

The Future of Systems Engineering

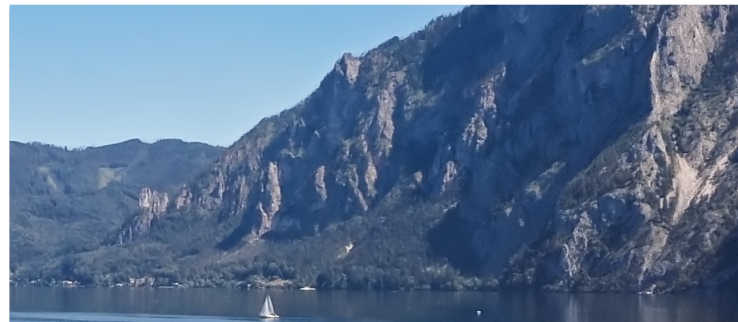
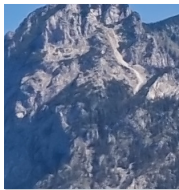
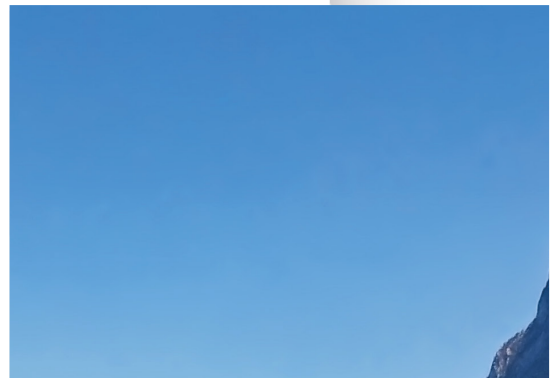
Exploring MBSE

Trends in Research and Industry

MBSE Summit 2024 Report

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MBSE Summit 2024





MBSE Summit 2024

Model-based system engineering (MBSE) is becoming increasingly important, especially due to the growing use of software in all technological areas. For example, the European Space Agency (ESA) writes in its Agenda 2025: „Revolutionising the traditional, document-driven approach to system development is key to ESA’s technology strategy and Agenda 2025.“ It aims to reduce the development time for spacecraft by 30% and improve cost efficiency by an order of magnitude with each generation. „However, achieving these ambitious goals requires not only technological improvements, but also a change in the spacecraft development process and in the way engineers think. This can be achieved with MBSE.“

With this in mind, it is only logical that the 3rd MBSE Summit at Lake Traunsee was fully booked for the first time with over 90 participants and will of course be continued in 2025 (2 - 3 June 2025). The MBSE community meeting of industry and science once again started with keynotes on SysMLv2, „The beauty of MBSE“, engineering for long-life systems and a look at the transport sector. This was followed by intensive discussions in small groups on various MBSE focal points. It became clear that MBSE is still very much on the move and that events like the one in Traunkirchen between users and science are essential for further progress.

In this spirit, we are already looking forward to welcoming you back to Traunkirchen next year: The fourth MBSE Summit will take place from 2 - 3 June 2025!

MBSE Summit is organised for you by LieberLieber & Johannes Kepler University Linz (JKU)

#SECURITY

#MBSE

#STANDARDS

#SYSMLV2

#RESEARCH



Keynotes



Tim Weilkiens (oose): The Impact of SysML v2

The next-generation modeling language, SysML v2, is about to be officially born this year. So people are wondering what impact does it have for me, for us, for my organization, for the community or for the world. Of course, the talk will also highlight the motivation and main features of SysML v2, but we're not going to go through the dictionary element by element. I can promise you that there will be books that do this better than a keynote.

We will focus on the impact of SysML v2 on different time horizons and dimensions. What impact will it have if I implement it today, in 2 - 3 years, or even further in the future? We will touch on very concrete practical modeling questions but also visionary scenarios. To do this, we will naturally look at aspects of SysML v2. For example, the API, which is technically simple but has game-changing potential. Or the textual notation, which will have a major impact, including opening the door for large language models.

You will learn a lot about SysML v2 and get plenty of food for thought. A good basis for further discussions with the participants at the conference.



Florian Beer (Robert Bosch GmbH - Chief Software Architect ADAS): The beauty of MBSE – reducing efforts by extending the scope

Model-based system and software engineering targets on providing a single source of truth for our engineers. The goal is to provide orientation, support with the alignment of interfaces between partners and between disciplines. By formalizing information in models, it becomes machine-readable and persistent. If we look into the real world, in many cases MBSE is not seen as a support but a hurdle by the development team. "Why should I spend the effort to document this in this tool, I anyhow don't search there", "My component has too many different users, I just care about my part. That MBSE introduction often comes with "big-upfront" ideas driven by architects in a central department is for sure no support factor in the innovation process.

