Ansys

TAKE A LEAP OF CERTAINTY:

The Need for Interconnectedness to Support the Challenges of 2023 and Beyond

State of the Industry

When considering the industrial revolutions that have marked the development of economies, engineering has been responsible for much of the progress over the last century.[1] As we stare into the fourth revolution, Industry 4.0, which focuses on the current trend of automation and data exchange in manufacturing technologies, the key question is – how does this affect the future of engineering? While risks from COVID-19 variants, cyberattacks, and environmental challenges are still expected to impact the industry in the near future, Industry 4.0 and the digitalization of data and processes will contribute to a more sustainable and competitive market.[2]

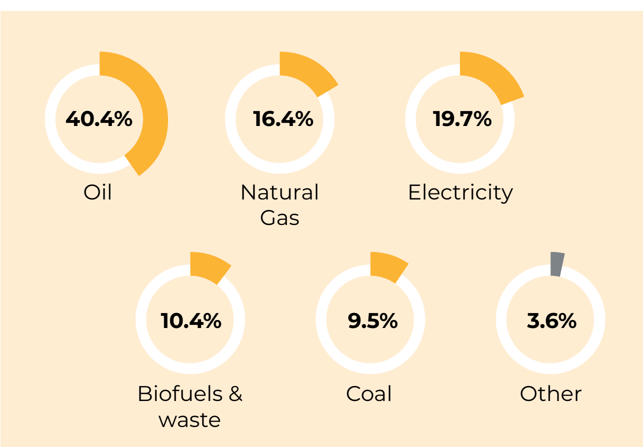
1. Current Challenges and How to Overcome Them

CHALLENGE 1

Sustainability and the Future of Engineering

The burning of fossil fuels has generated most of the energy required to sustain the industry for more than a century. Even today, oil, coal, and gas still provide about 80% of our energy needs. Using fossil fuels for energy has exacted an enormous toll on the environment, from polluting the air and water to exacerbating global warming.

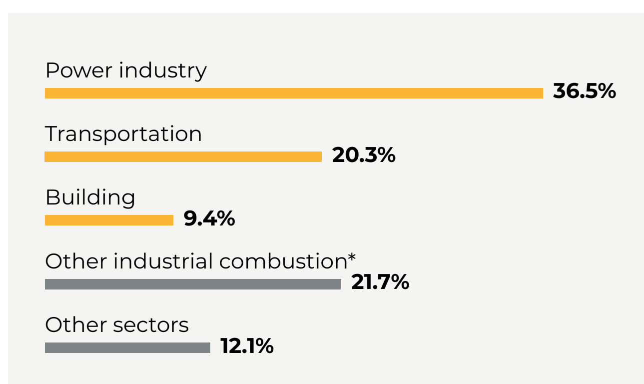
Share of world total final consumption in 2019, by source[3]



As a result, global energy-related carbon dioxide emissions continue to rise, reaching a record 36.3 billion tons in 2021, the highest-ever level, as the world economy recovered strongly from the COVID-19 crisis.[4]

The industrial manufacturing sector, with its history of heavy reliance on fossil fuels, overproduction, and waste, is one of the largest emitters on earth. In Europe alone, the industry emits a total amount of 880 million tonnes of carbon dioxide equivalents annually.[5] The industry has, however, been aware of its environmental profile and thousands of manufacturers worldwide have committed to the Science Based Targets initiative to help curb emissions and limit global warming.

Distribution of global carbon dioxide (CO_2) emissions in 2020, by sector[6]



* Includes combustion for industrial manufacturing and fuel production

> **"Our goal or challenge is to continue to feed the market with what we have while aligning research and development to pursue new concepts and innovations and design new products that are compatible with sustainable resources."**
>
> *A development engineer at a German gas turbines and steam turbines company*

Engineers have played and continue to play a key role in the future of sustainable development. Whether it is building new products or working on technologies that will innovate the future, they are instrumental in designing, architecting, and building the way products, goods, and services are delivered and consumed.[7] So the important question for engineers is how does the industry continue to support the future of industrial manufacturing while also making the process more sustainable using renewable resources?

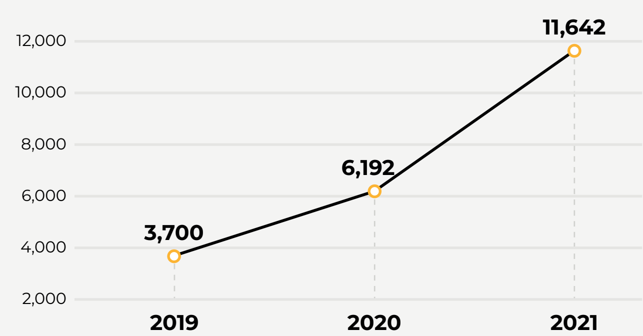
It can be argued that the solution starts with the engineers. They are at the source of the problem which puts them in a perfect position to be able to suggest improvements and use upcoming technology to enact change.[8] Regulations put in place by governments, such as REACH, an EU regulation,[9] are being implemented to further support the environment, and it will be up to the industry and individuals to understand how to move forward.

CHALLENGE 2
Instability within the Supply Chain

Supply chain issues, or crises even, have been the recurring nightmare since the pandemic struck in 2020. COVID-19 disrupted everything from economics and how people work to material shortages and increased pressures on infrastructure and security.

