effzett

FORSCHUNGSZENTRUM JÜLICH'S MAGAZINE

Special issue

Bright prospects

Jülich unveils Europe's first exascale computer JUPITER

GOOD TO KNOW
Facts and figures about JUPITER

BETTER TOGETHER
Why supercomputers and quantum computers are a perfect match

PERFECTLY DESIGNED
JUPITER is ideal for AI applications

A new dimension in computing

JUPITER is Europe's first supercomputer to exceed the exascale threshold – and the fastest computer on the continent. This marks the beginning of a new chapter in high-performance computing (HPC) at Forschungszentrum Jülich in the heart of North Rhine-Westphalia (NRW). JUPITER delivers the immense computing power that science and industry need to find answers to the pressing questions of our time. "Whether it be the digital transformation, climate protection, or the energy transition – we need this computing power to tackle many of today's major challenges. JUPITER will be a catalyst for research and innovation. It will help us gain knowledge and develop solutions that we urgently need," says Prof. Astrid Lambrecht, Chair of the Board of Directors of Forschungszentrum Jülich, emphasizing the significance of the new exascale computer. JUPITER will provide a major boost to artificial intelligence (AI) and data-intensive applications in particular – enabling more precise simulations, analyses that were previously impossible, and the training of large AI models.

JUPITER sets new standards. Its modular architecture makes it flexible, allowing for the integration of quantum computers and other future technologies. It is also the most efficient of the five fastest supercomputers in the world.[1] With more than 60 billion floating-point operations per watt, JUPITER demonstrates that supercomputing and energy efficiency can go hand in hand.

JUPITER is a collaborative achievement. It was developed at the Jülich Supercomputing Centre (JSC), built by European partners from science and industry, and funded by the EU, the German federal government, and the state of NRW. The project is the result of more than a decade of intensive and dedicated work – and is a clear demonstration of Europe's collective strength to achieve groundbreaking technological advances.

"JUPITER marks the culmination of more than ten years of research and development," says Prof. Thomas Lippert, director of the JSC. "As the world's most advanced and versatile exascale system, it represents a unique innovation. JUPITER opens up completely new possibilities for science and industry in Europe."

"By connecting supercomputers with quantum computers for the first time, highly complex challenges can also be tackled in ways never before possible. We have the technology and expertise to harness this potential," says Prof. Kristel Michielsen, head of the Jülich UNified Infrastructure for Quantum computing (JUNIQ) and head of the "HPC for Quantum Systems" division at JSC.

The future of exascale computing in Europe begins with JUPITER.

[1] TOP500 list of the world's fastest supercomputers (as of June 2025)

2 Editorial
A new dimension in computing

4 One for all
JUPITER is a force to be reckoned with. Europe's fastest computer opens up new possibilities for many areas – from AI and brain research to climate simulation.

12 One supercomputer – many high-profile projects
Researchers from across Europe can use JUPITER – and are already testing hardware and applications in the early access programme JUREAP. Here, they offer insights into some of the projects.

14 A supercomputer for AI
Prof. Thomas Lippert, director of the Jülich Supercomputing Centre, explains what makes JUPITER so exceptional.

16 JUPITER: facts and figures

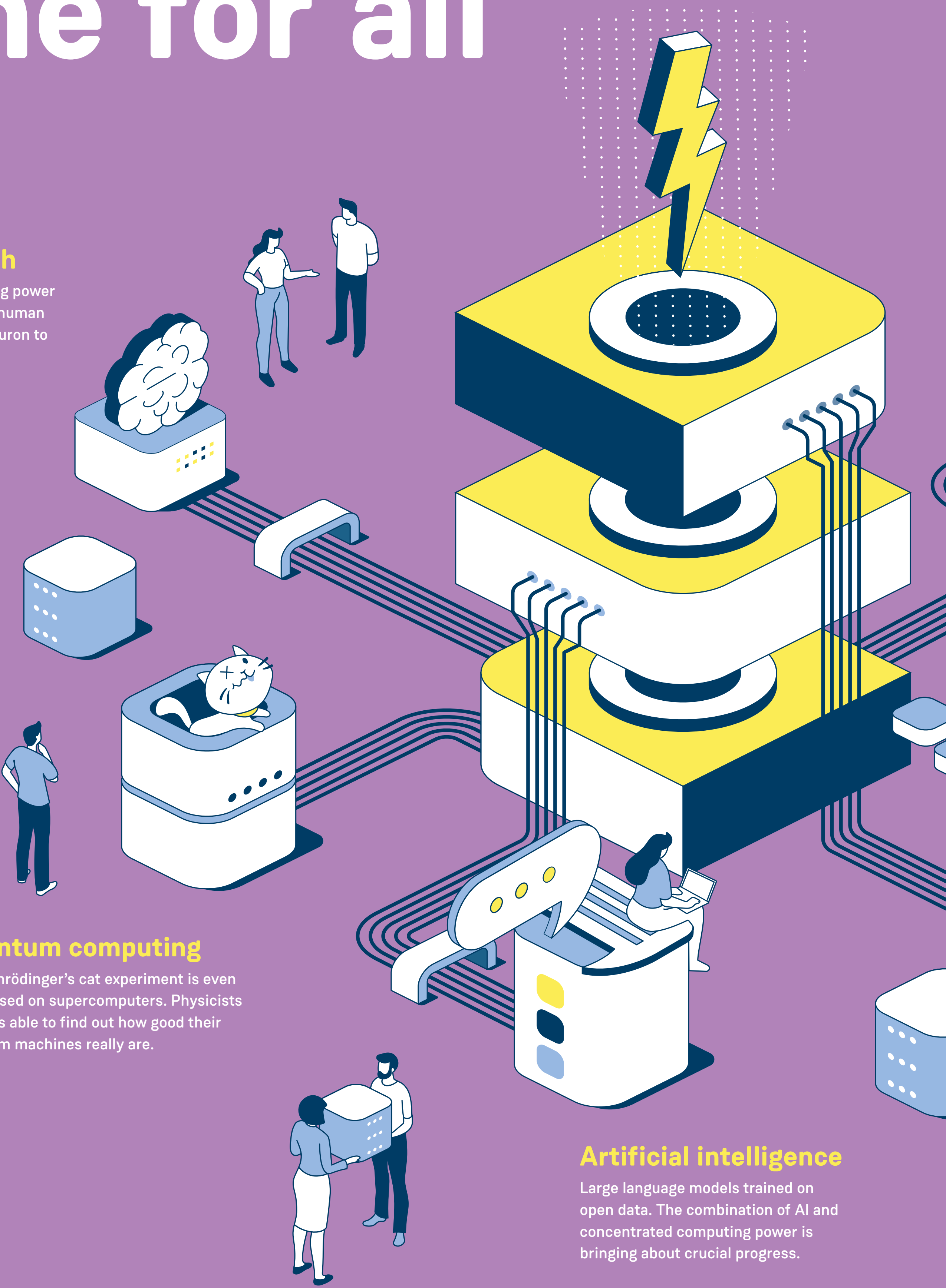
20 Power duos
Hybrid systems of quantum computers and supercomputers combine the best of both worlds.

