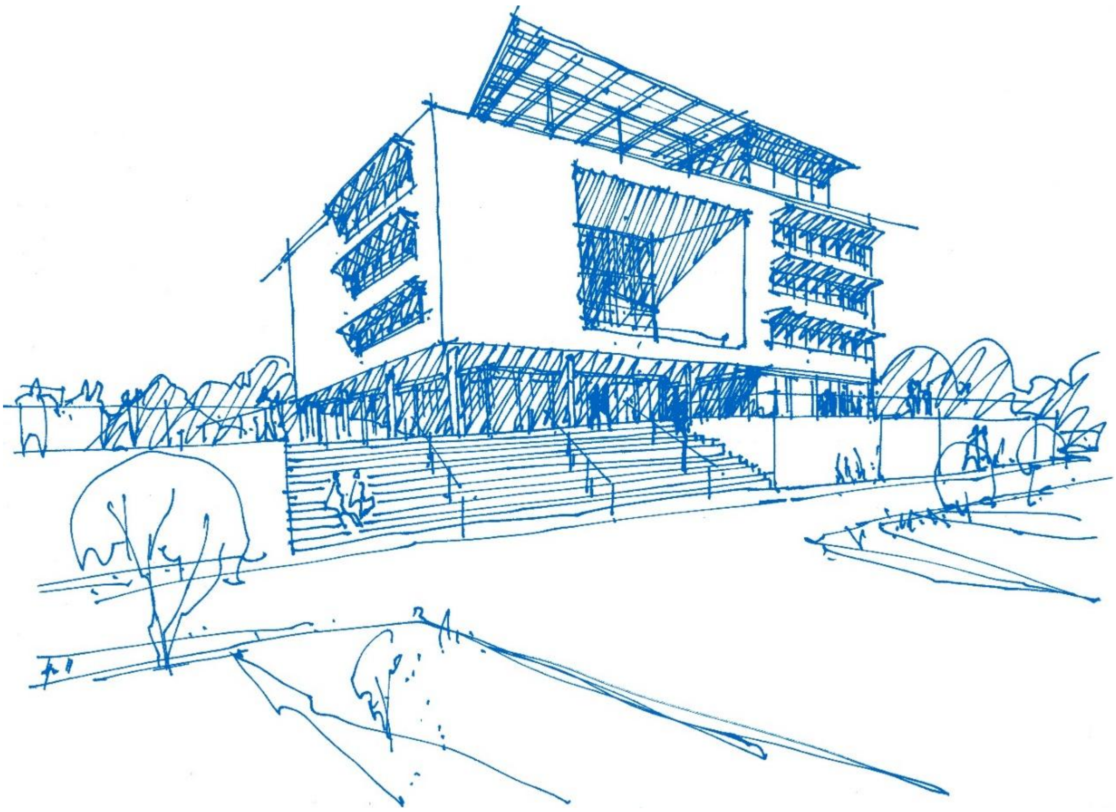
Summary and Recommendations

Supercomputers, Artificial Intelligence and Europe's Technological Sovereignty

Workshop on 16 and 17 March 2026 at the

TUM Institute for Advanced Study



TUM Institute for Advanced Study
TUM School of Computation, Information, Technology
Bavarian Academy of Sciences (BAdW)
European Academy of Sciences and Arts (EASA)

Preface

International fellows at the TUM-IAS conduct research alongside their TUM host professors and PhD students in the field of ‘Data, Deep Learning and Applications’. This gave rise to the idea of organising the workshop ‘Supercomputers, Artificial Intelligence and Europe’s Technological Sovereignty’. We asked ourselves what it means for university and state-funded research institutions in Germany and Europe that major global industry players, with enormous financial resources, are increasingly conducting their own research and dominating the markets. Against this backdrop, it seemed sensible to us to bring together the expertise of specialists from universities, the Max Planck Society, the EU and international companies within the framework of a workshop. The aim was to discuss and outline pathways towards an innovation-friendly, sustainable and sovereign European infrastructure for supercomputers and AI, which would be available to the research community with minimal restrictions.

We would like to express our sincere thanks to our TUM colleagues Professor Dr. DDr.h.c. **Klaus Mainzer** (*President of the European Academy of Sciences and Arts*), Professor Dr. Dr. h.c. **Arndt Bode** (*President of the Bavarian Transformation and Research Foundation and Vice-President of the Bavarian Academy of Sciences*), Professor Dr. **Helmut Krcmar** (*Vice-President of TUM Campus Heilbronn, 2018 to 2024*) and Professor Dr **Hans-Joachim Bungartz** (*Dean, TUM School of Computation, Information and Technology*) for their dedicated and invaluable support in designing and organising the workshop, selecting the invited speakers and drafting this summary. It should be noted that Klaus Mainzer, Arndt Bode and Helmut Krcmar are members of the TUM Senior Excellence Faculty as TUM Emeriti of Excellence. Klaus Mainzer und Michael Molls sind Mitglieder der Europäischen Akademie der Wissenschaften und Künste.

The format of the event organised by TUM IAS, which featured exclusively invited specialists and their short presentations, facilitated in-depth discussions, partly based on abstracts submitted and distributed in advance. We would like to take this opportunity to thank all participants once again for their valuable input. The outcomes of the two-day event, including the recommendations, are summarised in this paper.

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Emeritus of Excellence
Speaker TUM Senior Excellence Faculty, 2015-2025
Director TUM Institute for Advanced Study

Dr. Ulrich Marsch
Managing Director TUM-IAS

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RECOMMENDATIONS

EXECUTIVE SUMMARY

Digital sovereignty is a fundamental prerequisite for Europe's sovereignty

European sovereignty must be guided by Europe's vision of its self-determined future, built on the foundations of democracy, fundamental rights and the rule of law.

Sovereignty does not mean self-sufficiency, but rather the existence of choices that enable action. Real choices (options) come at a cost. To put it pragmatically: "Europe must be able to stand on its own two feet – even if it does not want to, even if it does not always do so, and even if it sometimes proves more expensive."

Anyone wishing to catch up must run faster than the frontrunners, or must put themselves in a position to be able to run faster in the near future. In concrete terms, this means that resources for digital services must be channelled to Europe; at least 30 per cent of IT resources should be allocated to the promotion and use of solutions that foster sovereignty. In this way, the resources needed for Europe's race to catch up will be maintained.

A 'European HPC and AI Chips' moonshot project is necessary, possible and feasible. This requires clear objectives, determination, staying power, resources and skills. Staying power requires resolve.

It is not just about chips and data centres, but about the entire tech stack: the software dimension must be taken into account and integrated.

HPC centres and gigafactories for AI[1] must complement one another to enable hybrid solutions. Simulation is indispensable, but can be improved and made more cost-effective through hybrid approaches (AI, quantum computing, photonics).

The mindset must shift from 'managing scarcity' to 'availability of abundant resources'.

Away from 'mine-yours thinking' towards 'transparency of resources and open innovation ecosystems'. Our approaches to AI should combine 'brute force' (USA) with 'high precision' and 'sustainability' (EU). The European solution: winning through greater ingenuity rather than competing for even more 'brute force' solutions costing billions.

Hope is not a method: take action today!

- Digital sovereignty is part of corporate and political risk management
- KPIs at Supervisory Board level: proportion of the budget allocated to components that promote sovereignty
- KPIs at the political level: systemic transparency
- Promoting open source as an innovation ecosystem
- Involvement in organisations / co-operatives that promote self-determination
- D^2S^2's aim: We can and should set an example, both in data protection and in digital sovereignty!

Time is of the essence: if you want to catch up, you have to run faster than the leaders!

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[1] Very large data centres specifically designed for the development, training and operation of complex artificial intelligence.

