White Paper

TRUMPF Digital Reference Architecture

V1.01

Contents

"A solid and reliable execution of the Enterprise Architecture discipline is fundamental for the successful digital transformation of TRUMPF."

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Abstract

Over the past decade, many definitions have been published in a bid to make the digital challenge more tangible: two-speed (bimodal) IT by Gartner, IT and OT (Operations Technology), IoT (Internet of Things), Industrial Internet (in the US), Industrie 4.0 (in Germany), Digital Transformation, etc. Although all these initiatives have addressed many valid pain points in theory, it has been a challenge for larger manufacturing companies to create a common understanding within the company about the digital future. Motivated teams actively pushed their individual projects relevant for TRUMPF. The main obstacle, however, was aligning all of them to one technological vision in order to optimally and efficiently support business needs.

To aid this vision, TRUMPF developed a company-wide digital reference architecture, colloquially called the "Double-C-Frame". It supported the communication among the different teams and started an alignment of the various technological initiatives in different maturity levels. The TRUMPF Digital Reference Architecture serves as a common language between the digital product development teams and the IT project teams on an operational level as well as a tool for strategic alignment for top management.

The outcome is a more efficient and cross-company coordinated process for technological decisions in order to leverage innovations, effectively manage digitally ambitious TRUMPF projects and react flexibly to market changes.

Challenge – the Need for Architecture

The term "Internet of Things" (IoT) was coined around 2005 and described the emerging importance of integrating more and more devices into an existing ecosystem of hardware and software. In 2012, the German term "Industrie 4.0" emphasized the relevance of software and system integration in the heavy machinery industry. For many years, there were theoretical discussions as well as active initiatives to standardize the scattered technology landscape driven by companies and government, while other information-intensive industries like banking or media were disrupted much earlier by software-driven products due to their IT dependency.

For TRUMPF, as a high-tech company, the focus is on building excellent machines and lasers with sophisticated technologies. In former times, mechanical and electronical technologies dominated the core products of TRUMPF. However, in the last 20-odd years, software has gained importance in the development and maintenance of high-tech machines (see Figure 1). The increasing software impact in the products required a mindset change followed by organizational changes as well as a shift in skills from pure mechanical and electrical engineering toward software know-how combined with engineering knowledge. To understand this fundamental shift, TRUMPF has been engaged in many initiatives and companies to shape the future in the right direction (Industrial Internet Consortium, MindSphere World e.V., Open Industry 4.0 Alliance, Platform Industrie 4.0, Standard Council Industrie 4.0, VDW, VDMA, ZVEI, etc.).

From these valuable discussions with industry partners, TRUMPF learned three important lessons:

- In the past, enterprise IT was the dominant software in the world of manufacturing companies. The main focus was on developing machines (i.e. hardware as the core business). Software played only a minor role by enabling machine functions or offering separate software products in addition to machines. Due to the rise of IoT and increasing software influence on machine functions, the software in core products now plays a crucial role in managing smart factories by connecting products together and moving toward cloud services. This shift therefore calls for more focus on software (product IT).

- A reference architecture from the industry communities is not suited to the (internal) needs of TRUMPF. It has a strong IoT focus on integrating with other partners. However, a starting point is to have a solid internal view on the overall architectural landscape of TRUMPF.

- As similarly started by Gartner in its two-speed IT article, TRUMPF must bring both software worlds together and effectively manage their interaction: the customer-oriented software product world (incl. IoT) driven by business units and the company-internal software world driven by the Enterprise IT department.