We provide an example, where extending the scope shows a clear benefit for the development team without big-upfront or top-down roll-outs. For safety-relevant products according to IEC 61508 or industry-specific derivatives of this norm we nowadays have some kind of standard. System architecture in SysML, software architecture in UML or tool supporting code generation and cross-functional teams working on the safety analysis in FMEA and FTA.



Keynotes

When target to faster release cycle and shorter time-to-market, the benefits of a single source and alignment between the disciplines become evident. Combined with change-based reviews and automation support for consistency checks, the workload can be shifted from large post-development analysis workshops into the development teams.

We assume, that a basic architecture model showing the decomposition structure, data flows and control sequences is created anyhow in the architecture team. By extending this standard model with one meta-element “FailureMode”, which is used to model cause-effect chains from the bottom-layer up to the violation of a safety requirement and relations to mitigation measures for preventing and controlling the failure modes, the safety analysis can be performed by the development team.

The approach is simple and easy to learn. Of course, you need coaches to bring the safety background into the teams, but you replace large meetings late in the development process with technical discussions in the product definition phase.

By extending the scope, we get more competence in the team, reduced efforts and a better risk mitigation. What do we learn for innovation topics, and MBSE introduction is for sure an innovation for an organization, from this? Identify the pain of the team (here: longly FMEA sessions) and provide a solution for the pain (Safety Analysis integrated in the architecture). This reduces opposition as the gain (here: self-control of time) is greater than what must be given up (personal favorite text-based documentation style). That’s the beauty of MBSE: You extend the scope a little, but having a shared ground-truth for the different teams creates a huge benefit.



David Hetherington (System Strategy, Inc. - Principal Systems Engineering): Mission Engineering for Long-Life Systems

Long-life systems are extremely challenging to engineer. Sometimes executive stakeholders don’t understand the scope of the problem. In other cases, the long-life of the system is a surprise. Finally, there are the cases in which an organization procures a technology system without any planning for anything beyond the initial deployment. At Systems Strategy, Inc some of our client engagements are specifically about helping clients model the least awful course of action in managing a large system of rapidly aging technology components.

In this presentation, we will first discuss several concrete examples of organizations that failed to plan realistically and ended up floundering in awkward attempts to manage the



Keynotes

headaches. In reviewing these concrete cases, we will dig a little deeper into the more subtle aspects of this problem. In particular, we will discuss:

1. Financial Risk - Who accepts the responsibility for the uncertain future?
2. Human Resources - Humans are part of the system too.
3. Unsustainable Business Models - What if our business model was only laid out to look profitable for the next three months?
4. Warehousing - This strategy is not as easy as it sounds.
5. Open Market Buys - We forgot to build a warehouse.
6. Organizational Transitions - What if the support organization is no longer in existence 20 years from now?

With this background, we will present a study case of a hypothetical business that is fully aware of the challenge at the beginning. The study case will show how Mission Modeling using the Unified Architecture Framework can be used to set up a trade study of strategies to mitigate the challenges. Finally, we will give a brief demonstration of how simulation in SysML and other tools can be used to evaluate the trade study options and help the business decide on a strategy.



Univ.-Prof.in Dr.in Cristina Olaverri-Monreal (Johannes Kepler Universität Linz; Präsidentin IEEE Intelligent Transportation Systems Society 2022, 2023): Transportation Revolution through Automation

Transportation-related decision-making significantly impacts CO2 emissions, thus contributing to climate change. The incorporation of automation and connectivity into this framework introduces a transformative dimension. Physical and virtual interconnections, make it possible to evolving transportation demands through digital technology by leveraging sensor integration within information and communication technologies, These dynamic scenarios are crucial in shaping decision-making processes related to traffic safety, a topic that will be thoroughly explored during the presentation.



Breakout Sessions

The most important results

Challenges on the Road to Digital Twins for Buildings - The need for open data models for achieving BIM

Introduced, moderated and summarised by: Sabine Sint, University of Technology Vienna

Implementing digital twins for buildings comes with many challenges and considerations. To fully understand the vision and potential pitfalls, we need to delve into the reasons for adopting this technology, the methodology based on MBSE, and the contrasting scenarios of what the future might hold.