PROSPECTS FOR UNIVERSITY RESEARCH

JÜRGEN PFEFFER, TUM School of Social Sciences and Technology: „Data as the basis for new fields of research'

The lecture explores the study of human behaviour using data, in particular through the analysis of networks (e.g. social media such as TikTok or Twitter). It is not just about the data that people generate, but about how **behaviour can be reconstructed and understood from it**.

One area of focus is **network dynamics** (e.g. how topics spread, how people are connected and how structures change). Methods such as **statistical modelling** and the use of **Large Language Models (LLMs)** for text analysis play an important role in this context.

The key challenges are:

- Modelling complex networks (scaling issues, e.g. >1000 nodes are difficult to manage)
- Technical scalability and computing power
- Fine-Tuning vof LLMs (z. B. experimental projects such as „DemocraGPT"[2])

A comparison between Germany and Austria highlights **the German decentralisation** of research and business. This contrasts with a trend in AI: **the centralisation of power in a few key technologies.**

The role of supercomputing is viewed critically: whilst it is important for cutting-edge performance, it is not necessarily required across the board. Instead, **medium-level computing** power could be sufficient for many applications. At the same time, data volumes (e.g. 100 TB per day on Twitter) show that scaling remains a key challenge.

Discussion

There is ongoing discussion about the need for **support staff** to assist those in non-technical disciplines (e.g. the humanities and social sciences) in using technology. Furthermore, there is a shortage of **IT-savvy specialists** in these fields.

Other key points:

- **Low-threshold access** to computing facilities and the avoidance of downtime are important
- Demand for computing resources will rise sharply
- Only a few projects actually require maximum HPC performance
- Large volumes of data (e.g. social media) represent valuable resources
- There is a tension between **high computing performance and flexible availability**
- At a structural level, the European **pyramid structure of users** is mentioned, as well as new initiatives such as **AI factories**, which place greater emphasis on interactivity.
- Finally, it is emphasised that universities should play an important role in **improving access, usage and skills**; however, it remains unclear who is specifically driving this development

CARLA SOPHIE RIEGER (TUM/CERN): *"Research at the interface between AI and high-performance computing – perspectives from early-career researchers"*

This article examines these topics from the perspective of young researchers working at the interface between quantum computing and high-performance computing.

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[2] Development of an AI-supported conversation training programme to promote democratic dialogue

The integration of quantum computers into HPC ecosystems is regarded as one of the key challenges of the coming decade. With the European Quantum Strategy, the EU has created a strategic framework to underpin this development – but how can structures such as EuroHPC be further developed to meet the specific requirements of quantum computing (QC)? Similarly, energy efficiency is gaining importance as a design principle for future quantum architectures – the Quantum Energy Initiative in Grenoble aims to create a robust framework for assessing costs and benefits in this regard. At the same time, fundamental questions arise regarding the use of classical HPC and QC infrastructure. We need to explore how researchers from different disciplines can be supported in using these systems efficiently through parallelisation, scaling and code optimisation. The development of more flexible access models also deserves attention in order to provide scope for exploratory QC and AI research – even though the specific computing requirements are often difficult to estimate in advance, whilst at the same time ensuring that the systems are utilised effectively.

Key challenges and questions

- Classical simulation of quantum systems is reaching its limits, as it scales exponentially → limited efficient simulability
- Unclear boundaries between classical scalability and the potential of quantum computing
- How can HPC and quantum computing be efficiently combined in terms of data processing?
- How far are we still from scalable, fault-tolerant quantum computers?

Technological approaches

- Hybrid methods (a combination of classical HPC and quantum computing) as a key approach
- Integration of quantum computers into HPC systems
- Use of quantum computers as accelerators within classical HPC infrastructures

Resources & Use

- Frequent discrepancies between available and actually utilised resources in HPC workflows
- The aim of more efficient resource utilisation (e.g. through optimisation, scaling)
- Industry partnerships support research projects, but are no substitute for open European infrastructure

People & Access

- Young researchers need better access, training and suitable infrastructure

Future Prospects & Assessment

- The focus could shift from ‘quantum advantage’ to ‘quantum energy advantage’ (see the ‘Grenoble Quantum Energy Initiative’)
- Alongside performance, costs and energy efficiency are also becoming crucial in the field of quantum computing.

KLAUS MAINZER, EASA: *„Research, teaching and computing power – quo vadis, Europe?*

The development of high-performance and supercomputers is deeply rooted in the history of European technology and science. After the Second World War, a computing infrastructure was indeed established in Germany to meet the needs of science and research-based industry. However, global leadership was lost to the USA, for example. In order to safeguard the political, economic and military sovereignty and independence of Europe and Germany in the future, we must strive to assume a leading technological role in global competition. To this end, the best and most powerful computing technologies must be available in Germany in future. The driving force behind this development is the dramatically increasing demand for computing power for AI infrastructures (e.g. AI factories).

However, computers and data centres should not only be powerful, but also energy-efficient and environmentally sustainable. This requirement reflects a performance and research profile that is in line with European values and sets us apart from other competitors. In line with the UN’s Sustainable Development Goals (SDGs), this commitment to values should already be reflected in the training of future developers and users. The European Academy of Sciences and Arts is currently establishing an international and interdisciplinary AI platform to achieve these objectives.

Key points on the European supercomputing strategy

- Europe must avoid over-regulation and bureaucracy so as not to stifle innovation.
- Dependence on energy and technology imports should be reduced, and domestic renewable energy and new smart (modular) nuclear energy should be promoted.
- The defence industry is becoming increasingly important for the development of supercomputers.
- Germany/Europe must make its mark with new (!) research ideas and innovations that are not necessarily capital-dependent.
- Germany offers high-quality and affordable education, but is losing many graduates to other countries.
  In a democracy, high levels of investment require social engagement.
- Economic, political and military pressures demand multilateral competitiveness.

Technological trends and opportunities

- Drones, AI and new nuclear weapons are driving up the demand for computing power.
- Statistical data optimisation in the ‘machine learning’ of existing AI must be expanded to include physical knowledge (partial differential equations) in order to improve and refine solutions (Physical AI).
- Supercomputers therefore serve not only to statistically optimise large volumes of data using neural networks (machine learning with generative AI), as in conventional AI, but also to solve complex mathematical equations in fields such as the natural sciences, engineering and economics.
- Neuromorphic chips modelled on the brain (neuromorphic computing) can avoid the von Neumann bottleneck[3] and reduce energy consumption.
- Memristor[4]-photonics combinations in neuromorphic computing are regarded as promising and energy-efficient technologies.
- Photonics chips also open up the path to quantum computing.
- The combination of statistical data optimisation and physical knowledge (Physical AI) is seen as a new driver of innovation, requiring both new AI software (automatic differentiation) and supercomputers**.**

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[3] The fundamental speed limit in digital computers

[4] The memristor is an electronic component and a key technology for energy-efficient AI hardware and

neuromorphic computing which avoids the von Neumann bottleneck by integrating memory and processor.

Discussion & Recommendations

- In Germany, investment decisions require more justification, whilst other countries are quicker to allocate funds.
- Energy efficiency (e.g. in neuromorphic computing and quantum computing) is a clear and sustainable focus area which, in line with the EU's Green Deal, represents a quintessentially European research profile.
- Breakthroughs and new ideas in AI and supercomputer technology continue to depend on human intelligence and basic research; by supporting these areas, Germany and Europe can make their mark even without the capital and energy input of the major powers.
- Although AI requires increasing computing power (e.g. AI factories), it should be efficient, explainable and controllable, and thus develop a typically European profile.

