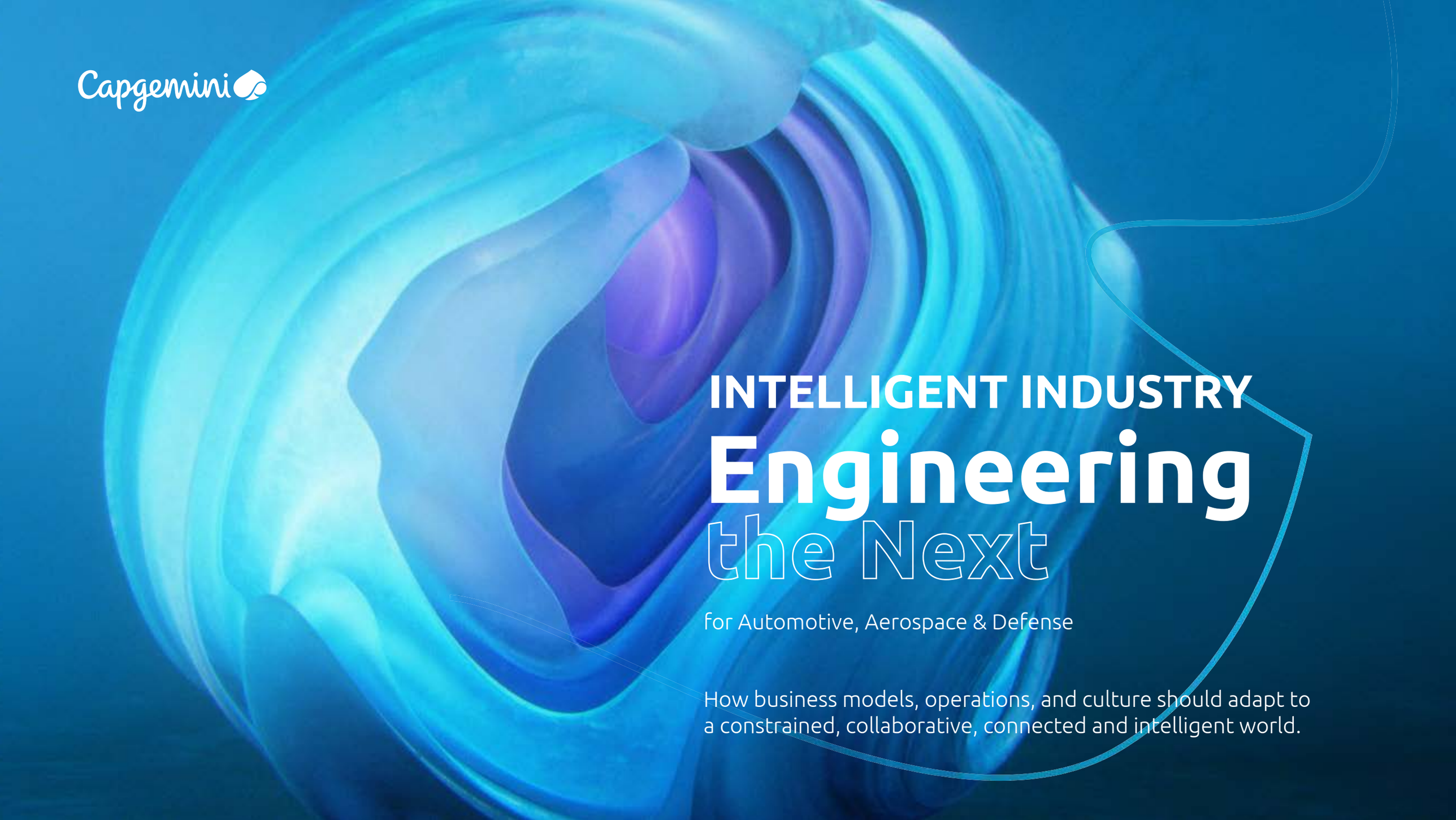
Capgemini



INTELLIGENT INDUSTRY
Engineering the Next

for Automotive, Aerospace & Defense

How business models, operations, and culture should adapt to a constrained, collaborative, connected and intelligent world.

EXECUTIVE SUMMARY

The threats of climate change, finite natural resources, and threats to biodiversity, along with rapidly emerging new technologies mean that large, engineered products - such as cars, planes,and satellites - need to be reconceived to run on clean energy and use sustainable or recycled materials.

In doing so, they need to improve the user experience, or these sustainable innovations will not be accepted. That means ensuring smooth, efficient, safe, and cost-effective transportation, with increasing automation and embedded intelligence.

Engineering is being called upon to drive the needed innovation and scaled deployment of the key technologies to address climate change. Those who step up to the challenge will provide differentiators that secure their legacy, sovereignty, and revenues for years to come. But to get this right, the role of engineering will need to transform.

ENGINEERING MUST ADAPT TO A RESOURCE CONSTRAINED WORLD, BOTH IN TERMS OF MATERIALS AND SKILLED RESOURCES.

Value and differentiation will move from physical attributes toward intelligence and autonomy, where products become driven by software, data and embedded AI. Systems will make autonomous decisions about trajectories, routes, how to respond to the unexpected, and user comfort.

AI and Generative AI will transform both the product functionality itself, e.g., the nature of machine interaction, but also bring productivity opportunities along the entire product development lifecycle.

AI systems bring new changes and challenges in the safety-critical industry and are subject to concerns about ethics and trust. New sustainable designs will benefit from AI and foundation models through prompt engineering, fine-tuning, modeling and developing simulated test scenarios for validation.

FUNDAMENTAL TO THIS IS THE MOVE FROM A SILOED WORLD TO A WORLD OF COLLABORATIVE DATA ECOSYSTEMS. ENGINEERING COMPANIES HAVE TO ACCESS AND INTEGRATE NEW SKILLS AND DATA-DRIVEN TECHNOLOGIES – FROM ADVANCED COMPUTING TO NEW MATERIALS. THAT MEANS COLLABORATING WITH A WIDE RANGE OF SUPPLIERS, PARTNERS AND START-UPS IS A KEY PREREQUISITE.

It means multi-skilled engineering teams - physical and digital, in-house and outsourced - will join forces and work together on increasingly complex products.

The new environment means close collaboration between engineering, manufacturing and after-sales to cover the product and service life cycles end-to-end. This demands new organizational structures and digital engineering technologies to enable secure collaboration, information sharing and real-time feedback. On top of that, majority of the boardrooms have Generative AI on their agenda, because they believe that it is accelerating product design and customer experience.

THIS IS NOT A SINGLE HANDOVER FROM THE OLD WORLD TO THE NEW. IT IS A TRANSFORMATION JOURNEY YOU WILL NOT WIN IN A SPRINT, NOR IN A MARATHON – IT IS MORE ABOUT A TRIATHLON. IT WILL REQUIRE ORGANIZATIONS TO CHANGE THEIR BUSINESS MODELS TO DELIVER INTELLIGENCE AND SUSTAINABILITY, AND RESHAPE THEIR OPERATIONAL MODEL TO BE AGILE, COLLABORATIVE AND RESPONSIVE.

To achieve that, they will need to transform skills, culture, leadership, and the use of data-driven technologies. It is a journey that will take time, commitment, and creativity. If you haven't started already, you must start today to be and stay competitive.

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INTRODUCTION

This paper draws on 30 interviews with engineering leaders to understand the global drivers reshaping engineering, and the transformations that are needed to ensure that companies with engineering at their heart can progress on this journey.

Parallel to this, the entire engineering industry has been taken by surprise by the recent advances in AI, and is now rapidly seeking to understand its short and long-term implications.

Every day, I see how the engineering world is transforming. From the pivot to sustainable products and supply chains, to putting digital at the heart of physical products, to adjusting strategies for a volatile world.

The organizations that will be tomorrow's winners are rethinking both their business and operating models and building a whole new range of capabilities and expertise from their teams and partners.

Key success factors to ensure the disruptive transformation of the originally hardware-driven world are software, data-driven decision making and the successful integration of Artificial Intelligence.

Roshan Gya
Capgemini Invent, CEO

I strongly believe, that after years of optimizations, industrial organizations must now fundamentally rethink the product development cycle in order to successfully launch the next generation of products in a very different world to the one we have always known.

Engineering is instrumental in achieving such objectives. From design concept and sourcing of materials to product life cycle and recycling, engineers will need to reinvent themselves to deliver sustainable products in a world of finite resources.

William Rozé
Capgemini Engineering, CEO

Source: * Capgemini Research Institute: CREATIVE AND GENERATIVE AI | GENERATIVE AI IN ORGANIZATIONS CUSTOM GENERATIVE AI FOR ENTERPRISE | GENERATIVE AI FOR SOFTWARE ENGINEERING

The year is 2040, and you are looking forward to a well-earned holiday, after another year of successful engineering in a transformational period. You book an autonomous electric taxi to pick you up from your house.

As you get in, the car recognizes you and automatically adjusts the seating, temperature, lighting and playing music to your preferences and your mood. You lie back and enjoy a smooth trip to the airport.

As you board the hydrogen-powered plane, you marvel at the changes in design from the ones you knew for most of your life. Gone is the long fuselage and protruding wings, replaced by a wider body, providing space for the hydrogen tanks, and wings—made from lightweight bio-based composites—flowing out from the back.

As you take off, you smile at the smoothness, thinking of the AI-supported feature your company designed to make micro changes to wingtips to counteract turbulence, making your journey both safer and more comfortable.

You can't resist checking your phone—perhaps the satellites that now provide lightning-fast internet way above the ocean are a mixed blessing. But your personalized AI-driven assistant pushes you some good news: The latest IPCC [Intergovernmental Panel on Climate Change] report is out, and the world has hit its 2050 net zero targets, with the report lavishing particular praise on those engineers who spent the past decades decarbonizing transport.