The first step was to make these lessons learned explicit in internal communication with various stakeholders and factor them into strategic (technological) decisions about both worlds. The second step was to align both worlds. Like in most companies, there are sometimes gaps that need to be closed between business units and IT departments.
TRUMPF was convinced that the basis for closing the gap was a common understanding of the technology landscape with an overall reference architecture supporting the future mindset of the organization.
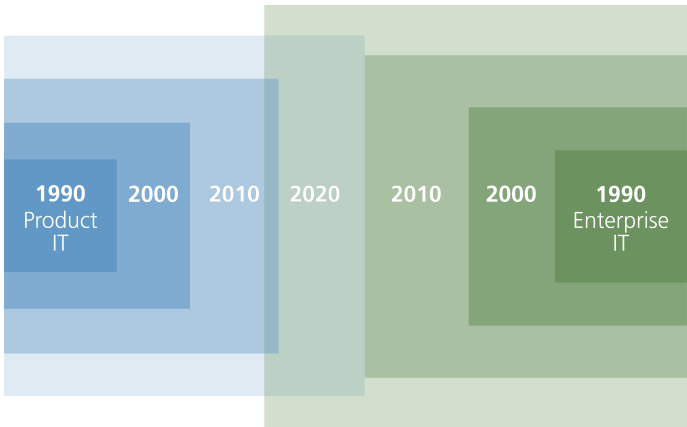

Figure 1:
The trend of central cloud services and software-driven R&D forced both worlds (enterprise IT and product IT) to interact together.

History – Bringing IoT and IT together

As an outcome of these engagements in the initiatives, a general demand for an overall digital strategy was identified in 2017 to put more strategic emphasis on the upcoming IoT/Industrie 4.0 topics. TRUMPF set up a three-month-long project to align all business units and central units with a joint digital approach. The result was a clearly defined and measurable digital strategy named TRUMPF Digital Ambition. A digital architecture was identified as a technical enabler for the digital transformation, with data management as a second crucial enabler that had to work hand in hand with architecture (see Figure 2). Major digital projects were started with the launch of the digital strategy. An overall TRUMPF-wide architecture was missing to align these projects technically – a gap that became more obvious when architectural decisions were communicated among the business divisions and IT.

Therefore, two years later, in 2019, the Digital Transformation department and the IT department jointly organized a workshop series over three weeks called Campus Mode with all associated architects, software developers and managers (in total about 50 participants) working on enterprise IT systems and software(-driven) products. The Product Management team delivered over 80 use cases as part of the future product portfolio strategy. The lively and often controversial discussion helped to form the basis for a company wide reference architecture and outlined a common understanding for the future collaboration model between business and IT.

For a technical common basis, the workshop organizers developed a quick reference architecture (version 0.1) to structure the various workshop participants in line with the relevant topics (see Figure 3). Two months later, a version 0.5 was illustrated with a common key visual to better align with top management when making technical decisions.

The hard work began once the workshop was completed. The challenge was to keep all stakeholders continuing the discussions and motivating them to shape the digital future of TRUMPF.
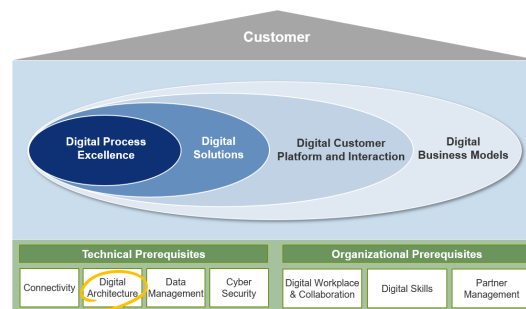
As an engineering company, TRUMPF has cross-functional steering boards for technology decision-making regarding mechanical and electronic technologies. However, technology decisions for information technology were made in the business units without an overarching board.

Hence, an architecture steering board and an architecture working group were founded to close this gap. Several organizational aspects needed to be addressed:

- The biggest obstacle was to align the different mindsets and interests toward one common goal and a common understanding of how to continuously work together on the common technology stack.
- Top management commitment was essential to making it happen. This came in the form of TRUMPF's CDO, who fully supported this endeavor.
- The roles in the organization had to be clearly defined and aligned with the rest of the organization so that the architects could have an impact on the (development) teams.