22 Jülich research at a glance

24 Publication details

JUPITER – Europe's Fastest Supercomputer Explained
youtu.be/TFcq_luBeVw

One for all



Brain research

Concentrated computing power is used to simulate the human brain – from a single neuron to a neural network.

Quantum computing

The Schrödinger's cat experiment is even being used on supercomputers. Physicists are thus able to find out how good their quantum machines really are.

Artificial intelligence

Large language models trained on open data. The combination of AI and concentrated computing power is bringing about crucial progress.

Energy research

Whether it be a wind turbine, hydrogen turbine, or battery pack, the exact flow model of the high-performance computer can also be turbulent.

Climate research

As accurate as tomorrow’s weather forecast: how will the global climate develop over the next 20 or 30 years?

More information on JUPITER: go.fzj.de/effzett-jupiter_en

Jülich is home to Europe’s first exascale computer, JUPITER. The versatile supercomputer will be one of the world’s most powerful AI machines and opens up new possibilities for simulating complex systems. Its applications range from the quantum cosmos to issues relating to the energy transition.

The first supercomputer in Europe was launched in 1965. The CDC 6600 at the CERN research centre was able to perform three million floating-point operations per second. Any current smartphone would exceed this performance by countless orders of magnitude. And now, 60 years later, the Jülich Supercomputing Centre (JSC) is home to the great-great-great-grandchild of CDC 6600, JUPITER. It is the first computer in Europe to reach the magical threshold of one quintillion (a “1” followed by 18 zeros) floating-point operations per second. That is roughly equivalent to the performance of around one million modern smartphones, or around 333 billion CDC 6600s. This makes JUPITER an exascale-class supercomputer.

But JUPITER’s record speed is not an end in itself. The simulations performed on the powerful supercomputer will provide insights that cannot be gained through purely experimental or theoretical means. JUPITER is a technological all-rounder that can handle a wide range of different applications. These applications address some of the biggest challenges of the future from the smallest to the largest scale – from the behaviour of individual quanta to global climate models, and from molecular processes in neurons to large language models.

JUPITER’s flexible architecture enables a wide range of applications. The supercomputer’s Booster module works on the basis of graphics processing units (GPUs), which are particularly suitable for a variety of highly parallel applications, as presented here. The Cluster module, in contrast, is suitable for more variable tasks with complex execution patterns, such as some physics simulations of interactions between elementary particles in atomic nuclei. With this approach, JUPITER is well positioned to serve both classic high-performance computing (HPC) simulations and advanced artificial intelligence (AI) methods.

From weather forecasting to climate simulation

A typical application that would have been inconceivable for decades without the computing power of supercomputers is weather forecasting. Germany's National Meteorological Service (DWD) uses the ICON atmospheric model, a modular open-source software. The software can be used to calculate short periods of time with a high spatial resolution, enabling weather forecasts to be made for the coming days based on current measurements and observations. It is also possible to work with a lower resolution and simulate the development of the global climate over decades. "However, we want to look much further and more accurately into the future – creating detailed, long-term climate forecasts," explains meteorologist Dr. Sabine Grießbach (JSC).

How will the global average temperature change if we continue to pump CO_2 into the atmosphere? And what about extreme weather events? Will we experience heat waves more frequently in future? And with what intensity?

Thanks to JUPITER's computing power, ICON will be able to answer these questions with greater accuracy than ever before. The crucial advantage that JUPITER offers the model is a smaller mesh size. ICON covers the Earth in a grid of triangles. It then calculates the relevant parameters such as temperature, pressure, and humidity for each of these grid cells. The mesh size of the grid indicates approximately how wide an individual triangle is. For current weather forecasts with ICON, the mesh size is around 13 kilometres. This means that phenomena with a smaller scale, such as clouds, can fall through the cracks, so to speak.

← Sabine Grießbach wants to use JUPITER to create detailed climate forecasts.

"With JUPITER, we can change that and simulate the future of the climate with a spatial resolution of about one kilometre," explains Dr. Lars Hoffmann (JSC), an expert in atmospheric research and modelling: "We can thus bridge the gap between weather and climate modelling. And extreme events such as violent thunderstorms and heavy rainfall will be depicted much more realistically on the computer than they are today." Following initial work on the JEDI test system, tests are now being carried out on JUPITER in collaboration with the Max Planck Institute for Meteorology and the German Climate Computing Center (DKRZ).

JEDI is the first module of JUPITER. It was installed in April 2024 and features particularly efficient GPUs from the world's leading chip manufacturer, NVIDIA. The same hardware is also used in JUPITER's Booster module.

An important aspect will be how the weather and climate models work with the latest generation of graphics cards used in JUPITER. "We are currently investigating which software libraries and settings allow ICON to run fastest on JUPITER," reports Grießbach.

Artificial intelligence on the supercomputer

Another application that benefits from JUPITER and its NVIDIA GPUs is machine learning. In particular, generative AI, which produces images and text, has impressively demonstrated in recent years with language programs such as ChatGPT that these algorithms can come remarkably close to human language.

Large language models (LLMs) are trained with a multitude of texts. They use these texts to learn the probability of one word following another – and can thus form a meaningful sentence, word by word. The model therefore needs to memorize vast amounts of linguistic building blocks and how they relate to each other.

"A leap in the quality of these language models was only achieved when they were trained with numerous parameters on huge amounts of data. And that was only possible because high-performance computers were used," explains Chelsea Maria John (JSC). In a team focused on algorithms and methods for computing accelerators, such as JUPITER's GPUs from NVIDIA, she works at the interface between AI and supercomputers.

Her main focus is an open-source language model that she co-developed in a German project called OpenGPT-X: "OpenGPT-X was a German consortium of ten partners from research, industry, and the media. Within the project, Teuken-7B was trained – a model that can handle various European languages, but primarily German." The software for training such LLMs also runs on JUPITER. Its processors are tailor-made for AI.

"This makes it possible to train large language models much faster and more efficiently. However, we also have to ensure that the tasks are distributed evenly across all processors," says John.