LEO SCHWINN, TUM: *„The Munich Data Science Institute MDSI of TUM“*

MDSI is essentially a new central hub of TUM for anything related to Data Science and AI. The idea is to facilitate collaboration between people working on AI on a fundamental level, for example, developing new AI methods and researchers in other fields like physics, medicine, management, and others who have a lot of data they want to analyze, where AI could be useful.

The goal of the MDSI is to provide infrastructure, education, and support to connect people from different disciplines to work effectively together.

The MDSI also provides support for data management. For example, by regularly conducting courses that teach specific fundamentals of AI research. But also through personnel, by providing a central point where people can ask these technical questions, so that they do not have to become experts in AI and computer science.

Ideally, we can connect people with diverse skills to solve interdisciplinary problems effectively.

To accomplish this, the MDSI manages a set of computers accessible to its affiliated members.

Similar to LRZ and other compute clusters, this reduces users' workload. Specifically for people from other fields, this can be helpful. However, most of the computing resources used in MDSI-related projects are somewhat decentralized, as most PIs affiliated with the MDSI have their own resources. For example, the GPUs in their lab (LRZ) are resources from Helmholtz Munich, and so on.

To facilitate these research projects, the MDSI also provides seed funds for smaller-scale interdisciplinary projects. Many successful projects have already been conducted, with some receiving awards.

A list of projects can be found on the website.

Key points regarding the use of computing resources in Germany/Europe

- **MDSI** has its own computing resources, which members can use to launch interdisciplinary projects.
- At **TUM**, PhD students are often not trained in how to apply for computing time; this is usually handled by their professors.
- For 'small-scale' users, access to HPC resources in Europe is difficult; there is a lack of individual research access.

Discussion & Challenges

- The Ministry of Science wishes to secure computing resources for scientific purposes so as not to favour commercial use.
- Basic research is increasingly shifting to companies, some of which have their own computing capacities.
- Giga-factories and commercial providers (e.g. Amazon) are profit-driven and differ from traditional research computing centres (e.g. LRZ Jülich).
- Federalism often leads to many small, uncoordinated requests; pooled use would be more efficient.

Perspectives & Recommendations

- HPC should primarily be used as a tool for cutting-edge scientific projects; SMEs have so far been barely involved.
- Cooperation between the Ministry of Science and the Ministry of Economic Affairs is considered necessary, particularly for quantum computing.
- New business models could facilitate innovation, whilst research is, to some extent, shifting to companies.

DISCUSSION AND SUMMARY OF PERSPECTIVES ON UNIVERSITY RESEARCH

Key topics

- Europe takes a different approach to the US by placing a central focus on energy efficiency in high-performance computing (HPC) and AI.
- Physical AI and Physical Machine Learning involve both software and hardware; both aspects must be taken into account.
- AI should complement, not replace, human intelligence, whilst taking ethical considerations and energy efficiency into account.

Challenges & Use

- Commercial services (Google Cloud, Amazon Web Services, Azure, Giga-Factories) are often too expensive for the scientific community and not ideally suited to large models.
- Allocation issues with HPC resources: usage times are not allocated efficiently; redundant time slots should be utilised more effectively.
- Access to HPC/AI resources must be standardised and simplified, including for the humanities and social sciences.
- Different billing and administrative methods make it difficult for non-specialists to use these resources.

Objectives

- To emphasise energy efficiency, resilience and sustainability in HPC and AI systems in Europe.
- AI should complement, not replace, human intelligence; ethical considerations must be taken into account.
- Physical/Extended ML and AI are not the be-all and end-all – explanatory systems and thought processes are crucial.
- Better structures, standardised access and simplified use for the scientific community, SMEs and non-specialists.

- Make better use of redundancies in computing capacity (e.g. at TUM) rather than managing scarce resources through bureaucracy.
- Standardise different billing methods; facilitate access for all academic groups.
- Focus on intelligent, flexible capacity rather than maximum scale; weigh up specialised versus universal resources.
- European initiatives should create optimal working conditions, regardless of chip supplies, and promote abundance and diversity.
- Giga-factories and US initiatives are not currently ideal for German science.
- Objective: to operate HPC and AI systems efficiently, user-friendly and sustainably, taking into account the technical and cultural aspects of resource utilisation.

Strategic Recommendations

- Europe should create structures that enable the best possible working conditions, regardless of chip supplies.
- Instead of further bureaucratic rules: promote a culture of abundance, allocate resources transparently and efficiently, and emphasise diversity and the value of resources.
- Develop narratives that make technical complexity understandable, e.g. regarding LLMs, quantum computing or chip manufacturing.
- A culture of abundance could be established in institutions such as TUM through transparency and the positive use of resources.

EUROPE’S SUPERCOMPUTERS – INFRASTRUCTURE

THOMAS LIPPERT, Director Jülich Supercomputing Centre (JSC) and Goethe-University Frankfurt: *“JUPITER for Simulation and AI - Perspectives of the Jülich Supercomputing Center (JSC)”*

I would like to give you a brief insight into the planning, construction, and use of the JUPITER exascale computer. JUPITER's name says it all: it stands for Joint Undertaking Pioneer for Innovative and Transformative Exascale Research. JUPITER was planned in a long process dating back to 2009. During this time, not only did new techniques for simulating complex systems develop, but also so-called DEEP Neural Networks (DNN), as represented today by generative pre-trained transformers. So, it is no surprise that JUPITER was designed as a “dual” system from 2020 onwards. JUPITER can handle the largest simulation calculations and AI training tasks. JUPITER will run the largest climate simulations and also develop the first competitive German and European frontier models. JUPITER is Europe's first step into the exascale dimension and frontier models. This comes with many challenges in terms of energy efficiency, cooling, scalability, resilience, and data systems, which will also have to be overcome in the planned European AI Gigafactories.

Theses on the future development of AI, HPC and Europe’s technological sovereignty

Promoting sovereignty in key technologies: Germany and Europe must achieve independence in the most important key technologies in order to be able to set their own priorities, reduce dependencies and avoid monopolies. These include, amongst others, chips, cloud technologies, artificial intelligence, quantum communication and quantum computing, as well as new energy technologies.

The significance of artificial intelligence: AI is both a key technology *sui generis* in the sense of a ‘general-purpose technology’ and a dual enabler for key technologies such as robotics, autonomous driving and automated manufacturing on the one hand, and for key sciences such as biology, chemistry, materials science, climate science and physics on the other.

The growing use of sovereign AI: Sovereignty in AI is becoming increasingly important in sectors such as finance, insurance, and the wholesale and retail sectors. Autonomy and sovereignty are indispensable in areas such as security, defence and critical infrastructure. Resilience to crises requires sovereign control over data and infrastructure.

HPC for AI: High-performance HPC systems are urgently needed so that Germany can train and utilise frontier models independently for the economy, public administration, defence and society – and, not least, for science. AI gigafactories on the scale of 100,000 GPUs and >50 MW of computing power must be established soon.

Value creation through tools and experts: Hardware is only effective if it is used wisely. Therefore, the creation of development tools for modelling, quality assurance and security must be promoted, and the training of experts and skilled workers in AI must be prioritised.

Using open-source models: To get off to a quick start with our own frontier models, we should definitely make use of existing open-source LLMs and multimodal models, provided that the data, tools and training methods are also fully open. We must avoid reinventing the wheel and missing the boat in the process.

Don't just follow developments: AI is currently evolving rapidly towards multi-agent systems and RAG[5]. Ministries of science and major research funding organisations must create programmes to enable universities and research institutes to take the lead in such new developments.

Increasing market share: Germany's primary objective must be to increase its market share in the AI sector to more than 3 per cent. From an estimated €190 billion in global AI turnover in 2023: UNCTAD (2025) expects this to rise to almost 5 billion by 2033. For Germany, turnover of 150 billion is forecast for 2033. 'First-to-market' key technologies are of crucial importance here.