One of the first tasks for the architecture working group was to rethink and redesign the architecture and establish it as the enterprise-wide "TRUMPF Digital Reference Architecture" (version 1.0, see Figure 3). Over the next two years, the reference architecture was continuously improved in five iterations to the current version 2.1.
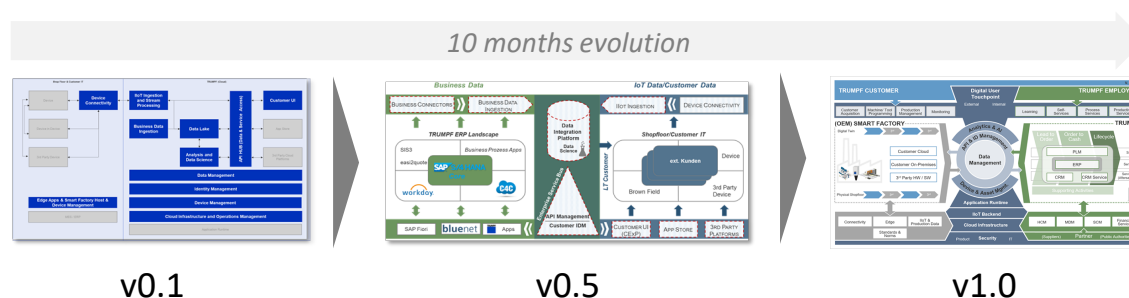

10 months evolution

v0.1   v0.5   v1.0

Figure 3:
Architecture evolution from a quick draft for discussion to a first publishable version.

Architecture – TRUMPF Digital Reference Architecture

The TRUMPF Digital Reference Architecture closes the gap between product IT and enterprise IT by addressing all layers of TOGAF within a single framework so that we have a common language and big picture for entering into deep-dive discussions together. It is not solely a technical reference architecture, but also has elements of (customer-relevant) processes and outlines broad data flows between the two IT worlds.

The TRUMPF Digital Reference Architecture is also internally known as Double-C-Frame due to its inverted C in blue on the left and the blue-green C on the right (see Figure 4).The two "Cs" arranged back-to-back and provide the core structure of the TRUMPF Digital Reference Architecture, which consists of three major architecture areas:

I. Left-side "C" in blue: the perspective of the products and services offered by TRUMPF to its customers' smart factories (product world).
II. Right-side "C" in green: TRUMPF internal core value chain (enterprise world).
III. Connecting column in the middle: combining product architecture and enterprise architecture with essential architecture building blocks relevant for both worlds.

The architecture landscape in Figure 4 is a conceptual view that consists of architecture building blocks (ABBs). ABBs provide a dedicated scope of functionality and comprise different technologies used to offer these functionalities. Nevertheless, the customer is the focus of all our activities, which is shown by the light-blue block spanning the very top from left to right.

The left side (I) represents the TRUMPF customer's view on its value streams within their smart factory (see light blue and grey arrows). In the past decades, traditional physical machines were surrounded and enhanced by software for machine control, lightweight human machine interfaces and CAD-programmable systems. However, this serves only as a starting point to building a smart factory. Machine connectivity, edge computing and Industrial IoT back-end technologies unlock the potential to interact in new ways with the customer.

