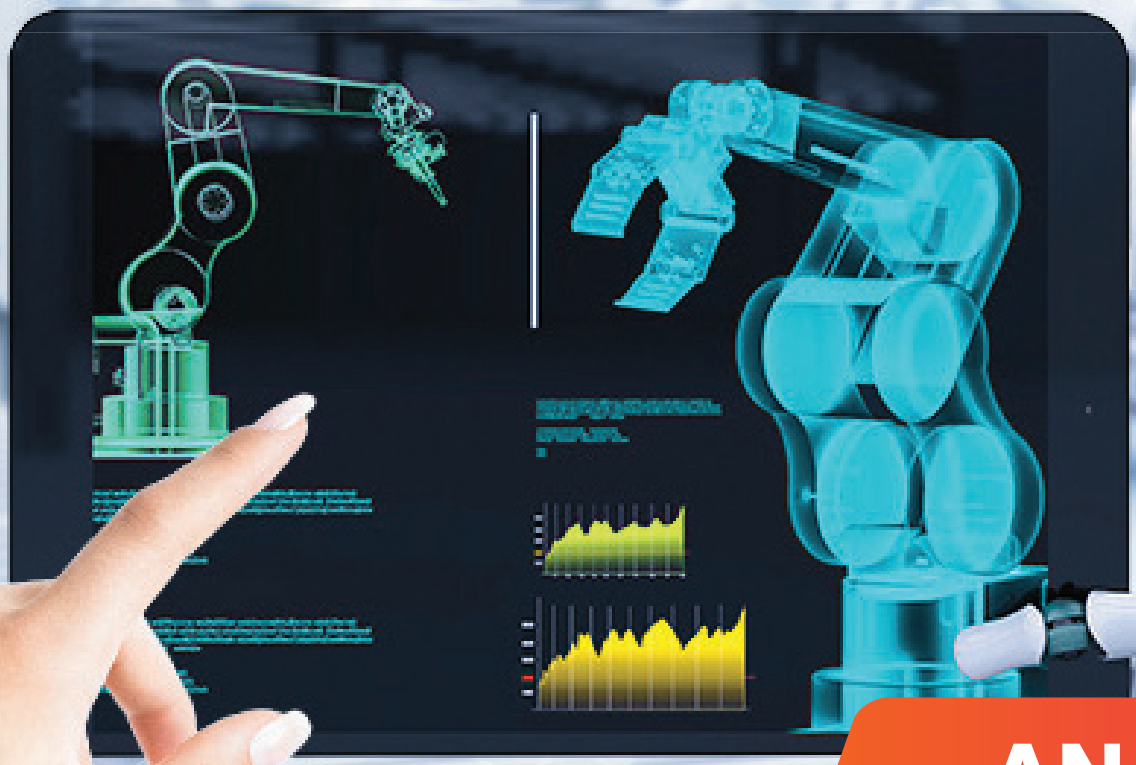
25º Seminário Internacional de Alta Tecnologia

30 SET 2021

25 ANOS SCPM

ENGENHARIA DE SISTEMAS INTELIGENTES PRODUTO-SERVIÇO



ANAIS

Editado por Klaus Schützer

25° Seminário Internacional de Alta Tecnologia

Engenharia de Sistemas Inteligentes Produto-Serviço

Editor

Prof. Dr.-Ing. Klaus Schützer

Soluções Computacionais para Projeto e Manufatura

30 de Setembro de 2021

Piracicaba, SP

SCPM

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para Projeto e Manufatura
Prof. Dr.-Ing. Klaus Schützer

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Laboratório de Sistemas Computacionais para Projeto e Manufatura e Seminário Internacional de Alta Tecnologia

O Laboratório de Sistemas Computacionais para Projeto e Manufatura (SCPM), foi criado em agosto de 1995 para iniciar um grupo de pesquisa no Brasil que pudesse dar prosseguimento ao trabalho que eu havia desenvolvido em vários projetos europeus, durante o período de doutorado junto ao *Institute for Production Management, Technology and Machine Tools* (PTW) da *Technical University of Darmstadt* (TUD), Alemanha.

O modelo para a concepção deste novo espaço para pesquisa e ensino baseou-se nos institutos alemães de pesquisa vinculados às universidades e com autonomia para definir os temas de pesquisa e buscar recursos necessários para seu autossustento e financiar sua atuação nacional e internacional.

Para tanto, minha experiência de sete anos como pesquisador junto ao PTW foi determinante. No retorno para o Brasil trouxe dois projetos aprovados. O projeto para a realocação de pesquisador do *Deutsche Ausgleichsbank* disponibilizou recursos para a aquisição de hardware e software, já garantindo a continuidade das pesquisas iniciadas no doutorado. O Projeto *Feature Based Design*, aprovado pelo Programa *Keep in Touch* da Comissão Europeia, incluindo 4 outros parceiros europeus, garantiu recursos de mobilidade pelos três anos iniciais, permitindo a inserção internacional do laboratório recém-criado.

Dessa forma o SCPM foi concebido visando atender os seguintes objetivos:

- construir um laboratório de pesquisa direcionado à qualidade científica e à aplicação dos resultados,
- ter autonomia na definição e estabelecimento de linhas de pesquisa,
- ter como referência o modelo de financiamento dos institutos de universidades alemãs,
- buscar o desenvolvimento de parcerias universidade-empresa e projetos de pesquisa aplicada,
- buscar autonomia financeira para financiar projetos de pesquisa e permitir sua atuação nacional e internacional,

e contou inicialmente com dois alunos de iniciação científica.

O início das atividades de pesquisa abriu perspectivas para o desenvolvimento de novos temas e o desafio para a aquisição de projetos de pesquisa aplicada dentro de uma parceria

universidade-empresa. Essas oportunidades a curto e médio prazo apontaram as seguintes necessidades a serem atendidas:

- estruturação e ampliação das atividades de pesquisa com integração e o financiamento de mestrandos em tempo integral,
- recursos para ampliar a infraestrutura de hardware e software,
- divulgação de trabalhos de pesquisa e resultados alcançados,
- recursos para participar de eventos e reuniões internacionais,
- intensificação dos contatos com empresas visando projetos de pesquisa aplicada.

Aproveitando a experiência também adquirida no PTW como participante da organização dos eventos de divulgação tecnológica organizados pelo instituto, propus, ainda no final de 1995, ao diretor daquele instituto, na época o Prof. Dr.-Ing. Herbert Schulz, a co-realização de evento semelhante no Brasil. Dessa parceria nasceu o Seminário Internacional de Alta Tecnologia visando atender os seguintes objetivos:

- divulgar para a indústria os mais recentes avanços tecnológicos e modernos processos de trabalho desenvolvidos dentro de uma parceria Universidade-Empresa,
- divulgar os resultados de pesquisa do SCPM e de seus parceiros acadêmicos,
- buscar recursos para financiar as atividades de pesquisa e bolsistas do SCPM.

Em outubro de 1996 aconteceu o 1º Seminário que extrapolou a capacidade de público no auditório da universidade, demonstrando o grande interesse e necessidade de um evento no modelo proposto.

Esse modelo contemplou desde o primeiro Seminário a participação apenas de *Keynote Speakers* selecionados e convidados pelo Comitê Científico Internacional, cuja atuação é totalmente independente da gestão administrativa do evento, garantindo uma separação entre o patrocínio necessário para a sua realização e a escolha do conteúdo técnico a ser apresentado. Os palestrantes são convidados entre professores/pesquisadores que desenvolvam projetos de pesquisa aplicada com empresas, e dirigentes industriais que desenvolvam projetos com universidades dentro de um objetivo comum de alcançar diferenciais para seus produtos e processos de trabalho.

Em 1997 juntou-se a essa proposta o *Department for Computer Integrated Design* da TUD e em 2004 o *Institute for Machine Tools and Factory Operations* da *Berlin Institute of Technology* (TUB), demonstrando o acerto do modelo proposto que chega agora à sua 25ª edição.

Figura 1: Capa dos dez primeiros Anais do Seminário Internacional de Alta Tecnologia.

O grupo de alunos de graduação, mestrado e doutorado que se reuniu no SCPM concentrou-se em três principais linhas de pesquisa: Manufatura Inteligente e Fábrica Digital; Desenvolvimento Integrado do Produto; Tecnologia de Usinagem com Altíssima Velocidade. Essa equipe desenvolveu ali seus trabalhos de pesquisa ao mesmo tempo em que estava inserida em todas as atividades desenvolvidas no SCPM em tempo integral, permitindo que obtivessem uma formação mais ampla do que somente o seu trabalho de pesquisa que garantia a titulação almejada.

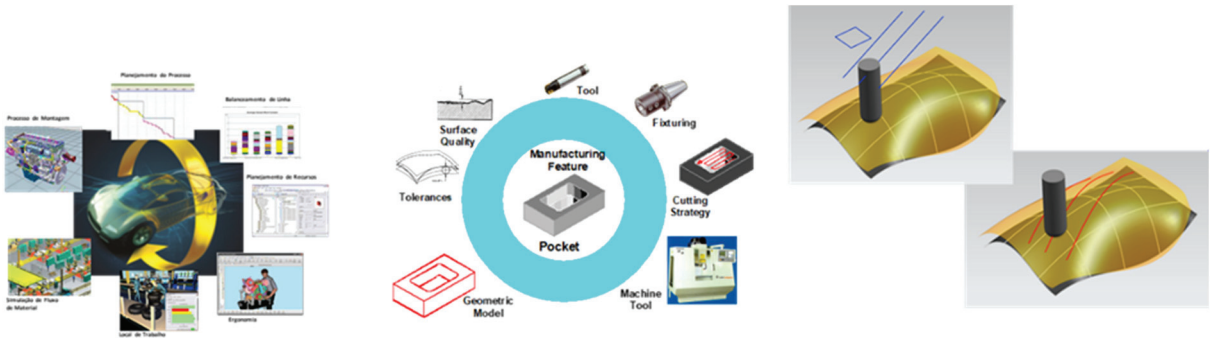

Figura 2: Linhas de pesquisa do SCPM.

A intrínseca relação das duas primeiras linhas de pesquisa acima mencionadas, Fábrica Digital e Desenvolvimento Integrado do Produto, com o uso dos recursos digitais, aliada à chegada da Internet ao chão de fábrica na chamada 4ª Revolução Industrial, representou para essa equipe um passo a mais na evolução dos trabalhos que vinham sendo realizados e não uma revolução, disruptiva para alguns pesquisadores.

A atuação do SCPM no ensino superior também sempre apresentou um caráter desafiador e inovador. Ainda em 1996, e nos anos seguintes, enquanto o ensino das disciplinas relacionadas ao tema projeto era focado no desenho técnico mecânico, passei a oferecer a disciplina de projeto do produto incluindo aulas práticas de CAD 3D. Ação semelhante ocorreu

em 1997 para a disciplina de processos de fabricação que passa a incluir aulas práticas de CAM 3D, sendo os primeiros cursos de que se tem conhecimento no Brasil a utilizar sistemas CAD/CAM 3D no processo e na manufatura.

Em 2010 incluí nas aulas práticas da disciplina gestão do produto um sistema PLM para que grupos de alunos passem a interagir com um sistema de gerenciamento de dados do produto durante o processo de desenvolvimento do produto. Esse trabalho resultou em 2014 na criação de uma Fábrica Ensino para Processo de Desenvolvimento do Produto, que oferece aos alunos uma experiência muito próxima da prática industrial que encontrarão nas médias e grandes empresas. Essa contribuição para o ensino foi apresentada em várias publicações internacionais e congressos, sendo muito bem recebida.

Paralelamente, o Seminário Internacional de Alta Tecnologia foi beneficiado desse caráter inovador e das parcerias firmadas com universidades no Brasil e no exterior. Os temas discutidos nos eventos ao longo desses 25 Anos contaram com o binômio universidade-indústria e sempre fomos os pioneiros a trazê-los para o Brasil, destacando por exemplo: 1996 – Tecnologia HSC; 1998 – PLM e Normas STEP; 2001 – Manufatura Avançada; 2007 – Manufatura Digital; 2011 – Fábrica Digital; 2012 – *Smart Products*; 2014 – *Industrie 4.0*; 2017 – Trabalho 4.0; 2019 – *Lean 4.0*; 2021 – *Smart Product-Service Systems Engineering*.

Para que esse trabalho de divulgação tecnológica pudesse ser realizado, o apoio de empresas e organizações no seu financiamento foi imprescindível. Por essa razão destaco aqui sete Órgãos de Fomento e tinta e oito empresas que ao longo dos 25 Anos deram seu apoio para a realização do Seminário Internacional de Alta Tecnologia.

Figura 3: Empresas e organizações que apoiaram o Seminário Internacional de Alta Tecnologia.

Como resultado de todos esses esforços, o SCPM pode reunir uma equipe de pesquisadores em tempo integral composta por doutorandos, mestrandos, alunos de iniciação científica e pessoal técnico de apoio. As atividades científicas desenvolvidas e bolsas de pesquisa foram financiadas na sua maioria com recursos gerados através de projetos de pesquisa nacionais e internacionais, além da prestação de serviços e projetos em parceria com diversas empresas. A estratégia de desenvolver seus projetos de pesquisa o mais próximo possível das indústrias viabiliza uma rápida implementação dos resultados tecnológicos obtidos.