Key topics & developments

- Neuromorphic computing is designed to utilise AI capabilities efficiently.
- The demand for supercomputers is rising steadily, driven largely by AI applications.
- Energy efficiency is crucial; photonic computing offers high performance potential with very low energy consumption.
- Photonic chips: developed entirely in Germany, energy-efficient, an innovative alternative to standard chips on the market.

Current challenges

- HPC hardware to date has been market-driven, but often fails to meet specific scientific requirements.
- Nvidia dominates the market (16-bit chips, rising costs of up to 50,000 USD per chip).
- Quantum and neuromorphic computing are still in their early stages and are currently only suitable for specialised applications.
- There is a lack of standards for chiplets and for independent hardware integration.

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[5] Retrieval-Augmented Generation: a technique in which language models (such as ChatGPT) specifically retrieve external or in-house data before generating a response, in order to provide more accurate and up-to-date information.

Future Prospects & Recommendations

- Establishment of tiered HPC structures: European, national and smaller institutional centres.
- Lower precision (16-bit) may be sufficient depending on the situation.
- Promoting Europe's autonomy in chip development, without aiming for complete self-sufficiency.
- Seek partnerships; invest in national chip development; Proposal: 30 % of the AI procurement budget.
- Emphasise digital sovereignty as part of national or European sovereignty.
- Positive examples: Bavarian photonic chip, energy-efficient systems in Jülich

Key points on JUPITER & the European HPC/AI strategy

- The JUPITER project began in 2009; since then, development of new methods for complex simulations and deep neural networks (DNNs, e.g. generative transformers).
- Challenges: energy efficiency, cooling, scalability, resilience and data management – also relevant for planned European AI gigafactories.

DIETER KRANZLMÜLLER, Director of the Leibniz Computing Centre at the Bavarian Academy of Sciences and Humanities and Ludwig Maximilian University of Munich: *"Blue Lion – the new Bavarian supercomputer and photonic approaches"*

Project Stargate is a major US project to build several AI supercomputers, involving enormous investment (up to USD 500 billion in total, with the first phase costing approximately USD 10 billion and the final phase around USD 115 billion) and a planned power consumption of around 5 GW. The demand for supercomputers is growing steadily, particularly due to the increasing use of AI.
A key factor here is **energy efficiency.** High hopes are pinned on photonic computing, which consumes significantly less energy than conventional technologies whilst offering high performance potential. Particularly noteworthy is the fact that a photonic chip of this kind was developed entirely in Germany.

The new Bavarian **Blue Lion supercomputer** will be operated at the Leibniz Supercomputing Centre (LRZ) from early 2027. It delivers around 30 times the computing power of its predecessor, SuperMUC-NG, and combines traditional simulations with artificial intelligence:

Key data and architecture

- **Performance and processors**: The supercomputer is based on the high-performance NVIDIA Vera Rubin architecture and utilises the next generation of HPE-Cray technology.[6]
- **Investment**: The project is funded by the German federal government and the Free State of Bavaria with a total of up to 250 million euros.
- **Cooling and energy**: Blue Lion is 100 per cent directly liquid-cooled. With water at temperatures of up to 40 degrees flowing through the racks, the waste heat can be used directly to heat offices and buildings at the Garching Research Centre.
- **Photonics and the future of computing**: To overcome the energy demands and physical limitations of classical computing power, intensive research into photonic and optical technologies is being carried out at the LRZ.

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[6] This is a converged HPC/AI supercomputing infrastructure that offers the highest CPU and GPU density per computer rack and the highest input/output performance per storage rack.

- **Quantum integration:** Approaches such as photonic quantum computing are being developed to seamlessly link classical HPC processors with optical quantum computers, thereby enabling hybrid workflows in the natural sciences and cryptography.
- The latest updates, Blue Lion prototypes (Blue Cubs) and scientific applications can be followed directly on the website of the Leibniz Supercomputing Centre (LRZ).

The Leibniz Computing Centre (LRZ) relies primarily on the **SuperMUC-NG** system for **artificial intelligence** and uses the **WSE-2 superchip** (Wafer-Scale Engine) from Cerebras Systems for handling extreme volumes of data:

- **WSE-2 (Cerebras superchip):** The chip is as large as an entire wafer. It combines 850,000 computing cores on a single surface and is specifically designed for deep learning and the rapid processing of massive datasets (big data).
- **SuperMUC-NG:** The LRZ's current main supercomputer in Garching has been specifically upgraded with graphics processing units (GPUs) to combine traditional scientific simulations with artificial intelligence methods.
- **Further technology:** In addition, the LRZ is researching and testing novel technologies such as **quantum computers** and **photonic (light-based) computers** to solve AI tasks even more energy-efficiently**.** For **photonic co-processors (Q.ANT),** researchers are optimising traditional algorithms (such as matrix-vector multiplications) so that they run on optical units, thereby drastically reducing energy consumption**.**

At the Leibniz Computing Centre (LRZ), AI superchips (such as the Cerebras WSE-2 or photonic co-processors) are primarily controlled via standardised **HPC programming environments and libraries**. **Programming** is usually carried out at a low level of abstraction in languages such as **C, C++, Python or Rust** using AI frameworks.

The **integration and programming** of these systems at the LRZ are based on the following key points:

- **Standard languages**: Researchers use programming languages such as **Python, C++ or Rust** to write their AI models and workloads.
- **Libraries**: Widely used libraries such as TensorFlow, PyTorch or scikit-learn are employed for the actual AI development and training.
- **Optimisation**: Specialised APIs, libraries and drivers provided by the LRZ abstract the low-level communication and enable the software to efficiently manage direct access to AI accelerators (GPUs or specialised chips).

Recommendations for the scientific community and policymakers:

- AI cannot replace HPC, but it can complement it very well; therefore, interdisciplinary research into HPC and AI should be expanded and more closely linked to fields of application.
- Further develop open research infrastructures and data platforms in Europe.
- Strengthen the training and qualification of skilled personnel in HPC, AI and data science.
- Invest in HPC and AI infrastructures in the long term.
- Strengthen European technological sovereignty through home-grown key technologies and collaborations.
- Create an innovation-friendly environment and facilitate the transfer of research to industry, as well as access for SMEs to HPC and AI resources.

ERWIN LAURE, Max Planck Computing and Data Facility: *„Future of High-Performance-Computings“*

The growing demand for high-performance computing (HPC) is being further fuelled by AI and data-driven science. Large industrial systems such as ‘Colossus’ demonstrate that industrial AI infrastructure is becoming increasingly powerful and is dominating the market, whilst traditional academic HPC appears very small by comparison. This is also shifting the balance between scientific and industrial computing power: Whilst HPC was traditionally dominated by research institutions, today it is large technology companies that are driving development forward.

A key problem is that the market for high-performance computing and AI hardware is heavily dominated by a small number of players. Nvidia, in particular, occupies a prominent position, as the company not only provides powerful graphics processing units but has also built up an extensive software ecosystem. This combination of hardware and software creates strong dependencies. Many applications, frameworks and AI models are closely tailored to Nvidia’s technologies, making a switch to other providers difficult and costly. Furthermore, specialised chips and accelerators – such as those for reduced-precision calculations like 16-bit (or lower) operations – are becoming increasingly expensive. Such formats are particularly important for AI applications because they enable high computing power whilst minimising memory and energy requirements. The rising costs and market concentration therefore raise the question of how an affordable and independent computing infrastructure for science and industry can be secured in the long term.