These new opportunities are new digital services offered either as Software-as-a-Service (SaaS) solutions, online updates for machine software or sophisticated machine and factory control solutions. These services combined form the foundation for business models, such as Equipment-as-a-Service, where TRUMPF operates with partners the smart factory of its customers. Additionally, these solutions give TRUMPF the possibility to attract and retain customers with an enhanced digital experience based on the MyTRUMPF customer interaction platform and to utilize new sales channels via online shop systems. From an architecture perspective, a major challenge is to create connectivity to new machines, but also to the installed base. Due to the long lifecycle periods of machines, it is important to also perform retrofit activities to include the existing machines within a smart factory ecosystem. Once machine connectivity is realized, digital services require computing and storage resources in the smart factory – either to meet very low latency or highly critical operation demands. Therefore, a combination of edge computing and cloud services ensures a flexible foundation to offer the described smart factory services.
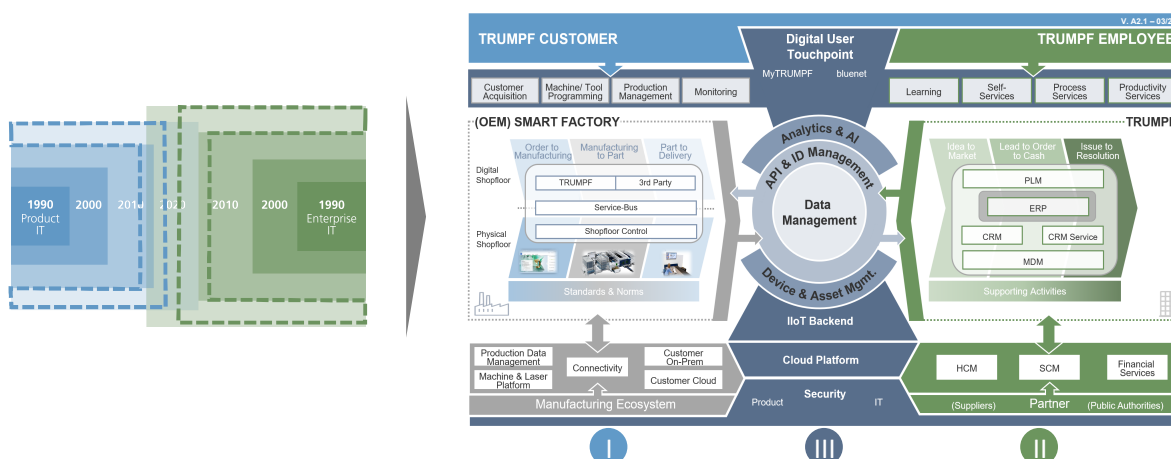

Figure 4: TRUMPF Digital Reference Architecture, also known as Double-C-Frame combines product IT and enterprise IT using joint architecture building blocks.

Smart factory services are only possible if the product architecture of customers is integrated into the TRUMPF enterprise architecture. Hence, the right side (II) of the TRUMPF Digital Reference Architecture outlines the perspective of TRUMPF's internal value chain with customer relevance. This illustration represents the end-to-end company value chain. The TRUMPF Digital Reference Architecture is structured in the primary value streams "Idea to Market", "Lead to Order to Cash" and "Issue to Resolution." The primary value streams are enabled by supporting activities or secondary value streams (human resources, supply chain management or financial services). All value streams are enabled by process and data leading systems clustered in cross-industry system categories. Within a manufacturing company, these are: Product Lifecycle Management system (PLM), Enterprise Resource Planning System (ERP), Customer Relationship Management (CRM), CRM Service (or Field/Customer Service Management System) and Master Data Management (MDM).

From an architecture perspective, it is mandatory to utilize the data managed in these systems to develop the digital services. For example, information about the purchased machines per customer, service cases performed or purchased license agreements are core data objects to develop digital services. Additionally, the process leading enterprise systems are essential to manage the digital services across their lifecycle from development in combination with physical machines, digital sales channels via MyTRUMPF, entitlement management to invoicing.

The core of the TRUMPF Digital Reference Architecture is the column in the center (III). It is an essential part that connects the customer's perspective of the smart factory (product architecture) on the left side with the traditional enterprise architecture of a manufacturing company on the right side.

Within this framework, architecture platforms are developed to not only support the digital ambition of TRUMPF to develop digital services for customers, but it also enable the internal digitization of TRUMPF's value streams. The overall architecture strategy beneath the ABBs, such as the cloud platform, data management, API and ID management, analytics and AI, and digital user touchpoints (customer UI), is based on the following hypotheses:

- *Highly adopted **enterprise standard platforms** accelerate the digital ambition due to a common foundation and reduced initial efforts per initiative.*
- ***Cloud technologies** and **cloud-based enterprise** platforms are key to scale and innovate.*
- ***Loosely coupled systems** and **composable architectures** are elementary to adaptability to new requirements and to managing complexity.*
- ***Data management and data architecture** are key to easily combining data of multiple sources and to providing fast and reliable access to data consumers.*
- ***Common User Interfaces (UI Library)** are core to create a convincing user experience.*
- ***IT and Information Security** are essential in every architecture and require enterprise standards.*