As the industry attempts to find ways to work around the problems, including developing new supply chains and building new partnerships, a response may not be generated as soon as required to get the industry back on track.

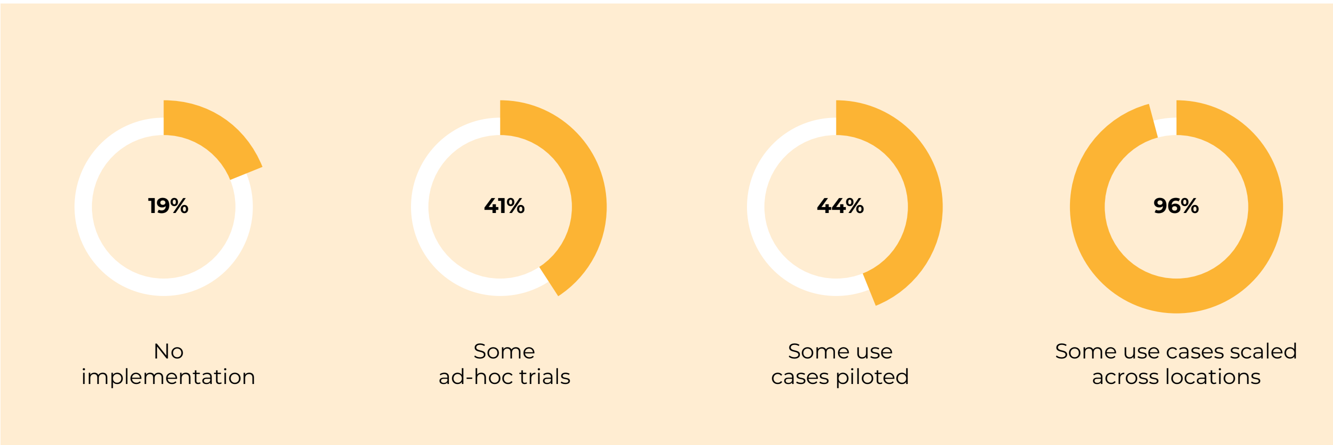
Number of supply chain disruptions worldwide from 2019 to 2021[10]



> **"The pandemic increased the prices, but they were increasing slowly. Now, the prices got higher within just 2 weeks. It's not 10% to 20%, we're talking about an increase of 50% to 100%."**
>
> *A constructor at a Polish hydro valves company*

Industry 4.0 will be instrumental in supporting the changes needed to address certain problems. Organizations that had already implemented some solutions before the pandemic felt less impacted than those that had not.[11]

Maturation of Industry 4.0 implementation in relation to crisis response in 2021[12]



With supply chains still needing to find the perfect balance between delivering the right services for the right price at the right time, the digitalization of the supply chain is crucial. Predictive planning and a connected technology foundation are integral to meeting demands and supply chain fluctuations. Accelerating the adoption of digital technologies could also support bringing operational efficiencies to scale.

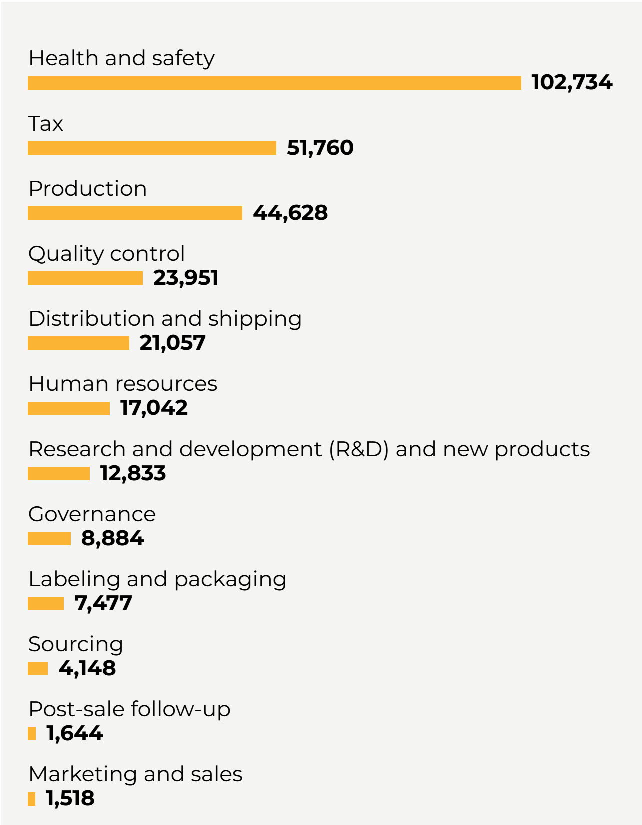
CHALLENGE 3
Heavy Regulations

Like many other industries, the industrial manufacturing segment has been facing increasing local and international regulation and compliance measures. Too many regulations become a heavy burden on companies and slow down the economy.[13]

The following chart shows that U.S. manufacturing companies faced a striking 297,696 restrictions on their operations from federal regulations in 2017, and new rules and policies have since been adding up rapidly.

