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Unveiling the next frontier of engineering simulation

Digital engineering in an AI world

This article is a collaborative effort by McKinsey and NAFEMS. Its authors include Alessandro Faure Ragani, Jan Paul Stein, Roger Keene, and Ian Symington.

Product development is an essential part of economic growth and social progress. Big industries, including automotive, aerospace and defense, telecommunications, medical devices, and consumer products, expect a third of their sales to come from new products. Over the next five years, that means $30 trillion in revenues depend upon successful product development projects in those sectors.

With so much value at stake, advanced product development capabilities are a key strategic priority for companies. And those capabilities increasingly depend upon access to sophisticated digital technologies, along with the skills, processes, and organizational structures to use them effectively.

In one 2021 McKinsey survey of R&D leaders, three quarters of respondents said that digital product development is essential in their organizations. Those leaders acknowledge that digitization is still a work in progress, however, with half admitting that they don't currently have the capabilities they know they need.

In this paper, we focus on one area of digitization with central relevance to the product development process: simulation. The ability to simulate product performance and behaviors in a virtual environment has been the catalyst for profound changes in the way engineering is done, offering product development teams the ability to derive new insights, identify and fix issues earlier in the cycle, and accelerate product testing and validation.

Simulation in flux

Simulation is also going through a period of significant technological disruption that is creating new opportunities and challenges for users in multiple areas. Those disruptions are affecting almost every aspect of the simulation value chain. Cloud-based simulation platforms are emerging as an alternative or addition to traditional workstation-based infrastructure. New analytical approaches, such as meshless methods and multiscale modelling, are extending the application of simulation to new domains and new types of problem. Inputs derived from sensor data, closed loop simulation and digital twin technologies are narrowing the gap between the real and virtual worlds.

Finally, recent rapid progress in the evolution of artificial intelligence (AI) and machine learning (ML) technologies is changing the way simulation is done. Supplementing computationally intensive numerical models with AI systems trained to generate comparable outputs can deliver orders-of-magnitude increases in simulation speed. Between 2016 and 2021, for example, the number of academic papers on the use of deep learning models as surrogates for conventional numerical simulation increased thirty-fold. AI can also reduce the level of expertise required to perform simulation, a consistent limitation on its wider use.

Where are we going next?

Together, the desire for further digitization of the product development process and the availability of powerful new tools and technologies are driving increased investment in simulation. This dynamic and fast moving environment creates challenges for users, however. Should they be racing to adopt cutting edge simulation technologies, or working to embed existing tools more firmly into their organizations and processes? What are the key factors driving the success of simulation-based digital product development, and what is holding companies back?

To investigate these questions, a new survey, conducted by McKinsey in partnership with NAFEMS, explores the current and expected future

state of simulation in product development. The survey was distributed in April 2023 to NAFEMS members representing simulation technology providers and users from a wide range of industry sectors. The 176 respondents work at organizations of different sizes, with annual revenues that range from less than $500 million to around $50 billion. 57 percent of respondents were users, rather than providers of simulation tools, and they represent many different organizational levels, from frontline engineers to senior executives.

We asked participants 24 questions about their current and future priorities for the selection and use of traditional numerical simulation tools. And to build a picture of the adoption of emerging simulation technologies, we included a deep dive into use of AI- and ML-based tools in the product development process. Here are five key insights from the survey.

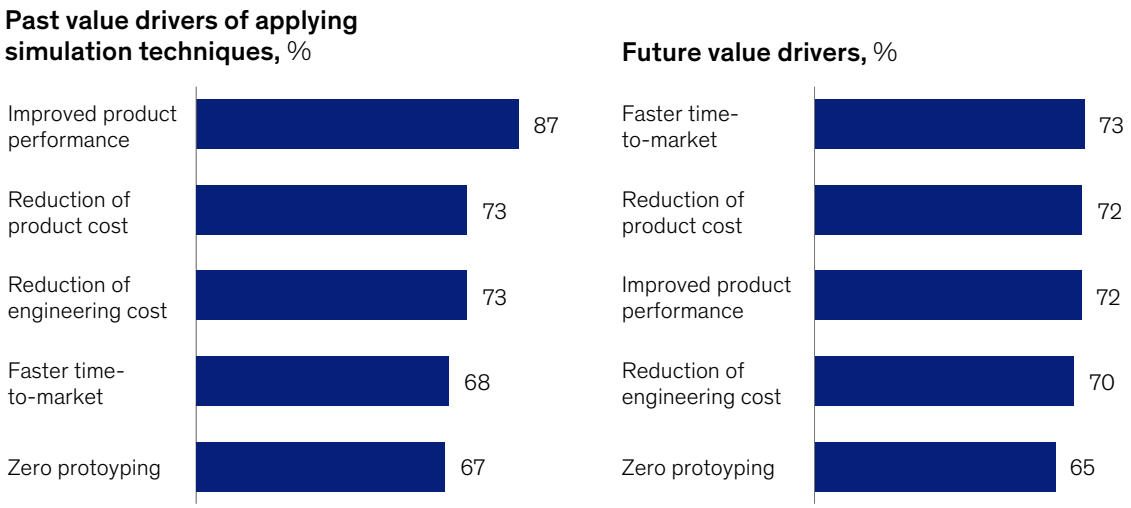
1. The business case for simulation is shifting