Adoption – Daily Use of the Architecture

In order to work cross-company, together with the business units and IT, both worlds (IT and IoT) must understand the business needs and the value each ABB provides toward the overall architecture. As in many companies, business priorities are dynamic from time to time. The responsibility of the enterprise architects together with the middle management in the business units is to manage these dynamics and define steerable metrics to measure success of systems clearly. It is thereby important to align short-term objectives with strategic hypotheses of the reference architecture. To operationalize the architecture strategy and architecture hypotheses, each ABB is underpinned based on architecture principles. These are the foundation to discuss architecture questions within projects and initiatives that impact the TRUMPF architecture. They ensure that the TRUMPF Digital Reference Architecture is considered appropriately within operative business.

Additionally, dedicated persons for each ABB were announced to work together on the joint architecture. These experts manage the strategy for the ABBs they are responsible for, align with core stakeholders of the business units to set priorities according to their business value and align with the surrounding ABBs of the TRUMPF Digital Reference Architecture.
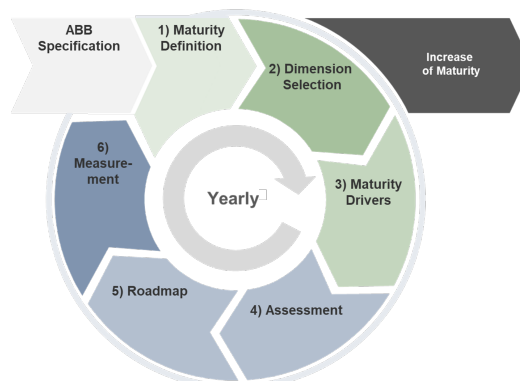

Figure 5: TRUMPF Architecture Maturity Assessment Process.

The ABB owners are in charge of taking the next steps regarding the future technology strategy for their ABB and assessing the current ABB status in terms of technical maturity and business needs. It requires a mindset change together with the teams to jointly challenge the status quo and to extract the business value of each ABB.

At TRUMPF, an ongoing project was started by the Enterprise Architecture team to assess the ABBs. The initial focus was on the core ABBs and the IT ABBs. In a subsequent step, the ABBs on the left, which focus on the smart factories of the TRUMPF customer, will be assessed in collaboration with the business units. Figure 5 shows a standardized approach, supported by generic templates to be used for every ABB review. This enables transparency and comparability between the assessments.

Besides the strategic ABB reviews, TRUMPF has managed to align various technical teams of different organizational units to work toward a common target architecture. New technologies continuously appear, and the architects have to evaluate whether the business benefits outweigh the cost of implementation and migration. Standard processes for technology assessment, technical concept evaluation and instant problem solving by understanding the complex interdependencies is the day-to-day job of the enterprise architects (more strategic), domain architects and solution architects (more operational). Therefore, most ABBs have established regular working groups to bring ABB experts together to discuss aspects addressed by an ABB, such as architecture innovations and business needs.

New business needs mostly arise as a result of new digital products and services, digitization projects and IT projects initiated within the TRUMPF Digital Ambition strategy. Here, business and IT outline the relevance and value of every initiative or project based on the TRUMPF Digital Reference Architecture. The reference architecture serves as a general overview map (like Google Maps for the planet) in which every architect can zoom in and explain the contribution of a project or system toward the common target architecture. Consequently, the architects can use a common language (i.e. reference architecture) to communicate with.

For the central and the right pillar in the Double-C-Frame (see Figure 4), it is particularly challenging in some cases to define the business value. For example, a migration project like S/4 Hana is not a choice regarding business values, but it has to be executed due to software provider strategy and their predefined technology conditions. However, this can be viewed as a chance to force the business to standardize the process landscape, which has grown organically but not systematically. TRUMPF has started two large process initiatives for redefining the order-to-cash value stream for TRUMPF core and after-sales products.