THIS IS JUST ONE POSSIBLE FUTURE SCENARIO, AND WE ALL KNOW THAT PREDICTING THE FUTURE IS A RISKY BUSINESS. BUT IT IS CLEAR THAT BIG CHANGES, AND CHALLENGES, ARE COMING TO ENGINEERING.

PREPARING ENGINEERING FOR MULTIPLE FUTURES

5 MEGA TRENDS

The future of engineered products and organizations is being shaped by global megatrends, which place new constraints on supply and demand, but also new opportunities from innovative technologies. These shape the products and services that businesses and consumers want or need, which defines how they should be made.

We see five megatrends shaping the future of engineered products and the organizations that deliver them, with important impacts within and across industries.

1 THE ENVIRONMENTAL EMERGENCY

People, businesses and governments are increasingly concerned about the impact of human activity on the climate, biodiversity, and health. Companies with engineering at their heart are under consumer and regulatory pressure to change to low and zero environmental impact products.

2 GEOPOLITICAL INSTABILITY

After decades of globalization, the trend is shifting toward localization. Geopolitical instability and protectionism are constraining international trade and redrawing supply chains, but also creating new jobs and engineering business opportunities in Western countries. Building on the ethics issues around autonomous driving and media manipulations, the disruptive developments of AI are increasing calls for a worldwide AI regulation framework.

3 THE CONNECTED CUSTOMER

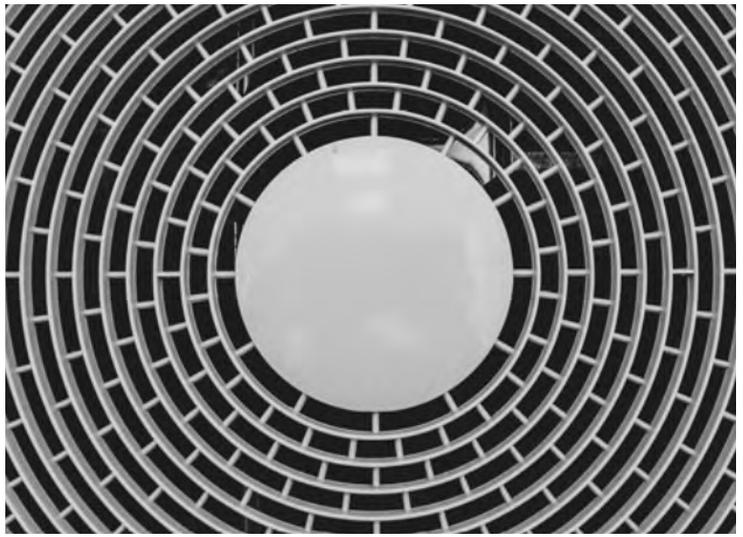
Customers expect easy-to-use, secure, intelligent and autonomous experiences-from ordering food and taxis to booking holidays. 66% of consumers would seek advice from AI on personal interaction or relationships. Businesses, too, want rapid data-driven decisions about assets and customers. These digital services need to be built around ease of use, convenience, connectivity, privacy, and security.

4 NEW PLAYERS, NEW COMPETITION

New players with new models are challenging the old way of doing things. Companies such as Tesla, SpaceX or Vertical Aerospace, are building digital-first organizations that allow rapid innovation, simulation, and testing on digital platforms, as well as ongoing digital relationships with the end user.

5 THE AVALANCHE OF TECHNOLOGY INNOVATION

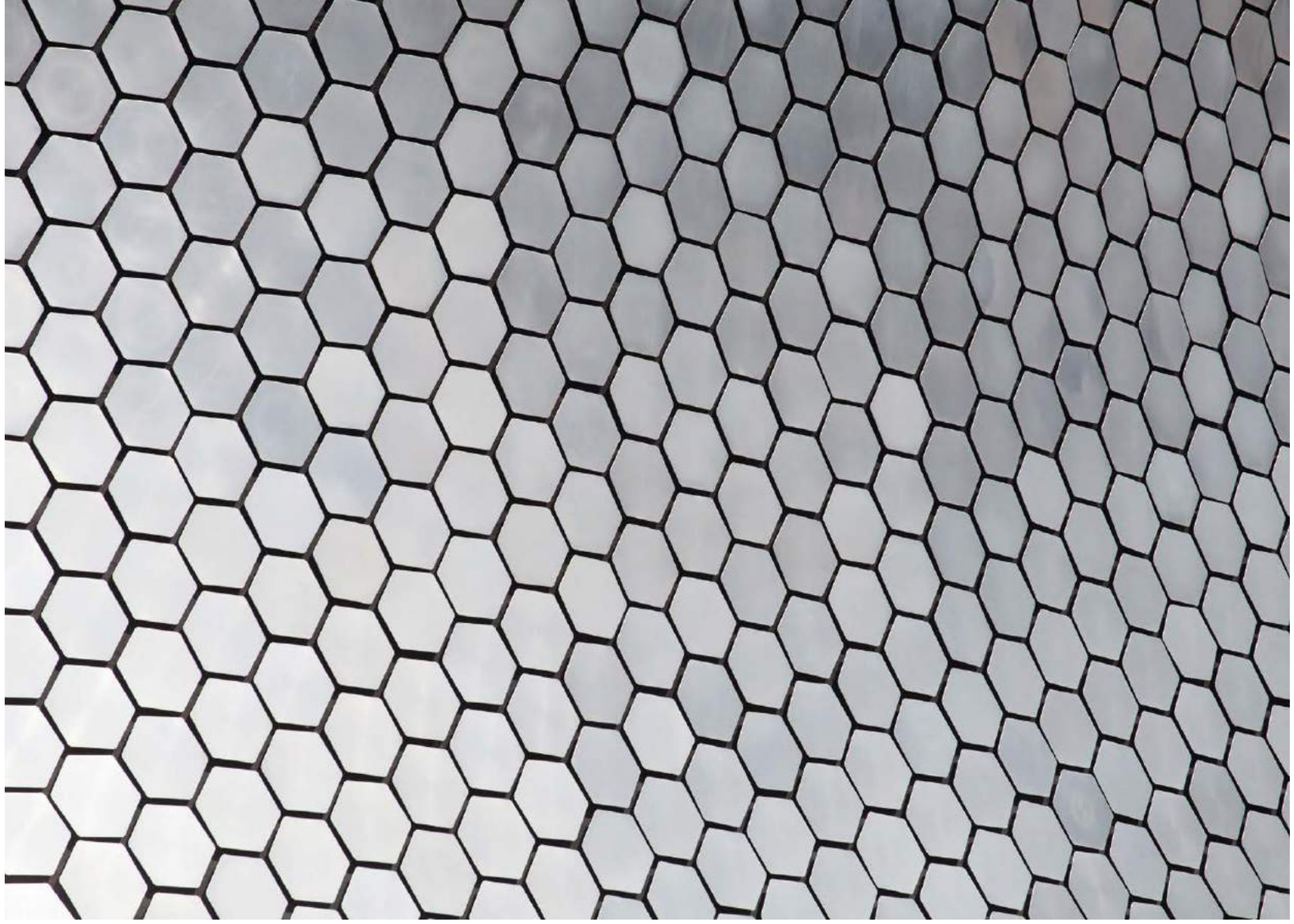
New products and ideas—materials, sensors, Generative AI, and so on—are emerging from start-ups, universities and corporate R&D almost daily. Many of which could transform engineered products, with an open and collaborative approach. Next to the tech giants, the start-ups and open-source communities are driving the technology development and publishing new tools and features every day.



WHILE THERE ARE NUANCES BETWEEN INDUSTRIES AND COMPANIES, THESE 5 TRENDS WILL HAVE A BROAD IMPACT ACROSS ENGINEERING. IT CREATES THREE OVERLAPPING FUTURES: CONSTRAINED, INTELLIGENT, AUTONOMOUS, AND COLLABORATIVE.

#1 - The future will be **constrained** because sustainability requirements place limits (notably emissions limits) that constrain what can be produced. At the same time, engineering teams will need to compete for finite resources (e.g. lithium) or for resources that do not have an adequate pipeline in the short term (e.g. chips and software engineers). The principles of circular economy will need to be embedded early in the design phase.

#2 - The future will be **intelligent** and **autonomous** Firstly, in use, because customers increasingly place a premium on physical products—including cars, planes and satellites—that are connected, software-driven devices that deliver sophisticated digital and automated services. Secondly, the engineering design activity is impacted by new AI-enabled digital tools. These tools bring innovation and productivity improvement to both physical and software designs. Such tools enable designs, whether it be an autonomous driving software function or an entire hydrogen plane engine, to be simulated and virtually tested accelerating innovation and product cycles.



#3 - The future will be **collaborative** because the only possible way to deliver this level of transformation is to bring together many new technologies (e.g. AI and biomaterials) and skills (e.g. software and data). It means building ecosystems of new suppliers, processes to assess and onboard emerging technologies, and partnerships with start-ups, universities, other industries, and even competitors.

And it means digital tools and industry-specific platforms that allow multiskilled distributed teams to collaborate on the same project will have to be developed.

CROSS-SECTOR CHALLENGES

> *Many major disruptions will come from complementary players who will find common agreement.*
>
> **Rémi Bastien**
> *FISITA, CTO*

While each industry faces its own challenges, many challenges are cross-cutting.

