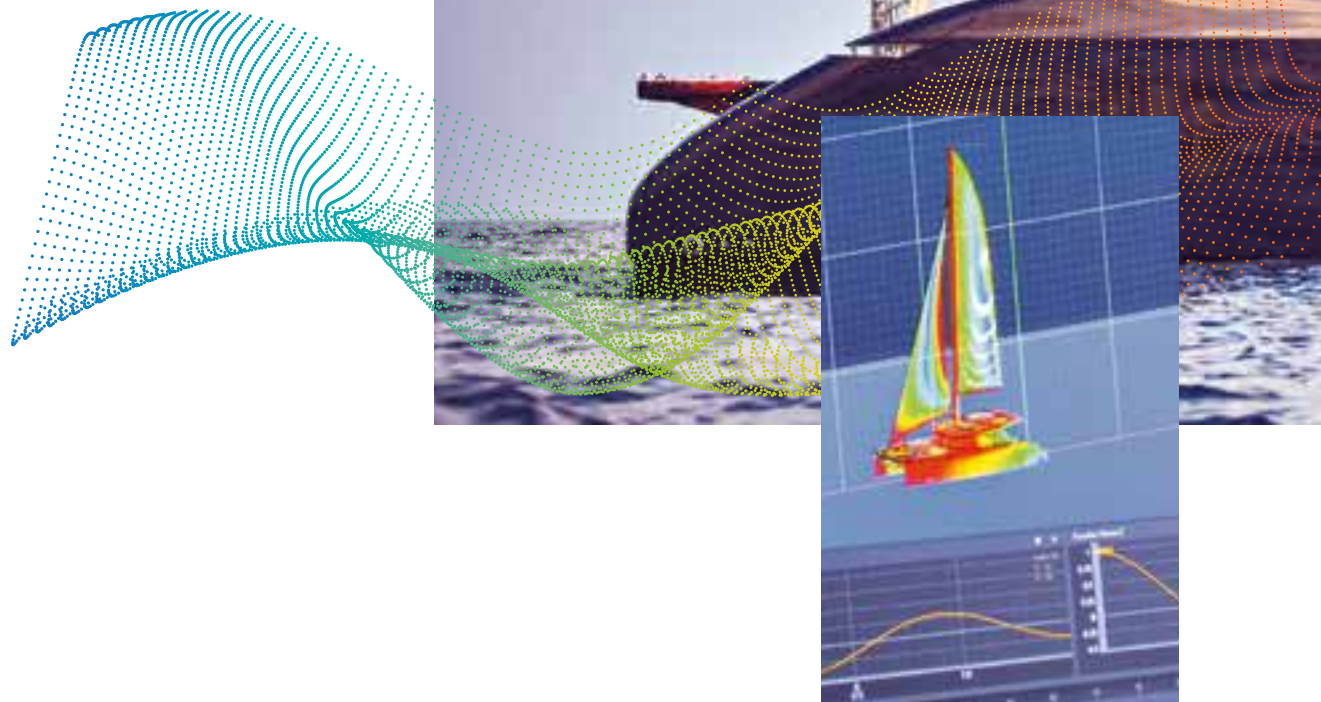
SUNREEF YACHTS
LUXURY CATAMARANS

Sunreef Yachts was founded in 2002, with the aim of creating a whole new market segment of luxury catamarans for private clients. The young company's approach immediately appealed to many yacht owners, because a multihull is more stable and offers more spacious living space than a narrower, longer single-hull vessel. A catamaran also has greater range, because there is less friction between the hull and the water and, therefore, less drag and better fuel consumption when the engine is being used. Sunreef Yachts' shipyard is located in Gdansk, Poland.

Dances with robots

Imagine two dancers:
a human and a robot…

Not a humanoid like those that appear in science-fiction films or made by Japanese manufacturers, but an industrial robot that is 2m (6.5 feet) tall and weighing 900kg (1,984 pounds)!

For Swedish dancer and choreographer Fredrik Rydman, a robot is an exceptional dance partner, executing his sequences to perfection, completely in time, performing lifts with absolute security.

The dance shatters preconceptions about our relationship with machines, and the emotion that the audience feels is derived from the implied questions raised by the piece.