The TRUMPF Architecture Steering Board (management board) and TRUMPF Architecture Working Group (expert council) comprise experts from different business units who jointly make decisions and propagate the outcome to the various teams (see Figure 6). The committees coach and steer the architecture discussions based on a common architecture strategy. This culture is essential for a successful enterprise-wide architecture management and continuous improvement of the reference architecture toward a common goal.
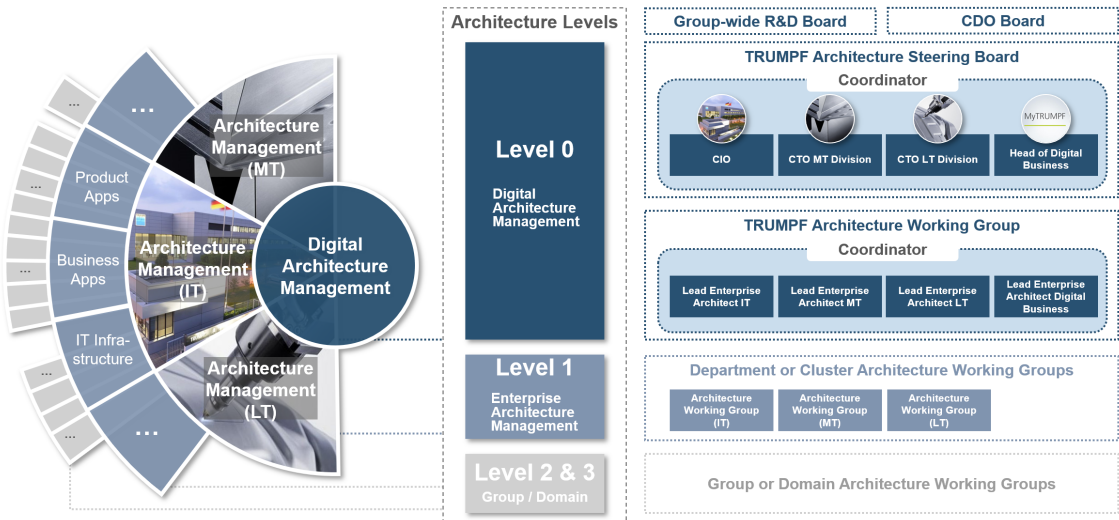

Figure 6:
Structure of the TRUMPF Architecture Governance.

Future – Joint Journey of IoT and IT

The authors are convinced that in this complex world the companies that can manage their architectural landscape efficiently (speed) and effectively (business outcome) will be successful in the future. The TRUMPF Digital Reference Architecture is therefore the foundation:

- to iteratively adapt to new requirements and be circumstanced fast (agile architecture),
- to understand the core competencies of the company as a differentiator in the market and focus on developing it within the company,
- to outsource commodity services or buy off-the-shelf cloud-based software for commodity services,
- to understand the data flows and integrations among the systems to derive the dependency risks and ensure a loose coupling of solutions,
- to clearly define single-source-of-truth data sources to avoid misleading data management in a poor quality,
- to document the architectural insights and work with managed backlogs among the cross-functional teams,
- and to transparently determine technical debts and (once in a while) reduce them by integrating them into the sprint planning of the teams.

The architects need a clear view on how both worlds (IoT and IT) are properly "glued" together by core architecture building blocks (e.g. data management, cloud or integration management) and highly standardized APIs. A clear mandate for the enterprise architects in the organization is key to making technology decisions quickly. Enterprise architecture tools with a well-documented architectural landscape, including drill-down possibilities into the architecture details, are necessary to provide transparent information among all architects, to make data-driven decisions and to speak the same "language." The TRUMPF Digital Reference Architecture serves as a general map in which each architect can zoom in for details. The outcome is a more efficient and effective process for architectural decisions for the future.