> **"Your product has to comply with all these legislations, so that has been the biggest challenge moving forward. [...] There are more and more structured legislations that you have to conform to, compared to 30 years ago."**
>
> *A senior application manager from a UK brushed motor manufacturer*

U.S. federal regulations faced by manufacturers in 2017[14]



Regulations are also costly and small manufacturers suffer especially from high compliance costs: Every year an average small manufacturer (a company with fewer than 50 employees) in the U.S. pays USD 34,671 in compliance costs per employee, three times as much as the average U.S. company. It is therefore no surprise that federal regulations were cited by 88% of surveyed small manufacturers as a top challenge, according to the National Association of Manufacturers (NAM).[15]

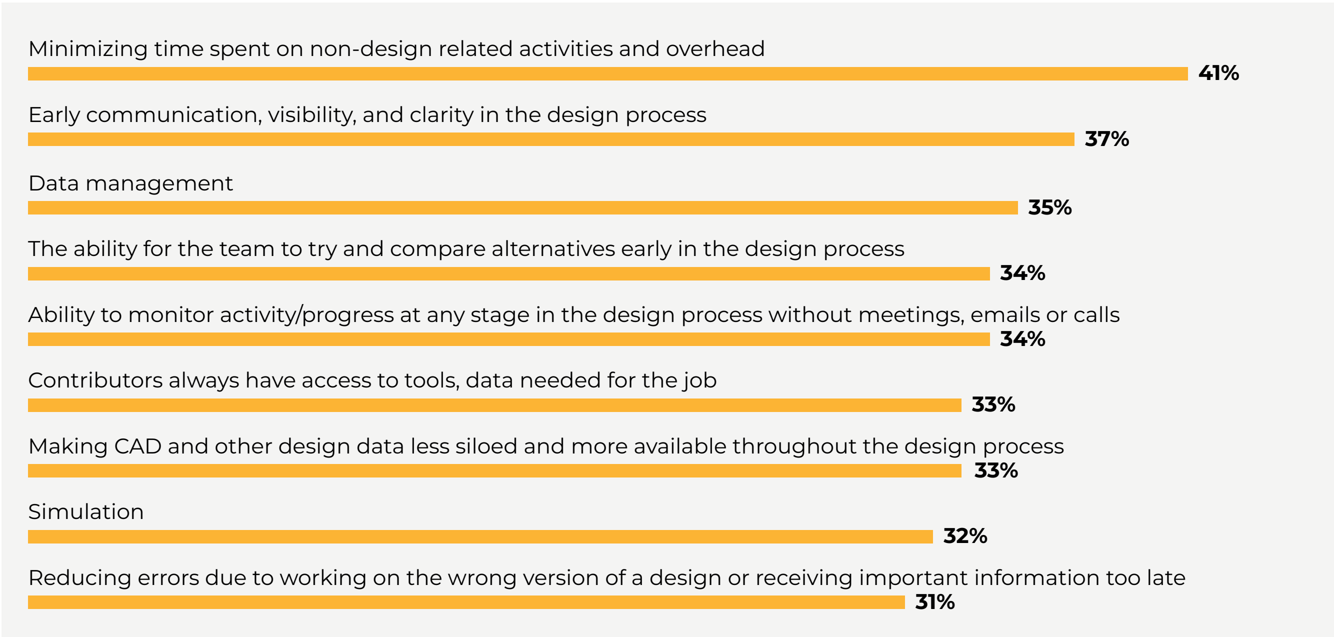
The great variety of companies within the industrial manufacturing sector also means that a diversity of regulations needs to be followed. Regulations also quite often span across multiple areas, such as REACH, which aims to improve the protection of both human health and the environment while also promoting alternative methods of assessment. While REACH is focused on the use of chemical substances, regulations are being put in place for the reduction in emissions along with an increased focus on renewable energy sources. This means that regulatory bodies such as the Environmental Protection Agency in the U.S. can exert significant influence over engineering practices, materials specification, and waste-control systems.[16] Regulations like this require organizations to adapt quickly and effectively.

CHALLENGE 4
The Product Development Cycle

To stay relevant, manufacturers need to keep up with or even guide consumer needs with innovative products. The capital-intensive nature of the industry means that cost pressure is high. Companies are constantly looking for ways to decrease the cost of new product development and reduce time to market. Efficiency is key.

The need to go faster and cheaper and other product management challenges are reflected in a survey of global manufacturers, which shows that minimizing overheads and time spent on non-design-related activities is the area that manufacturers need to work on the most. Companies also still struggle to decide on the best approach early in the design process to avoid costly redesign at a later stage. The need to improve on early alignment in the design process and try out alternatives before launching the full production cycle is big.