The show makes us think differently about the way artificial intelligence and robots are becoming part of our lives.
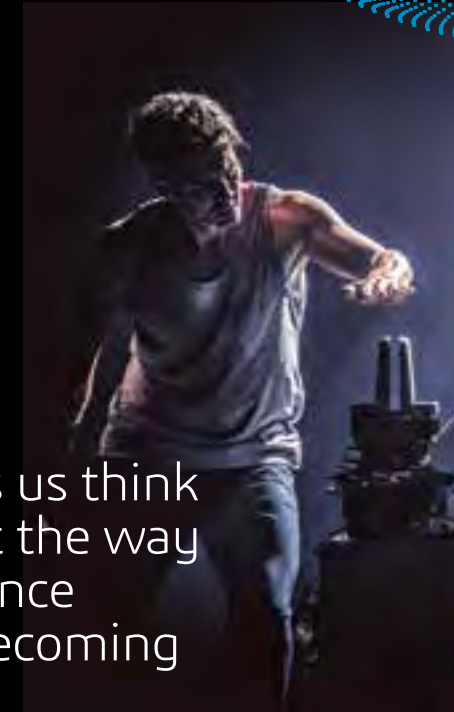
What do robots dream of?

ABB has operations in more than 100 countries and 136,000 employees. It is a world leader in electricity networks, industrial automation and robotics. One of its managing directors, Michael Larsson, sees how quickly the manufacturing sector is changing, and believes that technology's role is to improve the way in which humans and robots collaborate. "We want to be certain that our technologies are safe," he says, "and that humans and robots can share the same workspace." He stresses that the traditional factory needs to change, and that work is needed to develop the sustainable factories of the future. The first robots carried out repetitive, programmable and unchanging tasks, with humans controlling them from afar. He explains that in the manufacturing industry, it is now possible to imagine a collaborative robot working alongside humans in every part of the plant, with changes in demand leading to dynamic adjustment of the production process and the creation of new products. He emphasizes how sustainable processes will be integral to all stages of production in future factories.

Highly versatile

"What we want to do," Larsson explains, "is to integrate collaboration, simplification and digitalization to enhance flexibility and productivity. Collaboration means making the most of what needs to be done by humans and what can be done by robots. For us, creating a collaborative work envelope provides an opportunity to develop efficient technologies that allow them to work together." Traditional manufacturing concepts with monolithic assembly lines and conveyor belts are disappearing. ABB now uses automatically guided vehicles and mobile robots to produce items in a more flexible environment. This reduces the amount of floorspace required and allows a factory to better respond to demand. "The approach also allows our customers to be highly versatile," adds Larsson. "They can start on a small scale and increase volume as required. Because we use standardized production cells, we can add more cells to take production to the next level." This means that the factory doesn't need to be oversized at the start of a product's lifecycle, since production can be expanded when needed, depending on production requirements and market developments.

* A collaboration between ABB and Kulturhuset Stadsteatern.

Because virtual universes
are universes of the
possible, because the digital
revolution is opening up
immense opportunities,
because progress only
has meaning if everyone
can participate and benefit
from it, we are there.

WE WILL
BE THERE
TOMORROW

The **3D**EXPERIENCE Lab is accelerating
its expansion and bolstering its global network
to develop projects that have a positive impact
on society. It works with startups, giving them
preferential access to the **3D**EXPERIENCE platform
and customized assistance. The projects
it supports can now be experienced in Dassault
Systèmes' Museum of Innovation.

Dassault Systèmes set up its first **3D**EXPERIENCE Lab in France in 2015, and very soon expanded it into the United States and India. It now works with more than 30 startups and 15 incubator, technology and fab lab partners across the world.

The **3D**EXPERIENCE Lab was designed both as an ideas laboratory and a startup accelerator, with the aim of supporting disruptive innovations that have a positive impact on society. It has also joined forces with multinational companies to accelerate promising projects in specific sectors. Its growing community of 1,200 mentors provides expertise in disciplines as diverse as design, simulation, regulation and marketing.

COMMITTED STARTUPS

The **3D**EXPERIENCE Lab supports the United Nations' 17 sustainable development goals. Each startup project is associated with and committed to one of these goals. For example, Agreenculture designs agricultural robots, aiming to help "end hunger, achieve food security and improved nutrition and promote sustainable agriculture". In the healthcare sector, Damae Medical (devices to detect skin cancer), FEops (simulations for heart interventions), Gyrolift (new mobility solutions), Inali (prosthetic hands), PKvitality (bio-wearable solutions), Digital Orthopaedics, Exact Cure and Gyrolift aim to "ensure healthy lives and promote well-being for all at all ages", while Leka intends to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all". The goal of Eel Energy and SparkCharge is to "ensure access to affordable, reliable, sustainable and modern energy for all", while SplashElec is helping to "reduce inequality within and among countries". XSun's drones and XYT's urban vehicles, meanwhile, intend to "make cities and human settlements inclusive, safe, resilient and sustainable".