Reunir parceiros para desenvolver projetos mais arrojados foi a marca do trabalho do SCPM, o que resultou em parcerias estratégicas com institutos da TUD e TUB já mencionados. O resultado foram inúmeros projetos de pesquisa em conjunto propiciando um contínuo intercâmbio de alunos de graduação, mestrado e doutorado, além de professores de ambos os lados, garantindo aos participantes uma excelente formação acadêmica e social. Quero neste ponto agradecer de forma muito pessoal aos seguintes colegas pelas sólidas parcerias desenvolvidas ao longo desses 25 Anos, bem como pela confiança e amizade em que elas redundaram:

- Prof. Dr.-Ing. Eberhard Abele – TU Darmstadt / PTW
- Prof. Dr.-Ing. Reiner Anderl – TU Darmstadt / DiK
- Prof. Dr.-Ing. Joachim Metternich – TU Darmstadt / PTW
- Prof. Dr.-Ing. Herbert Schulz – TU Darmstadt / PTW – in memoriam
- Prof. Dr.-Ing. Rainer Stark – TU Berlin / IIT
- Prof. Dr.-Ing. Eckart Uhlmann – TU Berlin / IWF
- Prof. Dr.-Ing. Matthias Weigold – TU Darmstadt / PTW

Alguns resultados dessas destacadas parcerias para a pesquisa e o ensino são:

- Doutores formados: 5 (tempo integral); além de 4 co-orientações com TU Darmstadt
- Mestres formados: 23 (tempo integral); além de 9 orientações na TU Darmstadt
- Especializações: 2
- Trabalhos de Graduação: 23
- Iniciação Científica: 49
- Bolsista atividade / estagiário: 9

- Alunos de intercâmbio na TUD, TUB, IGB e HSRM: 33
- Alunos e pesquisadores de intercâmbio recebidos: 14
- Participação em conferências internacionais e presença junto às universidades parceiras
- Participação e filiação na Internacional Academy for Production Engineering - CIRP
- Artigos completos publicados em periódico indexado: 63
- Livro publicado: 1
- Capítulos de livros: 13
- Trabalhos publicados em anais de eventos: 160

Considero que a colheita foi boa, diante das barreiras que enfrentamos. E os resultados só foram possíveis porque o trabalho em equipe foi eficaz e eficiente, desde a estrutura interna do SCPM até os parceiros externos.

Comemorar 25 Anos de atuação, assim, é necessariamente agradecer cada pessoa, empresa e instituição que acreditou e contribuiu com a proposta. A ciência se faz compartilhando preocupações, necessidades e recursos, de olho na superação do presente, com competência e criatividade.

Meu muito obrigado a todos.

Prof. Dr.-Ing. Klaus Schützer

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Apresentação

O Laboratório de Sistemas Computacionais para Projeto e Manufatura (SCPM) realiza anualmente desde 1996 o Seminário Internacional de Alta Tecnologia, sempre trazendo para o seu público os mais recentes desenvolvimentos tecnológicos e inovadores processos de produção desenvolvidos dentro de uma parceria universidade-empresa e validados por casos de sucesso em empresas que se destacam pela inovação.

Temas como Tecnologia HSC, Manufatura Avançada, Fábrica Digital, *Smart Products*, *Industrie 4.0*, Trabalho 4.0, *Lean 4.0* foram apresentados pela primeira vez no Brasil nesse evento, por pesquisadores e profissionais reconhecidos internacionalmente.

O **25º Seminário Internacional de Alta Tecnologia – Engenharia de Sistemas Inteligentes Produto-Serviço** se inova inclusive no seu formato. Depois de 24 anos sendo realizado com grande sucesso em formato presencial, realiza o 25º evento de forma online para atender os requisitos sanitários vigentes. Com esse novo formato consegue atingir mais de 1.000 inscrições de 20 países no fechamento desses Anais na semana que antecede o evento.

Os desafios e oportunidades trazidos pela era da digitalização, no bojo da 4ª Revolução Industrial, e a integração dos produtos na Internet com a implantação do IPv6 nos obrigam a considerar um produto não mais apenas pelo que aquele objeto físico oferece, mas sim quais serviços aquele produto oferece, inclusive a possibilidade de aquisição apenas do serviço desejado, obrigando as empresas a reverem seus planos de negócio.

O tema definido pelo Comitê Científico Internacional para este ano é Engenharia de Sistemas Inteligentes Produto-Serviço, que será discutido por representantes de universidades e empresas da Alemanha e do Brasil.

Apresentamos o contexto em que o tema se insere com uma palestra específica, e passamos a detalhar diversos aspectos e implicações desse tema, destacando: a Engenharia Digital em direção a um paradigma digital baseado em dados no desenvolvimento de produtos; a inteligência de engenharia; a aplicação de componentes de máquinas sensorizados e sensores inteligentes; além da apresentação de estratégias para a transformação digital de indústrias e casos de sucesso de sistemas produto-serviço e de transformação digital de empresas.

Trouxemos ainda para a palestra de abertura a discussão do papel preponderante da inovação como desafio para universidades, indústrias e governo por um palestrante que tem todo seu histórico profissional marcado pela inovação continuada. Desejamos a todos uma leitura produtiva desses Anais que comemoram também o Jubileu de 25 Anos deste evento.

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Parceiros

Agradecemos nossos Parceiros que possibilitaram a realização do 25º Seminário Internacional de Alta Tecnologia.

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Prof. Dr.-Ing. Johann-Dietrich Wörner

Johann-Dietrich 'Jan' Wörner has been elected as President of the National Academy of Science and Engineering (acatech) on March 19th, 2021. He took up duty with immediate effect. Previously, from July 2015 until February 2021 he served as Director General of the European Space Agency (ESA). From March 2007 to June 2015, he was the Chairman of the Executive Board of the German Aerospace Center (DLR). Jan Wörner was born in Kassel, Germany, in 1954. He studied civil engineering at the Technical University (TU) Berlin and TU Darmstadt, from where he graduated in 1985. In 1982, as part of his studies, he spent one year in Japan, investigating earthquake safety of nuclear power plants. Until 1990, Mr. Wörner worked for consulting civil engineers Koenig und Heunisch. In 1990 he returned to TU Darmstadt, where he was appointed as a professor of Civil Engineering and took over as Head of the Test and Research Institute. Before being elected as President of TU Darmstadt in 1995, he held the position of Dean of the newly established Civil Engineering Faculty. Jan Wörner headed the university from 1995 to 2007 and succeeded in making it the first autonomous university of the Federal Republic of Germany. Jan Wörner has received honorary doctorates from New York State University at Buffalo (USA), technical universities of Bucharest (Romania) and Mongolia, the Saint Petersburg University for Economics and Finance (Russia) and École Centrale de Lyon (France). He has also been awarded the honors of Knight of the French Légion d'Honneur. Jan Wörner was a member of the administrative boards of École Centrale Paris, École Centrale de Lyon, TU Berlin, the Instituto Superior Técnico, University of Lisbon, the Arts and Music University in Frankfurt. Before joining ESA as Director General, Jan Wörner was head of the German delegation to ESA from 2007 to 2015 and served as Chairman of the ESA Council from 2012 to 2014.

✉ jan.woerner@wneng.de

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acatech advises policymakers and the public, supports policy measures to drive innovation, and represents the interests of the technological sciences internationally. In accordance with its mandate from Germany's federal government and states, the Academy provides independent, science-based advice that is in the public interest. acatech explains the opportunities and risks of technological developments and helps to ensure that ideas become innovations – innovations that lead to greater prosperity, welfare, and quality of life. acatech brings science and industry together. The Academy's Members are prominent scientists from the fields of engineering, the natural sciences and medicine, as well as the humanities and social sciences. The Senate is made up of leading figures from major science organisations and from technology companies and associations. In addition to its headquarters at the acatech FORUM in Munich, the Academy also has offices in Berlin and Brussels.

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NATIONAL ACADEMY OF SCIENCE AND ENGINEERING

Innovation – The key challenge for universities, industries, and government

Abstract

Innovation is the last aspect of a chain from Inspiration, Invention, to Innovation. The universities have to support the understanding that we should go beyond existing knowledge. The same holds true for politics: They have to fund disruptive ideas.

Keywords

Innovation; Global Challenge; Interdisciplinarity.

Innovation –
The key challenge for universities, industries, and government

Jan Wörner, President acatech

30th September 2021

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DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN

Global Challenges

- climate change
- migration
- mobility
- communication
- energy
- shortage of resources
- demographic development
- conflicts and catastrophes
- health
- …curiosity