SUSTAINABILITY AND POWERTRAIN TRANSFORMATION

Both automotive and aerospace must change their powertrain to address customer and regulation requirements. The massive shift toward Electric Powertrain is undermining the internal combustion engines (ICEs), which are linked with brand positioning, trust and user experience, throwing the market for new products wide open. As most Original Equipment Manufacturers (OEM) source battery cells from third parties, automotive must negotiate to outsource a new product feature that is a key differentiator, while aerospace must manage the shift to biofuel/hydrogen and in some cases, electric.

SHIFTING RESPONSIBILITY FROM THE DRIVER TO THE ENGINEERS

The automotive, aerospace, and defense industries are being reshaped by embedded intelligence, delivering levels of autonomous AI navigation, in-use optimization, and user/usage insight.

Human decisions are progressively shifting to devices, including autonomous ‘drivers’ or ‘pilots’. As such, there are new levels of responsibility on the OEM, and the need to run countless scenarios in the verification and validation process.

NEW VALUE CHAIN = NEW ECOSYSTEM

As the complexity of products increases, there is an evolution of the value chain. The role of semiconductor companies as well as hyperscalers are taking strategic roles in engineering industries. The development of products that need to communicate with their surroundings will require new ecosystems to manage the interfaces and create communication protocols.

GENERATIVE AI AND FOUNDATION MODELS

A Generative AI market potential of ~20 BN USD in 2024 and a compound annual growth rate of +35% is expected and will heat the war of technology and limited talents.
Thus, Generative AI is set to radically change how software and Systems are developed and that impact goes far beyond coding assistants.

AUTOMOTIVE CHALLENGES

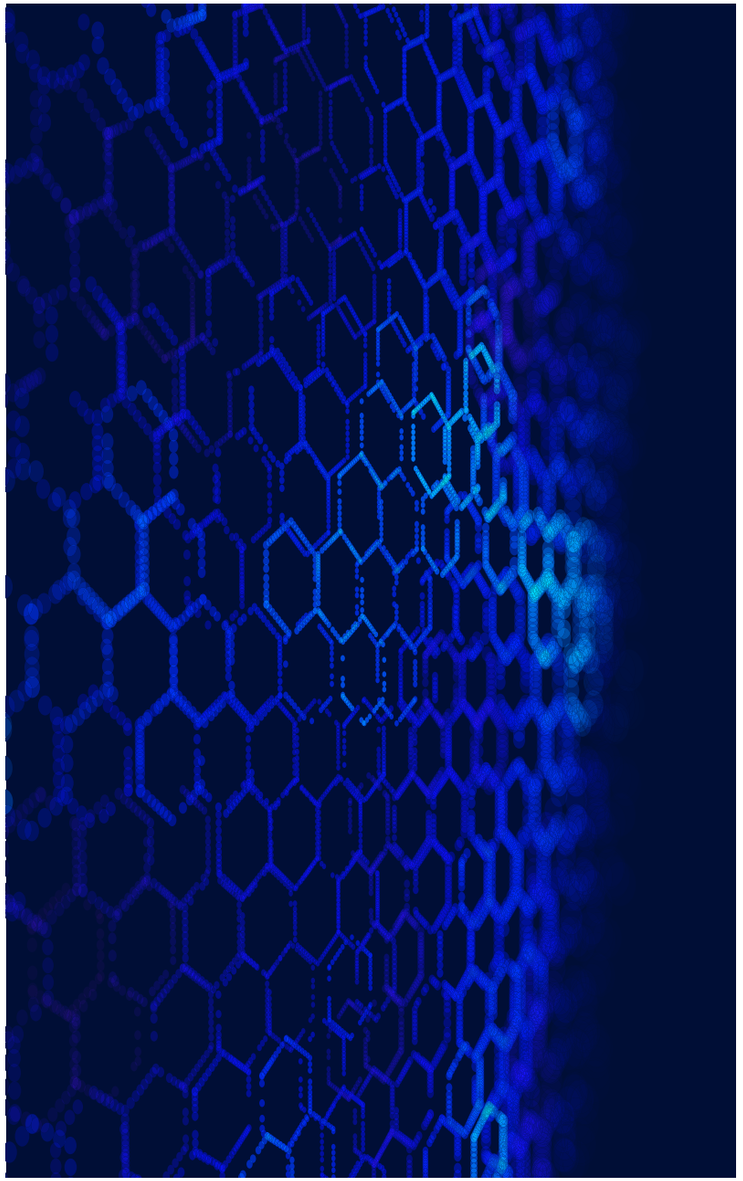
Automotive will be completely transformed by two changes: electrification, driven by the need for sustainability; and softwarization, under pressures from driving automation and advancing user experience.

Some of the challenges the industry faces include:

- Continued focus on optimizing batteries and electric powertrains for EVs. As the market grows and ICE bans come in, global EV sales are due to rise from 2 million in 2020 to 73 million in 2040, representing 100% of new sales in European markets.
- The need to manage this growth even as concerns rise about EV batteries' raw material scarcity.
- Progression through levels of autonomy toward self-driving, and in-car digital services, delivered under new connected 'as-a-service' business models, obliging the industry to accelerate the softwarization of the vehicle (infotainment and connectivity platforms, high-performance chips, ability to upgrade) and change the physical architecture (sensors, actuators, control units).
- Resilience of the supply chain as demonstrated by the recent conflicts and stop-and-go of production after lockdown periods.
- The transformation of OEMs into "mobility providers" as the future of mobility becomes multi-modal.
- The need to break down the silos and focus on an end-to-end customer-centric approach to ensure the internal and external data-driven development and participation from the AI actors.
- Rapid reduction in innovation cycles and intense competition from tech giants and digital startups, forcing OEMs to re-invent their engineering structures.

> *Assisted and automated vehicles will be the main product disruption in the automotive Industry in the coming 10 years.*

Dr. Tino Fuhrmann
Volkswagen, Systems Engineer SoS

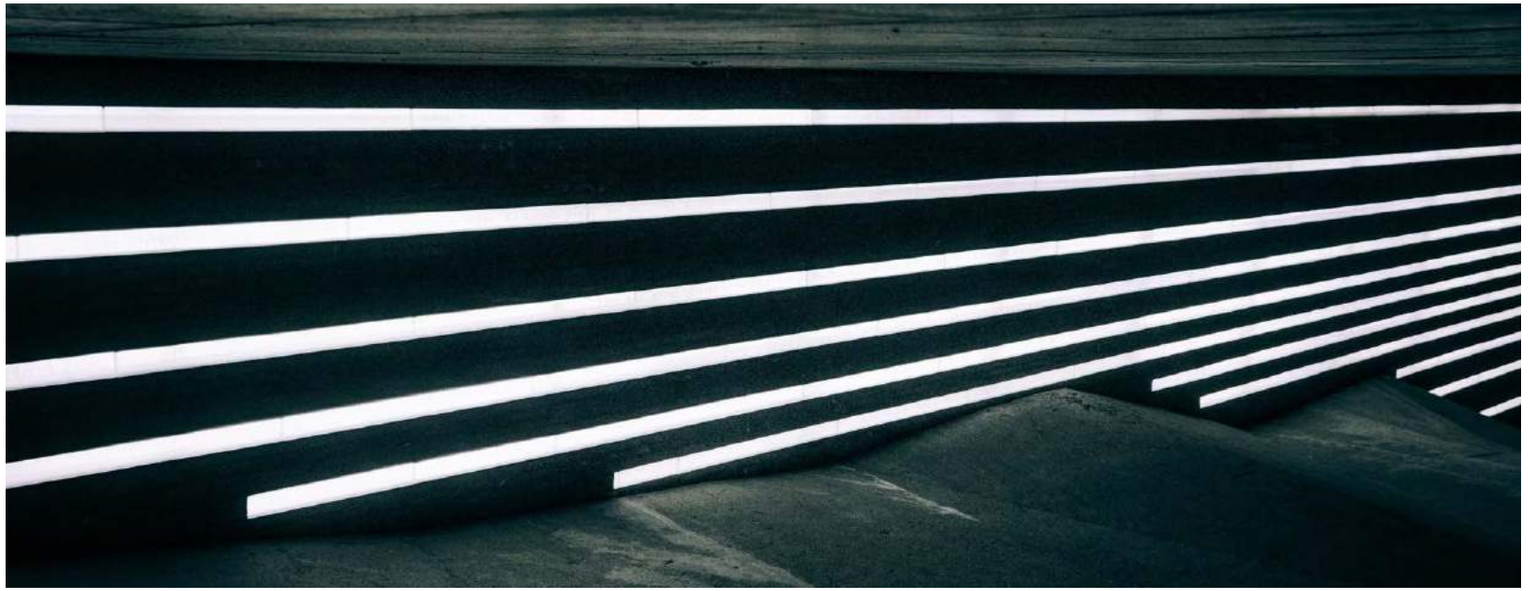


CIVIL AEROSPACE CHALLENGES

Aerospace faces the massive challenge of decarbonizing an industry that is almost entirely reliant on fossil fuels, while also developing whole new modes of air transport.

Some of the challenges the industry faces include:

- Managing a new era of growth, fuelled by new demand and fleet retirements (Airbus and Boeing project a doubling of the number of aircraft in the next 20 years).
- The emergence of new aviation companies in diverse applications (electric vertical take-off and landing, EVTOL, commercial UAV) will challenge the future operation of this industry with new approaches.
- Industry commitments to net zero that will need new low and zero-carbon propulsion, including sustainable aviation fuel (SAF), battery, fuel cell, or hydrogen.
- An inevitable disruption: The market for large planes is not yet disrupted due to the challenges of replacing combustion engines, long product life cycles, and strict safety regulations. But change is coming.
- Demand for fuel/energy efficiency requiring improvement in design and materials, weight reduction, and topology optimization.
- New engineering approaches are required to achieve this rapid evolution of products, harnessing generative design and AI algorithms to ideate and develop new concepts and validate their performance.
- Pressure on operators and air traffic management services to optimize flight trajectories while accommodating increasing demand in limited airspace.
- Certification of new aircraft and systems to rigorous, established standards while meeting the speed and cost constraints of agile engineering programs (using digital engineering & certification by analysis).
- Embracing digital services enabled by software, generative AI and aerospace future, for performance optimization, and customer experiences. 78% of industry executives believe that Generative AI will make their product design and services more efficient and 76% believe it will help them design more inclusive, accessible products and services.