After a blind storming session where we imagined our lives and work in 2040 with digital twins, we collaborated to develop a vision of where we wanted to go.

Why?

Adopting digital twins primarily aims to simplify everyday life and work. Digital twins free up human resources for more meaningful activities by automating routine and tedious tasks. They also enable remote communication, which is increasingly vital in our interconnected world. Digital twins promise to increase efficiency and comfort by streamlining operations and providing personalized solutions. Furthermore, they contribute to greater sustainability through optimized resource usage and energy-efficient operations. Digital twins enhance individuality support, catering to users' needs and preferences.

How?

Based on MBSE: Digital twins are developed with a focus on safety, ensuring that sensitive data is protected. They are designed to be highly energy-efficient, reducing the environmental impact. Reliability is another cornerstone, guaranteeing

consistent and dependable performance. Interoperability is crucial, allowing seamless data exchange between different systems and companies, thereby facilitating broader collaboration and innovation. The MBSE approach seems to be suitable for ensuring these aspects.

What?

Digital twins promote exchange and interoperability between companies, breaking down silos and fostering collaboration. They are learning systems that continuously improve based on new data and experiences. Interaction with digital twins should be natural and intuitive, making them accessible and user-friendly.

By developing the vision, the next step was determining the worst effects, what we would take for granted, and what would be exceptional in providing digital twins.

Worst Case Scenario Digital Twin 2040

In the worst-case scenario for 2040, implementing digital twins could have significant drawbacks. There is a risk of losing individuality, as the pervasive nature of digital twins might overshadow personal traits and preferences. The concept of the transparent person could become a reality, where individuals have little privacy. This could lead to a lack of trust in the technology and the institutions utilizing it. The digital divide might widen, exacerbating social inequalities as some populations are left behind. Total surveillance could become a norm, infringing on per-



sonal freedoms. Uniformity might prevail, with a single dominant digital twin model overriding diversity and innovation.

In addition to these effects on society, the following facts could apply to technology: Manual solutions to the challenges are still prevalent. These solutions often involve redundancy, leading to inefficiencies and increased chances of error. The technology level can still be at the status quo of 2024.

Self-Evident Digital Twin 2040

When we think of natural things for digital twins, the implementation of digital twins by 2040 would be characterized by high ethical standards, ensuring that these systems are developed and used responsibly. Interoperability enables various industries to benefit from seamless data integration at a basic level. Accessibility would be a key feature, making digital twins available to a broad audience. High reliability and energy efficiency would be standard, minimizing downtime and environmental impact. Measures to prevent misuse would be in place, ensuring that digital twins do not cause harm even in the event of faults.

Extraordinary Digital Twin 2040

The extraordinary vision for digital twins by 2040 involves intuitive systems capable of learning and recognizing individual needs. These advanced digital twins would be able to identify and rectify errors autonomously. Full interoperability would be a reality, enabling seamless integration across various platforms and industries.

Next Steps

To achieve this vision, several next steps are crucial. Promoting interoperability across industries will be vital for maximizing the benefits of digital twins. Understanding and sharing the current status quo will help identify gaps and areas for improvement. Establishing test environments

will enable the safe and controlled development of digital twin technologies.

In conclusion, while the path to realizing the full potential of digital twins for buildings is full of challenges, their efficiency, sustainability, and convenience make them a worthwhile goal. By addressing the potential pitfalls and focusing on ethical, reliable, and interoperable solutions, we can work towards a future where digital twins improve our lives meaningfully.

Finally, it should be remembered that sustainability should be considered from the outset, following the principle of „sustainability by design“.

Statements



The MBSE Summit 2024 has been a unique opportunity to discuss challenges and exchange solutions, to foster the multi-disciplinary network and to advance the field in a trust-building environment. Chapeau, and continue this excellent work!

Univ.-Prof. Dr. Gerti Kappel, Dean of the Faculty of Informatics, Technical University of Vienna



Model-based Security - MBSE as a bridge between security and system design

Introduced, moderated and summarised by: Christoph Schmittner, AIT Austrian Institute of Technology

The breakout session on Model-based Security by Design at the MBSE Summit was designed to explore the integration of security analysis within the model-based engineering process. The session started with a discussion on current practices and methodologies, from manual approaches to the first tool-based approaches. We discussed how to enable and integrate security within systems modeling. We focused on the evolution from traditional security approaches to a more unified and efficient model-based security by design methodology.