The 24,000 GPUs in the Booster module are designed to process data in a highly parallel manner. In contrast, conventional processors (CPUs) are particularly good at performing complex calculations in rapid succession. To perform these calculations, they have a small number of powerful processing cores. GPUs, on the other hand, have more processing cores that are not quite as powerful, but which work hand in hand simultaneously. This parallel computing allows them to perform the relatively simple individual operations that are carried out for AI, for example, faster than conventional processors.

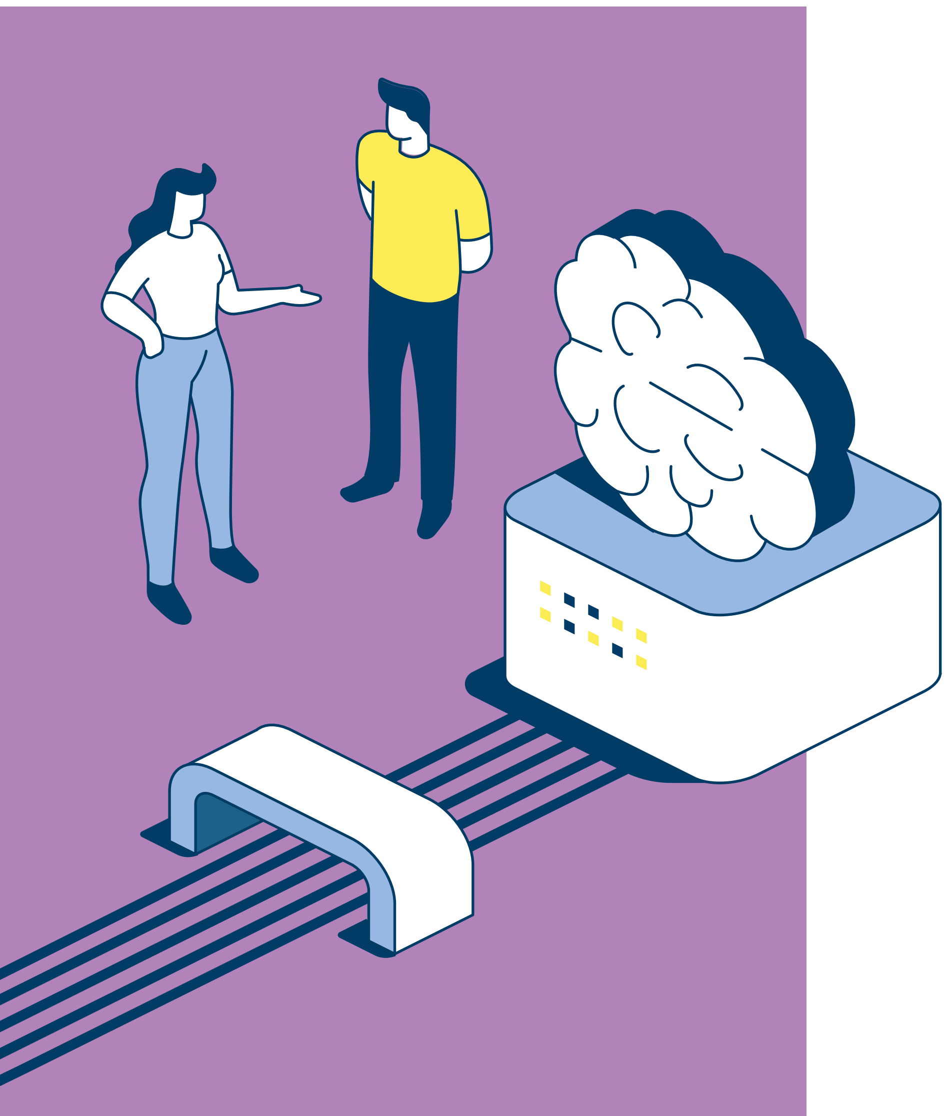
← Chelsea Maria John requires the computing power of JUPITER to develop open-source language models.

"Another challenge is to minimize energy consumption. Training language models involves a very high level of electricity consumption." This is another reason why JUPITER was designed to be particularly energy efficient (see page 18).

Well prepared

JUPITER offers great opportunities for users. To harness its potential for groundbreaking science from the very beginning – and to integrate it directly into the system's development process – the JUPITER Research and Early Access Program (JUREAP) was launched. In JUREAP, HPC specialists and domain scientists work closely together to optimize algorithms and methods as well as the system itself. More information can be found on pages 12 – 13.

Brain cells simulated in the electronic brain



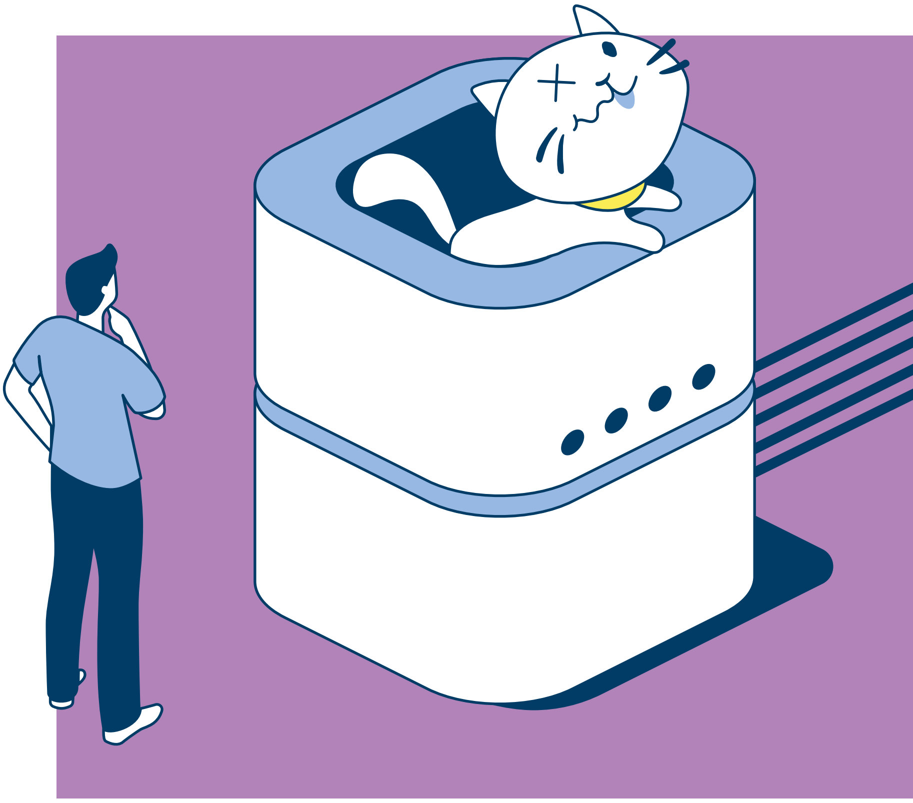
Large language models (LLMs) work with artificial neural networks inspired by the way the brain works. Dr. Thorsten Hater (JSC) is focused on the nature-inspired models of LLMs: neurons that communicate with each other in the human brain. He wants to use the exascale computer JUPITER to perform even more realistic simulations of the behaviour of individual neurons. Many models treat a neuron merely as a point that is connected to other points. The spikes, or electrical signals, travel along these connections. "Of course, this is overly simplified," says Hater. "In our model, the neurons have a spatial extension, as they do in reality. This allows us to describe many processes in detail on the molecular level. We can calculate the electric field across the entire cell. And we can thus show how signal transmission varies right down to the individual neuron. This gives us a much more realistic picture of these processes."