The strategy adopted by many scientific institutions to date has been to procure available hardware from the market and deploy it for their respective research purposes. However, this approach is increasingly reaching its limits. Hardware developed by industry is primarily geared towards the requirements of large commercial markets, in particular AI applications used by large corporations. Scientific requirements, however, are often more diverse: they range from numerical simulations, climate models, materials research and particle physics to bioinformatics and data-intensive experiments. Not all of these applications benefit to the same extent from the same chip architectures. If data centres simply purchase whatever is available on the market, there is a risk that scientific needs will be given only secondary consideration. This can lead to losses in efficiency, both in terms of computing power and in energy consumption and costs.

Future technologies such as quantum computing and neuromorphic computing offer interesting prospects in the long term, but are not yet mature enough to replace traditional HPC or AI infrastructures on a large scale. Quantum computers promise enormous advantages for certain classes of problems, but remain at an early stage of development. Significant challenges remain in terms of error rates, scalability, stability and practical usability. Neuromorphic systems, which are modelled on the functioning of biological neural systems, could also play a role, particularly in energy-efficient AI applications. Nevertheless, both technologies remain niche solutions for the time being and cannot meet the rapidly growing demand for computing power in the short term. The further development of classical and specialised semiconductor technologies therefore remains crucial for the coming years.

Against this backdrop, a tiered system of data centres is proposed for the future, linking European, national and institutional levels. At European level, particularly large and powerful systems could be provided, to be used for strategically important tasks, international research projects and large AI models. National supercomputing centres could complement this by meeting the specific requirements of individual countries and enabling broader scientific use. Institutional supercomputing centres at universities and research institutions would continue to play an important role, as they are closer to the respective user groups and can respond more flexibly to local requirements. Such a multi-tiered model could help to allocate computing resources more efficiently whilst also increasing security of supply. A key aspect of this is establishing in-house chip development and, at least to some extent, chip production in Europe. The aim is not to achieve complete self-sufficiency, as global supply chains in the semiconductor industry are highly complex and international cooperation remains necessary. Rather, the aim is to reduce critical dependencies and strengthen digital sovereignty. Europe should be in a position to set its own technological priorities and develop hardware that is better tailored to scientific, industrial and societal requirements. This includes energy-efficient architectures, specialised accelerators for AI and simulations, and open software and hardware ecosystems that reduce dependence on individual manufacturers.

Specifically, it is suggested that a significant proportion of public AI budgets be invested in national and European chip development. Around 30 per cent of AI funding could be used for this purpose to build up in-house expertise in the areas of design, manufacturing, integration and software support. This would be important not only from a technological perspective, but also for economic and security policy reasons. Those with their own computing infrastructure and chip technologies can drive innovation more independently and are less vulnerable to supply bottlenecks, export restrictions or geopolitical conflicts.

There are already promising initiatives in Germany and across Europe. Examples include photonic chips from Bavaria, which use light rather than electrical signals for certain computational operations and could therefore, in the long term, enable high computing speeds with lower energy consumption. Energy-efficient approaches from Jülich also demonstrate that new architectures are being developed in the HPC sector that are better tailored to scientific computing requirements. Such projects highlight that Europe possesses the relevant expertise. However, it will be crucial not only to support these approaches as individual projects, but also to embed them in a coordinated long-term strategy.

Overall, it is clear that the future of high-performance computing cannot be secured solely by purchasing ever-larger systems. What is needed is a strategic combination of high-performance infrastructure, in-house technology development, international cooperation and targeted funding. Only in this way can we ensure that science, industry and society continue to have access to sufficient, affordable and sovereign computing power in the future.

DISCUSSION AND SUMMARY ON EUROPE’S SUPERCOMPUTER INFRASTRUCTURE

Key topics

- Supercomputer infrastructure has traditionally been required for the numerical simulation of a wide variety of applications. Over the last 10 years, in addition to these ‘classic’ supercomputer applications, very high demands on computing capacity have emerged in the fields of artificial intelligence and big data processing.
- Supercomputers require enormous amounts of energy for operation and cooling, thereby placing a strain on households, the supply infrastructure and the environment. Energy efficiency and site selection are therefore of great importance.
- The public, traditional supercomputing infrastructure in Germany and Europe is generally well organised and is funded from EU, federal and state budgets. There is not (yet) sufficient infrastructure in place to meet the specific needs of artificial intelligence (‘AI gigafactories’).
- Coordination of the traditional infrastructure is carried out in Europe by the Euro-HPC Joint Undertaking (JU), and in Germany by the Gauss Centre for Supercomputing (GCS e.V.) for the federal supercomputers and by the NHR (Association for National High-Performance Computing) for the state supercomputers.
- Supercomputers in the highest performance class are developed and manufactured exclusively outside Europe. This applies to both the hardware and the system software. The US manufacturer NVIDIA currently holds a monopoly on processor chips and systems in the highest performance class. Europe is therefore not self-sufficient in these areas.

- Germany has particular expertise in innovative technologies that may prove significant for supercomputing (both traditional and for AI) in the future: photonics in the field of energy-efficient technologies, and quantum computers in the field of unconventional computer architectures and programming models.
- In the field of algorithms and application software, however, Germany and Europe possess expertise of the highest standard.
- The same applies to the infrastructure and operation of supercomputers.
- Europe also possesses strong expertise in the design, operation, applications and use of cloud systems.

Challenges and Opportunities

- In the field of hardware, expertise must be built up gradually. In doing so, the strengths existing in various European countries should be brought together, shared and further developed.
- In the field of software, Europeans must work together to determine whether a gradual transition to open-source solutions can reduce dependence on the US (e.g. Microsoft)
- European cloud solutions must be specifically promoted and their use encouraged

Objectives and strategic recommendations

- Further strengthen German and European strengths, and gradually compensate for and eliminate weaknesses or gaps in expertise – even if this proves very costly.
- Promote the development of research infrastructures and data platforms in Europe – covering hardware, software and applications.
- Conduct a targeted analysis of the competition between traditional supercomputing and supercomputing for AI, and identify and promote potential synergies.
- Establish a tiered performance pyramid: gigasystems – supercomputers – cloud systems
- Gradually develop self-sufficiency for Europe as far as possible, through targeted funding of new technologies and by promoting the use of existing European technologies.
- Promote unconventional or niche technologies, some of which already represent a particular European strength: in the short and medium term in the field of energy-efficient technologies by supporting photonics; in the longer term in the field of various quantum technologies, including quantum computers and quantum programming.

CORPORATE STRATEGY AND DIGITAL SOVEREIGNTY

HELMUT KRCMAR, TUM: „Corporate strategies and digital sovereignty“

- The interplay between dependency, sovereignty and self-sufficiency shapes corporate strategies; objective: to preserve options.
- Hyperscalers (cloud backbone)[7] account for only around 15 % of the EU market; gigafactories (5 sites, each producing ~100,000 AI chips) as the European response for industry, research and government.
- Complete self-sufficiency is not possible; dependencies exist at several levels (suppliers, third parties).
- Key conflict: the Cloud Act versus European data law; the EU framework contains no regulations on chips.

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[7] A cloud computing provider that delivers computing power, storage and network infrastructure on an extremely large scale globally.

- Three infrastructure strategies:
    1. Use existing hyperscalers
    2. EU-only for maximum digital sovereignty
    3. Hybrid/multi-cloud

- Europe lacks its own data centres and chips to ensure digital sovereignty.
- Dependence on external providers (e.g. Microsoft) increases costs and risks; alternatives are urgently needed.
- Highest risk: disruption to IT and supercomputing infrastructure.
- State control of supercomputers requires clear strategies: multiple supercomputers, outsourcing of workloads, and allowing for diversity.
- Investments must be comparable to and justifiable within budgetary constraints.
- The legal framework and conservative risk management in Germany make rapid adjustments difficult.