During the session, it was highlighted that the transformation from the structure of system models directly from SysML's internal block diagrams to security is an important milestone. This removes the redundant step of modeling the system again in separate security environments, thereby enhancing the interoperability and cohesion between system and security engineering efforts. Furthermore, this direct transformation approach can significantly improve the integration of security considerations into the engineering workflow. By enabling a more seamless integration of security, there is greater compatibility and synergy between security and systems engineering. This not only simplifies the process but also ensures that security is embedded as a core component of the system's architecture, enhancing its robustness against potential threats. There was a debate on the security process integration—whether the process, the quality gates, or the end results should be

the priority. The discussion suggested that while all aspects are important, there should be a balanced approach.

It was also pointed out that automation is crucial for end-user acceptance, by reducing manual efforts and delivering tangible benefits to users. This was linking back to the keynote on architectural safety analysis. The utilization of model-based engineering techniques was recognized as instrumental for the automation. This can facilitate a more dynamic and responsive framework, allowing both security and system teams to collaborate more effectively. The ability to work within a shared and comprehensible model-based framework can reduce gaps in security coverage, ensuring a comprehensive and secure system design. Here the integration of security with other system concerns such as safety was seen as interesting next steps. This linkage ensures that the system is not only secure but also robust in other dimensions of system integrity, creating a holistic model that addresses multiple facets of system performance.

Regarding the transformation, it was discussed, that a next step should be the utilization of more available information from the model, including functions, states, and other parameters to enrich the security analysis and provide information. This use of model data can ensure that security is more aligned and aware of the actual system functionalities and complexities. This was also seen as a point for discussion regarding the bi-

directional transformation, e.g., if the result from security are only security requirements or also if changes in the system model and the security model can influence each other. Finally, we discussed the Security Metamodel in Enterprise Architect and the distribution of security-related information.

Overall, the session showed the progress made towards realizing an integrated model-based security approach, but also the steps still necessary. A recurring theme throughout the session

was the importance of keeping the security integration process as simple as possible. This is to ensure that the process is not only thorough but also manageable and devoid of unnecessary complexity, which can be a barrier to effective implementation.



How AI impacts MBSE - Is it only replacing existing methods or does it create new opportunities?

Introduced, moderated and summarised by: Stefan Klikovits, Johannes Kepler University Linz

The breakout session on the impact of AI on Model-based Systems Engineering (MBSE) was attended by 27 participants from diverse backgrounds, including academia and industry, some of them identified themselves as tool users, others as tool builders. The session was structured around four key questions, with participants divided randomly into groups to discuss each question. Groups swapped their questions after 15 minutes, and after an additional 10 minutes of further discussion and work, the questions were passed to a third group, which analysed and presented the combined results of the previous discussions and opening the floor for clarifying

questions. In the following, we summarise the discussion's findings.

What is the role of AI in enhancing MBSE?

Participants identified several potential roles that AI can play in an MBSE context. AI can support model development by automating repetitive tasks and providing intelligent suggestions. It can control and verify model consistency to ensure that models adhere to specified standards. AI can also derive models from initial requirements, aligning them with design specifications, and speed up the model creation process.

By simplifying complex tasks, AI can make MBSE more accessible to non-experts. Additionally, AI can efficiently identify differences between model versions, optimize models for performance, and facilitate the transfer of models between different formats (e.g., from paper drafts to digital models). It can also provide explanations and engage in conversations about models, help complete partial models, and generate product lines from models, creating a model platform.

Which AI techniques and tools can be used in MBSE?

Various AI techniques and tools could be employed in MBSE to enhance its capabilities. A chat or conversation interface powered by AI can support users in model development, while customized versions of Large Language Models (LLMs) Generative Pre-trained Transformers (GPTs) can be tailored for specific MBSE tasks. Natural Language Processing (NLP) can be utilized for understanding and generating model-related documentation, and computer vision can interpret visual data useful in model creation and verification. Graph-based databases can efficiently manage the relationships and dependencies within models. The collaborative interaction between humans and AI, termed as human and AI symbiosis, can further enhance model development and maintenance.

What are the potential benefits of using AI in MBSE?

The benefits of integrating AI into MBSE are numerous. AI can lead to significant time and cost savings by automating tasks. It can help minimize errors and ensure model consistency, thereby lowering the entry barrier for users with less expertise. AI can quickly train and update models based on new software versions and aid in the digitization process, ensuring all model arte-

facts are digital. The fear of missing out and the power of data drive the adoption of AI, which can also automatically identify beneficial possibilities within models, thus enhancing overall efficiency and innovation.