The upcoming architecture challenges have to be addressed holistically, including business capabilities, business processes and the supporting technology and system landscape. Expanding the architecture management activities into further dimensions also requires growing the architecture community by establishing a common mindset regarding how and why architecture management supports the business and digital ambitions of TRUMPF. Long-lasting architecture management success can only be guaranteed if structures such as roles and responsibilities, lightweight architecture processes, communication structures and architecture methodologies are established. To ensure the success, the middle and top management have to continuously ask the teams about every digital project in terms of its impact on the architecture.

For TRUMPF, there is no room for two-speed IT in separated silos. Both worlds (enterprise IT and product IT) must be closely aligned in order to achieve scalable and stable back-end systems without compromising the high development speed in the front-end systems for customers. The TRUMPF Digital Reference Architecture is the basis for this alignment.
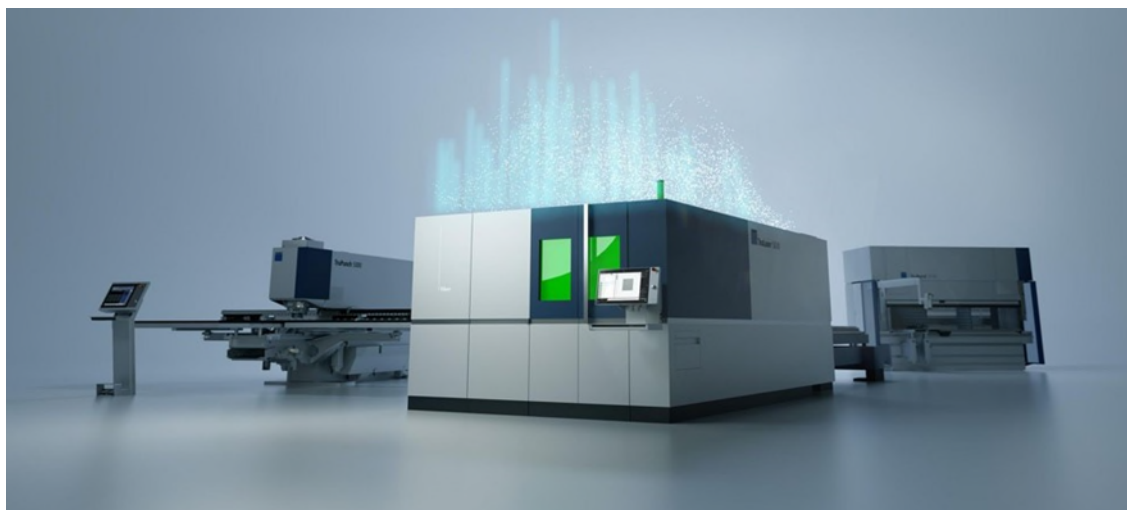

Figure 7: Enable and integrate the TRUMPF core products, such as the machines, into the digital world.

9

Figure 8: TRUMPF headquarters near Stuttgart, Germany, and a view of the TRUMPF customer center.

About the Company

TRUMPF was founded in 1923 as a series of mechanical workshops and has since developed into one of the world's leading companies for machine tools, laser technology and electronics for industrial applications. The software solutions pave the way to the smart factory, enabling their customers to implement high-tech processes in industrial electronics. In the fiscal year 2020/21, the company generated a turnover of 3.5 billion euros, with 14,767 employees in over 70 countries worldwide.

About the Authors & Acknowledgements

Arun Anandasivam was part of the team that defined the TRUMPF Digital Ambition strategy and one of the key organizers of the Architecture Campus in 2019, with over 50 experts. He emphasized the need for a coordinated IT and IoT architecture at TRUMPF. At the end of 2019, he established a governance unit, architecture steering board and architecture working group comprising of the business units and the IT.

Cornelius Löffler has helped to shape the enterprise architecture community since 2020 and is currently the lead enterprise architect at TRUMPF. In his role he is in charge for the architecture steering board and architecture working group. He recently published the version 2.1 of the TRUMPF Digital Reference Architecture.

Thomas Schneider as the CTO for the machine tool business was one of the key player in driving the architectural thinking into the organization and aligning the development teams towards one central architecture. He was the first member of the architecture steering board.

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