Our survey shows that expectations about the value provided by simulation are shifting. Asked about their use of simulation tools today, improved product performance was the top value driver by a significant margin, mentioned by 87 percent of respondents. When we asked about expected future sources of value, however, performance improvement dropped to third place, squeezed between product cost and engineering cost reduction. The new top priority, jumping from fourth place today into a narrow lead, was faster time-to-market.

This shift may be indicative of changes in the way simulation tools are integrated into product development. When it is expensive and difficult to do, companies may use their limited simulation capacity to solve difficult, product performance problems. As tools get faster and more accessible,

Exhibit 1

The business case for simulation is shifting, with faster time-to-market and reduced product cost as key future value drivers.



organizations begin to use simulation as a standard part of their engineering workflow, aiming to streamline and accelerate the product development process.

2. Still early days for AI and ML

Classical techniques, such as finite element analysis, computation fluid dynamics, and multibody simulation, are still the dominant approaches to simulation. Given that all respondents had a connection to leading simulation industry association, it is unsurprising that 99 percent of them were using these approaches to some degree in their organizations, with more than half applying them at scale.

In stark contrast, only five percent of respondents say that their organizations have fully integrated AI- and ML-based methods into their product development processes. Interest in these emerging technologies is high, however, with just over 60 percent of other respondents saying that their organizations are using them in proof of concept or pilot projects.

3. Automotive pulls away

Our survey reveals clear differences between industries in the adoption of leading-edge simulation technologies. Users from the automotive sector were most likely to have experience of AI and ML approaches, with 76 percent saying that their organizations were at least experimenting with these systems. That rate is 7 percentage points higher than aerospace and defense, the second-place industry. And automotive respondents were 1.6 times more likely to use AI-based simulation than those from the machinery sector.

Exhibit 2

Classic simulation use is significantly ahead of AI- and ML-based simulation use.

Companies' uses of classical vs AI/ML simulation techniques by technology maturity level,
% of companies