For the simulations, Hater uses a program called Arbor. This allows more than two million individual cells to be interconnected computationally. Such models of natural neural networks are useful, for example, in the development of drugs to combat neurodegenerative diseases like Alzheimer's. The physicist and software developer would like to simulate and study the changes that take place in the neurons in the brain on the exascale computer.

Completely different changes control processes of learning and forgetting. Hater would also like to gain a better understanding of these processes through simulations: "The fascinating thing about our brain is that it is not a static structure. The idea that we can simulate it as a network with fixed connections is therefore wrong. Our brain is plastic, which means it changes within minutes, hours, or even days, for example by strengthening or weakening the connections between neurons. And it is precisely these processes that we want to simulate on the supercomputer in future."

The Arbor simulation software has already been adapted to the hardware of the JUPITER Booster module. The NVIDIA GH200 superchips are a combination of CPU and GPU, a system on a chip. In this form, the two processor types work together particularly efficiently because they are also closely coupled to each other spatially. This results in a high bandwidth and, therefore, a fast data flow.

← Thorsten Hater wants to use the exascale computer to simulate processes in the human brain more realistically.



Quantum computer simulated on a supercomputer

For Dr. Dennis Willsch (JSC), the type of processors used for JUPITER calculations is of secondary importance: "Our simulations can run on any computer that has a Fortran compiler installed – even on a standard laptop."

Nevertheless, the physicist typically uses high-performance computers to run JUQCS. This is software that can be used to simulate universal quantum computers. These machines use the exotic rules of the quantum world to solve specific tasks faster than a supercomputer – at least in theory. For example, the Shor algorithm, which can be used to crack certain encryption systems, should be calculated very quickly by a quantum computer.

JUPITER

The exascale computer JUPITER was procured by the European supercomputing initiative EuroHPC Joint Undertaking (EuroHPC JU), which is providing 250 million euros in funding for the supercomputer. The German Federal Ministry of Research, Technology and Space (BMFTR) and the Ministry of Culture and Science of the State of North Rhine-Westphalia (MKW NRW) are each contributing a further 125 million euros in funding via the Gauss Centre for Supercomputing (GCS).

In practice, however, there is no machine yet that has enough qubits for this task. A qubit is to a quantum computer what a bit is to a conventional computer.

Another problem is that "in the existing prototypes of quantum computers, many errors occur in the qubits. We therefore simulate these quantum computers under ideal conditions on normal computer systems. This shows us what the result should look like in theory, and we can use it to assess the quality of the real result," says the physicist. However, there is a limiting factor in the simulation – the memory of the computer on which the simulation is run. "The memory is the real sticking point," says Willsch. "And the memory requirement grows exponentially – it doubles for each additional qubit."

A laptop can handle about 32 qubits with its memory. The record on a supercomputer is 48 qubits. JUPITER has enough memory to add a few more qubits to the simulation, says the researcher.

← Dennis Willsch will use the supercomputer to investigate the world of quanta and simulate universal quantum computers.

"On an exascale computer, we could surpass the threshold of 50 qubits. That would be a new world record."

The NVIDIA GH200 superchip combines fast memory on the GPU side with energy-efficient main memory on the CPU side. Thanks to the integrated architecture, it is possible to use both memory areas homogeneously. The Booster module is therefore able to provide over 5 petabytes of memory that can be used by applications. This is equivalent to almost 650,000 standard laptops.

Hydrogen turbines and wind farms

The applications on which Mathis Bode (JSC) works are much more commonplace. He investigates the flow phenomena of liquids and gases. "This includes the aerodynamics of cars and aeroplanes, for example, as well as the processes inside turbines and engines."

Flow simulations also play an important role in many aspects of the energy transition: How can battery packs be cooled efficiently? How can air conditioning systems be designed to keep a building at a constant temperature in an economical way? What is the optimum design for the rotor blades of wind turbines to ensure that they harvest as much energy from the air as possible? Mathis Bode also sees potential for using hydrogen as a future energy source: "In a hydrogen economy, we will need hydrogen power plants in the near future. To develop these plants, it will be necessary to simulate the processes inside them, for example inside the turbines. JUPITER allows us for the first time to depict real, industrially relevant conditions on a supercomputer. It also delivers the simulation results in a much shorter time."