What are the potential risks and challenges of introducing AI into the MBSE world?

However, the integration of AI into MBSE also presents several risks and challenges. Data issues such as quality, quantity, biases, and potential licensing problems pose significant challenges. Privacy concerns must be addressed to ensure data protection. The sustainability of AI is another concern, as AI training is resource-intensive, requiring substantial infrastructure and a knowledgeable team. Overreliance on AI technology can create dependencies that may become problematic if the technology fails or evolves. Ensuring the correctness and reproducibility of AI-generated models remains a critical challenge, necessitating careful consideration and ongoing efforts to mitigate these risks.

Statements



Attending the MBSE Summit 2024 was an incredibly valuable experience for me. The boat trip and the social dinner on the opening day created a relaxed atmosphere that fostered a fruitful exchange. The inspiring keynotes from domain experts were thought-provoking and insightful. Additionally, the opportunity to exchange ideas with numerous experts in the field of Model-Based Systems Engineering was invaluable throughout the event. Overall, the summit was highly beneficial, allowing me to gain new ideas, impulses and valuable contacts in this field.

Stephan Reuter, Group System Development Manager, Valeo Schalter und Sensoren GmbH



The Power of Standards: Unleashing the Potential of MBSE

Introduced, moderated and summarised by: Daniel Siegl, LieberLieber Software and Tim Weilkiens, oose

During our session with Tim Weilkiens, we had the unique opportunity to gain firsthand insights into the progress and process of the SysML v2 standardization efforts at the Object Management Group (OMG). This provided us with a deeper understanding of the challenges and complexities involved in the standardization process, particularly in the context of a major industry-standard like SysML.

During the session, we explored the topic of standardization, focusing on its relevance, implementation speed, and current applicability. Several frustrations emerged regarding the process of creating and maintaining standards. A key challenge is the difficulty in securing funding for participation in standards committees, leading to a shortage of contributors. Ironically, this lack of participation later results in complaints about missing features in the standards. Standardization often requires not just technical expertise but also „political“ negotiations and compromises, which can dilute the original vision and create a tension between user-friendliness and provider satisfaction. Additionally, the process demands an early blueprint for everything, complicating future adjustments and feature changes. Furthermore, the underlying reasons for certain design choices are often not systematically documented or published, leaving users questioning the rationale behind the standards.

For a standard to be widely accepted, its users need to understand the business case behind it. However, standards are often lengthy, difficult to interpret, and prone to misinterpretation, which can lead to the need for expensive training. Users sometimes ignore the rules and best practices,

and there's often a lack of interoperability among „standardized“ tools and models, complicating practical application. Additionally, many standards are costly, limiting their use in education and training.

Beyond these issues, the standardization process itself can be frustrating. Different groups developing standard parts may fail to harmonize their efforts, leading to overlooked errors. The process is typically slow, so results are delayed; however, rushing specifications can render them unimplementable. Committee work can feel opaque due to fluctuating attendance, changing group members, and a lack of professional management in some cases.

Despite these challenges, there are potential solutions. Public funding for standardization bodies could encourage broader participation, allowing for earlier expansion of the group. Providing examples and reference implementations alongside the standards can help users better understand and apply them, with non-trivial application examples being particularly valuable. In terms of documentation, in addition to the often dense specification, there should also be more accessible application documents and community-oriented resources.

Professional moderation of standardization groups and an iterative development approach could also improve the process, supporting incremental development and allowing for the evolution of standards over time. Sometimes, the best starting point is simply a minimum viable product.



by Michael Jastram

Guest Article

About the Keynote speech of Florian Beer (Bosch)

Case study: How Bosch managed to drastically reduce FMEA costs with AbRA

I am always on the lookout for examples of how MBSE can create real added value. Florian Beer, Chief Software Architect ADAS at Bosch, demonstrated this at the MBSE Summit using a practical example. He used the fact that meetings, and FMEA workshops in particular, are unpopular with many developers. The focus on a specific use case and pain point made this initiative a success. He has published the underlying AbRA approach on Open-MBEE.

„MBSE is a tanker, software is a speedboat“ (Florian Beer): This impression stems in particular from the success of agile methods in software development. However, agile approaches cannot be easily transferred to MBSE: agility works well with small teams, but the team size inevitably increases for complex products. In addition, errors in software development are „cheap“. In contrast, errors in system development, with expensive hardware and electronics, can be costly and lead to long delays.