Recommended measures for businesses

- Identify and manage dependencies:
- Political: mandatory systemic disclosure
- Business: dual sourcing, open source, alternative suppliers for critical components
- Consider sovereignty as a board criterion.
- Classify workloads and define the target architecture.
- Take action now: business and political risk management to minimise dependencies.

Business & political approaches

- Risk management as a key lever; Plan B and radial-flank strategies are necessary.
- New licences could be tied to a commitment to sovereignty.
- European strategy: promote interoperable standards, dual sourcing, open source and the innovation ecosystem.
- Combine various European components and approaches to supercomputing to reduce dependencies.

ROBERT JOZIC, Dieter Schwarz Digital GmbH: *„STACKIT Cloud as a European example of digital autonomy’*

Digital sovereignty and autonomy

- Many German companies are, in digital terms, more on a par with developing countries.
- Jurisdiction (e.g. US access, US cloud services) is a key risk; the current system is too fragile.
- Sovereignty = safeguarding freedom of decision-making; the most powerful lever for digital autonomy.
- Partial sovereignty (SEAL Level 4)[8] as a realistic goal, not complete self-sufficiency.
- Key areas for sovereignty: cloud computing, cybersecurity, data & AI, communications, workspace.
- Ecosystems comprising trusted contractual partners promote sovereignty and link academia and industry.

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[8] Sovereignty Effectiveness Assurance Level; effectiveness of sovereignty
Security Level (SEAL). The SEAL level serves as a minimum security standard.

Technology & Infrastructure

- Cloud principles: security by design, secure data centres, new technologies in secure ecosystems.
- Software is a bottleneck in cloud systems; open source facilitates interoperability and reduces dependence on dominant market players.
- The US AI Action Plan (July 2025) as a reference point; German initiatives such as Stackit (Schwarz Group) or IPAI (Heilbronn).

Value Creation & Investment

- AI-driven value creation requires focus; there is significant scope for differentiation at every stage right through to application.
- Investment in basic research is important for attracting talent.
- Interactions with European companies strengthen sovereignty.
- Brain drain and a lack of investment are critical shortcomings.

Strategic recommendations

- Do not aim for full sovereignty from scratch, but work step by step towards the SEAL-4 level.
- Determination and targeted investment decisions in cloud, data and AI are crucial.
- Use of open source and interoperable standards as a means of countering market dominance.

DISCUSSION

The importance of open source

- Open source as a differentiating factor against hyperscalers.
- Enables interoperability, low-threshold market entry and cooperation rather than competition.

Investment & Innovation

- A focus on innovation and future-oriented topics in investment is crucial.
- Talent development must be integrated.
- Long-term planning and a willingness to take risks are required; the European economy must solve cloud-related problems itself.

Competition & Market Strategy

- A free market system is based on competition; major investors in the US are, in some cases, hindering efficient operation.
- Identify opportunities for differentiation and put them into practice using software stacks.
- Implementation often fails due to bureaucracy; the foundations must be laid first.
- Strategies: Differentiate, adopt alternative positions vis-à-vis monopolies, and promote collaboration on software stacks.

SAI NARASIMHAMURTHY, ParTec AG: *„Sustaining Europe’s Leadership in Advanced Computing through Community engagement and co-design“*

This talk reflects on ParTec AG's experiences and illustrates how collaboration across research, industry, and public initiatives can drive technological leadership in Europe.

At the center of this is the dynamic Modular System Architecture (dMSA)—an innovative approach to building scalable HPC and AI supercomputers. Originally developed in Germany through close collaboration between ParTec and the Jülich Supercomputing Center (JSC), the dMSA has evolved into the architectural foundation for a number of Europe's most powerful systems, including the continent's largest operational HPC and AI supercomputer, culminating in JUPITER, the first Exascale-class system.

The talk highlights how this architecture has been shaped and expanded through a broad European innovation ecosystem. Collaborative research initiatives—including the DEEP and SEA [9] project families—have advanced modular supercomputing concepts and enabled the integration of emerging technologies. Together with the associated software stack, the ParaStation Modulo Software Suite, these architectural principles now also enable the integration of quantum computing systems with classical HPC/AI infrastructures.

Building on these foundations, ParTec continues to apply the lessons learned in new initiatives such as DARE[10] which aims to establish a RISC-V–based European supercomputing ecosystem[11]and SEANERGYS[12], focused on energy-efficient software stacks for future HPC systems. The same collaborative model is now also being applied to consult on and co-develop the next generations of AI infrastructure in Europe, working closely with partners and customers from the onset.

Active engagement with the European HPC community—through organizations such as ETP4HPC[13] and the EuroHPC Joint Undertaking's Research and Innovation Advisory Group (RIAG)—has ensured continuous dialogue with stakeholders and policymakers shaping Europe's advanced computing roadmap.

Ultimately, the talk argues that Europe's strength in advanced computing lies in its **community-driven approach**, bringing together industry, research centers, policymakers, and users to co-design the next generation of supercomputing systems.

Key themes & developments

- Collaboration between research, industry and public initiatives is crucial to driving Germany and Europe forward in advanced computing and R&I.
- ParTec: Development of extrascale systems leading to sovereign AI data centres; EU Strategic Advisory Group involved.
- dMSA (dynamic Modular System Architecture): modular, dynamic resource composition → improves scalability, performance and energy efficiency; forms the basis for the JUPITER supercomputer in Germany.
- Modular architecture allows for adaptation to different applications, improves efficiency and offers scalability, but also entails a high degree of complexity.

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[9] DEEP-SEA ("DEEP – Software for Exascale Architectures") will deliver the programming environment for future European exascale systems, adapting all levels of the software stack to support highly heterogeneous compute and memory configurations

[10] DA/RE is a centralised, cloud-based IT platform used throughout Germany that facilitates coordination and communication between grid and plant operators across all voltage levels.

[11] The RISC-V–based European supercomputing ecosystem is a strategic, multi-billion-euro initiative designed to establish **technological sovereignty** and digital autonomy for the EU. By utilizing the open-standard RISC-V **Instruction Set Architecture (ISA)**, Europe is building a complete, domestic hardware and software stack

[12] SEANERGYS aims to create an integrated European software solution that optimizes resource utilization and reduces the energy used for real-world workload mixes.

[13] ETP4HPC is an Industry-led think-tank guiding the development of the European advanced computing ecosystem

- Software development requires consortia; close collaboration with major research centres (including those outside Europe) improves alignment with user needs.
- dMSA lessons learnt are transferable to AI data environments → 'modular' AI factories are under development.
- Continuity and long-term funding are crucial to prevent the loss of ideas when projects change.
- Community engagement, collaboration and co-design are essential to stay closely aligned with current R&I projects.

Discussion & Challenges

- Open innovation is never completely open, as stakeholders have their own requirements; standardisation is difficult.
- Comparison with India: government-led impetus is crucial; collaboration is important, as there is a lack of local quantum companies.
- Lack of data centres in Europe; multiple supercomputing sites and digital sovereignty are necessary.
- Dependence on hyperscalers → rising costs; need for alternatives and a 'Plan B'.
- Outsourcing of workloads and a variety of providers are necessary; entrepreneurial risk management and risk appetite are crucial (highest risk: disruption).
- Government responsibility for supercomputing; long-term investment and optimisation across the entire stack are required.
- Open source is useful, but standardisation remains a problem

DISCUSSION AND SUMMARY: CORPORATE STRATEGY AND DIGITAL SOVEREIGNTY

Key Developments & Concepts

- Collaborative Research Initiatives (e.g. DEEP and SEA projects) promote modular supercomputing concepts and the integration of new technologies.
- Europe's strength lies in its community-driven approach: industry, research, policy-makers and users are working together to shape the next generation of supercomputing.
- Challenges & Recommendations
- Bureaucracy is a key obstacle; substance must be established first, before administrative processes take over.
- Nurturing talent and a focus on innovation are crucial.
- Collaboration and flexibility are essential; the European economy should act as a driving force in the cloud market.