SPACE& DEFENSE CHALLENGES

The space industry is facing a renaissance as low-cost commercial launchers rapidly open up opportunities for a new space economy. The defense industry is experiencing major technology push and innovation needs in the wake of changing geo-political situations.

Some of the challenges the space industry faces include:

- Rapid increase in launches: from 129 in 2011, to 1,807 in 2021, and a forecast of 11,746 small satellite launches by 2030.
- Shift from publicly funded space missions to the private entrepreneurial sphere, notably the deployment of galaxies of small communication satellites.
- Privatization has brought many innovations, most notably the reusable launcher, which owes much to new approaches: agile test and learn simulation, data and software.
- At NASA generative AI already brings risk reduction results and new designs they now call “evolving structures“. As Generative AI begins to accelerate the innovation capacity providing both concept improvement and new initial designs, engineers will extend from traditional ideation and creation to review and refinement.
- Huge opportunities for space economy, including on-orbit manufacturing, asteroid mining, and space-based solar power, estimated to exceed $1 trillion by 2040.
- Strategic issues of sovereignty, sustainability and regulations are emerging.
- New business models, particularly service-based ones (for terrestrial needs as well as for launches and satellite maintenance) must be explored.
- The defense sector sees challenges that are both technological (JADC2, Connected Battlespace, ..) and Operational (New threats, assymetric warfare, ..).

Addressing renaissance in Aerospace and Defense

- Leveraging AI by training it with data from digitally connected systems, sensors and organizational IP could help Aerospace and Defense organizations to explore new business models by enhancing E2E visibility and data access across the value chain.
- Possible use cases could be: accelerating design validations and certifications for product innovation, increasing safety and security by threat detection in civil and military applications, adopting new training approaches, streamlining supply chain, assembly, operations, and MRO processes, optimizing fleet management (aircraft, spacecraft, satellite, rovers, etc.) through predictive analytics, simulating space explorations, facilitating autonomous operations in flight, space, ground, sea and cyber domains.

> *As engineering businesses, we need to evolve from Technical Product Specification to Services/ Mission Specification for mobility and logistics in the Space industry.*

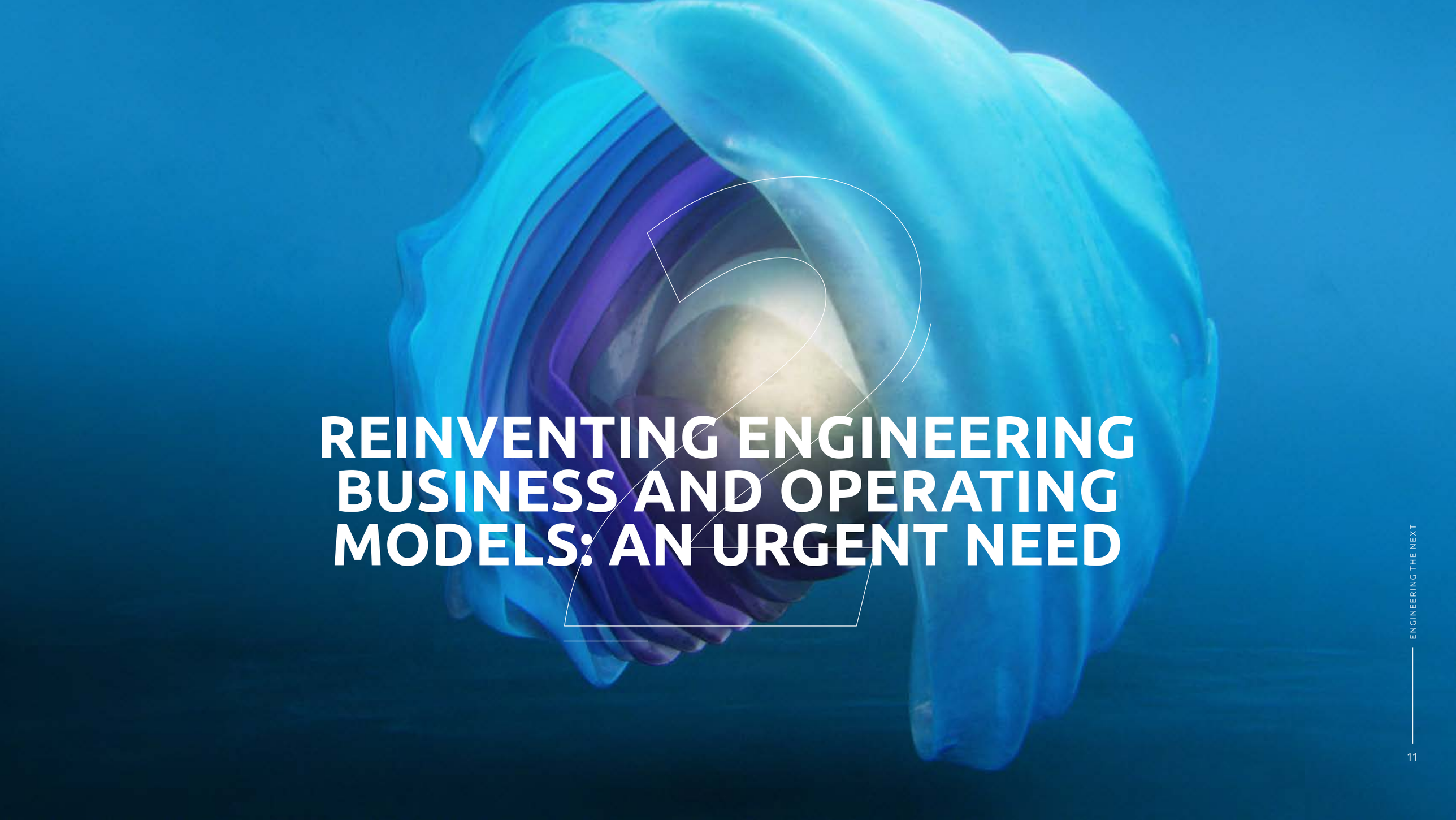
Jean-Luc Maria
Exotrail, CEO

> *Due to the complexity of the ‘system’ and the'unknowns', we need to make the business model and the operating model resilient to change.*

Simon Weeks
Aerospace Technology Institute, CTO

FOR THE COMPANY OF THE FUTURE TO SUCCEED, IT MUST BE READY TO FACE THESE THREE OVERLAPPING FUTURES.

TO DO SO, IT MUST MAKE DEEP AND PROFOUND CHANGES TO ITS BUSINESS MODEL, ITS OPERATING MODEL, ITS CULTURE, AND ITS DIGITAL ENABLERS.



REINVENTING ENGINEERING BUSINESS AND OPERATING MODELS: AN URGENT NEED

NEW BUSINESS MODELS

> *End-customer orientation is key to our strategy, in that the notion of services is just as important as the engineering of our product. You could say that we are not working on a launcher but on a launch service.*

Yohann Leroy
MaiaSpace, CEO

From ‘product-centric’ to ‘customer- centric’ and from ‘build-for-now’ to ‘build-to-evolve’.

Customers want intelligent and autonomous digital products that are seamlessly integrated into their everyday eco-system. The products provide safe and valuable services that save them time or help them in their lives, from assisted driving/flying and route optimization, to entertainment and remote maintenance (which will now include operations in space). For long term investments like cars, planes or satellites, they want to upgrade over time, so their purchases are not obsolete in two years.

Many also want new ways to pay, such as subscriptions, leases, customizations, and add-on services, rather than a one-off fee for a commodity product that has rolled off an assembly line.

These digitally enabled products need new business models. Just as smartphones allowed entertainment to move from selling CDs and DVDs, to offering personalized subscription services, industrial companies need to move from selling products to a continuous relationship with the customer.

Carmakers may still sell the basic unit, but then sell a range of add-ons—from driving assistance to advanced parking search, in-car entertainment services, or local guides—that users can turn on and off each month, or lease for short periods. Others may move entirely to ‘as-a-service’ leasing cars as needed, rented and customized via an app.

For many years, the engineering function focused on products designed for performance (weight, speed, robustness, etc.), with an emphasis on ‘Design to Cost’. The new context requires designing products around the customers’ needs and their individual preferences.

It also, by implication, means an ongoing relationship with customers, a move from ‘build and sell’, to ‘continuously engage’; from ‘long-lasting’ to ‘permanently-evolving’.
The current developments around AI, Gen AI in particular, will provide new tools to further transform the relationship between products and the end-customers bringing new levels of human-machine interaction.

ACROSS INDUSTRY LEARNINGS: INNOVATION BUSINESS MODELS

Plane engine manufacturers have been using jet engine sensor data to deliver engine management and predictive maintenance as a service for many years. Connectivity enables a business model that charges by flying hours rather than maintenance time, incentivizing optimal uptime on both sides.

In the past, a car was designed in 4 to 10 years with a given configuration for a target life of 10 years. An aircraft was designed in 8 to 15 years and its operational life was 25–30 years, with a change/refresh of the cabin every 5–6 years.