Since 2019, new startup incubator partners have joined the **3D**EXPERIENCE Lab's dynamic ecosystem, such as MIT Enterprise Forum CEE in Poland, Greentown Labs in the United States, Centech in Canada, OuiCrea and HAX in China, Tshimologong in South Africa, HEC business school in France and FabLab Communautique in Canada. For Frédéric Vacher, head of innovation at Dassault Systèmes, "The **3D**EXPERIENCE Lab shows the power of collective intelligence, open innovation and cloud platforms in enabling disruptive innovations that align with the United Nations' sustainable development goals".

Virtual twin and physical prototype

Dassault Systèmes' Museum of Innovation – an immersive virtual reality experience – is a way to discover the disruptive projects being developed with the support of the **3D**EXPERIENCE Lab. During the virtual tour, visitors pass through different exhibition spaces focusing on life sciences, cities and lifestyles, covering all of the Lab's areas of activity.

At their own pace, visitors can discover projects and startups offering personalized health solutions, creating more sustainable cities and designing more environmentally friendly products. Each project has its own individual space involving a real-time interactive 3D experience. During the tour – a genuine educational expedition – visitors can find out about the background to a project and understand how it contributes to the attainment of the United Nations' sustainable development goals, before diving into a virtual simulation in which they interact with a virtual twin of the project alongside its physical prototype. This virtual reality experience exists within a digital environment in the cloud, which means that it is dynamic and rapidly deployable. The Museum was officially launched in the Atelier des Lumières' immersive exhibition space in Paris. Dassault Systèmes has already introduced it to its offices in Boston, Pune, Shanghai and Munich and is planning to extend access to other countries in which the company operates, as well as linking up with science museums to share the experience with the general public.

The aim of the **3D**EXPERIENCE for Good hackathon was to design a prosthetic hand for the Ellen Meadows Prosthetic Hand Foundation to distribute to vast numbers of people around the world. There were three key requirements: the hand had to be cheap to produce, simple and durable.

More than 12 million people around the world have had a forearm amputation. In the last 15 years, the Ellen Meadows Prosthetic Hand Foundation has given away 50,000 LN-4s: low-cost, light, durable and functional prosthetic hands designed using pre-CAD technology.

Thanks to the generosity of its donors, the Ellen Meadows Foundation works with individuals and organizations around the world to find people who would benefit from one of these hands. The Foundation distributes its hands in three ways: through one-off events, partner organizations in individual countries, and responses to individual requests.

With the **3D**EXPERIENCE for Good hackathon, Dassault Systèmes joined forces with the Ellen Meadows Foundation to upgrade the LN-4 and reinvent the way prosthetic hands are designed. The aim was to design a new model that would meet certain usage and manufacturability requirements. Although asked to focus on the technical design, participants were also asked to factor into their design the need to ship more than 1 million of the hands, free of charge, to the most distant corners of the world. The five teams consisted of designers and engineers from various backgrounds, including students, teachers and those working in industry, all recognized in their fields and supported by Dassault Systèmes experts.

Remote collaboration

Unlike traditional hackathons that take place over a weekend, the five teams of design specialists each spent 120 hours, over the space of a month, bringing their ideas to life. Using their unique skills and talents and a range of leading-edge solutions based on the **3D**EXPERIENCE platform, each team's members collaborated remotely to develop their designs. The first time they met in person was to present the fruits of their labor, on February 10, 2020 at the **3D**EXPERIENCE World 2020 event in Nashville, USA.

TEMPORARY OR PERMANENT
Depending on the country's healthcare system, the LN-4 may be a temporary solution while the patient waits for a more sophisticated prosthetic limb. For others, it is the only way for them to regain hand movement.

FIVE TEAMS, FIVE APPROACHES, ONE GOAL

• **Team 1, Prosthetic ARMada,** improved on the Ellen Meadows Foundation's initial hand by enabling it to grasp objects: each finger can lock individually and whole-hand organic modeling makes it look similar to a real hand.
• **Team 2, Manbus Postca 2.0,** proposed a device fitted to the forearm with mechanical locking to give a more secure grip.
• **Team 3, DextR-3,** produced the winning design: a functional and simple hand inspired by the original design, but with an opposable thumb and index finger and whole-hand grip. The design is ambidextrous and the hand can be assembled in a left- or right-hand configuration using a simple screwdriver.
• **Team 4, Xtreme Team 4 Good,** developed a mechanism that is activated by bending the arm. The hand can grip objects but also open doors, and more closely resembles a human hand.
• **Team 5, The Five,** presented an articulated hand that can perform the main movements of a human hand.

For the last four years, La Fondation Dassault Systèmes has been supporting the education and research sector, and encouraging Dassault Systèmes employees to get involved.