→ **INNOVATION**

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GLOBAL CHALLENGE:
• Discovery
• Monitoring
• Raising Awareness
• Mitigation/Adaptation
→ curiosity, knowledge, action
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Digital Transformation
KEEP CALM IT'S THE NEW NORMAL
New Roles
New Structures
New Interactions
New Processes
New Opportunities…
…New Worries
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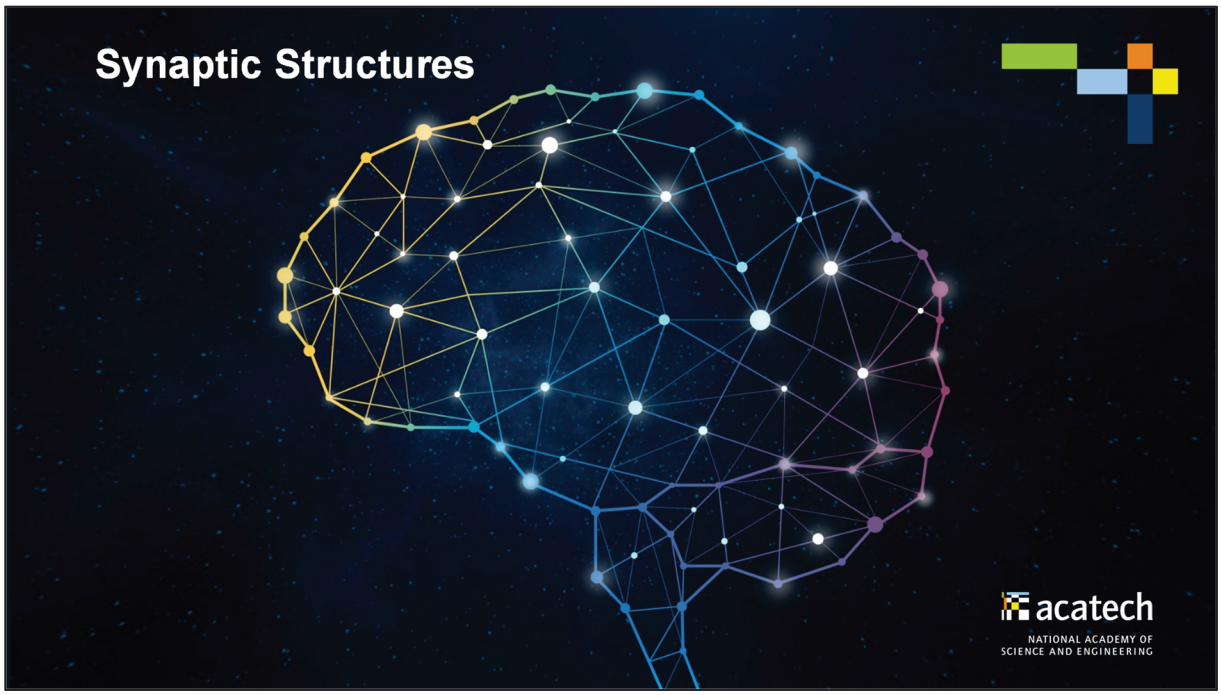
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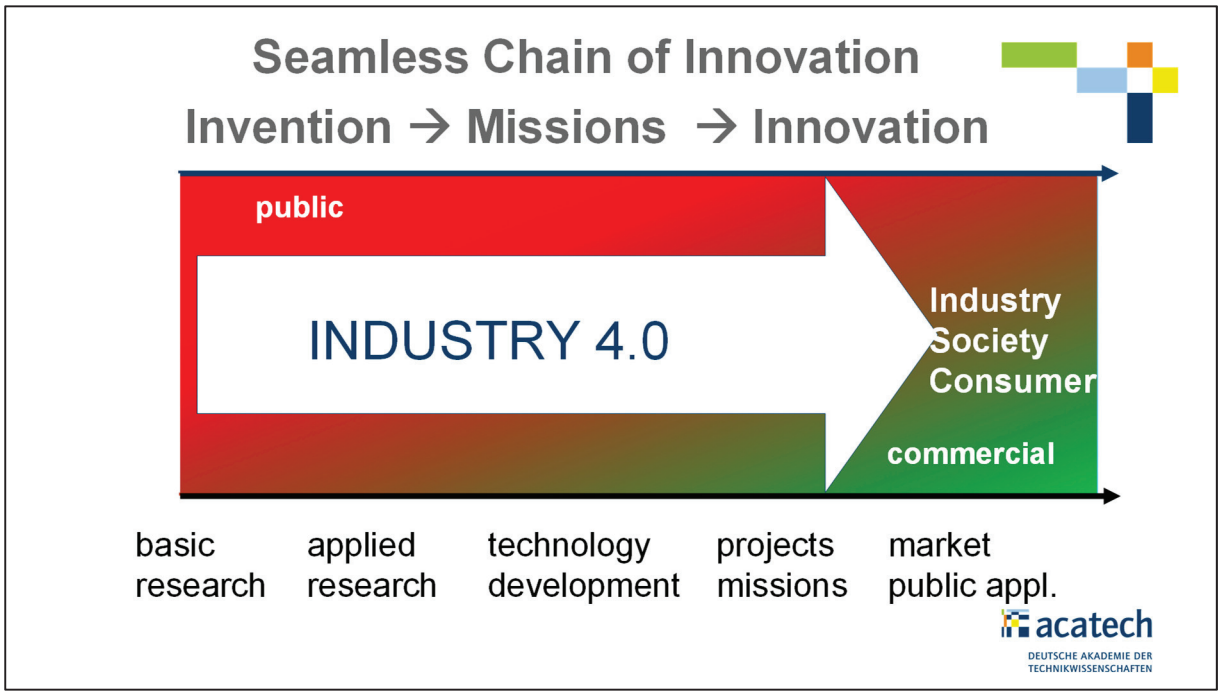
Seamless Chain of Innovation
Invention → Missions → Innovation
public
INDUSTRY 4.0
Industry
Society
Consumer
commercial
basic research
applied research
technology development
projects missions
market public appl.
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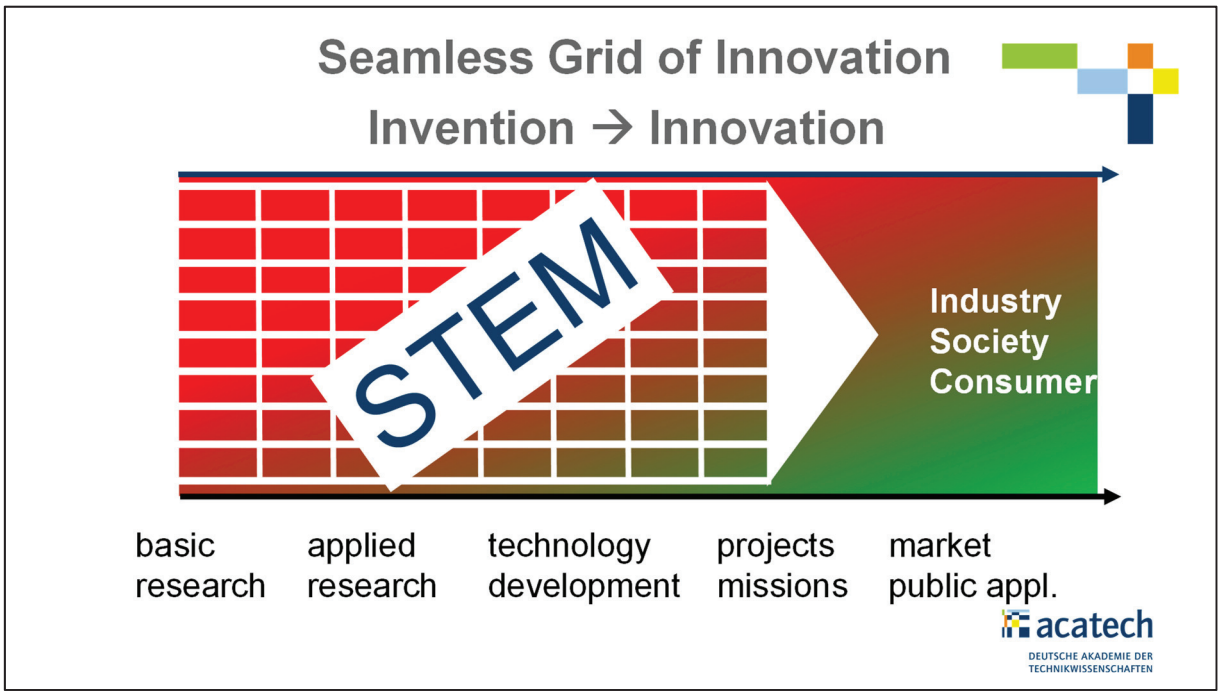
Seamless Grid of Innovation
Invention → Innovation
STEM
Industry
Society
Consumer
basic research
applied research
technology development
projects missions
market public appl.
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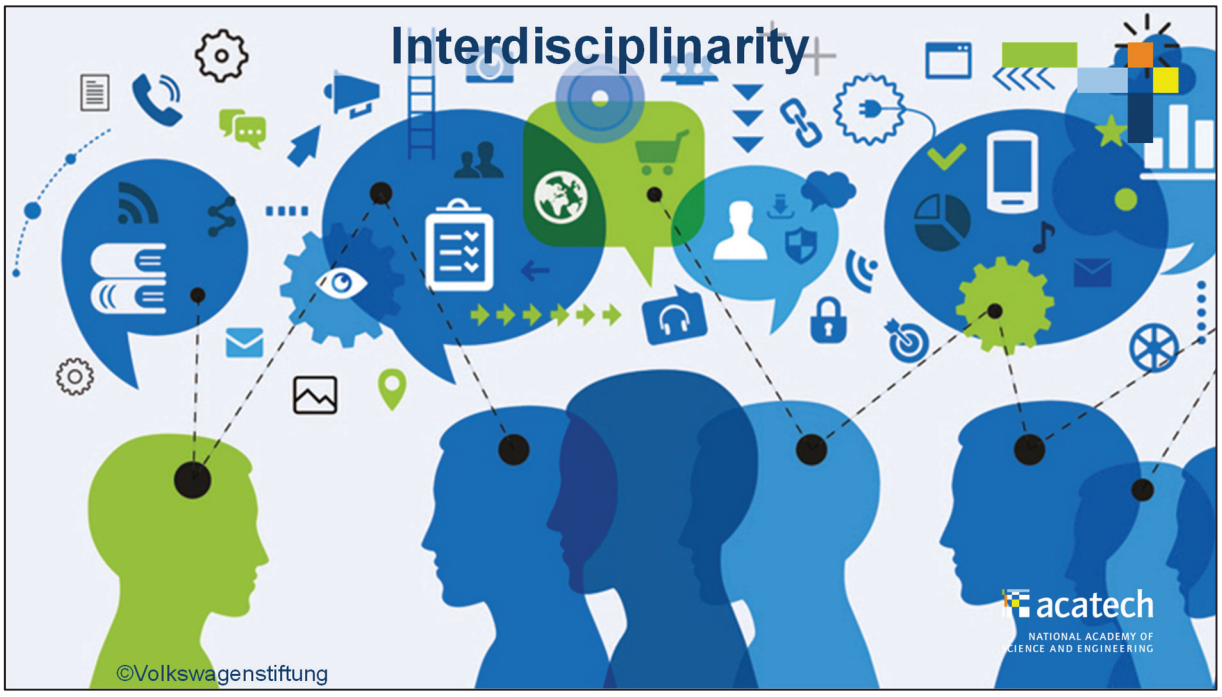
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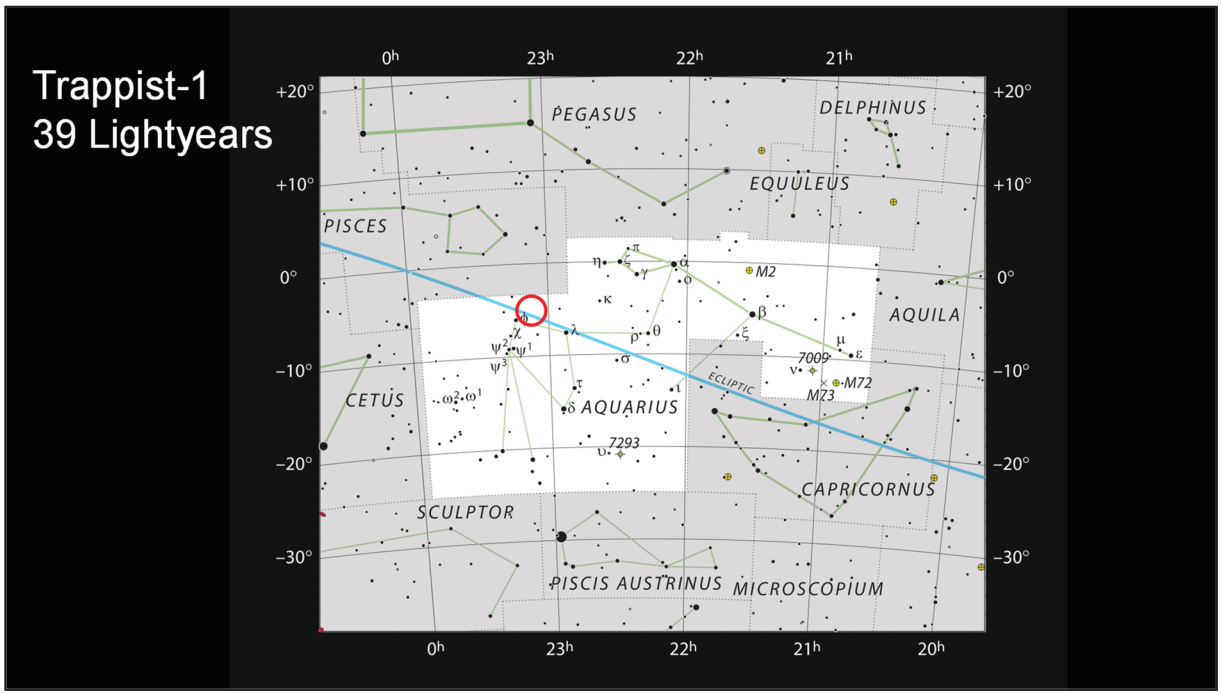
Trappist-1
39 Lightyears
0h
23h
22h
21h
20h
+20°
+10°
0°
−10°
−20°
−30°
PEGASUS