Top product development areas that manufacturers need to improve on[17]



> **"If you aim for a new product [and] you [test only] at the end of it, it's going to cost you more money to redevelop and redesign it. We try and build it into the structure of the product at the very, very early stages."**
>
> *A senior application manager from a UK brushed motor manufacturer*

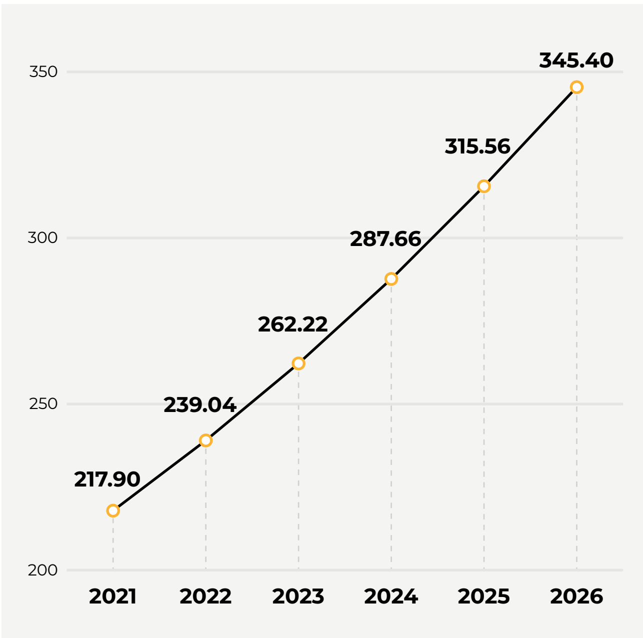
CHALLENGE 5

Increase in Cybersecurity Risks and Ransoms

High-profile cyberattacks across all industries in the past year have elevated cybersecurity as a risk management essential for most organizations. Surging threats during the pandemic added to the risk factor, with many facing an increase in phishing or ransomware attacks.[18] The manufacturing sector in particular faces a high risk of ransomware attacks, with more than 75% of those in the engineering sector encountering various forms of cyber breaches including phishing, worm viruses, and data deletion at the center of the attack.[19]

These threats have increased with Industry 4.0. With the new emphasis on the transparent flow of data, factory floors and equipment can no longer work in isolation, cut off from the main network. Now, everything is linked, and more people and systems have access to that network, opening up multiple gateways to cybercriminals.[20]

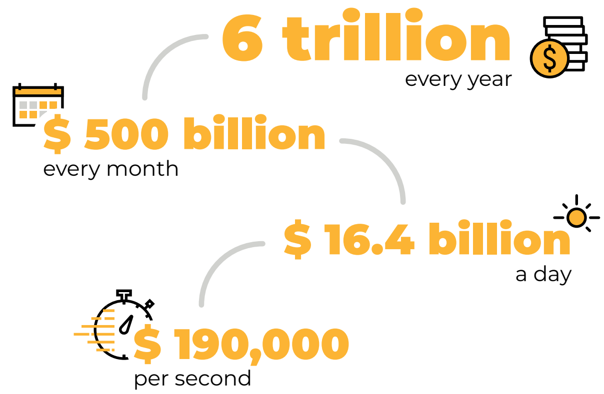
Size of the cybersecurity market worldwide from 2021 to 2026 (in USD billion)[21]



As a result, 82% of executives surveyed by Deloitte expect their organizations will invest more in cybersecurity in 2022, with nearly one-quarter budgeting at least 10% more than in 2021.[22]

Organizations should look not only at their cyber defenses, but also at the resiliency of their business in the event of a cyberattack. 85% expect their organizations will invest more in prevention in 2022, while 56% anticipate more for detection, and 29% plan to allocate more for areas of response.[23]

Global cybercrime damage costs in 2021[24]



Across all sectors of the industry, a need to deploy creative solutions to improve workforce perception and experience will be required in order to support the workforce moving forward.