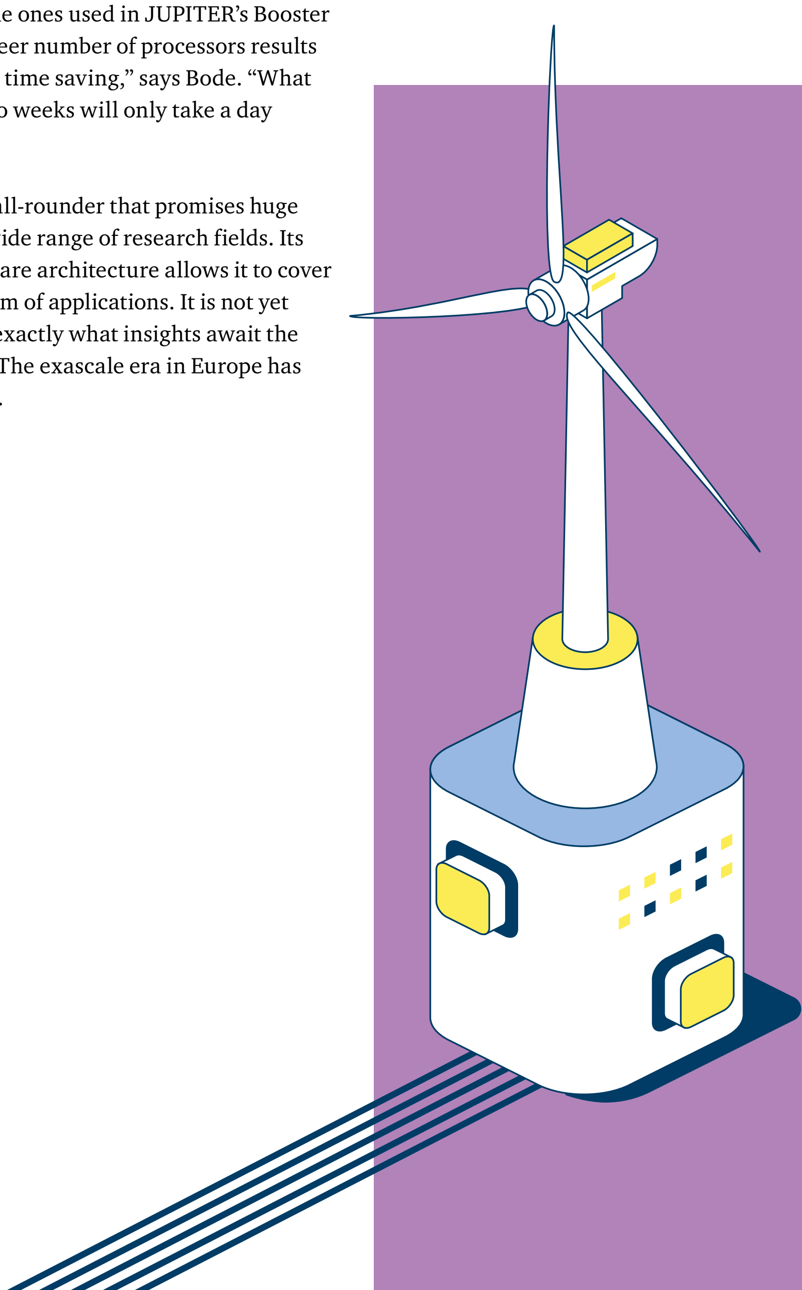
Flow phenomena are described by the Navier-Stokes equations. Solving these equations, however, is anything but routine. The differential equations are usually so complex that even supercomputers can only solve them approximately. Bode uses the nekRS software package for this purpose. In addition to pure fluid mechanics, the package can be used to take other processes into account, such as chemical processes that occur during combustion in an engine. "To do this, the program must consider the extreme conditions in the engine that influence the flow, such as high temperatures, high pressures, and strong turbulence," explains the flow expert. nekRS can also simulate all relevant variables of flow phenomena simultaneously without cutting off any important information, for example the geometry-driven flow or the smallest turbulent vortices. "Taking all this data into account in the flow is a real challenge for a simulation and results in enormous computing and memory requirements."

JUPITER is changing all that. "nekRS has already been optimized to work on graphics cards such as the ones used in JUPITER's Booster module. The sheer number of processors results in an enormous time saving," says Bode. "What used to take two weeks will only take a day on JUPITER."

JUPITER is an all-rounder that promises huge advances in a wide range of research fields. Its modular hardware architecture allows it to cover a broad spectrum of applications. It is not yet possible to say exactly what insights await the Jülich experts. The exascale era in Europe has only just begun.

ARNDT REUNING

← Mathis Bode can calculate complex flow phenomena faster and more accurately with JUPITER. This is relevant for many areas of energy supply.



One supercomputer – many high-profile projects

BIOPHYSICS

Prof. Dr. Gerhard Hummer, Director Theoretical Biophysics Department, Max Planck Institute of Biophysics, Frankfurt, Germany

We use biomolecular simulations and modeling to investigate how biological systems operate at the molecular level, advancing our understanding of how living cells work as a basis for new therapies and nanotechnology applications. With JUPITER, we aim to perform molecular dynamics simulations of the nuclear pore complex – the largest protein assembly in cells – to reveal how it regulates molecular transport. With hundreds of millions of atoms, these simulations need exascale computing to reach meaningful timescales. Exascale offers unique atomistic insights, advancing nuclear transport models and paving the way for improved control of gene trafficking, and the fight against retroviruses like HIV.

PARTICLE PHYSICS

Prof. Dr. Zoltan Fodor, University of Wuppertal, Germany

As particle physicists we are computing microphysical quantities, like the magnetic moment of an elementary particle, called muon. JUPITER will be more than ten times larger than its predecessor, enabling us to substantially increase the resolution of our “microscope” and to reach unprecedented precision. The results of these computations can be compared to currently running experimental measurements. If they differ, it will have profound consequences on the fundamental laws of Nature, like the existence of a not yet discovered particle or a presence of a new interaction.

AI: LARGE LANGUAGE MODELS

Prof. Dr. Alexandra Birch, University of Edinburgh, UK

We are researching multilingual large language models that cover the needs of European citizens. We are focussing on creating models that can reason in any language and can reason over long documents. JUPITER will help us to train these models with large amounts of multilingual data and to create large synthetic training sets of long documents and reasoning chains to unlock previously unachievable performance. This will lead to models which are useful for both researchers and industry and government having access to the best Generative AI models that address their needs across borders in the EU.

AI: COMPUTER GRAPHICS AND VISUALISATION

Prof. Dr. Björn Ommer, Head of Computer Vision and Learning Group, LMU Munich, Germany

Our research focuses on lightweight foundation models for video representation and generation, inspired by the success of generative approaches like Stable Diffusion. Through JUPITER, we aim to develop spatio-temporal compression and diffusion architectures that enable the creation of high-quality, accessible video models. Exascale computing plays a pivotal role, allowing us to train on vast datasets while optimizing model efficiency. This approach opens exciting possibilities for developing video models that generalize far beyond their training data. Such models have the potential to drive societal impact across diverse domains – from advancing medical imaging to improving autonomous driving – while fostering accessibility and innovation.

Scientists from all over Europe can use JUPITER. In a complex process, the European supercomputing initiative EuroHPC Joint Undertaking (EuroHPC JU) and the Gauss Centre for Supercomputing have reviewed and selected projects for particularly early access. These are now running in the JUPITER Research and Early Access Program (JUREAP), initiated and implemented by JSC, where they are testing and using hardware and applications while addressing scientific questions. The users themselves provide an insight into some of the projects.

FLUID MECHANICS

Prof. Dr.-Ing. Christian Hasse, Head of the department Simulation of reactive Thermo-Fluid Systems at Technical University of Darmstadt, Germany

Replacing fossil fuels with hydrogen, e.g., in CO_2-free power generation, is essential for achieving net zero emissions. However, the dynamics of turbulent, pressurized hydrogen flames differ significantly from those of conventional fuels and remain poorly understood. Exascale supercomputing is driving progress in fundamental science, it enables us to unravel the complexities of hydrogen combustion dynamics through direct numerical simulation (DNS). We can now resolve the shortest timescales down to nanoseconds and capture turbulent flame structures at the micrometer scale. With JUPITER, for the first time, exascale computing enables DNS under technically relevant gas turbine conditions – a milestone in Computational Engineering and Process Virtualization.