Now the target is to be in a permanent position to launch new intelligent functionalities that customers expect as technology evolves—from assisted driving/autopilot to in-flight VR—which can be added over the air or easily retrofitted. In 2021, Stellantis shared its connected services plans for putting 26 million "monetized connected cars" on roads by 2026. Early this year, BMW sent 4.7 million remote iDrive software updates to 30 models, while a Tesla Model X reportedly gets 27 software changes a day. These improvements—often small, contribute to the enthusiasm that connected vehicle owners feel for their digital cars.

This is not a launch and forget, but part of a continuous innovation loop, with engineers continuously collecting sensor data on vehicle performance and environment, then using that to learn about product use, continuously improve software and hardware, shorten validation and certification times, and iteratively improve the next generation of physical and digital products.

This concept of 'continuous product improvement' fundamentally changes pricing strategies. Cars have always depreciated from the moment they drive off the forecourt. But connectivity and software means that they may improve over their lifetime through new services. If carmakers can monetize the customer over the product's lifetime, then the incentives move away from maximizing the initial revenue, and toward customer acquisition. That is a fundamental change in thinking for the car industry pricing strategy. This pricing strategy target model has not been found yet as long as the huge infrastructure investments required to enable autonomous driving, continuous and visible software services upgrade for end customers won't be covered by the customers' willingness to pay for it.

> *A deep cultural shift is required: we need to develop and promote the "Engineering judgment" from our engineers. With the digital, simulation tools, ALM and generative AI, our engineers will be increasingly empowered by new capabilities (even "assistants") and their value will then rely on their capacity to use their judgment to challenge a requirement, a design, a process.*

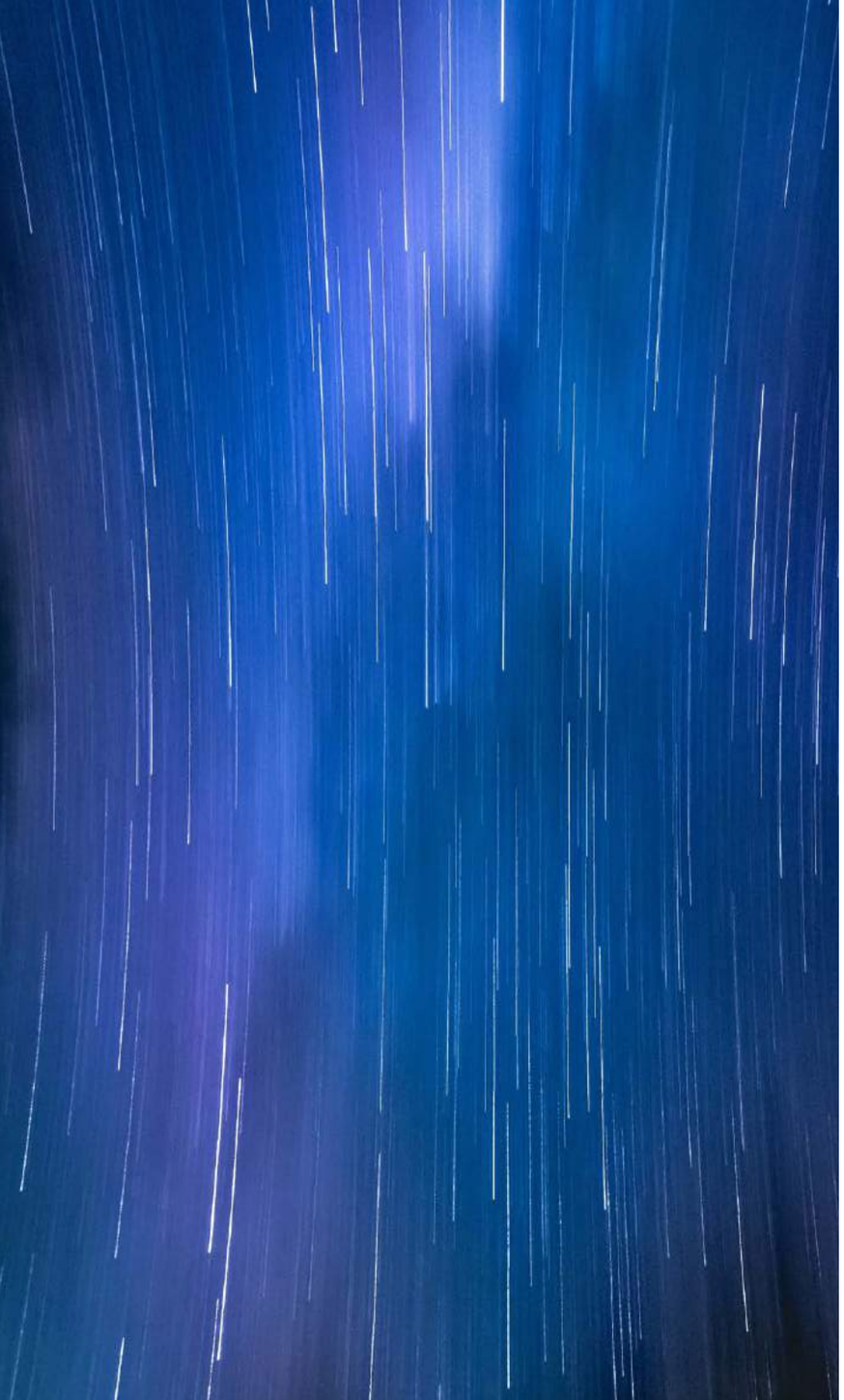
Olivier Flous
Thales, SVP Head of Corporate Engineering & Digital Transformation

> *The software part of the vehicle will be regularly updated, which needs to be integrated both in the software platform and the initial costs. The right balance must be found between user satisfaction and profitability for the OEMover time.*

Olivier Guintrand
Alpine Cars, Technical Director

> *We have to create a good quality product which lasts a long time, and we have to leverage sustainable material, reuse hardware, and upgrade both hard/software over the lifetime.*

Hiroki Ando
Honda Motor Co., Ltd., Development Process Transformation Division General Manager Senior Chief Engineer



Doing this means developing ‘platforms’ for physical products. Digital platforms—similar to computer operating systems—sit within cars, planes and satellites, designed to allow new software to be easily updated. This is particularly true for the space market, where access to the physical product remains problematic. Some hardware may also need to be modular with standard connections to allow the easy swapping of sensors, chips, or SIMs, for more powerful versions that support more advanced services, without having to scrap the whole product when something better comes along.

While connectivity is the transformational shift in how industrial businesses sell to and engage with customers, business models are also being reshaped by the other big customer demand: sustainability. Businesses will increasingly sell on their sustainability credentials; Renault already sells cars that are 90% recyclable and 30% recycled, for example. That in turn will create new markets for reusable used parts, selling them as replacements, or for whole new applications, which will mean new business lines and customer bases.

All of this means engineers need to reinforce the long-lasting move beyond the domain of creating optimal products and focus their efforts on thinking about the way people will interact with their products long-term.

KEY TAKEAWAYS

Challenge:

Rethink and adapt business models covering a longer product lifecycle and numerous upgrades to constantly renewed customer experience, while taping into data-driven service monetization.

CxO agenda:

- Pricing strategy (one-off transaction, subscription, micro payments…) and residual value management linked to continuous upgrades.
- Design strategy to promote intelligent, evolutive and sustainable products and services in a constrained world, with cost optimization.
- Make sure that your products or services architectures are able to handle continuous improvements and revenues (being modular, well interfaced, platform-based).
- Mindset shift: consider sustainability and circularity as an essential economic lever and brand value.

> *The space industry has long operated without a sustainability goal, like throwing away a car after the tank of fuel it was delivered with. There is now an exceptional field of possibilities in satellite services, specific launches, reusable launchers, maintenance and orbit corrections, extension of the life of equipment.*

Jean-Luc Maria
Exotrail, CEO

> *The business model is a determining factor. Traditional OEMs, even with hyper performance, are not guaranteed to keep their position in the long term. The product is changing. We need to change our business model to capture more value.*

Gilles Le Borgne
Renault Group, EVP Engineering

NEW OPERATING MODELS

For resilient, modular, open and service- oriented engineering.

Building intelligence and automation into products—as well as meeting the other transformative consumer demand of sustainability—requires changes to the engineering operating model. It will need to become more agile and collaborative in order to quickly adopt, develop and deploy new technologies outside of its traditional expertise and way of working, but also more resilient and adaptive as it pursues multiple experimental strategies in an uncertain and constrained world.

This is why the transformation of the engineering operating models must be structured around three interdependent axes:

- Deploying a “Systems of Interest” approach and structuring co-development processes between domains and between disciplines.
- Repositioning engineering as a value center.
- Creating and orchestrating new multi-tier ecosystems.

As the Engineering Service provider becomes a strategic partner, they bring more than just capacity or non-strategic activities. To become a strategic partner, what should they should do?

- First, to bring an E2E understanding is key.
- Secondly, the Service provider should take more responsibilities and risks.
- Most importantly they should bring technological solutions as well as engineering capacity and expertise.

SYSTEM OF INTEREST (SoI) AND CO-DEVELOPMENT PROCESS

Customer demands change far quicker than the lifespan of a car, a plane, or a launcher. While there have been talks for years of engineering companies adopting the tech mentality of ‘fail fast, learn fast, adapt’, and a relentless focus on ‘user experience’, these concepts are finally common talking points in the boardrooms of industrial companies.

Yet, these three industries considered here have long development cycles and heavy investments, so the product development life cycle process remains a key asset, though it will require major changes to its architecture and execution.

The concepts of System of Interest (SoI) and co-development are invaluable in managing complex and expensive programs. For example, in aerospace, the three SoIs are the product itself, its industrial system, and the associated set of services.