DELPHINUS
EQUULEUS
PISCES
AQUILA
CETUS
AQUARIUS
CAPRICORNUS
SCULPTOR
PISCIS AUSTRINUS
MICROSCOPIUM
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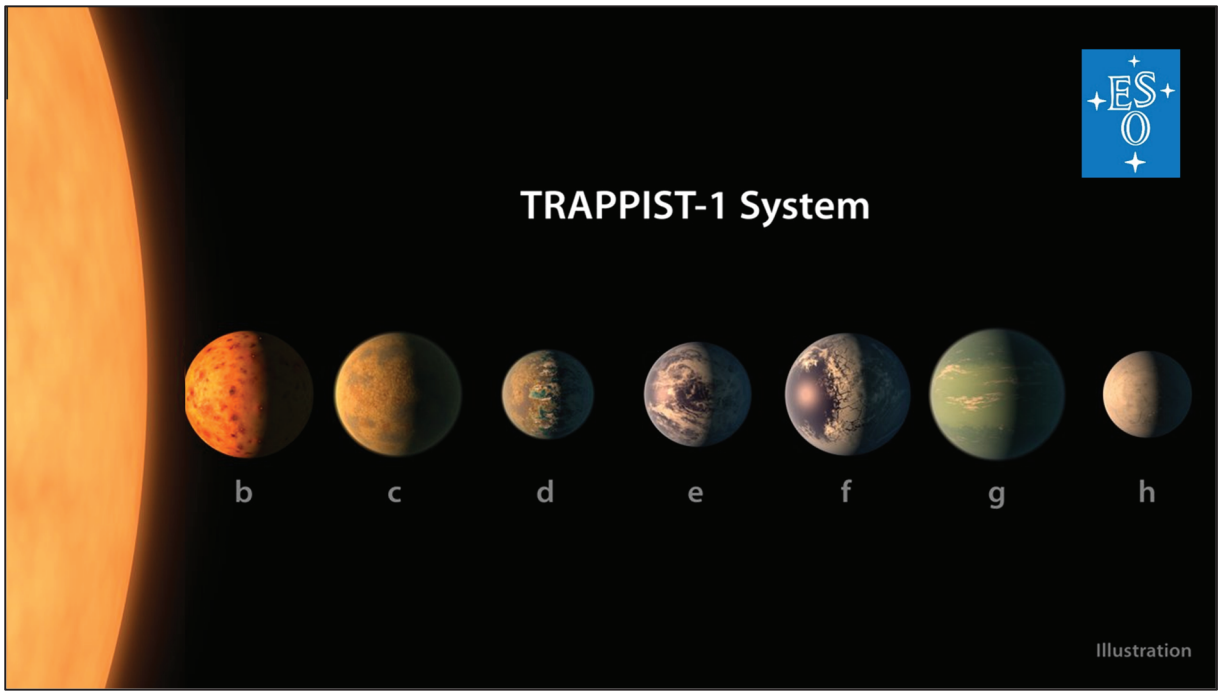
TRAPPIST-1 System
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Concurrent Design Facility ESA
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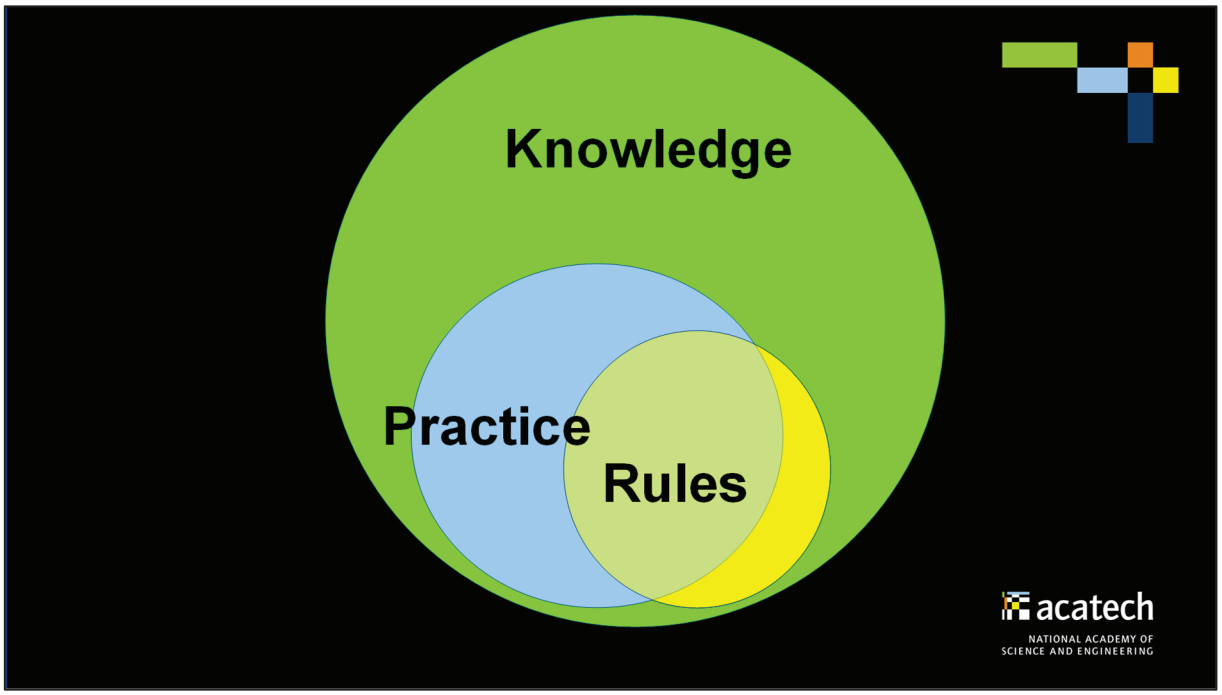
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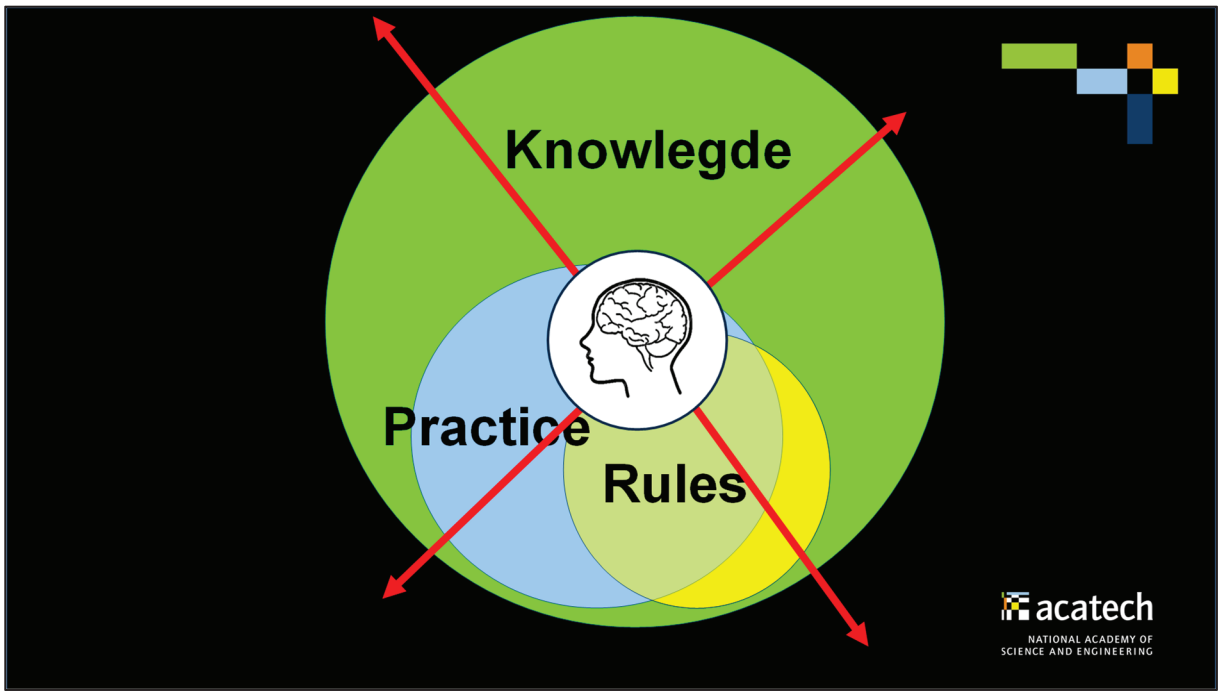
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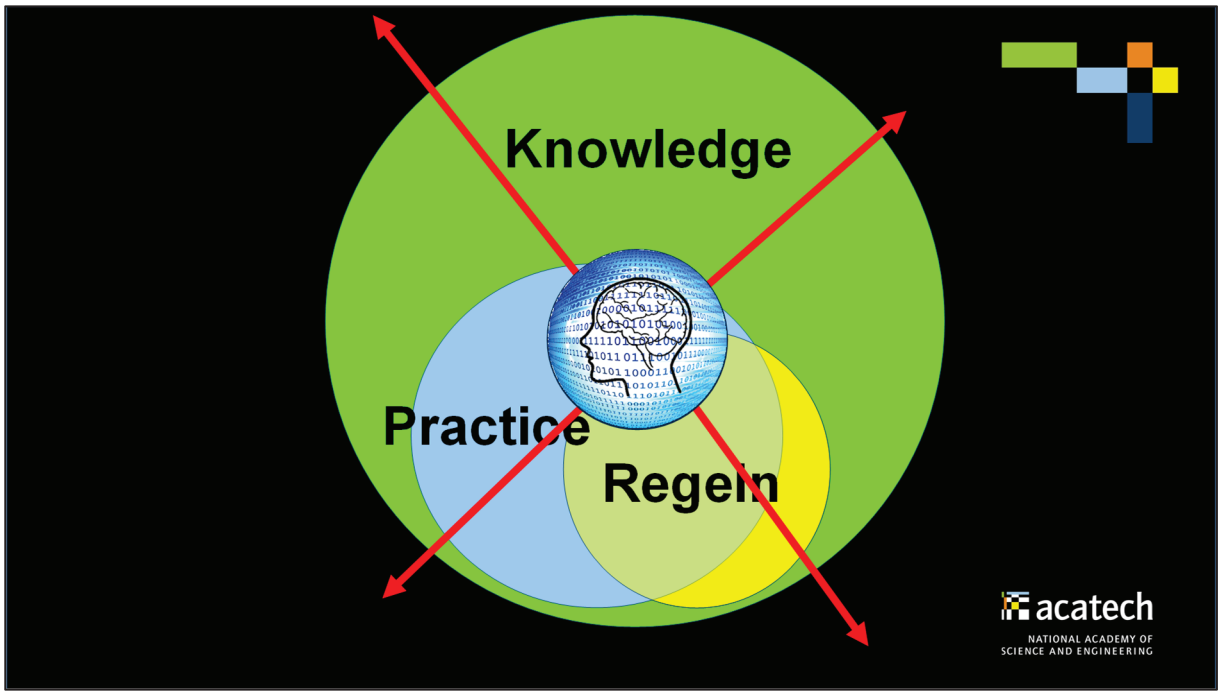
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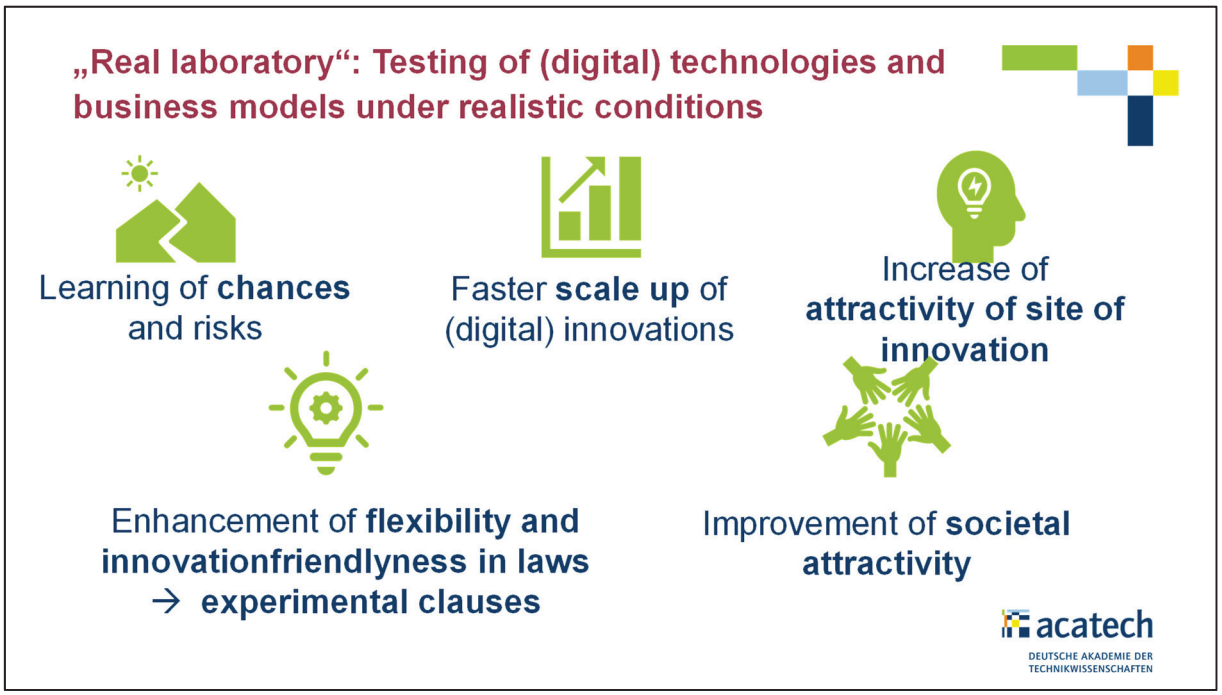
„Real laboratory“: Testing of (digital) technologies and business models under realistic conditions
Learning of **chances** and risks
Faster **scale up** of (digital) innovations
Increase of **attractivity of site of innovation**
Enhancement of **flexibility and innovationfriendlyness in laws** → **experimental clauses**
Improvement of **societal attractivity**
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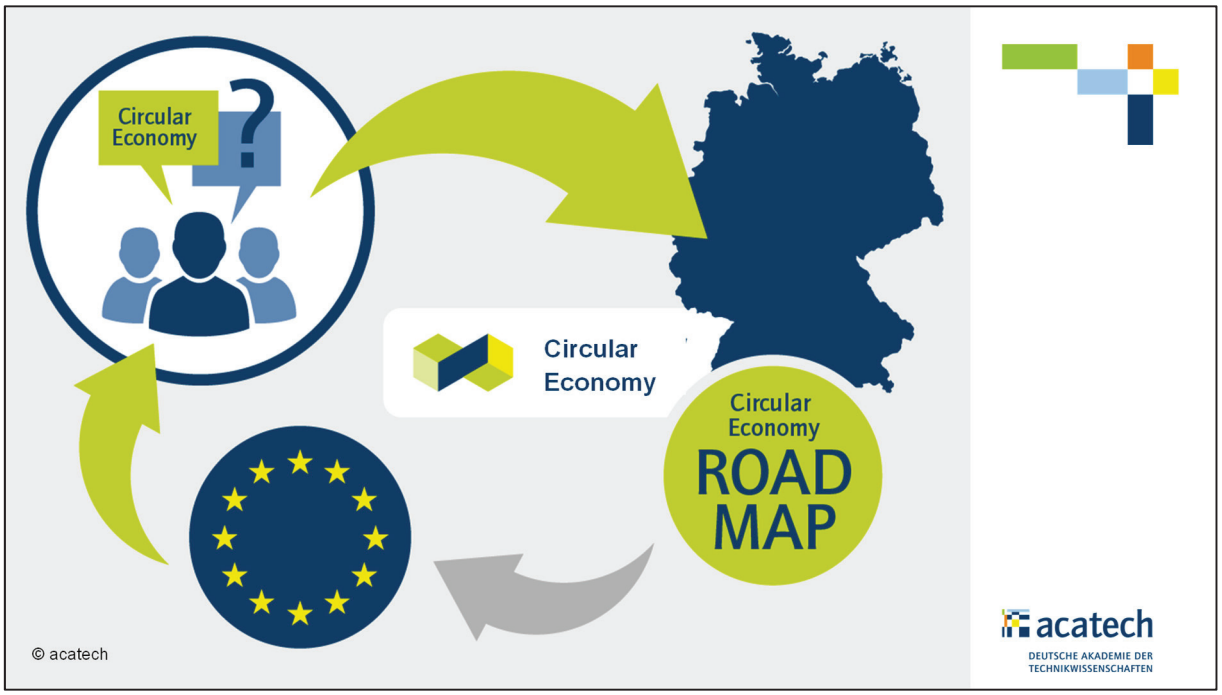
Circular Economy
Circular Economy
Circular Economy
ROAD MAP
© acatech
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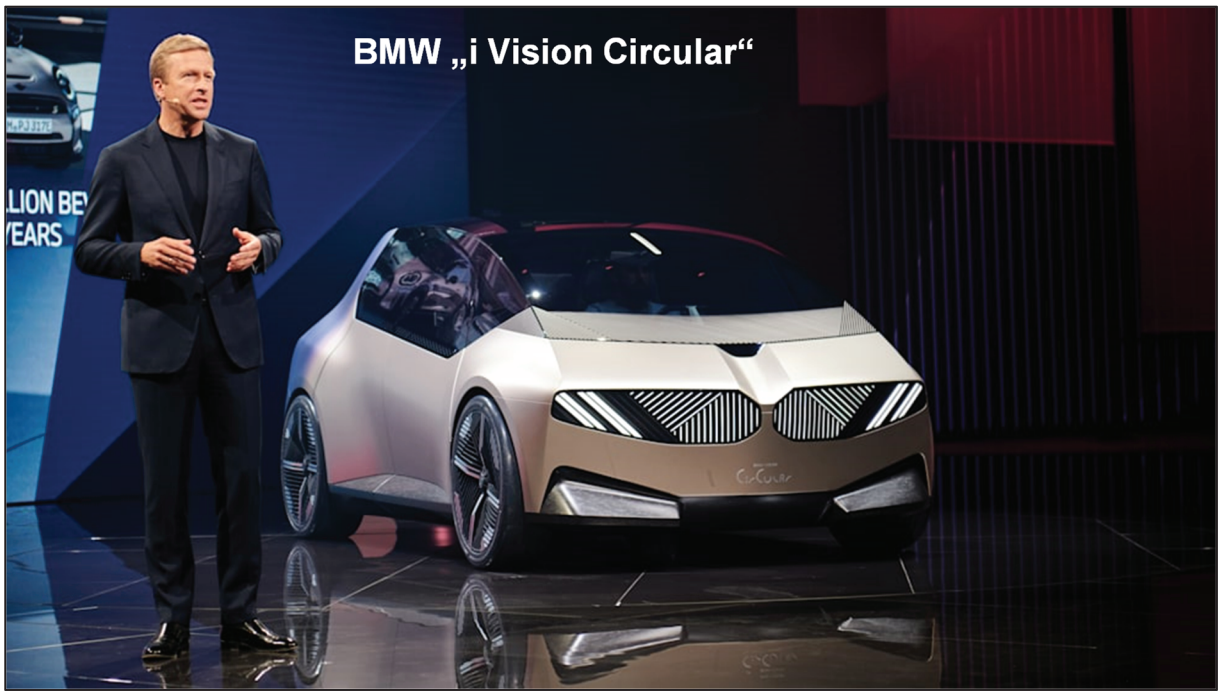
BMW „i Vision Circular“