AI: FOUNDATION MODELS

Prof. Dr. André Martins, University of Lisbon, Chief Science Officer at Unbabel, Portugal

Our research aims to develop the next generation of AI foundation models for language generation, equipped with advanced cognitive capabilities. By integrating concepts from machine learning, sparse modeling, information theory, and cognitive science, we adopt an interdisciplinary approach to push the boundaries of multimodal reasoning. Through JUPITER, we strive to scale multimodal and multilingual language models that support all European languages, addressing the limitations of existing models. The models trained on JUPITER will be openly released, benefiting the entire research community and European companies seeking to build advanced AI systems.

Preparing for exascale

In a multi-stage process, more than 120 projects applied to JUREAP for the very first calculations on JUPITER. To make the most of the NVIDIA Grace Hopper superchips, these applications were adapted in collaboration with a team of experts from the JSC. In extensive tests, they verified JUPITER's ability to efficiently perform large-scale simulations and AI applications – these ran on more than 3,200 GPUs of its predecessor, the JUWELS booster system. 15 European and 18 national projects, selected through an independent process, are now being scaled up to solve socially and scientifically relevant questions and demonstrate JUPITER's performance capabilities.

Additional project overviews:

Make JUPITER shine
go.fzj.de/effzett-jupiter-applications

Cutting-Edge Research
and AI with JUPITER
go.fzj.de/effzett-jupiter-eurohpc

A supercomputer for AI

JUPITER is not only Europe's fastest supercomputer – it also sets new standards in terms of energy efficiency and opens up groundbreaking potential for AI applications. In this short interview, Prof. Thomas Lippert, director of the Jülich Supercomputing Centre, explains what makes JUPITER so exceptional.

↑ Thomas Lippert standing between the JUPITER racks

Prof. Lippert, what is so special about JUPITER's hardware?
JUPITER is a dynamic modular supercomputer consisting of two parts: a highly scalable Booster module for particularly compute-intensive problems, which is massively supported by GPUs, and a Cluster module that can be used universally, especially for very complex computing tasks.

Why is JUPITER's modularity so important?
The modules can solve scientific problems separately or together, or even train an AI, depending on requirements. Modularity also ensures the system is open to emerging technologies – such as quantum computers, which open up entirely new possibilities for us. By connecting them with JUPITER, we're taking quantum computers in Europe to the next level.

How important is energy consumption for a system of this size and power?
The system is a pioneer in terms of energy efficiency. Its predecessor module, JEDI[1], topped the Green500 list of the world's most energy-efficient supercomputers two years in a row. And JUPITER itself was named the most efficient of the five most powerful supercomputers in the world when it entered the TOP500 list in June 2025.

What is the secret behind its outstanding energy efficiency?
Several aspects are at play here: We use particularly efficient computing units – specifically, an optimized version of the NVIDIA Grace Hopper Superchip GH200, which offers maximum performance per watt. We also have decades of expertise in tailoring hardware for energy-optimized high-performance computing. When procuring JUPITER, we made sure that the hardware was not only geared for maximum performance but also optimized for power consumption – for example, through direct hot water cooling. This is significantly more efficient than conventional cold water or air cooling. In the future, we'll also integrate the supercomputer

JUPITER AI Factory

The JUPITER AI Factory (JAIF for short) is being provided with around 55 million euros in funding by the European Commission, the Ministry of Culture and Science of the State of North Rhine-Westphalia, and the Hessian Ministry of Science and Research, Arts and Culture. Several leading German AI institutions have joined forces in this project. Besides the coordinating Jülich Supercomputing Centre, the main partners include the RWTH Center for Artificial Intelligence at RWTH Aachen University, the Fraunhofer Institute for Applied Information Technology, the Fraunhofer Institute for Intelligent Analysis and Information Systems, and the Hessian Center for Artificial Intelligence.
The JUPITER AI Factory also works closely with the German AI service centres WestAI and hessian.AISC, as well as the German AI Association (KI Bundesverband) as associated partners.

into the Jülich campus heating network, allowing it to contribute to the sustainable heating of our buildings. Moreover, JUPITER will be powered entirely by green electricity.

What role does JUPITER play in training AI? We keep hearing that Europe does not have sufficient computing capacity to keep pace with developments ...
First of all, we have been providing AI computing time to scientists at the Jülich Supercomputing Centre for years. When we put the GPU-based JUWELS Booster into operation in 2020 – at that time Europe's fastest supercomputer – it was a real turning point for the use of AI models. So Europe has the computing power, expertise, and experience to keep pace in the field of AI. And with JUPITER, we have now reached the next huge milestone. It is the culmination of more than 10 years of development efforts by JSC with European and international partners. It will be the world's most advanced and versatile exascale system, supporting ultra-precise simulations and the training of the largest AI models. Just to give you an idea: At full capacity, JUPITER could train a large language model (LLM) with over 100 billion parameters in less than a week.

Who can benefit from JUPITER's performance?
JUPITER benefits research and industry alike. Together with our partners in North Rhine-Westphalia and Hesse, we were commissioned to establish the JUPITER AI Factory (JAIF) in March 2025. As part of a network of 13 AI factories in the European Union, we form a central pillar of the European AI infrastructure. JAIF provides access to JUPITER to start-ups, SMEs, and industry, as well as research institutions and the public sector. To ensure that everything runs smoothly, we offer a comprehensive AI ecosystem with tailored support for all AI use cases – from training and consulting to next-generation foundation models and application optimization.

Thank you for your time.

"JUPITER benefits research and industry alike."

THOMAS LIPPERT

[1] short for "JUPITER Exascale Development Instrument"

JUPITER: facts and figures

1 quintillion

floating-point operations per second can be performed by the fully configured supercomputer JUPITER. That is equivalent to the performance of around one million modern smartphones.

JUPITER
stands for "Joint Undertaking Pioneer for Innovative and Transformative Exascale Research"

500 million euros
is the cost of the project, 250 million euros of which was provided by the European Commission, and 125 million euros each by the science ministries of Germany and NRW via the Gauss Centre for Supercomputing. JUPITER is being installed by the German-French consortium ParTec-Eviden.

40 ExaFLOP/s

can be achieved by JUPITER when performing lower-precision (8-bit) calculations, as commonly used for training AI models. In 8-bit sparsity mode, it can even reach 80 ExaFLOP/s. This makes JUPITER one of the world's fastest computers for AI.

Almost 1 exabyte

of storage capacity complements the computing power. It is distributed across an ultra-fast 30-petabyte flash module as a data accelerator, a more than 300-petabyte storage module, and a 370-petabyte data archive. A future storage upgrade is planned.