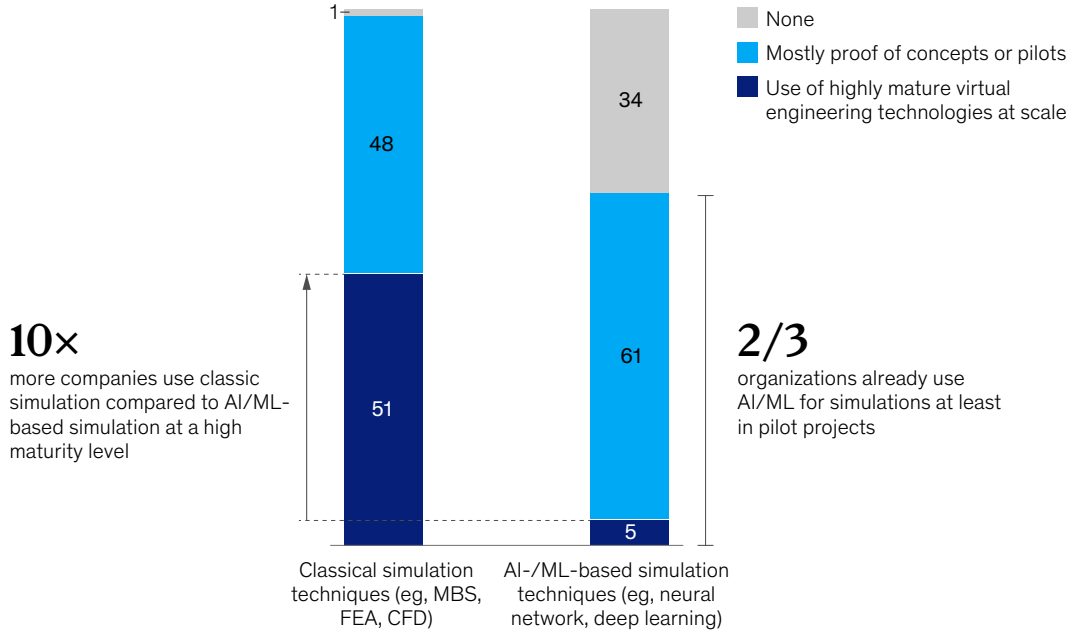
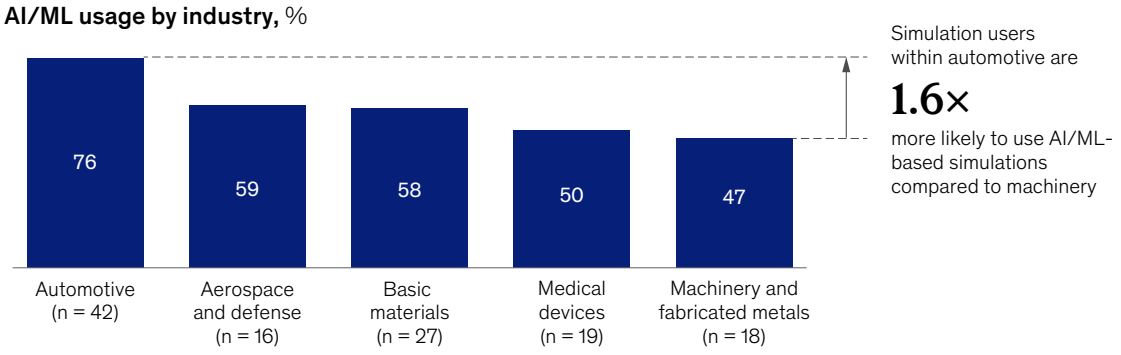


Exhibit 3

Automotive pulls away as the leading industry to put AI and ML to use.



This difference is likely to reflect differences in the overall level of digital maturity between sectors. Automotive companies have pursued ambitious digitization strategies for decades, an effort that has equipped them with a solid foundation of digital infrastructure and capabilities that supports the use of advanced tools.

Differences in business priorities may be another factor. The automotive sector is characterized by complex products and short development cycles, an environment that stands to benefit from the significant improvements in simulation speed offered by deep learning surrogate technologies and other AI-based tools.

4. Confidence drives adoption

We found further evidence of a link between the digital maturity and the adoption of advanced simulation approaches when we looked at the criteria considered by companies when selecting simulation tools. Users that were not concerned about "accuracy of results" in their tool selection were more than twice as likely as other users to have successfully operationalized AI- and ML-based simulation.

We don't believe that's because these users don't care about accuracy. Instead, it probably indicates a good understanding of the capabilities and limitations of simulation systems. Advanced users know how to integrate simulation into their processes and how to operate these systems to support decision-making in product development. Hence, they are more likely to be able to leverage the strengths while working around potential drawbacks of AI-/ML-based simulation approaches.

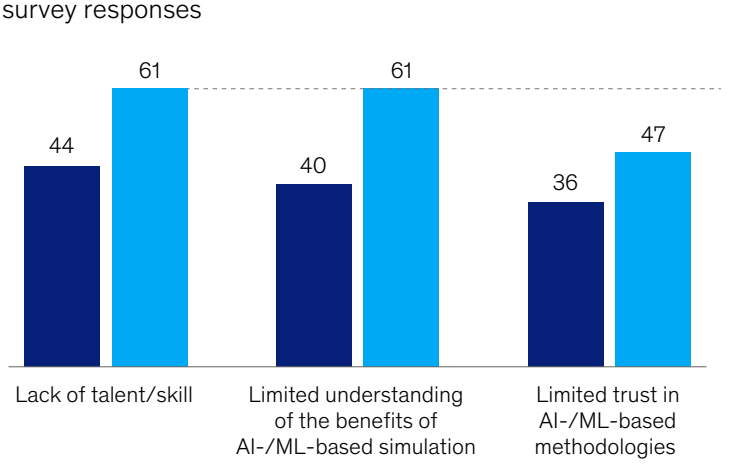
5. Talent, understanding, and trust are key impediments

Our survey asked about factors that stand in the way of greater adoption of AI- and ML-based simulation in their organizations. The top answers, mentioned by 61 percent of respondents, were shortages of the right talent and skills, and a limited understanding of the benefits these tools provide. The picture was slightly different among survey participants who are already using AI-based simulation. They were more likely to suggest that persuading other stakeholders to trust these new tools was a key impediment to their wider application.