acatech
HORIZONTE
Urban Mining
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DISRUPTIVE
INNOVATION
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SPRIN-D
BUNDESAGENTUR
FÜR SPRUNGINNOVATIONEN
DARPA
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TECHNIKWISSENSCHAFTEN

Antoine de Saint Exupery:

One should not want to predict the future, but to make it possible.

Il future non si tratta solo di prevederlo, ma di renderlo possible.

Quanto ao futuro, não se trata de prevê-lo, mas de torná-lo possível.

Pour ce qui est de l'avenir, il ne s'agit pas de le prévoir, mais de le rendre possible.

Die Zukunft soll man nicht voraussehen wollen, sondern möglich machen.

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Innovation –
The key challenge for universities, industries, and government

Jan Wörner, President acatech

30th September 2021

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Prof. Dr.-Ing. Reiner Anderl

Prof. Anderl was born in 1955 and studied mechanical engineering at the Universität Karlsruhe, Germany, where he received his diploma in 1979. He received the Dr.-Ing. degree in Mechanical Engineering at the Universität Karlsruhe in 1984. From 1984 to 1985, he served as the technical manager of a medium-sized company. He then returned as a senior engineer to the Institute for Applied Computer Science in Mechanical Engineering (RPK) at the Universität Karlsruhe. In 1991 he habilitated, and in 1992 he received the Venia Legendi, which includes the authorization to teach CAD/CAM technology. In April 1993, he accepted the call for the professorship for computer integrated design (Fachgebiet Datenverarbeitung in der Konstruktion, DiK) at the faculty Mechanical Engineering, Technische Universität Darmstadt, Germany. At the Technische Universität Darmstadt, he served as the dean of the faculty in Mechanical Engineering from 1999 until 2001. He has served on numerous faculty and university committees and commissions, including serving as pro dean, where he managed the mechanical engineering faculty business office. He was a member of the Zentrale Evaluierungs- und Akkreditierungs-agentur (ZEvA), a national accreditation council based in Hannover. Prof. Anderl has served as vice president at the Technische Universität Darmstadt from January 2005 until December 2010. Today, Prof. Anderl acts as scientific chairman of the Research Council of the Platform Industry 4.0. He is also a member of acatech, the German National Academy of Science and Engineering. Furthermore, Prof. Anderl acts as President of the Academy of Science and Literature, Mainz.

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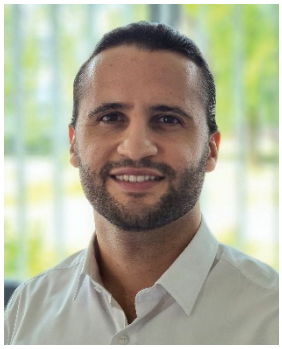
DiK - TU Darmstadt

The Department of Computer Integrated Design (DiK) was founded in 1993 at the Faculty of Mechanical Engineering of Technische Universität Darmstadt and is since then directed by Prof. Dr.-Ing. Reiner Anderl. Task of DiK is to reflect the importance of information technology for mechanical engineering. Therefore, the Department represents an interface between these two disciplines. Information technology is seen as an integral part of engineering and its application with respect to teaching and research constantly advances at the department. Computerized methods and tools are developed to improve and redesign the entire product development process up to the usage of the product. The DiK operates in the field of basic and applied research as well as contract research. The skills acquired here directly transfer into the development of lectures for the Bachelor and Master programs. Core-competencies of the department include the areas Industrie 4.0, Information Integration, Virtual Product Creation, and Distributed and Cooperative Work.



MSc. Serdar Bulut

Starting October 2013, Bulut participated in the double bachelor program of the Technical University of Darmstadt and Virginia Polytechnic University. In 2016 he obtained his B. Sc. degree from both universities in mechanical engineering. Subsequently, he started his master's at Technical University Darmstadt in partnership with Tongji University (Shanghai). In November 2018, he successfully finished his M. Sc. studies with his thesis titled “Definition and Quantification of the Complexity Experienced by Autonomous Vehicles in their Environment and Driving Task”. Since March 2019, Bulut has been working as a research assistant in the Department of Computer Integrated Design (DiK) in the project “Mittestand 4.0 – Kompetenzzentrum Darmstadt”

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The Department of Computer Integrated Design (DiK) was founded in 1993 at the Faculty of Mechanical Engineering of Technische Universität Darmstadt and is since then directed by Prof. Dr.-Ing. Reiner Anderl. Task of DiK is to reflect the importance of information technology for mechanical engineering. Therefore, the Department represents an interface between these two disciplines. Information technology is seen as an integral part of engineering and its application with respect to teaching and research constantly advances at the department. Computerized methods and tools are developed to improve and redesign the entire product development process up to the usage of the product. The DiK operates in the field of basic and applied research as well as contract research. The skills acquired here directly transfer into the development of lectures for the Bachelor and Master programs. Core-competencies of the department include the areas Industrie 4.0, Information Integration, Virtual Product Creation, and Distributed and Cooperative Work.

Smart Product-Service Systems Engineering

Abstract

Innovative products today are developed and engineered as so-called Smart Product-Service Systems. The new generation of products provides appropriate services as well as service functionalities attached to a product. An essential approach for these new performance levels is integrating sensors into the product, e.g., for supporting services such as condition monitoring, remote-diagnostics, remote-control, and tracking and tracing. Smart Product-Service Systems enable in this context also the development of new business models. This contribution introduces Smart Product-Service Systems and explains appropriate development and engineering approaches. Furthermore, the concept of Cyber-Physical Twins is being presented as a key approach for future Smart Product-Service Systems.

Keywords

Smart product-service systems; Smart agile engineering; Service layer concept; Product-service models.

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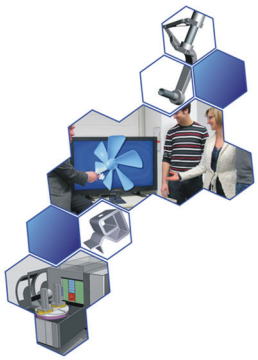
Smart Product Service Systems Engineering



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Research Network @ DiK

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Reiner Anderl

Serdar Bulut

PLATTFORM INDUSTRIE 4.0	Plattform Industrie 4.0 Research Council	Member
	Academy of Science and Literature	President
acatech	German Academy of Science and Engineering	Academician
TECHNISCHE UNIVERSITÄT DARMSTADT	Technische Universität Darmstadt	Head of Institute

Overview

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1. **Introduction**
2. Smart Product-Service Systems Engineering
3. Smart Product-Service Systems Concept and Architecture
4. Implementation Approach and Demonstration
5. Conclusion

Topics

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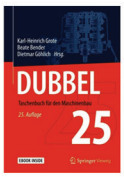
International competence and experience in the areas of

Virtual product development
- CAD, CAM, CAE, ...
- CAx process chains
- Data management (PDM, SDM, FDM, xDM)
- Product Service Systems Engineering



Industrie 4.0
- Cloud Computing, Edge Computing, Platform
- Digital factory/Smart Factories
- Cyber-physical systems, Components as information carrier, Digital twin
- New business models

Chapter 19:
Virtual Product Development

IT-Security for Industrie 4.0
- Security by Design
- Methods to protect against manipulation, knowledge theft and piracy

Additive Manufacturing
- Generation of computer-internal 3D geometric data
- 3D exchange data formats
- Digital Process Chain AM

From Product Service Systems to New Business Models

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New Internet Based Platforms Apps

Sale of Product Performance

New Services

New Business Models?

High added value through functional intergration

Sensor
Actuator
Controller
Adaptive Controller
Mechanics
Mechatronics
Adaptronic

Improvements through Cyber-Physical Systems

Connected and communicating Systems

Smart Plant
Smart Factory
Source: TU Darmstadt, Effiziente Fabrik 4.0
Smart City
Source: TU Darmstadt
Smart Grid
Source: TU Darmstadt, ESE
Smart Products
Smart Logistics
Smart Home

Cyber-Physical Systems supporting networking and communication

- Condition Monitoring
- Systems and Structural Health Monitoring
- Remote Diagnosis and Control
- Track and Trace

Industrie 4.0 Fundamentals

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Reference Architecture Model Industrie 4.0

Layers
Business
Functional
Information
Communication
Integration
Asset

Life Cycle Value Stream IEC 62890
Hierarchy Levels IEC 62264//IEC 61512
Connected World
Enterprise
Work Centers
Station
Control Device
Field Device
Product
Type
Instance

Source: Plattform Industrie 4.0 and ZVEI

Industrie 4.0 Component

I4.0-Compliant communication
I4.0 Component
Administration Shell, e.g. with
Positioning sets
wear data
Conditioning monitoring
Design
Manuals
Assets, e.g. electrical axes system
Message
External Interface
Calibration App 1
Robot Interface
External Interface
Calibration App 2
Camera Interface

Overview

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1 Introduction
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Smart Product-Service Systems

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A product-service system **combines** the value proposition of a **tangible product** and an **intangible service** (Morlock, 2016).
A **tangible product** is extended along its life cycle phases by **suitable services** (Schweitzer, 2010).

Smart services are **data-based services** that complement the range of purely physical products and allow **flexible and individual alignment** with specific **customer** wishes or expectations (acatech, 2018).

Smart product-service systems are **product-service systems** that make use of **smart services** and offer **value proposition** towards an **ecosystem** through **shared data** via the **Internet of everything (IoE)**.

Hardships of Conventional Product Development Practices

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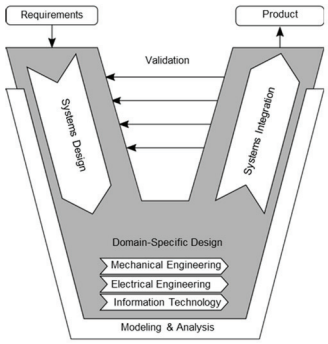

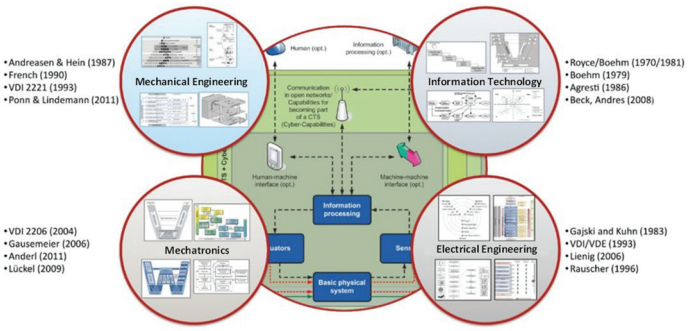

Source: VDI Verlag GmbH

Traditional product development features:
- Independent & parallel development of subsystems within distinct domains
- Static / rigid development process

Traditional product development is exposed to:
- Systems integration is challenging due to manifold and independent sub-system development
- Dynamic change of customer & market requirements

An agile and visionary product development strategy that supports interdisciplinary design is required to meet contemporary challenges

Engineering of Smart Product-Service Systems (SPSS)

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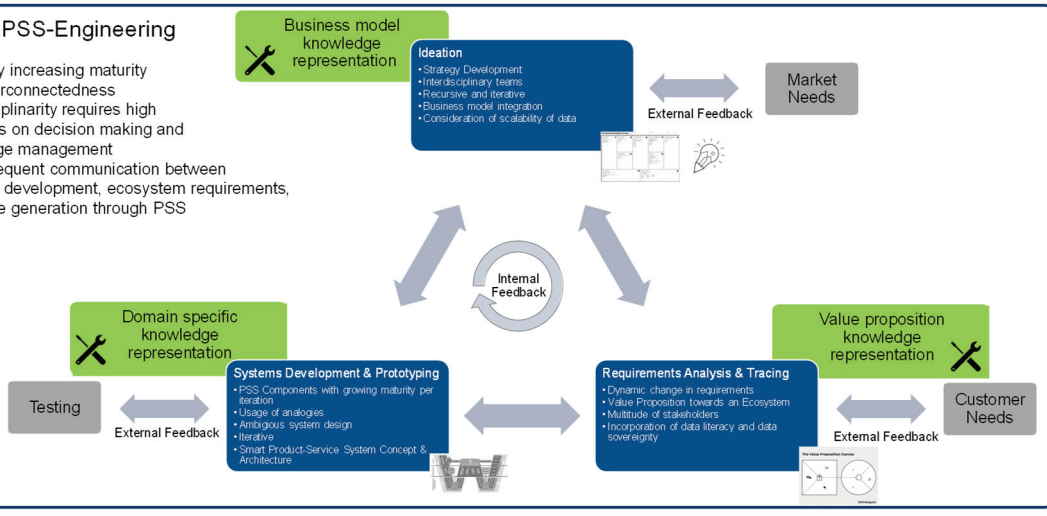
Holistic SPSS-Engineering

- Gradually increasing maturity
- High Interconnectedness
- Interdisciplinarity requires high standards on decision making and knowledge management
- Highly frequent communication between visionary development, ecosystem requirements, and value generation through PSS



Overview

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Value Proposition of PSS

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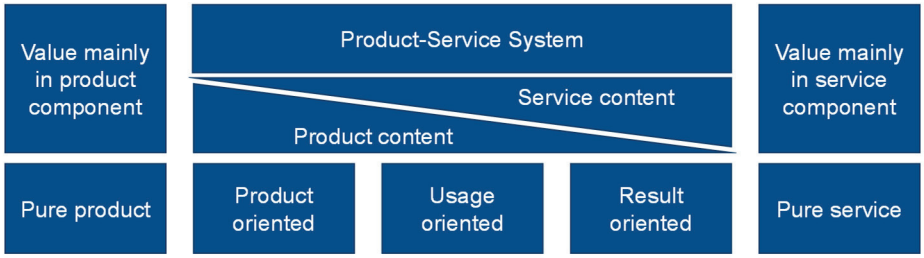