Co-development means you iteratively develop the three SoIs in parallel, with permanent feedback loops between all the product’s engineers, and all other relevant SoI actors.

With circularity targets in mind, we can also imagine a fourth SoI around materials. This represents the material lifecycle and operates across industries that use the material. For example, aluminium once used for aerospace can be reused in construction or automotive.

This way of working has to be managed and embedded across whole organizations. This will be a gradual transformation of the whole engineering function, with impacts on processes, training and culture, and with collaboration and agile principles as key levers of this transformation.

> *The size of these new systems means that we need engineers capable of modeling and dealing with complexity. That expertise must be acquired.*

Valérie Ferreboeuf
Associate Vice President Strategy and Planning at Université Paris-Saclay Associate Professor at CentraleSupélec

Didier Dumur
Professor at CentraleSupélec, Dean of Studies of the CentraleSupélec Engineer Curriculum

> *The future of engineering will rely on the ability to see the whole problem and take a systems-engineering approach—supported by digital infrastructure and data—to react quickly when an unexpected situation arises.*

Geoffrey G. Parker
Charles E. Hutchinson ‘68A Professor of Engineering Innovation at Dartmouth College

> *System of Systems approaches, MBSE, and simulation of complex systems will open new fields.*

Richard S Stapp
Northrop Grumman, Sector VP, Capabilities & All-domain integration

ENGINEERING BACK TO VALUE CENTER

The engineering community has experienced more than 20 years of optimization of execution models with off-shoring strategies to attractive countries with qualified engineers and attractive cost conditions. This has accelerated growth and allowed best-cost engineering.

This model is still partially valid, but we now see a more complex picture to navigate thanks to both new skills needs, the growing importance of cross-domain collaboration, and changing geopolitics.

Firstly, the engineering function produces a significant amount of value as a result of co-engineering, cooperation, reuse, assembly, and orchestration of ecosystems over different boundaries, locations, and countries. This makes the traditional model of 'customer and supplier' look outdated.

Secondly, software delivery centers are now often major drivers of innovation, rather than arms-length functions. And collaboration enables learning—engineering functions are absorbing best practices from software like 'user experience', 'agile development methods', and deploying AI use cases in production and development (e.g. computer vision, natural language processing or acoustic applications) which lead to quality improvements and more innovation.

Thirdly, engineering centers are increasingly required to act as service centers for internal and external customers and partners. There is a need for a much more joined-up and collaborative approach, with thought given to positioning critical functions—including those that are outsourced— within the value center of the business.

Learning from others: Innovative Ecosystems

- An international OEM is working with a hyperscaler to build a 'SmartCockpit' in the cloud, which it can customize for its cars.
- A satellite company is partnering with a cloud provider to develop machine learning tools to analyze earth observation imagery.
- A German OEM has built an ecosystem to develop automated driving technologies and beyond.
- Another OEM has a revenue-sharing agreement with a chip manufacturer, in exchange for access to processors for in-vehicle computing and AI.
- OEM are integrating AI and especially Gen-AI APIs and fine-tuning existing Large Language Models to test, learn and participate in the disruptive Artificial Intelligence developments.

> *We see a move in engineering from constantly evolving hardware, to creating a hardware foundation with software on top.*
>
> **Simon Weeks**
> *Aerospace Technology Institute, CTO*

> *Find the right partnering and make a strategy out of it to generate ideas from your ecosystem.*
>
> **Dr. Tino Fuhrmann**
> *Volkswagen, Systems Engineer SoS*

NEW MULTI-TIER ECOSYSTEMS

The model of full product development outsourcing to Tier 1 suppliers is challenged. In order to constantly produce digital and sustainable innovations—from in-vehicle AR displays to hydrogen fuel cells—companies need to build a diverse supplier and partner ecosystem.

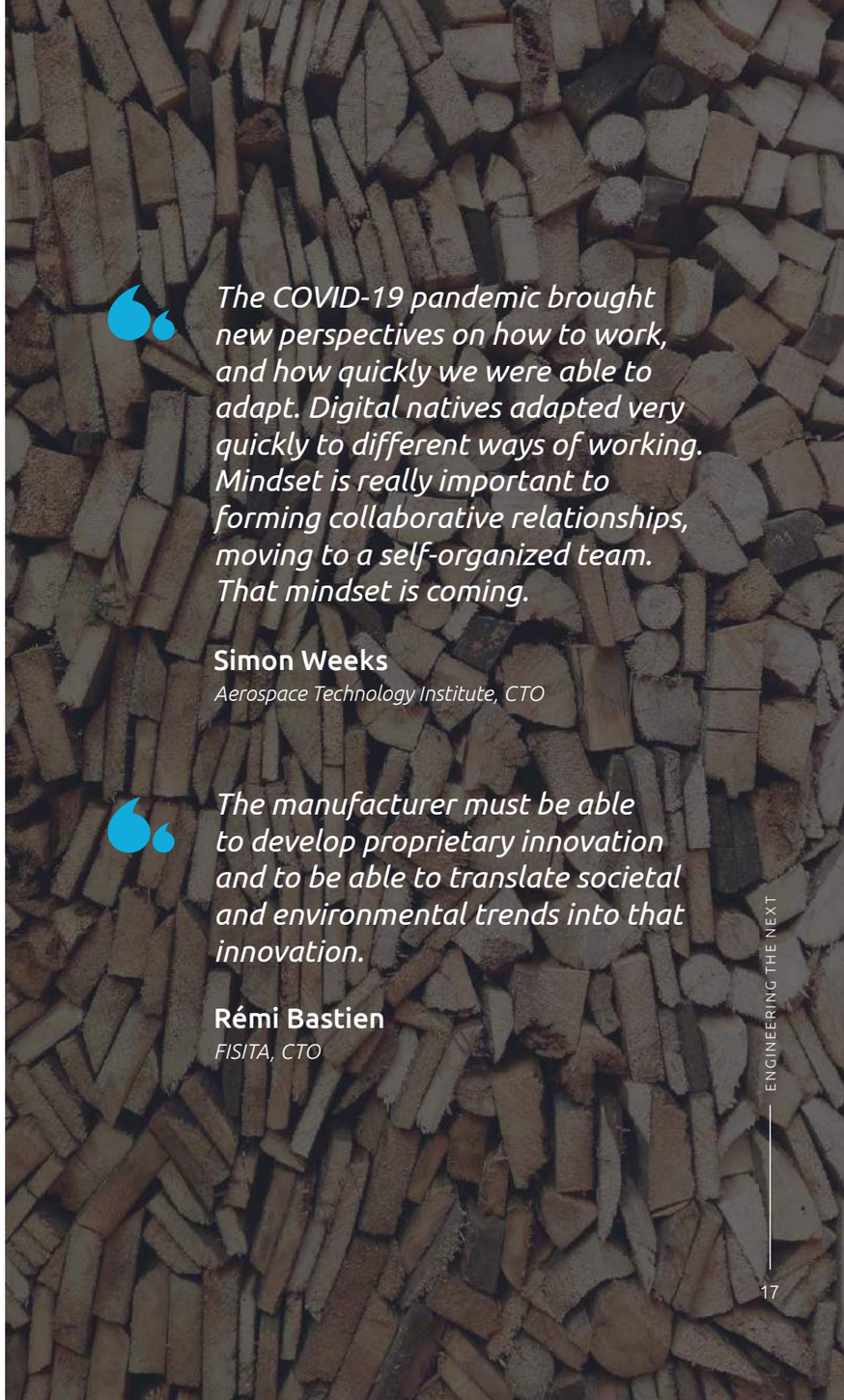
Engineering companies need to continue to create new relationships with suppliers and partners, including in domains outside of their comfort zones. They must have programs to spot promising startups and research, and shorten the process of onboarding suppliers and partners, which currently can take many months. They will need to pursue joint ventures to solve cross industry problems that they cannot solve alone.

A current example is the semiconductor market and value chain. OEMs used to outsource component purchasing to Tier 1s, but chips' strategic importance means the OEMs need direct, collaborative relationships with chip manufacturers (see 'Innovative ecosystems' on the previous page). That creates new relationships, and brings operational changes: OEMs need the skills to assess chip quality and performance, develop innovative functions on it, new supply chain models to ensure supply of a critical but constrained resource, and the digital infrastructure to collaborate with an innovative tech company.

All this demands a collaborative, agile, and communicative operating model— supported by digital technologies and data to enable innovation across diverse and distributed teams.

It should be noted that institutions, industry groups and standards bodies will need to play a role here. The future of ecosystem based engineering must be built on new shared norms, and common standards around data, AI, and the environment to enable the interoperability of ecosystems that will underpin the transformation of engineering.

Creating and orchestrating these ecosystems requires a solid core/non-core strategy. The relationship between investment and future sovereignty is undoubtedly the key element of the future of engineering. The tectonic movements that have begun around the value chain of industries are unlikely to subside.



> *The COVID-19 pandemic brought new perspectives on how to work, and how quickly we were able to adapt. Digital natives adapted very quickly to different ways of working. Mindset is really important to forming collaborative relationships, moving to a self-organized team. That mindset is coming.*

Simon Weeks
Aerospace Technology Institute, CTO

> *The manufacturer must be able to develop proprietary innovation and to be able to translate societal and environmental trends into that innovation.*

Rémi Bastien
FISITA, CTO

KEY TAKEAWAYS

Challenge:

As all Industry value chains are reshuffled, design a future-ready operating model for your R&D and Manufacturing functions in line with your market and enterprise context.