In particular, complex system developments require a documented architecture. All project teams must understand and internalise this. However, they often have their own language, which can lead to the architecture being ignored. Large software projects also need a little more structure, but have largely solved these problems with the help of package management, common standards and other techniques.

Concrete use cases lead to acceptance

So how can we use MBSE to develop an architecture that is actually used? It must always be up-to-date and help to solve specific challenges: We need a continuous architecture.

In continuous architecture, the architecture consists of building blocks. Teams are responsible for keeping them syntactically correct and internally semantically consistent. The architect, on the other hand, demands external semantic consistency. Here it helps to transfer functioning practices from software development such as unit tests, integration tests and continuous integration (CI) to the MBSE. Pull requests also represent a possible step towards agility.

AbRA: Architecture-based risk analysis

For safety-relevant products in accordance with IEC 61508 or industry-specific derivatives, certain analyses must be carried out with regard to reliability. These include FMEA or FTA, for example. However, creating and reviewing these analyses is tedious and often involves considerable effort.

Florian Beer and Jürgen Sauler have developed the Architecture-based Risk Analysis (AbRA) and published it on Open-MBEE. (AbRA actually deserves its own article). The aim of AbRA is to anchor failure modes directly in the architecture. Initially, the project team has to invest in a good architecture, but this approach has enormous advantages for the project. The workload for designing the analysis is better distributed among the various team members and the review of the failure modes is much more efficient as part of

architecture maintenance with AbRA. As a result, the number of large meetings can be reduced without any loss of quality in the analysis results. The work still has to be done, but in a much more pleasant (and meaningful) context.

At the same time, the benefits of the architecture for the teams have increased dramatically, leading to continuous maintenance of the architecture by the teams. Even if this is primarily about the FailureModes, the entire architecture benefits from this „crowd maintenance“. By bringing forward the failure analysis, problems with the architecture in terms of functional safety also come to light earlier.

Conclusion:

Florian Beer has shown beautifully how an MBSE strategy can lead to concrete use cases that bring real benefits to the teams and are therefore also put into practice. Specifically, AbRA at Bosch can be used to make risk analyses significantly more efficient and reduce the time and effort required for FMEA workshops. At the same time, the teams recognised the benefits of the architecture and carried out the necessary maintenance of the architecture independently.

By publishing AbRA, other teams can also benefit from this work.

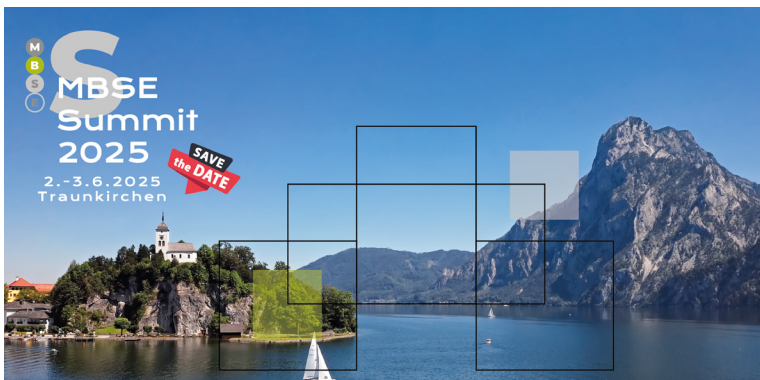
Statements



MBSE Summit 2024 was a fantastic event – I was honored to be invited to give a keynote presentation! My impression has always been that smaller, more intimate conferences often yield more value than the larger events. MBSE Summit 2024 supported and reinforced this and strengthened this impression. Start with a small group of key influencers. Add a fantastic venue and a lot of positive energy. The result is an exhilarating experience! Not only did I give a presentation, I also soaked up lot of new information both from the other speakers and other participants. I left the conference with several key insights that I am now carrying forward into my daily work.

David Hetherington, Principal, System Strategy, Inc.

MBSE Summit 2025



Would you like to attend the 4th MBSE Summit in Traunkirchen? (June 2 and 3, 2025) Then register now, we look forward to seeing you:

[MBSE Summit 2025 Registration](#)

In 2025, our MBSE Summit will take place in Traunkirchen for the third time. From 2. - 3.6.2024 the MBSE community will once again meet to discuss the latest trends.

Imprint

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