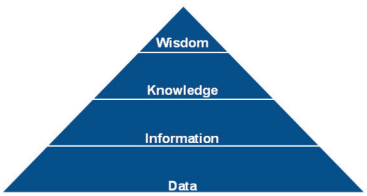

Value Proposition of SPSS

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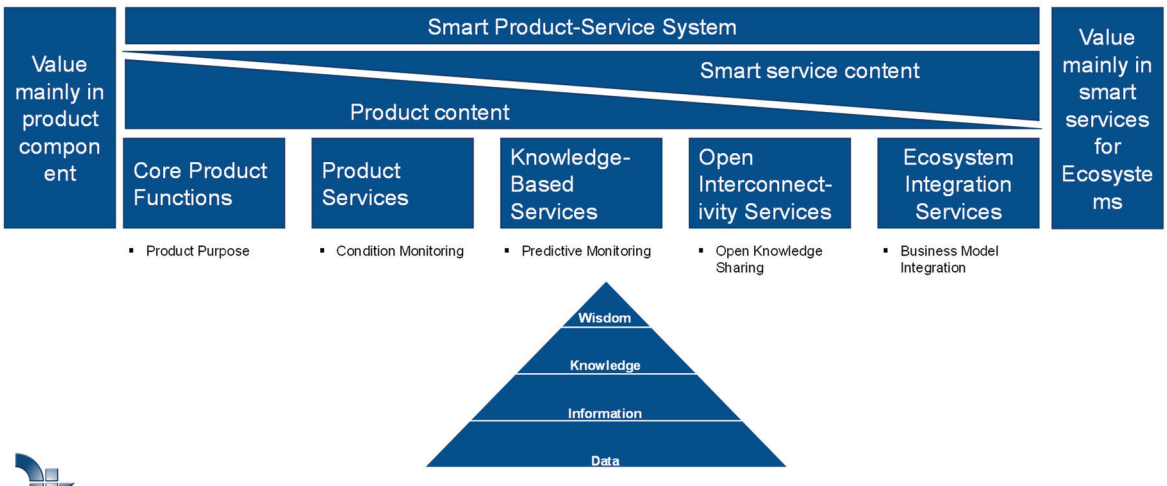

Smart Product-Service System Concept & Architecture

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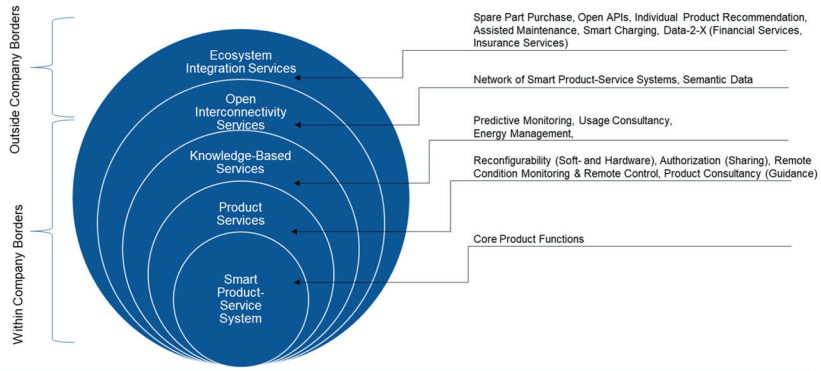
Smart product-service systems are designed to offer **value proposition**. They use distinct **goals** and combine various **service levels** alongside **product functions** to generate value through **shared data**.

Goals of SPSS

Service Levels of SPSS



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5 Conclusion

Implementation Approach and Demonstration: Robotic Vacuum Cleaner

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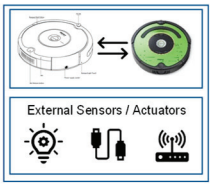
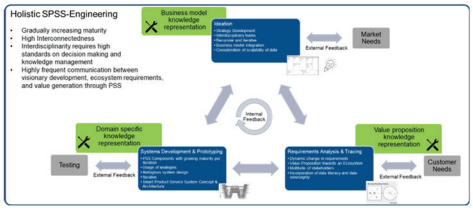
Demonstrator of the Smart Product-Service System



View of Stakeholder "USER"

Engineering Approach



Video of the Robotic Vacuum Cleaner

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SPSS Concept of the Demonstrator

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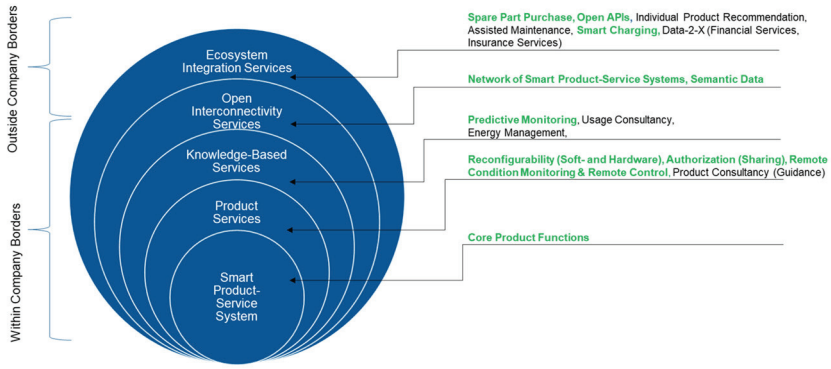
Goals of SPSS

- Provision of Data
- Increased SPSS Use-Cases
- Data Analytics
- Enhanced SPSS Usability
- Reduction of Emissions
- Influence on Human Behaviour
- Resource Optimization
- Product Recommendation

Service Levels of SPSS



Overview

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5 **Conclusion**

Conclusion

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Smart product-service systems require **domain specific knowledge** in mechanical engineering, electrical engineering, information technology, and business development.

Smart product-service systems are designed to appeal to a **dynamic customer** and **market behavior**. Therefore, they require highly **dynamic development process**. Incorporating **agile methods** supports **dynamic development process**.

The **goals** of **smart product-service systems** include **resource optimization** and **reduction of emissions.** Therefore, they may be used to introduce **carbon neutral products.**

Due to their **data-centric** usage and **scalability**, smart product-service systems are capable to offer **value proposition** towards an **ecosystem** of various stakeholders. The value proposition is based on **knowledge** gained through **shared data**.

Smart product-service systems offer a novel approach for **value proposition**.
Shared data paves the way for **shared value creation** and requires standards on **data modeling, data sovereignty** as well as **data literacy** for operators, manufacturers, and all kinds of service providers.

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Thank you for your attention !

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Prof. Dr.-Ing. Rainer Stark

Prof. Dr.-Ing. Rainer Stark studied mechanical engineering at Ruhr University Bochum and Texas A&M University. From 1989 to 1994 he worked as research assistant at the Chair of Design Engineering / CAD of the technical faculty of the University of Saarland. His PhD thesis is entitled “Development of a mathematical model on tolerance for the integration in (3D-) CAD systems”. From 1994 to 1997 he worked as a System Engineer in the Body Engineering department at Ford-Werke AG Cologne. In the following he focused on methods in virtual product creation and was promoted in 1997 to Technical Specialist for CAD, product modeling and product information management. Between 2002 and 2008 he was leading as European Technical Manager regional and global activities in Virtual Product Development and Methods within Ford Motor Company. During this time he also gave numerous guest lectures and presentations at the University of Bochum, the Saarland University Saarbrücken and at the University of Applied Science of Aix-la-Chapelle. Since February 2008 Prof. Rainer Stark is Director of the Chair Industrial Information Technology at the Technical University of Berlin. He has been Director of the Virtual Product Creation division of the Fraunhofer Institute for Production Systems and Design Technology (IPK) for more than 13 years and he was the Managing Director of the Department for Machine Tools and Factory Management (IWF) from April 2011 until March 2013. Prof. Stark is member of the German Academy of Technical Sciences (acatech), the scientific societies WiGeP (Scientific Society for Product Development), Design Society and CIRP (International Academy for Production Engineering) and board member of the ProSTEP iViP association. He is also an active member of the VDI (Society of German Engineers) board Product Development and Mechatronics, the Scientific Board of Industry 4.0 as well as the expert group National Competence Monitoring.

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IIT - TU Berlin

The Department of Industrial Information Technology is engaged in the advancement of digital solutions for the improvement and the enlargement of engineering operations in the entire cycle of virtual product creation. Areas of research are the intuitive and contextual modeling, intuitively operable and functionally tangible virtual prototypes, the functional product development as well as development processes and methodologies for product design and digital factory. The most important element of the teaching concept of our field of expertise is the content of model based engineering, information technology, virtual product creation and Industrie 4.0.

Industrielle Informationstechnik

The new Engineering Intelligence

Abstract

Smart socio-technical (Product) Systems of the future will differ significantly from the mechatronic technical systems of the 90ies of the last century and the early 2000th and are also a major technology push forward to the first generation cyber-physical product service systems of the last decade. The fast-growing demands of data linkages based on edge computing, 5G connectivity, Artificial Intelligence, and the corresponding data analytic services just form one new engineering capability dimension. The second dimension deals with the new capabilities of digital model representations for technical systems related to both, functional behavior and operational execution as well as the physical and cognitive interaction with humans. This interplay requires new (digital) Engineering capabilities based on a new "engineering intelligence core". This paper and presentation contribution analyses such a dilemma and explains how the future will look like with new types of "engineering intelligence", which are currently under research and first demonstration pilots. This new upcoming competition of the latest engineering intelligence and excellence of the future is not yet widely known. It tends to be pushed out in traditional industries – the risks and drawbacks associated with such delays are evident, and the competitiveness of future industrial systems highly depends on robust and consistent progress build upon close cooperation between research/science and industry.

Keywords

Industrie 4.0; Engineering Intelligence; Digital Engineering; Product Development; Simulation; Digital Factory.

1 Introduction

Smart socio-technical (Product) Systems of the future will differ significantly from mechatronic technical systems of the 90ies of the last century and the early 2000th. They also represent a major technology push forward compared to the first-generation cyber-physical product service systems of the last decade. The fast-growing demands of data linkages based on edge computing, 5G connectivity, Artificial Intelligence (AI), and the corresponding data analytic services just form the first new engineering capability dimension. The second engineering capability dimension deals with new ways of digital model representations for technical systems related to both, functional behavior, and operational execution as well as physical and cognitive interactions with humans. This interplay requires new (digital) engineering capabilities based on a new “engineering intelligence core”. This paper and presentation contribution analyses such new challenges and explains how the future will look like with new types of “engineering intelligence”. Those types are currently under research and are subject for first demonstration pilots. This new upcoming competition of the latest “engineering intelligence and excellence of the future” is not yet widely known. It tends to be pushed out in traditional industries – the risks and drawbacks associated with such delays are evident, and the competitiveness of future industrial systems highly depends on robust and consistent progress build upon close cooperation between research/science and industry.

2 Approach

This paper and presentation are based on both, the findings of a workshop on the topic of "required skills for the simulation of *Industrie 4.0* intelligence" and in addition on the considerations on engineering assistance systems. The workshop was conducted with 17 experts from industry and academia and was guided by the two main research questions:

- Research Question 1: What existing modeling and simulations are sufficient to capture and predict what level of I4.0 capabilities?
- Research Question 2: Which modeling and simulation capabilities (coupled, hybrid, or comprehensive) have not been researched and developed scientifically, or have been researched and developed little or not sufficiently?

The consideration of engineering assistance systems is based on various research projects on the design of assistance systems and have been validated in various studies through prototypical implementations and expert interviews.

3 Results

In the topic "Required skills for the simulation of *Industrie 4.0* intelligence", the following findings were obtained: [1]

RQ 1: What existing modeling and simulations are sufficient to capture and predict what level of I4.0 capabilities?

- For some isolated I4.0 capabilities, existing modeling and simulation theories are sufficient, including for planning value streams or recognizing patterns in the behavior of I4.0 systems. For example, predictive maintenance based on the recording and visualization of states of an *Industrie 4.0* solution using existing modeling approaches to geometry, information and state models is already increasingly being implemented in industry.

- At a higher level, there is a lack of linkage between the various modeling and simulation approaches; among other things, semantic models must be more strongly integrated into simulations for the assignment of real data to the relevant context. For complex approaches, especially when integrating people into simulations and directly into Industrie 4.0 system solutions, existing approaches to modeling and simulation, such as to competency models or cognitive models, are currently not sufficiently researched. [2]

- To simulate complete Industrie 4.0 intelligences, the coupling of modeling and simulation approaches is essential. The coupling of simulations via co-simulations is currently being increasingly implemented in industry. However, these are still time-consuming to create and thus only deliver limited benefits, which means that they are not yet sufficiently suitable for the implementation of complex Industrie 4.0 intelligences (for highly networked and self-aware functions).

RQ 2: Which modeling and simulation capabilities (coupled, hybrid, or comprehensive) have not been researched and developed scientifically, or have been researched and developed little or not sufficiently?

- Simulation coupling capabilities are increasingly considered in co-simulations, but require deeper industrialization towards more overarching linkable model classes and simulations. Co-simulations have been thoroughly researched and standardized so far, for example, with FMI and OPC UA standards, but have not yet arrived throughout the industry. Here, above all, the development of easy-to-use solutions is a crucial issue.

- For hybrid simulations, semantic linking of data is a major research topic, as this is only implemented in tailored individual cases. Hybrid simulations are in the process of fundamental exploration, for example, in the hybridization of agent-based and event-discrete simulations. However, even here, there is still a lack of semantic linking of the

data in order to be able to perform context-sensitive simulations end-to-end. Without this aspect, the development and industrialization are not achievable.

- Comprehensive simulations are not to be found at all so far: Here, there is a lack of a more abstract representation of the considered overall system for the simulation, e.g. via corresponding system models. The only use case so far are data exchange models, for example using the STEP standard for geometry models. For comprehensive neutral simulations, there is a lack of a more abstract representation of the considered overall system for the simulation, for example via corresponding system models. On the basis of these models and simulations, many aspects of the general optimization potentials can be addressed later, such as the linking of simulations and models.

Future development capabilities will require new types of engineering intelligences that can be implemented via digital assistance systems. Cognition-supporting assistance systems are used to provide information to support engineers in their decision-making processes (Figure 1). [3, 4] For this the context of data has to be considered and contextualized in order to provide the right information to the right person at the right time. [5] Assistance systems can carry out this task and thus support the activities of engineers. A distinction is made between two basic types of engineering activities:

- Direct activities: „traditional engineering“ (e.g. planning, modelling, designing, simulating, evaluating)
- Indirect activities: „searching and finding“ (e.g. obtaining information, sorting, structuring, documenting, reporting)

Direct Engineering Activities have received a lot of assistance in the last decades, however also indirect Engineering activities become more important in a data-driven engineering environment and hence need additional assistance systems.