MAJOR GERMAN AND EUROPEAN RESEARCH PROJECTS

Mainframe computers and supercomputers pose a challenge for large-scale research in Germany and Europe. To draw a comparison with another large-scale research project, fusion research is examined below, followed by an analysis of the perspective of the EU's Directorate-General for CONNECT.

PHILIPP ULBL, MPI for Plasmaphysics: *„Fusion Research, Supercomputing, and AI“*

- **Political context:** Fusion research is of central importance for long-term energy security. The energy requirements of supercomputing underline the importance of long-term energy security.
- **Nuclear fusion & concepts:** What is nuclear fusion?

  - Objective: To fuse hydrogen into helium, thereby generating energy.
  - One technical approach involves confining the **fusion plasma** using strong magnetic fields (‘magnetic cage’)
- **Challenge**: Turbulent transport in the plasma boundary layer determines heat transfer and thus the performance of **future power stations**. Accurate simulation is therefore essential.
- **Supercomputing & Simulation:**
  - Tools such as the GENE code family simulate plasma turbulence.
  - New developments: GENE-X specialises in boundary layer turbulence in complex geometries such as tokamaks and stellarators.
  - Spectral algorithms + GPU = up to 500× faster than traditional methods.
- **Use of AI:**
  - AI could be used to simulate plasma turbulence.
  - Initial studies on sub-scale turbulence achieve up to 700× faster simulation times using AI-supported algorithms applied to simplified turbulence models.
  - Effective integration of AI can significantly accelerate research.

KILIAN GROSS, EU Directorate-General CONNECT: *„Technological Sovereignty and Innovation’*

CONNECT develops and implements policy strategies to prepare Europe for the digital age. This includes investment in research and innovation, as well as the introduction of reliable green digital technologies for the benefit of the economy and to improve people’s lives. Through funding, legislation and policy initiatives, steps are being taken to ensure that Europe leads the way and remains independent in critical digital technologies such as artificial intelligence, shared data spaces, high-performance computing, 5G, microelectronics, blockchain and quantum technology. Europe aims to become a global leader in the fields of the data economy and cybersecurity. The aim is to promote the single market, in which all businesses can invest and compete on equal terms, develop, market and use digital technologies, products and services, and in which the rights of creators and consumers are respected. High-speed networks for all businesses and households are to be developed, as there can be no digital transformation without connectivity. The call is for an innovative, fair and sustainable digital transformation of society that puts people at the centre and respects democratic values, fundamental rights and cultural diversity. By promoting the digital skills of people in Europe, the digital divide is to be bridged.

New guiding principle & objectives

- The aim is to achieve technological resilience in Europe in order to withstand periods of international conflict. This involves key facilities (‘showpoints’) that are independent of global supply chains.
- The aim is not complete self-sufficiency, but sufficient strength to safeguard European interests (Tech Sovereignty Package, cloud development, Quantum Act).
- There is a call to expand AI ecosystems: integrating AI into vertical value chains, developing ‘giga-factories’, and establishing a legal framework as the basis for an ‘AI continent’.
- Supercomputing is only one part of the strategy for rapid development and competitiveness.

Specific measures & infrastructure

- Munich is regarded as a pioneer: the “Industrial AI Cloud”, opened by Deutsche Telekom and Nvidia in Munich’s Tucherpark in February 2026, is one of the largest AI

facilities in Europe. The high-performance data centre, equipped with around 10,000 Nvidia Blackwell GPUs, serves as specialised infrastructure for industrial AI applications, ensuring data sovereignty and enabling the training of complex models.
- Infrastructure and technology in Europe must therefore be strengthened and a chip value chain expanded. Unfortunately, there are currently hardly any AI chips developed in-house in Europe.
- Following the model of the Chip Act, a Quantum Act is planned to secure a strong quantum ecosystem involving start-ups and to prevent European companies from relocating to the US.

Discussion and questions

- The JUPITER & Hardware Initiative is unprecedented:
- Prior to the launch, there were discussions about whether Europe was too late.
- Response: The project is capital-intensive, but indispensable. The aim must not be merely application, but also the development of our own capabilities, so as not to become a ‘second-hand’ continent for the major powers.
- Chip development & AI factories
- Europe’s independence must be strengthened through the shared strategic interests of the Member States.
- The establishment of competitive factories (as part of the Chip Act 2) is necessary. As the example of Japan shows, an established ecosystem attracts imitators.

1. Business landscape & scaling challenges
    o Europe often lacks high-performing scale-ups because the costs for companies are too high, particularly compared to the US.
    o A short-term solution is vertical value creation. In the long term, however, a more comprehensive strategy is required.

    o Unfortunately, venture capital is difficult to mobilise in Europe. This is often due to the regulatory framework in Europe, which offers too few incentives (unlike in the US).

2. Giga-factories & financing
    o The criticism is that funding mostly goes to ‘monopolists’. On the other hand, the European share must be safeguarded.
    o ‘Buy European’ initiative: Without concentration, there can be neither efficiency nor competitiveness. The German and EU ‘scattergun’ approach poses the greatest threat to international competitiveness.

    o The concept of networking and cooperation in Europe should indeed create markets and added value, but this will not be possible without a focus on efficiency.

3. Supercomputing & Sovereignty
    o Europe can only achieve independence in supercomputing through cooperation, as the capital requirements are enormous.
    o Giga-factories are a means of establishing the European market and securing technological sovereignty.

DISCUSSION AND SUMMARY: MAJOR GERMAN AND EUROPEAN RESEARCH PROJECTS

Focus of the research

- In the past, research was more focused on the core of the plasma. Today, it is recognised that the boundary regions (boundary layer turbulence) are also crucial to the overall behaviour.

- The physics of plasma turbulence is a complex multi-scale, multi-physics problem involving a wide range of phenomena and interactions.

Start-ups & Innovation

- European fusion research has long been dominated by ITER (tokamak). With seven partners, the project is certainly international, but it is (too) large, expensive and subject to delays.
- In contrast, start-ups can pursue new concepts, optimise existing solutions and employ innovative approaches such as high-temperature superconductors (HTS).
- Examples: Commonwealth Fusion (USA) uses HTS technology. Proxima Fusion (Germany) is pursuing the stellarator concept.

Perspectives

- The path of research is crucial (“The journey is the destination”).
- Optimism fosters diverse approaches and new players who address problems and drive innovation.
- The EU Directorate-General is developing policy strategies to equip Europe for the digital age. These include investment in research and innovation, as well as the introduction of green digital technologies. The aim is to ensure Europe’s technological resilience – not complete self-sufficiency, but sufficient strength to be able to safeguard European interests.

ENERGY EFFICIENCY AND SUSTAINABILITY OF SUPERCOMPUTERS

Energy efficiency and sustainability are objectives that should become hallmarks of Europe in the context of the Green Deal (EU) and the SDGs (UN). First, the strategy of a medium-sized German company will be presented. In times of armed conflict, new challenges arise, which will be examined using the example of Ukraine:

AXEL AUWETER, MEGWARE GmbH: *“Energy optimisation and cooling strategies in HPC operations”*

Over the course of its more than 35-year history, MEGWARE Computer Vertrieb und Service GmbH has established itself as one of Europe’s leading supercomputing specialists. MEGWARE develops, designs, manufactures and markets the latest generation of supercomputers, many of which feature in the TOP 500 list of the world’s most powerful HPC systems.