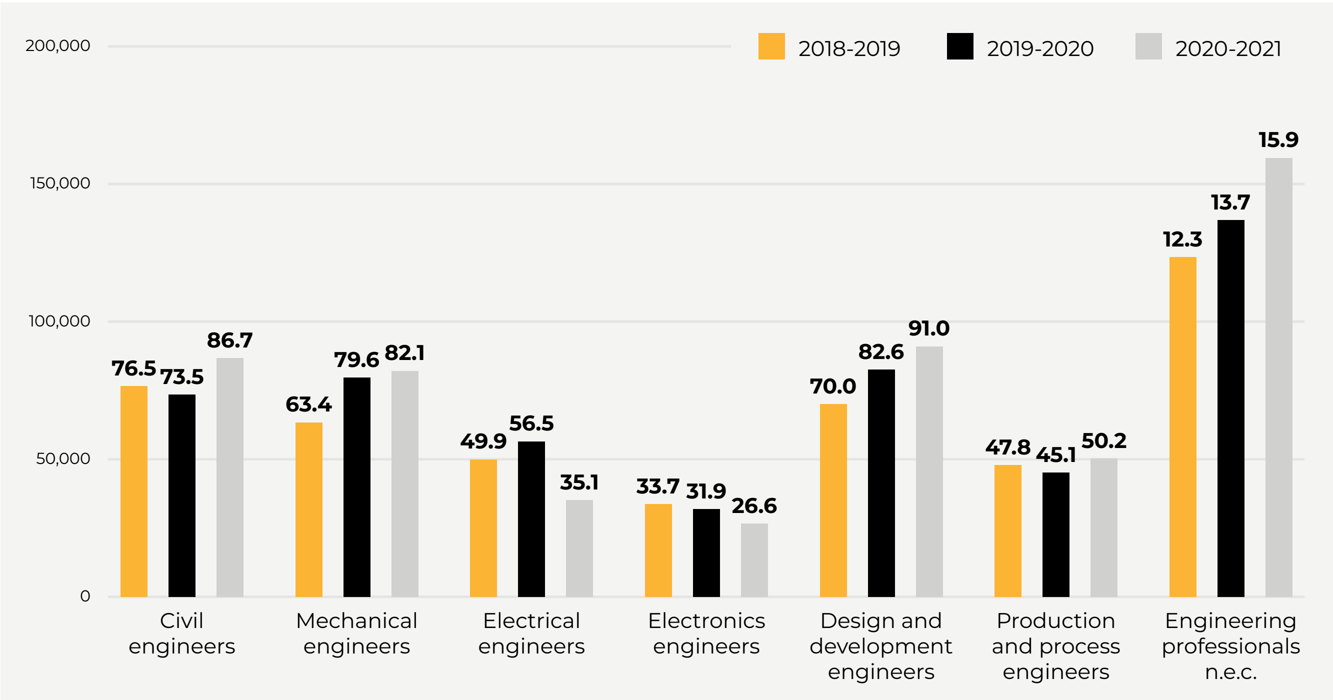
CHALLENGE 6
The Great Resignation

A record number of unfilled jobs are likely to limit higher levels of productivity and growth in 2022. Last year, it was estimated by Deloitte that there would be a shortfall of 2.1 million skilled jobs by 2030.[25] However, it is not just the “traditional” jobs in civil, mechanical, and electrical engineering that will contribute to the shortfall; there is a growing need for multidisciplinary engineers working in the areas of renewable technology, additive manufacturing, the digitalization of industry, and 6G networks to name but a few.[26]

While engineers have mostly come from countries like the UK, Germany, and the U.S. in the past, recent trends have demonstrated that emerging countries are producing engineers in significant numbers.[27] This then has an impact on where engineering is happening globally, with different countries pulling and attracting engineers to their projects, leaving a dearth in other countries.

In the UK, this is further exacerbated by an aging workforce, with 19.5% of engineers currently in employment expected to retire by 2026, leaving a significant gap in skills, knowledge, and experience.[28]

Full-time engineering professionals in the UK (October to September), by occupation (in thousands)[29]



> **"Always trying to find top talent for the business, [...] trying to bring people in at the right level, that's always a challenge. [...] We've probably exhausted the supply of talent locally."**
>
> *An R&D team lead at a UK scientific instrumentation company*

In a survey by Deloitte, 38% of executives reported that their top priority was to attract new workers in 2022, followed by retention (31%) and reskilling (13%).[30] Yet as Industry 4.0 and the adoption of digitalization transforms the workplace, automation of recurring tasks could help to reduce the impact within those sectors experiencing a labor shortage.[31]

2. The Future of Engineering – Interconnectedness

The industry needs to look towards Industry 4.0 technologies to support these challenges. The outlined technologies will be a defining factor in finding and understanding the solutions, while the focus for engineering will be on the integration of the technology – horizontally, where organizations focus on competition supported by knowledge-sharing practices, and vertically, where engineers drive a flexible production line.[32]

When both these components are in place, it allows for a complete system of engineering integration where knowledge is shared for efficiency and growth and the future sees an industry of interconnectedness characterized by organization, productivity, and flexibility.[33]

Industry 4.0 can help address the above-listed challenges in the following ways:

SUSTAINABILITY

Virtual Prototyping

While physical prototyping will always remain a part of the industrial design process, limiting its use while augmenting the adoption of virtual prototyping can significantly reduce the use of raw materials, decrease costs, and increase speed to market. Virtual prototyping, through rapid digital simulation, enables engineers to analyze and optimize their design models already in the early stages. This helps engineers get things right when producing the physical prototype, reduces or avoids the need for re-design and redevelopment altogether, leading to a more sustainable process.

SUPPLY CHAIN INSTABILITY

Digital Twin

Digital twin technology is one of the top components of the digital transformation in industrial manufacturing as it increases productivity and revenue. While a digital twin is a virtual representation of real-world entities and processes synchronized at a specified frequency and fidelity, in this case it is essentially a virtual supply chain replica that consists of hundreds of assets. It allows for increased attention within the industry due to improvements in technical and computational capabilities with operations technology. The deployment of digital analytics enables the analysis of digital data from a multitude of sources and identifies where volatility and uncertainty exist, as well as where optimization is possible.[34]

> **“[...] The digital twin is of great interest to us for precisely the following reason: we only manufacture the product in small quantities and then pass it on to our colleagues, but we still receive queries. The digital twin gives us the opportunity to ask questions and to receive requirements [...] .“**
>
> *A development manager at a German hydraulic systems company*

Additive Manufacturing

Additive manufacturing (AM) aims to reduce the impact of supply chain trade issues through its ability to produce parts locally and on-demand, with the additional benefit that the assembly of several parts can be produced at once, involving the procurement of a single raw material rather than procuring multiple parts and then assembling them. This is a natural ability of AM since it has virtually no geometric restrictions, unlike other manufacturing techniques.[35] AM also allows for the creation of small-scale prototypes for testing purposes before going full scale, enabling more sustainable approaches.

REGULATIONS AND COMPLIANCE

Smart Data Information Management

At the center of compliance management is the issue of data management. Siloed data within an organization can result in inaccurate or poor records that fail to meet the need for comprehensive and accurate compliance reporting. Smart data information management makes sure that data is properly and effectively captured and categorized, allowing for transparent and efficient access across departments and functions. This enables manufacturers to quickly react to changing regulations with accurate reporting.