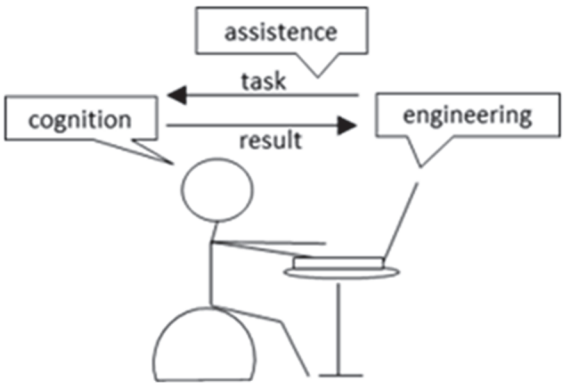

Figure 1: Components of a digital engineering assistance system

It can be concluded that the degree of support required by an assistance system depends on the task at hand. [6] For an increased degree of support, correspondingly more data and/or higher-quality data is required (Figure 2) [3]. The range of engineering support extends from low (manual activities in which humans carry out all decisions and actions themselves) to high (decisions and execution autonomously by a computer).

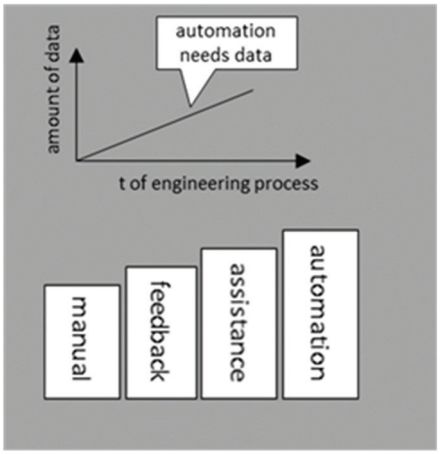

Figure 2: Higher level of engineering support require more and better data

4 Discussion

Based on the present level of research and development regarding “required skills for the simulation of *Industrie 4.0* intelligence”, recommendations were made for further consideration of the topic. These recommendations were categorized based on who is best suited to carry out this research. Basic research (university research) addresses topics that lack methodological foundations. Two major research topics for this type of research are:

- Cognitive models (in addition to AI models) that can represent human behavior are also increasingly required. Here, it is necessary to find efficient ways of creation and integration.
- Architectural models are not executable by definition, which means that the interactions of the Industrie 4.0 solution cannot be simulated. The task is to determine how static system models can be converted into dynamic system models or component-specific simulations and coupled with them.

Collaborative research (consortium research with industry partners) researches topics with good fundamentals but a lack of industrial application. Hence, the following aspects should be considered here in the future:

- Current models and tools need to create more ways to incorporate humans as part of the influences on the problem

- Combining real (physical/operation) data with the simulation data to optimize the simulation and improve the prediction quality needs to be explored.

Finally, collaborative research in clusters (cross-industry and cross-university research organized in clusters) considers overarching challenges in industry and should focus on the following:

- Uniform semantics must be achieved between *Industrie 4.0* solutions and the associated models. This allows solutions to be exchanged efficiently and their functions to be expanded.
- Preparation of training data for the use of AI in I4.0 intelligence and simulations is another cross-industry research aspect.

From these research avenues, topics for further research directly emerge regarding the engineering assistance needed in the development of new intelligences. These include the following issues. Fundamental technical and data induced parameters that are decisive in the development of intelligent solutions must be researched further. In addition, it is not yet clear what level of digitization and virtualization is appropriate to support engineers in their new engineering activities and types of collaboration. This is accompanied by research on the quantity and quality of data required for the development of these new engineering intelligences. This is also linked to new engineering methods and tools required, since products and their intelligences also must be further developed for in-situ field development, which means shorter iterative development cycles. Finally, one driver here will be entirely new engineering activities associated with new types of data and models.

5 References

[1] Acatech, “Benötigte Fähigkeiten zur Simulation von Industrie 4.0-Intelligenzen”, Acatech, 2021.

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[5] S. Gogineni, K. Lindow, J. Nickel, and R. Stark, "Applying Contextualization for Data-Driven Trans-formation in Manufacturing", in IFIP Advances in Information and Communication Technology, vol. 592, Advances in Production Management Systems. Towards Smart and Digital Manufacturing, B. Lalic, V. Majstorovic, U. Marjanovic, G. von Cieminski, and D. Romero, Eds., Cham: Springer International Publishing, 2020, pp. 154–161.

[6] A. Parasuraman and D. Grewal, "The Impact of Technology on the Quality-Value-Loyalty Chain: A Research Agenda", Journal of the Academy of Marketing Science, vol. 28, no. 1, pp. 168–174, 2000, doi: 10.1177/0092070300281015.

The New Engineering Intelligence

25th International Seminar on High Technology

Technische Universität Berlin
Industrielle Informationstechnik
Fakultät für Verkehrs- und Maschinensysteme (Fakultät V)
Institut für Werkzeugmaschinen und Fabrikbetrieb
Fachgebiet Industrielle Informationstechnik
Prof. Dr.-Ing. R. Stark

Introduction of Prof. Dr.-Ing. Rainer Stark

- Study of Mechanical Engineering at Ruhr-University Bochum
- Integrated 1-year study at Texas A&M University, USA, in Mechanical Engineering (research projects with NASA)
- Research assistant at the Chair of Design Technology / CAD in the Technical Faculty of the Saarland University in Germany
- System Engineer within Body Engineering in Ford of Europe
- (Senior) Technical Specialist CAD, Product Modeling and Product Information Management in Ford of Europe
- Technical Leader / European Manager Virtual Product Creation & Methods in Ford Motor Company (incl. responsibilities for Jaguar, LandRover, Volvo and Mazda)
- Director Industrial Information Technology at the Berlin Institute of Technology (School of Mechanical Engineering and Transport Systems, Institute for Machine Tools and Factory Management)
- Active membership in WiGeP, Scientific Society for Product Development, member of the VDI advisory board for Product and System Development, member of the Industrie 4.0 Research Council, Chairman of CIRP STC Dn, Board Member of the prostep ivip association.

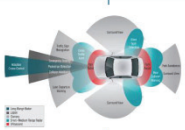
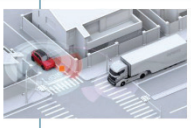
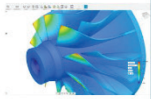
TEXAS A&M UNIVERSITY
UNIVERSITÄT DES SAARLANDES
Ford
Technische Universität Berlin

Agenda

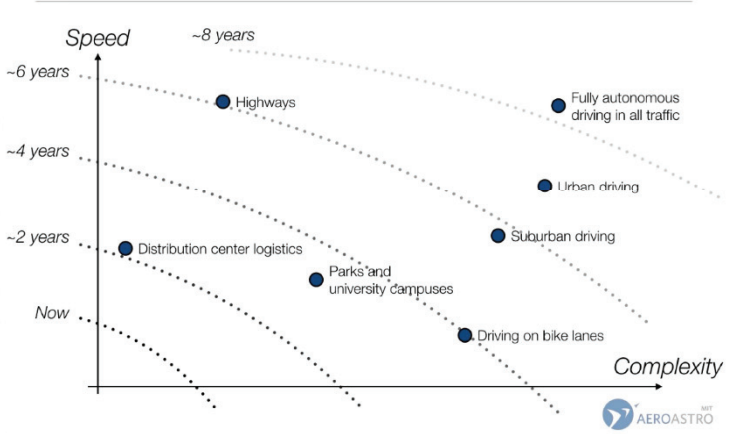
1. **Technology innovations drive product and engineering capabilities**
2. Industrie 4.0 intelligence and related simulation needs
3. Engineering assistance leveraging new engineering intelligence

Major technology push transforming industries and engineering

Based on Nokia Bell Labs

	1G (1980s)	2G (1990s)	3G (2000s)	4G (2010s)	5G (2020s)	6G (2030s)
Mobile Access	Analog	GSM < 2 GHz	UMTS < 2 GHz	LTE < 6GHz	5G < 100GHz	6G< 1THz
Compute Platform						
Increasing connectivity and intelligence in products						
CAD Capabilities						?

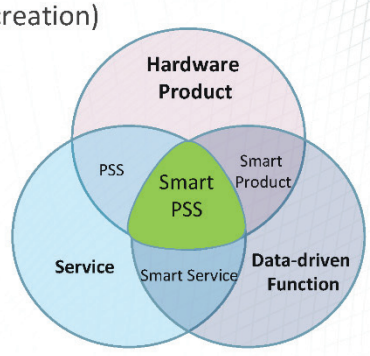
The future of autonomous driving will arrive gradually and does require new in-situ engineering capabilities (prediction, context awareness, SW adaption …)



Source: MIT AEROASTRO

Smart Product-Service Systems (Smart PSS) will arise as new business models (data services become essential for new digital value creation)

Video: Intel



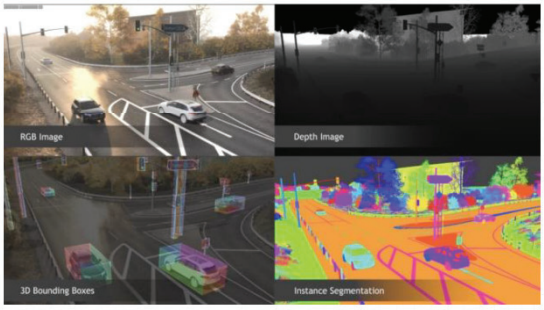
1 „MECHANIZATION“ | 2 DIGITIZATION | 3 FUNCTION EXTENSION | 4 SYSTEM OF SYSTEMS

Example (Waymo): Autonomous driving requires intense simulation capabilities

Engineering Goal:
- Designing the system to handle all types of driving tasks – intelligence to detect the high risk scenarios
- Handle (all) situations safely without human driver need for intervention – core focus on sensor models

Benefits of simulation
- Create unique scenarios from scratch
- Use logs from driving
- Create variations of initial scenarios
- Establish growing system intelligence

25k	10M	>7Bn
virtual cars, running 24/7	simulated miles per day	Miles in Simulation



Different views on simulated driving environments to obtain synthetic data to engineer reliable driving intelligence

Sources: Waymo

Agenda

1. Technology innovations drive product and engineering capabilities
2. **Industrie 4.0 intelligence and related simulation needs**
3. Engineering assistance leveraging new engineering intelligence

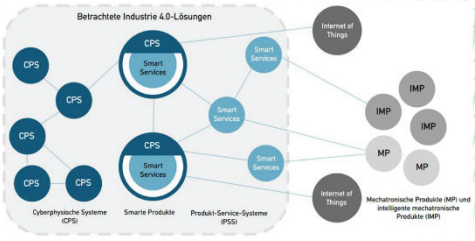
Definition of Industrie 4.0-Intelligence, -capabilities and -competencies

- **Industrie 4.0 competencies** are skills and abilities reserved for people that are used or required in the context of Industrie 4.0
- The potentials created by and for Industrie 4.0 solutions are referred to as **Industrie 4.0 capabilities** and can be found, among other things, in the area of planning, operating and securing I4.0 solutions
- **Industrie 4.0 intelligences** refer to capabilities of Industrie 4.0 system solutions which make it possible to achieve extended goals with regard to the compatibility of output, efficiency, resilience and sustainability (with the help of cyber-physical systems, e.g. in the form of digital twins and smart products).

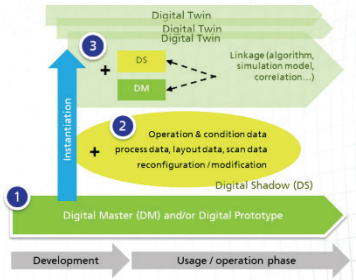
Intelligence is the ability of a system to achieve its goals under conditions of uncertainty. Rzevski (2003)

Source: Workshop – Simulation of I4.0 Intelligence (Fraunhofer IPK)

Example concept for Industrie 4.0 intelligence: matrix production (KUKA AG)



- Manufacturing (assembly) organized in flexible production cells
- Material and part delivery by AGV (Automated Guided Vehicles)
- Dynamic, flexible assignment of cell usage per production step and work order priority as well as maintenance situations
- Real-time preparation of CPS enabled work cell PLC and robot controls and in-situ quality inspection control and analytics
- Active leveraging of real time Digital Twins and hybrid AI



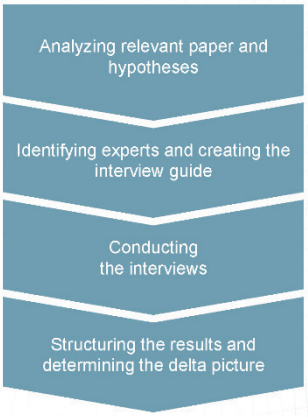
Required engineering capabilities to simulate Industrie 4.0 intelligences

- As a result of transformative digitization, added value is no longer created primarily by a singular cyber-physical product or production system, but by their **synergetic and dynamic networking to and interaction with higher-value, intelligent systems**.
- The ability of these systems to enable new forms of interaction, control, analysis and further development of technical systems in interaction with humans is referred to as **Industrie 4.0 intelligence**
- The **realization of Industrie 4.0 intelligences** requires socio-technical design, analysis and simulation with regard to the enabling of interactions, controls, and the performance of technical systems in closely coordinated interaction with competencies and capabilities of humans as part of new and further development as well as ongoing system operation.

Source: Workshop – Simulation of I4.0 Intelligence (Fraunhofer IPK)

Approach to identify missing capabilities to simulate I.4.0 Intelligences

- Expert surveys were conducted to identify missing capabilities according to the following process:
  - Analysis of the state of the art work on modeling and simulation capabilities in the context of Industrie 4.0
  - Experts with practical experience were identified via scientific contributions and public project presentations, e.g. interviews
  - Interviews were conducted with the aim of determining simulation methods used in practice in the context of I4.0 and targeted I4.0 capabilities, as a basis for I4.0 intelligence
  - The interviews were evaluated using a qualitative content analysis: categorization of named targeted capabilities, general optimization potentials as well as existing and required models and simulations



Source: Workshop – Simulation of I4.0 Intelligence (Fraunhofer IPK)

Findings from the study *Required simulation capabilities for I4.0 Intelligence (1/2)*

Research Question 1: Which existing model and simulation types are sufficient to capture and predict which level of I4.0 capability?