The Cluster module

from ParTec complements the Booster. It will have more than 1,300 nodes and is equipped with the new Rhea processor developed and manufactured in Europe by SiPearl. It targets data-intensive applications that place higher demands on serial performance and memory bandwidth. In climate research, for example, it will calculate ocean dynamics, while the Booster would model atmospheric processes.

24,000 GPUs

are installed in JUPITER's Booster provided by Eviden. At the heart of JUPITER, they are connected in around 6,000 nodes via a high-speed network. The innovative NVIDIA Grace Hopper superchips combine graphics processing Units (GPUs) with conventional central processing units (CPUs). They are particularly energy-efficient – and each one is like a mini-supercomputer, optimized for training artificial intelligence. JUPITER is capable of training a large AI foundation model with more than 100 billion parameters in about one week.

More details on JUPITER's architecture
A deep dive into JUPITER's building blocks
go.fzj.de/effzett-jupiter-tech

50 special containers

make up the high-performance modular data centre (MDC) that houses JUPITER. The containers sit on a concrete base covering an area of approximately half a football pitch (3,690 m²). Each container is equipped with its own transformer and cooling unit on the roof. This infrastructure can be quickly and flexibly adapted to accommodate new generations of computing hardware. Repairs can be carried out on individual units without bringing the entire system to a standstill.

≈ 12 megawatts

is the average power consumption of JUPITER. This makes the new data centre one of the most energy-efficient in the world.

51,000

network connections enable JUPITER to transmit three times more data than all global data traffic at any given moment.

Green IT

In June 2025, JUPITER was the most energy-efficient computer among the top five systems on the TOP500 list of the world's fastest supercomputers. JEDI, JUPITER's development system, tops the Green500 list of the most energy-efficient supercomputers. It achieves 72 billion floating-point operations per second per watt. The highly efficient NVIDIA superchips play a significant role in this achievement. But Eviden's hot water cooling system also contributes to this. This type of cooling is more efficient than conventional cold water or air cooling. In the future, waste heat from JUPITER will also be used to heat neighbouring buildings.

JEDI

is short for JUPITER Exascale Development Instrument. The world's most energy-efficient supercomputer is a precursor for JUPITER and features identical hardware to the JUPITER Booster. On JEDI, scientific simulations and AI models can be optimized at an early stage for calculations on JUPITER. This guarantees that the JUPITER hardware can be utilized efficiently right from the start – for example, in the JUPITER Research and Early Access Program (JUREAP). JEDI also serves as a platform for developing the JUPITER Management Stack, the software used to manage the system. This ensures that JUPITER remains reliably available to its users.

15 European and 18 national projects

will be the first to have access to JUPITER. They were selected for the JUPITER Research and Early Access Program (JUREAP). Experts at Jülich are now working together with European researchers to optimize the applications for JUPITER. The range of topics spans from the use of AI for video generation, climate models, particle physics, and energy research to molecular dynamics simulations for drug development.

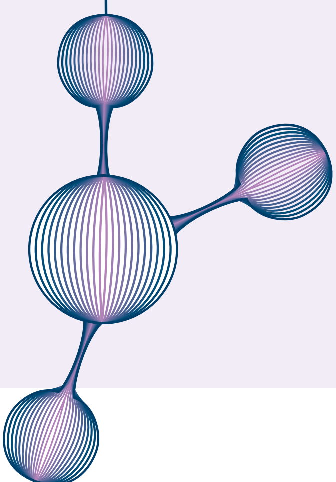
Further photos and information about JUPITER can be found in our newsroom fz-juelich.de/en/newsroom-jupiter

Power duos

Jülich researchers are combining quantum computers with supercomputers. Such hybrid systems are intended to unite the advantages of both worlds and crack previously unsolvable scientific puzzles. JUPITER, too, will become part of such a duo.

↑ Kristel Michielsen is the head of the Jülich UNified Infrastructure for Quantum computing (JUNIQ). The platform provides access to state-of-the-art quantum computers and the possibility to connect supercomputers to quantum systems that are already running.

10111



Supercomputers and quantum computers work completely differently. You could say that one is a traditionalist, one a revolutionary. Supercomputers perform reliable calculations according to the familiar rules of physics using ones and zeros. Quantum computers, on the other hand, come from the bizarre world of quantum physics: they use all numbers between one and zero, and are capable of an unimaginable amount at the same time – but they are still difficult to control.

In future, these unequal computing masters will work together as a power duo at Jülich. One such hybrid system is formed by the established JURECA DC supercomputer and JADE, a 100-qubit quantum simulator delivered by the French Company Pasqal, which has been in operation at the Jülich Supercomputing Centre (JSC) since the end of 2024. More will follow. The new exascale supercomputer JUPITER will be coupled with the D-Wave Advantage2 system, an annealing quantum computer recently acquired for the Jülich UNified Infrastructure for Quantum computing, or JUNIQ for short (see infobox). This duo creates new opportunities for breakthroughs in artificial intelligence and optimization, for example in the field of logistics. Such hybrid systems are also expected to find answers to some of the trickiest questions in modern science, such as modelling complex climate scenarios or the structures of giant molecules.

THE BEST OF BOTH WORLDS

"We want to combine the advantages of both systems," explains Prof. Kristel Michielsen from JSC. "The supercomputer does most of the work and ensures a stable workflow. The quantum computer steps in whenever its partner gets stuck or takes too long to solve the problem." One example would be climate simulations: "The supercomputer performs the central modelling, while the quantum computer takes on specific subtasks such as highly complex optimization questions." This could involve investigating atmospheric chemistry, for example, where the multitude of chemical particles and processes means that there is a huge number of possibilities to be tested.

As such modelling involves countless parameters, this would keep even the most powerful supercomputers – such as the new exascale computer JUPITER – busy for years or even decades. This is not the case with quantum computers. Unlike conventional bits, their computing units,

100101

qubits, can not only assume the values 0 and 1, but also any number of values in between. A quantum processor therefore has the potential to perform numerous operations in parallel, which is why it could calculate significantly faster and more efficiently than a conventional computer. “This saves time and energy,” says Michielsen.

JSC has already connected a small five-qubit system from German-Finnish manufacturer IQM to its JURECA DC supercomputer and carried out initial test experiments. A superconducting qubit system developed by Jülich researchers in collaboration with Goethe University Frankfurt and the companies ParTec and Quantum Machines will soon be added, as well as an ion trap system from the German start-up eleQtron. All three systems will be integrated into JSC’s supercomputing infrastructure and are part of the JUNIQ user infrastructure, where FZJ combines, develops, and tests a wide variety of quantum systems. “JUNIQ offers users the unique opportunity to find the most suitable quantum system for their needs and compare different concepts on a single platform,” stresses Michielsen.