PRODUCT DEVELOPMENT CYCLE

Materials Data Management

Management of materials information ensures organizations are using the optimum material for a specific application, while also providing the enterprise with access to the same materials data for consistent and reliable use. Using cost-effective alternative materials can further reduce production costs.

> **“[...] During development, it is important to find [...] alternative materials that may look different but deliver the same output, [...] also in terms of reducing costs.”**
>
> *A development manager at a German hydraulic systems company*

Simulation Software

Simulation software can be used at the very early stage of product development to simulate design prototypes, which can help to reduce the reliance on more costly physical prototyping and reduce time spent on prototyping, avoid expensive re-development, and speed up time to market. As simulation solutions are becoming more and more accurate, they have taken on a central role in the design process. This frees up valuable resources which can in turn be invested in the creation of better and more innovative products.[36]

> **"We need to employ virtual tools to limit the cost of development and maximize the amount of variations that you want to test."**
>
> *An R&D engineer manager at a Czech hydraulic systems company*

CYBERSECURITY

Analysis Software and Ensuring Security

The key elements to protect data from cyber attacks focus on ensuring that the most up-to-date software and analysis programs are implemented. As more connected systems are deployed and the opportunities for an attack increase, protecting against evolving threats is becoming a full-time task for manufacturers.[37]

The industrial manufacturing sector therefore needs to adopt a security mindset in order to spot potential threats with real-time vulnerability assessments and risk-based prioritizations.[38] Solutions such as incident response tools can help with the early detection of cyberattacks, whereas identity access management (IAM) plays a big role in securing safe access to sensitive operations and data in a company.[39]

RECRUITMENT

A Reskilled and Cross-Functional Workforce

With the projected shortfall of 2.1 million engineering jobs by 2030,[40] it is integral that both current and future generations retrain, educate, and upskill. While these skills include coding and programming, machine learning, and artificial intelligence (AI),[41] it is also important to encourage cross-functionality, particularly among design engineers.

Technology allowed for the development of Computer Aided Design (CAD), yet as we move from Industry 4.0 into the beyond, engineers are more often able to also perform deeper analyses of 3D models with computer aided engineering (CAE). While technology adoption will continue to play a key role in filling skills gaps as they arise, manufacturers cannot afford to stay stagnant as major trends reshape workforces across all sectors.[42]

Beyond Industry 4.0 – An Insight into Industry 5.0

While Industry 4.0 is centered around IoT connecting devices, the upcoming Industry 5.0 will be focused on the interaction between humans and machines. Although we're already starting to see this as humans work alongside machines and are connected to smart manufacturing via devices, the fifth Industrial Revolution is likely to continue the push toward more advanced human-machine interfaces. This will mean improved integration, allowing faster, better automation, along with an improvement in productivity.[43]

3. Solution

THE SOLUTION IS ANSYS

Ansys connects solutions to solutions, so data is transferred safely and automatically, and colleagues to colleagues, so they can work together across the globe on a complex project using a digital model as the single source of truth.

ANSYS WORKBENCH AND ANSYS ELECTRONICS DESKTOP

Ansys Workbench and **Ansys Electronics Desktop** are platforms that enable Ansys solutions to work together seamlessly without the need for manual transfer of data, which can slow things down and lead to errors. For example, an engineer who wants to simulate fluid-structure interactions can set up **Ansys Fluent** and **Ansys Mechanical** in Workbench to simulate the problem automatically, without intervention. Similarly, an electronics engineer who wants to analyze the interactions of various components whose signals might interfere with each other can use Ansys HFSS and Ansys Maxwell to perform the simulation together in Ansys Electronics Desktop.

On a broader scale, Ansys solutions support model-based systems engineering (MBSE), the definitive engineering process for ensuring that everyone working on a project is always using the same model, and that when any change is made to the model it is instantly available to everyone working on the project. MBSE was developed to replace static documents with "intelligent" digital models that contain everything important about the system — the requirements, architecture, and interfaces between the pieces of the system. Instead of paper documents that were at best organized into folders, these digital models are connected by a "digital thread" that can be followed to understand the entire design. MBSE involves the entire process of capturing, communicating, and making sure all the digital models we use to represent a system are coordinated and maintained throughout the entire life cycle of the system.

ANSYS MODELCENTER

Ansys ModelCenter is an intuitive, flexible, and open framework for performing MBSE. With ModelCenter, engineers can create and maintain a library of modeling and simulation tools and engineering workflows. They can automatically execute the workflows, leverage high-performance computing resources to perform trade studies, and ask "what-if" questions. These workflows connect to a systems architecture model (SAM) that serves as the authoritative source of truth for MBSE.

ANSYS GRANTA

Our market-leading **Ansys Granta** Materials Intelligence (MI) software ensures accurate, consistent, traceable materials information and analytics to meet your simulation, design and research needs. This is supported by a comprehensive library of the latest material property information.

ANSYS SCADE

Ansys Scade is a model-based embedded software development and simulation environment with a built-in certified automatic code generator, so you can align the design process according to your safety standard objectives, reduce development costs, and accelerate time to certification.