CxO agenda:

- Reposition Engineering from a “cost center” to “value center”.
- Use a ‘System of Interest’ approach, to ensure co-development and continuity of product engineering, manufacturing, and services.
- Foster innovation across diverse and distributed teams, to be more flexible, agile, lean, collaborative, and resilient.
- Position “sustainability” as a 4th design criteria at the same level as cost, quality & speed.
- Build flexible operating models to anticipate and/or adapt to short and long-term threats.
- Orchestrate a mandatory and interoperable partners ecosystem, with emphasis on horizon scanning, spotting promising startups, and research.

3 DEPLOYING THE ENABLERS OF CHANGE: SKILLS, DIGITAL, LEADERSHIP AND CULTURE

A NEW GENERATION OF TALENT

> *A transformation happens over several years. It is our responsibility to transform the engineering function to face new challenges. We take care of our employees by upskilling to new competences like software engineering; we collaborate with new agile and autonomous players. We work on mindset change to transform the job of engineer.*

Pierre-Yves Dachet
Stellantis, HR Leader for West Europe Engineering

For the future generation of engineers.

To master the transformation, companies must develop a breadth of new skills, and a collaborative culture to bring them all together. In order to deliver the agile engineering needed for sustainable, evolutive, and customer-centric products.

The World Economic Forum predicted in the latest Future of Job reports the reskilling need of 50% of our workforce within the next 5 years and ~69 new data and AI jobs.

That leads to a transformation in three areas: the new skills and mindset, the digital tools that underpin collaboration, and leadership to drive the cultural transformation.

The role of the engineering function is evolving quickly and becoming ever more transdisciplinary, as physical products are reinvented for sustainability and as digital services.

THE SKILLS TO DELIVER THIS TRANSFORMATION CAN BE DEFINED AS:

Strong fundamentals: Existing engineering disciplines are still highly important. Excellence in scientific thinking is critical for their development, but also important in the new digital world. It is the way engineers analyze and critique results obtained via digital means. As simulation results grow in complexity, an understanding of the underlying physics is key to understanding the simulation.

New skills: To deliver against customer expectations of ongoing improvement, softwarization (the overlaying of software onto the car, plane or satellite, which can control physical and digital systems and be upgraded over-the-air), plays a major role in engineered products.

Meanwhile, to meet sustainability requirements, new skills are needed in sustainable engineering and new sustainable technologies.

LEARNING FROM OTHERS: INNOVATIVE UPSKILLING

- An international OEM recently launched a Data and Software Academy to retrain over 1,000 employees per year and hire talent worldwide.
- A German OEM has invested €200 million ($206m) in an Electric Software Hub, which will house 1,000 programmers at its research-and-development campus, close to its Stuttgart headquarters, so they can easily work with any department.
- A German OEM's software division has an ambitious goal to do 60% of software development in-house, compared to an industry-wide goal of 20–30%.

BELOW IS A NON-EXHAUSTIVE LIST OF SPECIFIC NEW SKILLS AREAS THAT NEED TO BE SCALED UP:

- New materials expertise
- New energies expertise (Renewable energies, hydrogen, etc.)
- Combined software, IT/OT and connectivity
- High speed and Quantum computing
- Combined modeling and simulation, including Model- Based Systems Engineering (MBSE), multi-physics simulation, product life cycle management (PLM), life cycle analysis (LCA)
- Data and advanced AI, both for engineering processes and to be embedded in the products and services
- Sustainable design
- Open innovation
- Digital and classical socio-cultural analysis

> *We are no longer just engineers but business engineers.*
>
> **Gilles Le Borgne**
> *Renault Group, EVP Engineering*

> *We must ensure the upskilling of employees, especially towards new professions such as software.*
>
> **Pierre-Yves Dachet**
> *Stellantis, HR Leader for West Europe Engineering*

> *Non-attractive industries and companies that do not know how to recruit and retain people today may disappear in less than 10 years.*
>
> **Olivier Guintrand**
> *Alpine Cars, Technical Director*

Tomorrow's engineers will have to design products, services, and their economic models. We train students for three years but will need to train employees for 30 years.

Valérie Ferreboeuf
Associate Vice President Strategy and Planning at Université Paris-Saclay Associate Professor at CentraleSupélec

Didier Dumur
Professor at CentraleSupélec,
Dean of Studies of the CentraleSupélec Engineer Curriculum

We have to instill the mindset to transform the profession of engineers who have been working for 30 years in the company.

Pierre-Yves Dachet
Stellantis, HR Leader for West Europe Engineering

Soft skills: Finally, soft skills will become a key quality for good engineers, who will need to understand societal, environmental, and economic trends and business outcomes. Being at the heart of the company, engineering must move beyond the traditional hard skills and develop their ability to communicate with each other, with other functions, and with its changing ecosystem.

These skills need to be nurtured through a mix of recruitment and retraining, mixing the old and the new worlds. But delivering this will not be easy. Many of these skills take years to learn and hiring in some areas, particularly software, is subject to fierce competition.

THAT MEANS OUTSIDE HELP, THROUGH PARTNERSHIPS, CONSULTANTS AND ENGINEERING COMPANIES, WILL BE AN ESSENTIAL PART OF THE PLAN. THE BREADTH OF THE SKILLS NEEDED REQUIRES HARNESSING DISTRIBUTED TALENT AND PARTNERSHIPS AROUND THE WORLD INCLUDING REMOTE, ONSITE, OFFSITE, NEAR- SHORE AND OFFSHORE CAPABILITIES—A STYLE OF WORKING THAT MAY BE NEW TO ORGANIZATIONS USED TO PHYSICAL FACILITIES. IT ALSO MEANS OPEN INNOVATION PROJECTS WITH START-UPS, UNIVERSITIES AND EVEN COMPETITORS, WHICH MAY IMPACT COMPANIES THAT CURRENTLY LIMIT R&D TO THEIR OWN ON-SITE LABS.

And then there is the challenge of culture, mindset and diversity in the classical, hardware-driven industry. Creating a sustainable digital product means getting the traditional engineers, who have been with the company for decades, to work with new sustainability and software teams, who may have different priorities and ways of working. This needs collaborative tools and methods (design thinking, agility at scale frameworks, etc.) and access to the right data, at the right moment, for daily operational decision-making and training, and may need some serious 'carrots and sticks' to get everyone on board with this new collaborative way of working.

In my role I spend less time at location and more working virtually with teams all over the world.

Jean-Michel Billig
Stellantis, Head of Hydrogen Engineering

Great project managers have a systems architecture background. This is the backbone of leadership.

Rémi Bastien
FISITA, CTO

DIGITAL ENABLERS

> *Digital continuity offers us the opportunity to implement tools that bring together all our businesses. Aligning all the engineering disciplines with purchasing, finance and HR requires a lot of effort, and it's brutal. But I am a great believer in digital processes serving the business.*
>
> **Gilles Le Borgne**
> *Renault Group, EVP Engineering*

Like data, Artificial Intelligence will be the key prerequisite to create a new data-driven engineering space.

Innovating collaboratively and securely needs cloud-based digital platforms that allow collaboration on co-development (co-design, co-testing and simulations) with large teams working together on the same product and service. This will be critical as engineering teams are increasingly made up of diverse individuals with different skillsets and cultures, working around the globe, internal or external, picking up from each other as working days end in one time zone and start in another.

Digital Continuity must be seen as a framework that connects all data and contributors (including different engineering disciplines, strategic marketing, manufacturing, services, sales and aftersales, purchasing and finance) to the product/ services co-development into a data-driven value chain, in a virtual common environment.

On top of this framework, data-driven technologies like Virtual Reality (VR), Metaverse, IoT, cloud computing, real-time simulation (RTS), Artificial Intelligence (AI) specially Generative AI will be key prerequisites to enable the engineering space.

KEY FACTORS IN DELIVERING THIS TRANSFORMATION INCLUDE:

For example, with RTS, the simulation of complex products will become standard and allow engineers and other relevant stakeholders to interact directly with models and obtain results of simulations in real-time. We expect higher quality, acceleration and increasing automation of engineering processes as well as cost reduction by simulating the systems approach.

When developing data-driven and AI systems, we focus on the trustworthy, human-centric approach. On top of that, the technologies are also used to support humans in error-prone routine tasks or complex calculations.

The transparency of the quality of the data used is as relevant as the traceability of the data-driven processes and decisions of the system. The system allows the engineer to focus on added value tasks and use their engineering judgment for the final design. The current Generative AI development and its combination with other technologies will redefine the business along the entire value chain and disrupt the Human-Machine-Interaction of the engineers.

The organizations that combine all these frameworks and technologies, will create an innovative, collaborative and realtime simulation environment—both across multi-disciplinary engineering teams and the extended ecosystem— which will also provide rich, and reliable data for modeling and simulation of product design and test scenarios for all ecosystems.

Consequently, digital engineering tools should be connected to the data sources and platforms. And these digital enablers will all require well designed mandatory training on these new tools and processes to ensure that everyone is able to use them, and is excited to do so.

IT SEEMS PREDICTABLE THAT THE NEXT DECADES WILL BE DATA-DRIVEN AND FOCUSING ON INTELLIGENT HARDWARE-SOFTWARE CODESIGN.

A CONNECTED DATA-ECOSYSTEM AND THE INTEGRATION OF GENERATIVE AI COULD BE A SIGNIFICANT ACCELERATOR FOR THOSE ENGINEERING COMPANIES ABLE TO EXPLOIT IT... AND A DESIGN AID TO HELP DRIVE INNOVATION.

Nowadays, all engineering executives are discussing Gen AI, trying to understand the value and see through the hype 96% of the boardrooms have Generative AI on TOP of their agenda.

At the same time, the hardware driven engineering industry is facing the challenge of how to enable their data infrastructure to ensure a sustainable and future-proof data ecosystem. One of the biggest challenge is to move from AI PoC [Proof of Concept] phase into AI full roll-out phase.