Exhibit 4

Confidence in the capabilities of AI-/ML-based is driving adoption.

Key impediments for broad adoption of AI-/ML-based simulation versus classic simulation, % survey responses



3/5

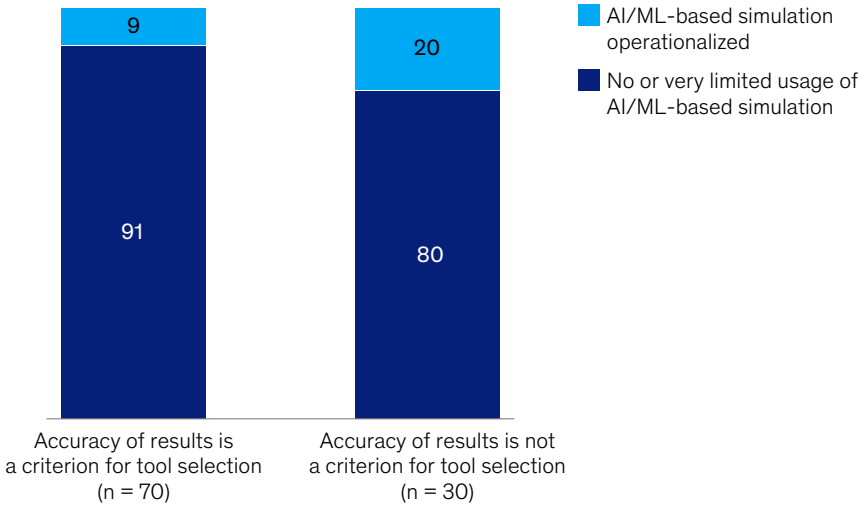
of organizations consider a lack of talent and a limited understanding of the benefits as a critical impediment towards adoption of AI-/ML-based simulation

Source: NAFEMS and McKinsey "Future of simulation" survey (Apr 2023)

Exhibit 5

Users which don't name accuracy as a key criterion for tool selection are 2x more likely to have already operationalized the use of AI-/ML-based simulation.

"Accuracy of results" as a criterion for tool selection, % of survey results



Takeaways

Our snapshot of the state of simulation offers a few key insights for both users and providers of these technologies. We believe that today's big challenges and opportunities arise in three main areas:

Capabilities are a perennial barrier to the integration of new technologies. Users should take a systematic approach to address skills shortages, hiring new talent to fill gaps and investing to upskill their existing workforce. And capability building shouldn't be limited to the engineers with hands-on responsibility for simulation tools: educating other stakeholders, including senior managers in the benefits and limitations of simulation technologies will support their wider adoption and integration into the product development process.

Technology providers also have a role in the efforts to overcome skills shortages. They can support their customers with training and support services, and foster a broader understanding of the value of advanced simulation through wider communication efforts.

Efficiency is becoming a key value driver for the adoption of simulation approaches and the selection of tools. Users can streamline and accelerate their product development processes addressing the challenges preventing greater adoption of simulation and assessing the potential benefits offered by high-speed AI- and ML-based tools.

Providers can align themselves with their changing customer priorities by ensuring their tools integrate smoothly into customer workflows and digital thread, and by communicating their ability to address new value drivers such as time-to-market.

Scalability is the next frontier for advanced simulation technologies. While adoption varies between industries, two thirds of the respondents to our survey are already experimenting with advanced AI-based simulation tools. Moving from pilot to full scale adoption is as much a cultural as a technological challenge. Users can foster understanding of, and trust in, new approaches by creating best practice lighthouses within their organizations and using top-management support to communicate success to other stakeholders. Providers can support their customers in those efforts, with a particular focus on industry sectors with a high impact potential and high likelihood to invest.

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NAFEMS is the independent home of engineering modeling and simulation, establishing high-quality simulation guidelines and benchmarks for the industry since 1983.