ANSYS MEDINI

Ansys medini is a model-based, integrated tool supporting safety analysis for safety-critical electrical and electronic (E/E) and software (SW) controlled systems. It allows for consistent and efficient application of industry guidelines, specifically tailored to industry standards, such as ISO 26262, IEC 61508, ARP 4761, ISO 21448 or MIL-STD-882E.

ANSYS MINERVA

Ansys Minerva boosts engineering productivity with efficient simulation process and data management (SPDM). With Minerva, engineers can secure critical simulation data, provide process and decision support, and deliver immediate benefits by connecting powerful simulation and optimization solutions to an existing ecosystem of tools and processes. Because Minerva is available for both on-premise and cloud deployment, it connects team members regardless of geography and functional silos.

ANSYS OPTISLANG

Ansys optiSLang is a process integration and design optimization (PIDO) solution that provides an organization with state-of-the-art robust design optimization (RDO) algorithms. It factors uncertainties and tolerance variations into account to automatically and efficiently identify the optimal configuration for a given design. OptiSLang facilitates all aspects of RDO, including design exploration, optimization, robustness, and reliability analysis. It's not limited to specific Ansys simulation tools, either. Organizations use optiSLang to create automated workflows that can incorporate simulations using virtually any Ansys or non-Ansys product. These workflows parse and pass data from one step to the next, and can run until design goals are optimally realized.

PYANSYS

To help in-house and open-source coders interconnect with Ansys simulation solutions, we developed a product called **PyAnsys**. PyAnsys is a family of Python packages that enable engineers to interact with Ansys products, including the Mechanical Ansys Parametric Design Language (MAPDL), Ansys Electronics Desktop, and others, in an unprecedented manner. The packages provide engineers with a modern programmable interface through which they can not only script the execution of a wide range of multiphysics simulations using the Ansys simulation stack, but they can also script whole workflows that incorporate simulation into other automated operations.

Using PyAnsys, an engineer could automate the execution of simulations in Ansys Fluent, for example, and then pass the simulation results to another

Python application — such as MatPlotLib, NumPy, or innumerable others — for further processing or analysis. The need to perform the manual activities associated with simulation setup, execution, and post-processing goes away when an engineer can write a simple Python script that orchestrates these activities in a consistent, automated manner.

In summary, Ansys products support interconnectedness within the Ansys product realm with Workbench and Ansys Electronics Desktop. ModelCenter and Minerva make it easier for organizations to implement MBSE and keep all their engineers worldwide connected through SPDM. And, finally, PyAnsys incorporates Ansys simulations into a broader ecosystem of automated processes, opening up new doors for interconnectivity worldwide.

4. Make It Real

CASE STUDIES

Integrating Model-Based Systems Engineering (MBSE) to Simulate the Mission Trajectory of the OSIRIS-REx Spacecraft

Leveraging MBSE improves the continuous verification of requirements and mission design parameters.

OSIRIS-REx – Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer – was designed by NASA to study the asteroid 101955 Bennu and conduct a sample-return mission. The mission's primary objective was to land a spacecraft of the surface of Bennu, collect a sample of at least 2oz and as much as 4.4 lbs. in weight, and return with the sample intact.

On September 5, 2016, an Atlas V rocketed from Cape Canaveral carrying the OSIRIS-REx spacecraft on a mission to discover the origin of our solar system by exploring the asteroid Bennu.

Bennu may help us find answers to the questions central to the human experience: Where did we come from? What is our destiny?

In October 2020, OSIRIS-REx conducted a "touch-and-go" maneuver to collect at least 60 grams, a far larger sample size than any other previous sample retrieval mission. On May 10, 2021, OSIRIS-REx started on a 2.5-year course back to Earth. The OSIRIS-REx mission was complex and daunting. Preparing for it required months of testing, modeling, and analyzing each step.

NASA contracted Lockheed Martin Space (LMS) to build the OSIRIS-REx spacecraft and provide mission operations. LMS also conducted simulations on the many parameters and constraints of the mission to ensure precise maneuvers and engagements.

Lockheed Martin Space developed a formal system architecture for both the mission and spacecraft that enabled them to quickly and accurately understand mission requirements and manage the relevant design parameters and their subsequent impact on various subsystems. The team used ModelCenter® to automate and integrate the mission simulation with this system model. This allowed them to identify potential problems early in the design process, verify complex mission requirements throughout the lifecycle of the spacecraft, and respond to inevitable requirements changes. LMS performed much more analysis than previous efforts, and their design tasks were accomplished seven times faster than their previous design process.

The mission had the following objectives:

- **Return and analyze a sample of Bennu's surface**
- **Map the asteroid**
- **Document the sample site**
- **Measure the orbit deviation caused by non-gravitational forces (the Yarkovsky effect)**
- **Compare observations at the asteroid to ground-based observations**

> **"Automating and integrating the simulation into this system model then allows the team to rapidly identify potential issues with changes to mission requirements, as well as perform continuous verification of requirements and mission design parameters throughout the life cycle of the spacecraft. The overall improvement versus the original process was about a 7x speedup in turnaround time."**
>
> *Phathom Athena Donald, Systems Engineer, Lockheed Martin Space*

Read more here on the case study to explore how Lockheed Martin planned for the mission using ModelCenter® to enable Model-Based Systems Engineering (MBSE) for the success of the mission.