Dassault Systèmes firmly believes that virtual universes can improve real life and help create a more sustainable world. La Fondation Dassault Systèmes uses a skills-based sponsorship approach with Dassault Systèmes employees helping to train and support young people interested in science and engineering careers. Here are four examples of that collaboration, showing how it helps young people and how the employees benefit too.

The race is on
Virtual worlds can help teachers motivate students and try out new ways of learning. In 2019, for the third consecutive year, students at the Apprentis d'Auteuil school in Meudon, France, took part in the "Course en cours," a novel educational project that gives students the chance to dream up, design, make, test and race a miniature racing car, and take part in a national competition. Dassault Systèmes employees helped these students, who have special social and educational needs, to model and build their car, as well as prepare an exhibition stand and an oral presentation. Stéphanie Tamho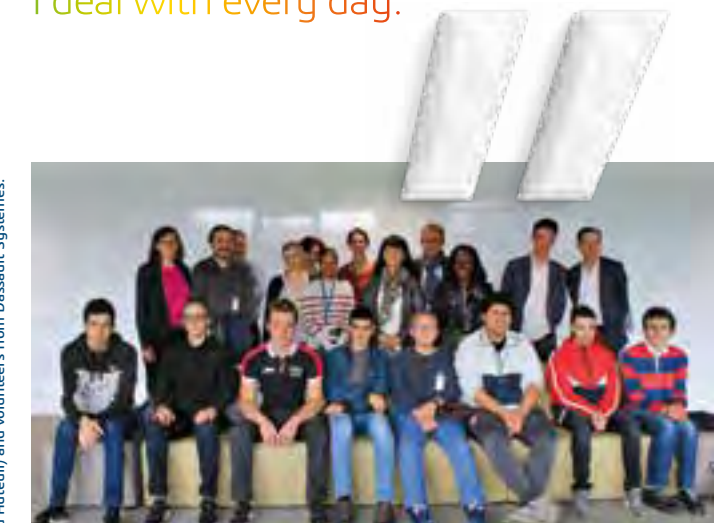ua, an employee who took part in the project, explained: "Working with young people is a real challenge: it makes you question your preconceptions

and forces you to think of different ways of passing on your knowledge." David Bonner added: "I love working with teenagers in general. It's a very interesting stage of life."

Mutual enrichment
The Institut de l'Engagement works with young people who, because of their educational, cultural, social or geographical background, financial situation or disability, have difficulties developing their plans for their future. Each year, the Institute helps 300 young people aged 16 to 30 to realize their plans, such as resuming their studies or starting a business. Dassault Systèmes employees sit on the selection panel, offer mentoring to those selected and take part in the Campus de l'Engagement, a three-day event that brings together the program participants with 150 speakers from partner companies to talk, think, work and interact in a mutually enriching way. Together, they take part in workshops, round tables, talks and debates, thinking of ways to address the

major economic, social and environmental challenges of today. Laurent Poinot, who sat on the selection panel and mentored an aspiring engineer, said: "When you take part in this kind of thing, you always get out more than you put in. Initiatives like this give new meaning to our day-to-day work."

Sébastien Massart co-led a session entitled "Creating experiences: from the virtual to the real?" during the Campus de l'Engagement event, taking him out of his usual working environment to talk to a curious and engaged audience.

Like a startup
In the 3Défi challenge, teams of junior high-school students, supported by their technology teachers, create a fictitious startup to design and 3D print a smartphone holder. The initiative was developed jointly by the La Main à la Pâte Foundation – set up by France's Académie des Sciences and elite university ENS – and La Fondation Dassault Systèmes. Each team designs prototypes using 3D design software and then 3D prints them at their school. The aim is to encourage innovation and creativity among students and introduce

them to both maker culture and the world of startups. Students have the chance to meet professionals and find out about technology careers and entrepreneurship. Philippe Minez said: "Working with these students is a valuable experience. The time we spend together, seeing their progress, gives real meaning to my work with La Fondation." Senior high-school students are not forgotten either. At the Lycée Louis-Bascan, final-year students of science and technology, with the focus on manufacturing and sustainability, receive help completing their technology projects. Specialist talks are arranged to give them valuable information about innovative business practices and to help them understand aspects such as "design thinking." "Taking part in these projects gives me great satisfaction," explains Sébastien Smetryns. "It's very fulfilling to pass on my knowledge and apply for purposes that are different to those I deal with every day."

❞ Working with young people is a real challenge: it makes you question your preconceptions and forces you to think of different ways of passing on your knowledge.

❞ It's very fulfilling to pass on my knowledge and apply for purposes that are different to those I deal with every day.

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