Company & Market Position

- MEGWARE GmbH (for 35 years) is an HPC systems provider and ranks amongst the top 10 mainframe system integrators.
- Positioning as an SME: Steady growth, integration with existing technology systems and the development of proprietary solutions characterise MEGWARE GmbH’s positioning as an SME.

Technological Expertise

- The company has over 15 years’ experience with water cooling, which meets the high demands of AI training.
- Central to this is the development of its own server and modular data centre concepts, featuring, for example, rapid installation times for cooling modules within a week.
- The company possesses interdisciplinary expertise in the fields of IT, electrical engineering, plumbing and HPC software support.

Supply Chains & Production

- The company relies on a multinational supply chain, sourcing components from China, Taiwan and Germany.
- It designs and manufactures its own electronic assemblies, whilst network cards are purchased from external suppliers.
- However, second sourcing is virtually impossible for an SME such as MEGWARE GmbH. Supplier audits in accordance with EU regulations are difficult to implement.

Challenges & Trends

- The fast-paced nature of the market and the new demands arising from the AI hype pose a major challenge for the company.
- Close collaboration with partners (e.g. for refrigeration systems) is essential.
- Whilst some components can be manufactured locally, complex circuit board components remain a critical issue

Discussion – Supply Chains & Second Sourcing in the HPC Sector

- There is a global dependency, as many components continue to come from international supply chains. The necessary expertise is already firmly established within the company.
- Second sourcing is practically unfeasible for an SME: there are too many different components that would need to be individually tested or developed in-house.
- Establishing a fully local ecosystem is currently difficult, as key design work (e.g. for Dell, Novum) is carried out in Taiwan.
- In Europe, unlike in the US, many components are still sourced globally. Core designs are concentrated in Taiwan.

IULIIA YAMNENKO, MPI for Quantum Optics, **“***Mainframe Computers and AI in Times of Conflict: Resilience, Potential and Partnerships, as Exemplified by Ukraine*”

Despite the ongoing Russian invasion, Ukraine is emerging as a remarkable hub for artificial intelligence (AI) and high-performance computing (HPC), with a strong focus on defence technology (DefenseTech), security and integration into European structures. Current developments include (as of 2025/2026):

1. Strategy and AI Development

- Ukraine aims to be among the top three countries in AI development and integration in the public sector by 2030.
- To this end, Ukraine has adopted the EU AI Act and participates in meetings of the European Artificial Intelligence Boards to align its AI standards with those of the EU.
- The state-funded defence cluster Brave1 plays a central role in the development of AI solutions for the military sector and works closely with international partners such as Palantir.

2. AI in the Defence and Security Sector (DefenceTech)

- AI is used extensively for processing drone data (FPV drones), target detection and swarm intelligence.
- Systems such as ‘Griselda’ process vast amounts of data from drone and satellite imagery in seconds to identify enemy positions.
- As part of the Palantir partnership, sensitive military data is being used to train AI models in order to improve battlefield analysis.

3. HPC and infrastructure investments

- Leading Ukrainian cloud providers are investing over 150 million hryvnia (approx. 3.75 million USD) in state-of-the-art hardware, including NVIDIA H200 Tensor Core GPUs, to enable the local training of high-performance AI models (LLMs).
- Ukraine is actively participating in EuroHPC (European High Performance Computing Joint Undertaking) projects and is working on integration into European AI factories.
- AI is increasingly being used to protect critical infrastructure from cyber-attacks.

4. Non-military applications

- In GovTech, AI is being used to streamline administrative processes and to translate legal texts as part of the EU accession process.
- Start-ups are using AI to optimise energy grids and for environmental monitoring.

The infrastructure must be protected against physical attacks:

There is a high demand for specialised skilled workers to achieve the ambitious goals despite the war. The AI transformation in Ukraine requires

- exponential growth in digital data in mathematics, physics, chemistry and biology
- the energy consumption of AI as a key challenge
- Concentration of global AI resources: USA (~300 billion USD), China (~200–250 billion USD), EU (~100–120 billion USD).
- Variation in national priorities: India (agriculture), the EU (ethical & trustworthy), the US (defence technologies).
- One case study is Israel, which, as a small nation, is making a major impact in cyber security, defence and AI start-ups (e.g. acquisitions by Google and ServiceNow).
- In contrast, in Ukraine

    - Its share of the global HPC/AI ecosystem is small (0.5 % compared with 30–40 % for the US and China).
    - The number of IT specialists is relatively high per million inhabitants.
    - A unique data resource resulting from wartime experience and digital transformation: human capital, defence data, social media, military medicine and information security.

- **Conclusion:** Ukraine cannot compete primarily on the basis of computing power, but can make a valuable contribution to the future of AI and HPC through data and expertise, combined with global infrastructure.

Discussion – IT Education & Dependencies in Ukraine.

- **Foundations of IT culture:**
    - Universities integrate all relevant IT components into their curricula.
    - War conditions have accelerated development, particularly through a focus on military applications.
    - A wide variety of specifications (e.g. drones) promotes adaptability and learning curves.
- **Dependence on external systems:**
    - The problematic dependence on Elon Musk’s systems (presumably Starlink) has largely been resolved, partly by taking the system offline.
- **Open questions:**
    - What further measures or resources are needed to further strengthen IT resilience and self-sufficiency?

RECOMMENDATIONS

- Europe's sovereignty must be guided by a vision of its self-determined future, including in the areas of mainframe computing and AI.
- Statistical optimisation of large data sets (today's AI based on machine learning using supercomputers) must be expanded to include physical knowledge in order to improve and refine solutions (Physical AI).
- The European solution: winning with 'high precision' (Physical AI) and 'sustainability' (Green Deal), rather than with 'brute force' (USA) and 'unlimited' energy and computing power!
- It is not just about chips and data centres, but about the entire tech stack: the software dimension must be taken into account and integrated.
- The following examples represent the first steps in European supercomputing and AI: JUPITER/Jülich (Europe's first exascale computer, ranked 4th worldwide), JEDI/Jülich (ranked number 1 on the Green500 list of the world's most energy-efficient supercomputers), the Munich AI Factory (Telekom/Siemens/Nvidia) with 10,000 Nvidia Blackwell GPUs and a computing power of 0.5 exaFLOPS.
- Neuromorphic chips modelled on the brain (neuromorphic computing) can avoid the von Neumann bottleneck and reduce energy consumption.
- Although quantum computing overcomes the computational limits of classical computers, it initially requires classical high-performance computers to act as simulators.
- Energy efficiency (e.g. in neuromorphic computing and quantum computing) is a sustainability issue that represents a typical European research profile within the framework of the EU's Green Deal.
- Europe must avoid over-regulation and bureaucracy so as not to stifle innovation in the face of global competition.
- Europe must invest in basic research in order to attract talent.

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Abbreviations

DNN = Deep Neural Networks
D^2S^2 = Design to Services and Systems
EASA = European Academy of Sciences and Arts
GPU = Graphics Processor Unit
HPC = High Performance Computing
HPE = Hewlett Packard Enterprise
KMU = Kleine und mittelgroße Unternehmen
KPI = Key Performance Indicators
LLM = Large Language Model
LRZ = Leibniz-Rechenzentrum der Bayerischen Akademie der Wissenschaften
MDSI = Munich Data Science Institute, TU München
QC = Quantencomputing
RAM = Random Access Memory
SEAL = Sovereignty Effectiveness Assurance Level
SME = Small and medium-sized enterprises
TB = Terybite
UNCTAD = United Nations Conference on Trade and Development

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