CASE STUDIES

Mercedes-Benz Validates ADAS Using Reliability Analysis Methods in Ansys optiSLang

Introduction

One of the most important current trends in the automotive industry is the development of advanced driver assistance systems (ADAS). Due to the ever-increasing complexity of ADAS, the safety validation of such systems is a major challenge. New methods have to be developed, as the previous certification and approval methods are not suitable for this use case.

Challenges

The required mileage needed to proof the probability of failure of the system is impossible to reach in field operational tests. Therefore, simulation is a key component to find critical scenario characteristics for safety function testing, validation, and even certification of highly automated driving systems. One of the greatest challenges here is the high number of simulations needed for testing, especially for very rare events (logical scenarios with low probability of failure 10^{-6}).

Engineering Solution

In this Pegasus conform simulation approach for AD Level 3, specific traffic scenarios are parameterized, simulated, and analyzed by a set of criteria. To reduce the parameter space, safety-critical input parameters are determined by applying Ansys optiSLang's Sensitivity Analysis with surrogate models including neural networks. The probability of failure for each traffic scenario is approximated using advanced reliability analysis methods (e.g., importance sampling) in Ansys optiSLang by using distribution functions for each input parameter.

Benefits:

Reliability analysis methods available in Ansys optiSLang enable Mercedes-Benz AG to reduce the number of concrete scenarios needed to proof a function by a factor of 1000 compared to classical Monte Carlo Sampling.

Reliability analysis can determine the risk per scenario class even for very low probabilities of failure (10^{-9}), which is a crucial requirement for certification and impossible with Monte Carlo Sampling.

With the advanced reliability analysis methods, the time savings is 90% compared to Monte Carlo Sampling.

This approach contributes the certification of Mercedes-Benz level 3 ADAS as one of the validation pillars.

1. https://www.intechopen.com/chapters/74074
2. https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/manufacturing-industry-outlook.html
3. https://www.iea.org/reports/key-world-energy-statistics-2021/final-consumption
4. https://www.iea.org/news/global-co2-emissions-rebounded-to-their-highest-level-in-history-in-2021
5. https://www.weforum.org/agenda/2021/06/manufacturing-industry-climate-change-goals/
6. https://edgar.jrc.ec.europa.eu/country_profile/WORLD
7. https://www.cxotoday.com/cloud/the-role-of-engineers-in-sustainable-development-is-critical/
8. https://www.greenjournal.co.uk/2019/11/what-sustainability-principles-are-most-key-for-engineers/
9. https://echa.europa.eu/regulations/reach/understanding-reach
10. https://www.statista.com/register/premiumtest#professional
11. https://www.linkedin.com/pulse/navigating-supply-chain-challenges-industry-40-ronald-van-loon/
12. https://www.mckinsey.com/business-functions/operations/our-insights/covid-19-an-inflection-point-for-industry-40
13. https://www.industryweek.com/the-economy/regulations/article/21961483/increasing-number-of-regulations-challenge-manufacturers
14. https://www.areadevelopment.com/business-climate/Q3-2017/regulations-impact-on-manufacturing.shtml
15. https://tresbudigital.com/the-most-important-issue-facing-small-manufacturers/
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21. https://www.marketsandmarkets.com/Market-Reports/cyber-security-market-505.html
22. https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/manufacturing-industry-outlook.html
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24. https://cybersecurityventures.com/cybercrime-damages-6-trillion-by-2021/
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26. https://newengineer.com/blog/overcoming-the-shortage-of-engineers-1509925
27. https://newengineer.com/blog/overcoming-the-shortage-of-engineers-1509925
28. https://www.jonlee.co.uk/blog/2020/01/whats-the-reason-behind-the-shortage-of-engineers-in-uk
29. https://www.nomisweb.co.uk/datasets/aps168/reports/employment-by-occupation?compare=K02000001
30. https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/manufacturing-industry-outlook.html
31. https://www.theengineer.co.uk/comment-key-trends-shaping-the-manufacturing-workforce-in-2022/
32. https://www.eit.edu.au/from-industry-4-0-to-engineering-4-0/
33. https://www.eit.edu.au/from-industry-4-0-to-engineering-4-0/
34. https://supplychaindigital.com/technology/evolution-digital-twins-supply-chain
35. https://supplychaindigital.com/digital-supply-chain/additive-manufacturings-rise-enabler-supply-chain-efficiencies
36. https://www.designnews.com/design-hardware-software/simulation-takes-bigger-roles-product-development
37. https://www.balbix.com/insights/cybersecurity-in-the-age-of-industry-4-0/
38. https://www.balbix.com/insights/cybersecurity-in-the-age-of-industry-4-0/
39. https://securityboulevard.com/2021/04/cyber-security-for-manufacturing-firms-5-reasons-5-ways/
40. https://www2.deloitte.com/us/en/pages/energy-and-resources/articles/manufacturing-industry-outlook.html
41. https://www.electronicspecifier.com/news/latest/upskilling-engineers-the-digital-gap-in-engineering
42. https://www.theengineer.co.uk/comment-key-trends-shaping-the-manufacturing-workforce-in-2022/
43. https://gesrepair.com/industry-5-0-will-affect-manufacturers/

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