To allow the quantum computers to fully leverage their strengths at the right moments, researchers first need to coordinate the communication and methodology of the two different types of computers. This requires software that takes into account both traditional and quantum mechanical approaches. If all this succeeds, the hybrid systems could answer important questions not only in climate research, but also in chemistry, medicine, materials science, finance, AI research, logistics, and quantum physics. Therefore, when it comes to major scientific challenges, it could prove to be a great advantage to have two systems cooperating that work in completely different ways.

JANOSCH DEEG

JUNIQ

JUNIQ – the Jülich UNified Infrastructure for Quantum computing – is part of Forschungszentrum Jülich’s large future IT ecosystem. This unique platform offers science and industry access to a wide range of quantum systems at various stages of development – including state-of-the-art commercial systems such as the D-Wave quantum annealer, quantum simulators like JADE, and continuously optimized experimental quantum computers from projects such as QSolid and OpenSuperQPlus.

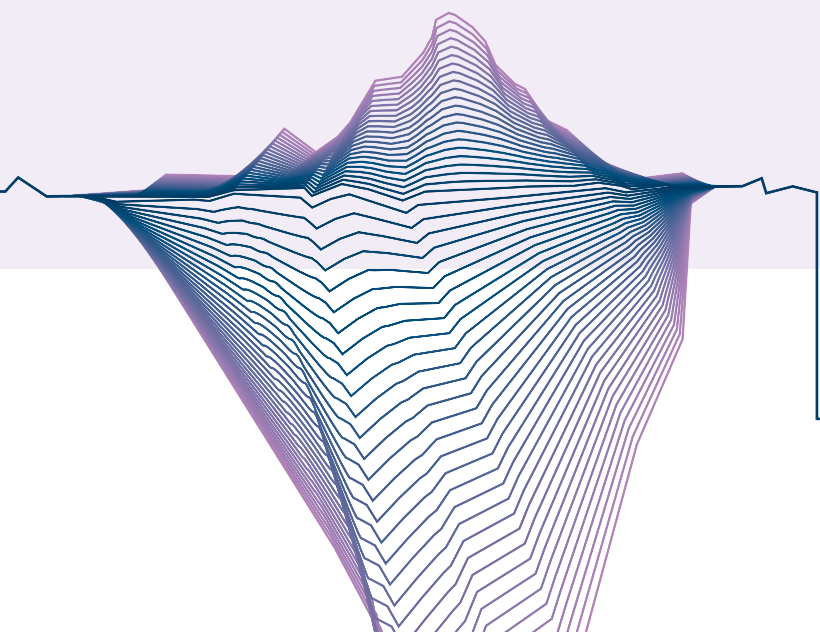
Through hybrid approaches, i.e. combining quantum computers with supercomputers, and the integration of artificial intelligence, complex problems can be addressed in completely new ways. Users also benefit from comprehensive support in the development of algorithms and applications for quantum computing.

More on JUNIQ
go.fzj.de/effzett-juniq_en

Extensive expertise

Forschungszentrum Jülich’s broad expertise in supercomputing and quantum computing really comes to the fore with the development of such hybrid computers on the Jülich campus. Back in 1987, the Jülich Supercomputing Centre (JSC) was the first high-performance computing centre in Germany. Today, Jülich operates five supercomputers – one of which is JUPITER, Europe’s most powerful supercomputer.

Jülich’s quantum research is also unique in Germany. The scientists cover the entire spectrum of quantum research – from quantum theory, hardware construction, and software programming to the testing and further development of finished components. Depending on the problem at hand, the researchers work with very different systems, each with their own characteristics – including a quantum annealer from the Canadian company D-Wave. This makes it possible to try out different techniques and power duos at Jülich.



101101

Jülich research at a glance

15
institutes

18
branch offices in Germany and abroad

238
football pitches
would fit on the 1.7 square kilometre campus of Forschungs-zentrum Jülich

973
million euros
was the total budget of Forschungszentrum Jülich in 2024

Supercomputers JUPITER and JUWELS
Quantum computing infrastructure JUNIQ
Jülich Supercomputing Centre

900 MHz NMR spectrometer
Institute of Biological Information Processing

Atmospheric simulation chamber SAPHIR
Institute of Climate and Energy Systems

EBRAINS
Institute of Neuroscience and Medicine

3
research priorities

Information

Energy

Bioeconomy

115
new patent applications
in 2024

2,390
publications
in 2024

Selected research infrastructures on the Jülich campus

Electron microscopes PICO and KRIOS
Ernst Ruska-Centre

DPPN
Institute of Bio- and Geosciences

Quantum technology
Helmholtz Quantum Center (in planning)

Nanotechnology
Helmholtz Nano Facility

At Forschungszentrum Jülich, almost 7,600 people work hand in hand with around 1,500 visiting scientists from 86 countries. We are one of the largest interdisciplinary research institutions in Europe and contribute to solving the grand societal challenges of our time as a member of the Helmholtz Association.

Further information
fz-juelich.de/en

More effzett is available at
fz-juelich.de/en/news/effzett

More on JUPITER
go.fzj.de/effzett-jupiter_en

Publication details

effzett Forschungszentrum Jülich's magazine, ISSN 1433-7371

Published by: Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Conception and editorial work: Dr. Barbara Schunk, Christian Hohlfeld, Armin Großek (responsible under German Press Law)

Authors: Arndt Reuning, Janosch Deeg, Tobias Schlößer, Dr. Barbara Schunk

Graphics and layout: SeitenPlan GmbH, Dortmund, Germany

Translation: Language Services, Forschungszentrum Jülich

Images: Forschungszentrum Jülich (p. 12, both images at the top), Forschungszentrum Jülich/Sascha Kreklau (title story, p. 2, p. 3 centre and bottom, p. 6 left, p. 8 top, p. 10, p. 11 left, p. 15, p. 16, p. 17, p. 18, p. 19, p. 20 top), Forschungszentrum Jülich/Bernd Nörig (p. 9 left), SeitenPlan (p. 20 bottom, p. 21, p. 22–23 (illustration)), SeitenPlan with material from Shutterstock.com (p. 3 top, p. 4–5, p. 6, p. 7, p. 8, p. 9, p. 11), Deutscher Zukunftspreis/Ansgar Pudenz (p. 13 right), TU Darmstadt (p. 13 left), private (p. 12, both images at the bottom)

Contact: Corporate Communications
Tel.: +49 2461 61-4661, Fax: +49 2461 61-4666, email: info@fz-juelich.de

Printed by: Schmidt, Ley + Wiegandt GmbH + Co. KG, Lünen, Germany

Print run: 500

RECYCLED
Paper made from recycled material
FSC® C015859