To ensure solid data value creation and knowledge transfer, silos must be broken down and we need to build a connected data-eco-system, which allows the access and use of the relevant data.
For example, the contextual data are the foundation in Data Analytics, Artificial Intelligence and the future of Generative AI.

In the last decade, the focus of industrializing AI was on singular AI Technologies and specific Application areas. For example, Computer Vision for Quality Control, Natural Language Processing for Chat-Bots or Acoustic Analytics for interfering noise. The future of Generative AI and the potential of the foundation models behind them is about merging and scaling.

Merging Technologies is about the fusion of AI Technologies like Natural Language Processing and Acoustic, text or audio, automatic design, generative design, book of Knowledge for trusted sources.

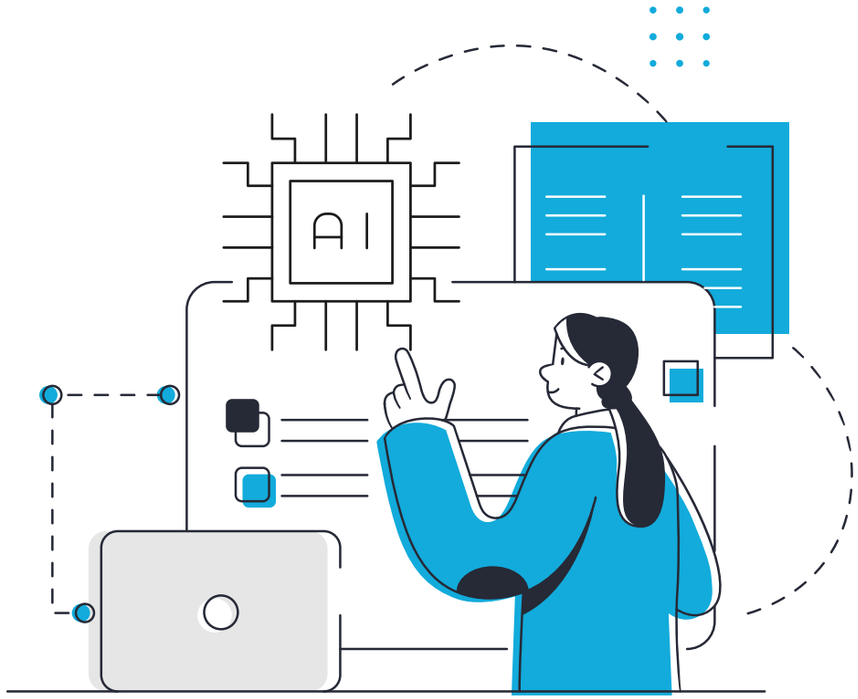
The application areas in the engineering domain are numerous (product and systems engineering, manufacturing, in field services, etc).
For example:

- Generating synthetic data or code
- Creating unique content
- Automating or accelerating design tasks to creating personalized experiences

To lift the potential of Generative AI in engineering, companies have to integrate the technology in their digitalization strategy, build scalable AI Platforms and qualify their engineers to use the AI tools in the data ecosystem.

> *The adoption of Gen AI in the engineering domain is transformative, but it will take time simply because we care about correctness. Its effective adoption will be about how you incorporate GenAI into the overall engineering flow, and how to link it with physics-based models which understand the relevant domain. Gen AI will not replace engineers, but engineering organizations who use Gen AI, will replace those who do not.*

Keith Williams
Chief Technology Officer, Executive Vice President at Capgemini Engineering



THE FUTURE ENGINEERING LEADERS

> *The best people are looking for the best jobs. As a leader, you must identify and attract talent on a global level, you must be a salesperson who can convince and attract good people.*
>
> **James Maher**
> *Czinger Vehicles, Director of Powertrain and Electrical*

Delivering the above will not be easy. It needs recruitment and cultural transformation. Failures of 'transplants' of startup profiles into traditional environments are frequent. Successful delivery will only be possible with strong leadership.

Future engineering leaders need to be both visionary, and good at an operational level of engineering. This enables them to combine understanding of technical possibilities with an understanding of societal needs and changing customer expectations, and to understand and promote digital enablers.

They need to be agile by nature, observing the changing world around them and be ready to make quick decisions and changes when needed.

They need to have a clear sense of purpose aligned to business goals, and who can bring everyone to work together toward delivering the final product, and its associated services.

They have to embody the cultural transformation where the figure of the engineer is no longer only at the service of product performance but also dedicated to the protection of the planet.

They also need to be inspirational and visionary, to attract a wide range of talent to their team from across industries, in a very competitive marketplace.

They will need to build bridges between diverse internal teams. From risk- averse safety engineers to software engineers who want to push out half- finished prototypes, from inspirational design officers to the complex and constraining reality of mathematics. And they must foster excitement about collaboration.

As engineering teams become more diverse, it is impossible for leaders to be experts in all disciplines. But they will need to understand multiple disciplines, and be able to help these disparate teams work together towards a business goal.

Such bold leaders are critical to the transformation described in this paper, and today's leaders will need to pay particular attention to finding and nurturing these engineering leaders.

KEY TAKEAWAYS

Challenge:

As all businesses are becoming Tech businesses, transform your engineering in areas such as Digital adoption, AI upskilling and culture to attract the best talents and leaders of tomorrow.

CxO agenda:

- Map the range of hard and soft skills needed and build an ambitious hiring strategy.
- Develop and maintain training and partnering plan.
- Select and deploy the digital processes, methods, tools, and platforms to enable digital continuity across multiple and distributed engineering disciplines.
- Invest in a data-driven approach, democratize AI and Gen AI tools, and systematize simulations for rapid and efficient innovation, with adequate governance.
- Nurture inspirational engineering leaders to drive the transformations and instill the new mindset. They must understand both the business and the technologies.

> *Technical skills, or at least 'technical credibility', is a must for an engineering leader. They need capacity to make decisions and show solidarity with the engineering team so that decisions are respected and trusted.*

Jean-Michel Billig
Stellantis, Head of Hydrogen Engineering

> *The two key skills of a top engineering leader are first to set the vision and then to get people excited about it.*

James Maher
Czinger Vehicles, Director of Powertrain and Electrical

CONCLUSION

An exciting future ahead...

Anticipating what the future will look like is always a complex exercise. This paper, developed with the help of 30 global executives from the automotive, aerospace and defense industries, brings some perspectives on what the future could be.

WE ARE UNDOUBTEDLY MOVING TOWARD A MORE CONSTRAINED WORLD, MEANING DECISION CRITERIA WILL INCREASINGLY DEMAND SUSTAINABILITY (USE OF RECYCLED RAW MATERIALS, ENERGY CONSUMPTION, LIFE CYCLE, ETC.) ON TOP OF THE TRADITIONAL CONSIDERATIONS OF QUALITY, COST AND PERFORMANCE. WE HAVE ALSO STARTED THE JOURNEY TOWARD INTELLIGENT PRODUCTS, WHERE EMBEDDED AI IS IMPROVING SAFETY AND BRINGING ADDITIONAL INSIGHTS TO DRIVERS, PILOTS AND OTHER USERS, TO HELP THEM MAKE THE BEST AND DATA-DRIVEN DECISIONS OR ADD VALUE TO THEIR EXPERIENCE.

It's only the beginning of that journey and we will move progressively to an era where data-driven decisions and the use of Artificial Intelligence will be a key prerequisite to creating a new data-driven engineering space. New product and digital ecosystems will emerge to create new services driven by higher connectivity and data sharing, responding to changing expectations from customers.

Companies have no choice but to embrace that transformation path to stay in the game.

This may sound like a challenge, but it is also an exciting opportunity for engineering to make the world a safer, more convenient place to live, and ultimately to solve the most pressing challenge of our time, avoiding devastating climate change and saving the world.

TO FACE THIS CHALLENGE, SIGNIFICANT TRANSFORMATIONS ARE REQUIRED, WHICH WILL DRAMATICALLY IMPACT THE FUTURE OF R&D.

- The business models will change, shifting from one-off transaction and depreciating residual value to subscription models and appreciating residual value.
- The value chain will be transformed with a stronger role for chips and computing, hyperscalers and data brokers, changing the bargaining positioning of OEMs.
- The organization models will change with R&D being back at the core of competitive differentiation.
- The product development cycle will, after years of optimization, be completely reengineered to adapt to the new product characteristics.
- AI and Generative AI will transform both the product functionality itself, e.g. the nature of machine interaction, but also bring productivity opportunities along the entire product development lifecycle.
- The engineering skillset will evolve both in terms of hard skills (systems engineering, AI, software, etc.) as well as much higher expectations on soft skills.
- There is no doubt that these changes will take time and the pace at which they will take place remains the biggest question. In recent years, we have seen that a) new players can disrupt legacy ones, forcing dramatic changes; and b) external events can force radical transformation that looked years away. Clearly, companies can adapt when they need to. But they should not wait to be forced. They should start today.

THERE ARE HUGE CHALLENGES AHEAD, BUT ANY MEASURED CONSIDERATION OF THE FUTURE OF ENGINEERING ORGANIZATIONS SHOWS THAT IT IS ALSO ONE OF THE MOST EXCITING TIMES IN HISTORY TO BE IN THESE INDUSTRIES.

WITH GRATITUDE

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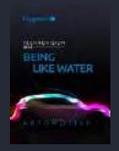

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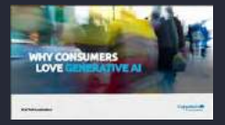

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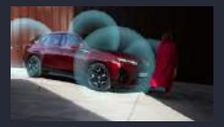

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