For certain isolated I4.0 capabilities existing modeling and simulation theories are sufficient, including planning of value streams or recognizing patterns in the behavior of I4.0 systems

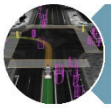
At comprehensive levels there exist lacks of linkages between various modeling and simulation approaches; e.g. semantic data models must become compatible to parameter driven simulations in order to couple real world data with upfront predictive engineering

To simulate complete Industrie 4.0 intelligences, the coupling of different types of modeling and simulation approaches is essential

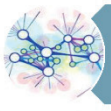
Source: Workshop – Simulation of I4.0 Intelligence (Fraunhofer IPK)

Findings from the study *Required simulation capabilities for I4.0 Intelligence (2/2)*

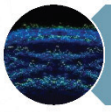
Research Question 2: Which modeling and simulation capabilities (coupled, hybrid, or comprehensive) have not been researched and developed yet, not sufficiently or scientifically profound enough ?



Simulation coupling capabilities are increasingly considered in co-simulations, but require deeper industrialization exposure towards overarching model classes and simulations

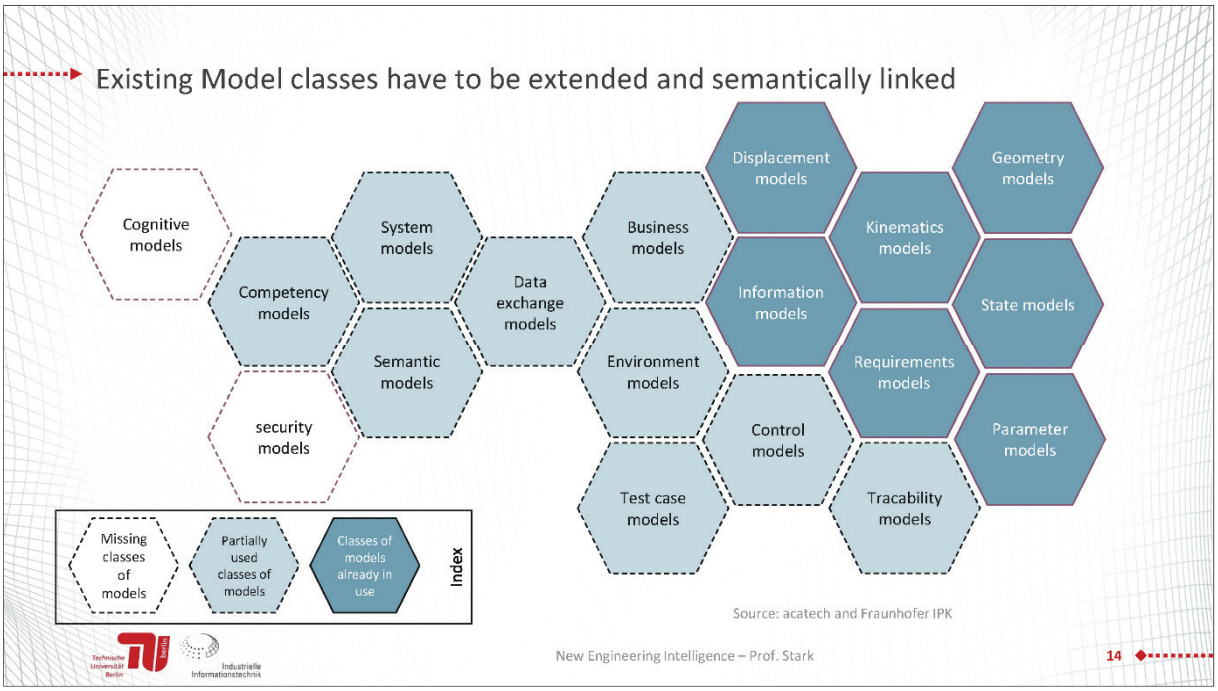


For hybrid simulations, semantic linking of data is a major research topic, as this is only implemented in tailored individual cases today



Comprehensive simulations are found rarely yet: there is a lack of a abstract representations of considered Industrie 4.0 systems to ease their simulations, e.g. via corresponding system models.

Source: Workshop – Simulation of I4.0 Intelligence (Fraunhofer IPK)


Existing Model classes have to be extended and semantically linked
Cognitive models
System models
Competency models
Data exchange models
Business models
Displacement models
Geometry models
Kinematics models
Information models
State models
Semantic models
Environment models
Requirements models
security models
Control models
Parameter models
Test case models
Tracability models
Missing classes of models
Partially used classes of models
Classes of models already in use
Index
Source: acatech and Fraunhofer IPK
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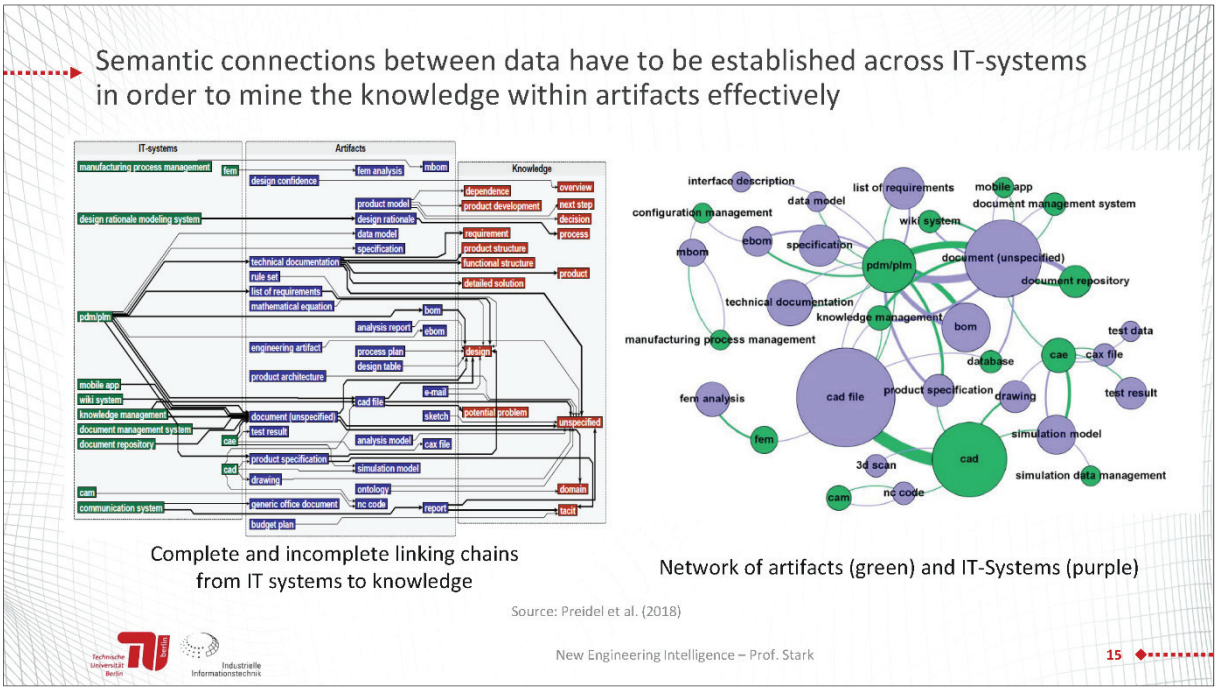
Semantic connections between data have to be established across IT-systems in order to mine the knowledge within artifacts effectively
IT-systems
Artifacts
Knowledge
Complete and incomplete linking chains from IT systems to knowledge
Network of artifacts (green) and IT-Systems (purple)
Source: Preidel et al. (2018)
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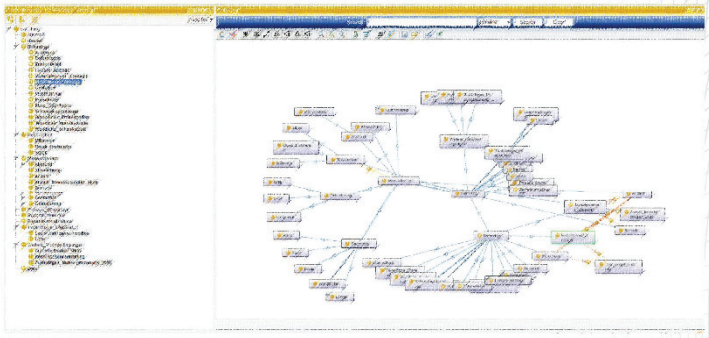
Semantic Information and Data Modeling for AI Applications

- Linking of expert knowledge and process parameters
- Creating semantic information models by mapping
  - interrelationships
  - dependencies
  - interactions

  to activities, information sets required for them, and their underlying data types
- Basis for semantic linking of existing data, e.g. for AI-supported damage assessment of technical systems



Source: IIT (Industrial Information Technology) TU Berlin

Recommendations for the future of simulating Industrie 4.0-Intelligences

Based on the present level of research and development, the following recommendations were made for future research:

- **Basic research**: topics that lack methodological foundations, including.
  - Cognitive modeling of human behavior
  - Conversion of static architectural models into dynamic models for simulation of the entire system
  - Establishing more detailed classifications and typologies of anticipated Industrie 4.0 intelligences
- **Collaborative research**: topics with good fundamentals and lack of industrialization
  - Integration of humans as part of simulation
  - Combining real world data and simulation data to optimize simulations
- **Collaborative research in research clusters**: overarching challenges in industry
  - Unified semantics between I4.0 solutions and associated models
  - Preparation of training data for the use of AI in I4.0 intelligence and simulations

Agenda

1. Technology innovations drive product and engineering capabilities
2. Industrie 4.0 intelligence and related simulation needs
3. **Engineering assistance leveraging new types of engineering intelligence**

New types of engineering intelligence are necessary to build intelligent products of the future

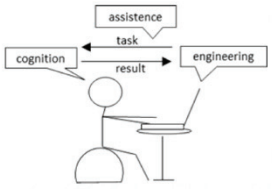
Future key engineering tasks

Modelling and simulating the necessary components to create I4.0 Intelligence	requires	New types of Engineering Intelligence to assist engineers with respect to:
Linking data, artifacts and simulations semantically	requires	
Managing the compute and software infrastructure	requires	hybrid interaction modes, in-site model updates, semantic reasoning …

Video: Ironman

First level approach: intelligent assistance systems are needed for increasingly challenging engineering tasks

- Distinction of Engineering Activities in:
  - ***Direct activities***: „traditional engineering“ (e.g. planning, modelling, designing, simulating, evaluating)
  - ***Indirect activities***: „searching and finding“ (e.g. obtaining information, sorting, structuring, documenting, reporting)
- **Direct Engineering Activities** have received significant attention of basic assistance in the last decades
- **Indirect Engineering activities** become more important in a data-driven engineering environments and need better assistance



Assistance for digital engineering activities

Definition of assistance

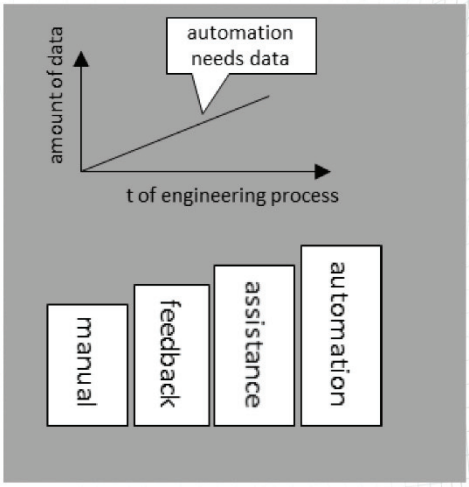
Cognition-supporting assistance systems are used to provide information to support employees in their decision-making processes.

Source: Stark, Brandenburg, Lindow (2021); Apt (2018)

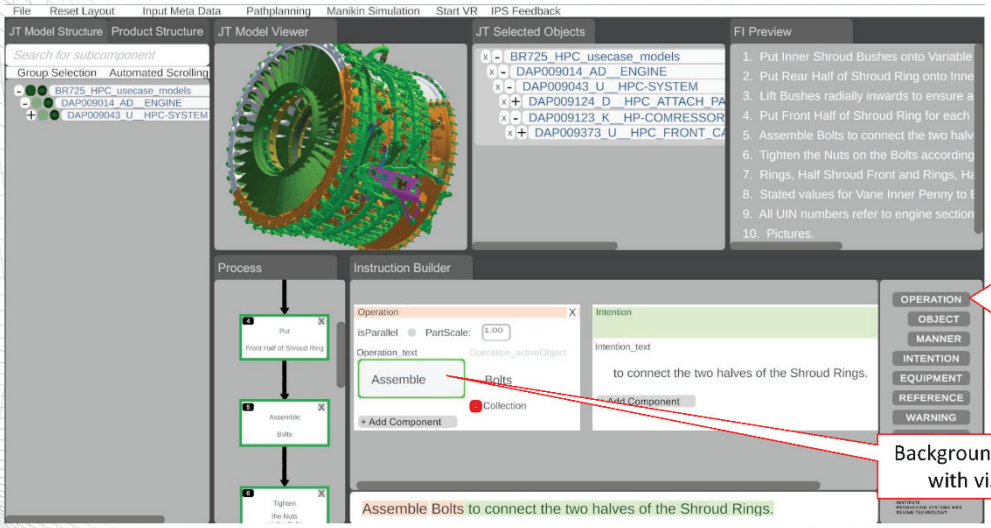
Different types of engineering tasks require respective levels of assistance

- Boundary conditions for assistance levels
  - Availability, quantity and quality of data
  - depends on the maturity and number of product artefacts already developed
- LOW level of assistance (“The computer offers no assistance: human must take all decisions and actions”)
  - E.g. design of new components and their technical documentation
- to HIGH level of assistance (“The computer decides everything, acts autonomously, ignoring the human.”)
  - Finding interrelationships in the different product life cycle phases

Source: Stark, Brandenburg, Lindow (2021), Parasuraman (2000)

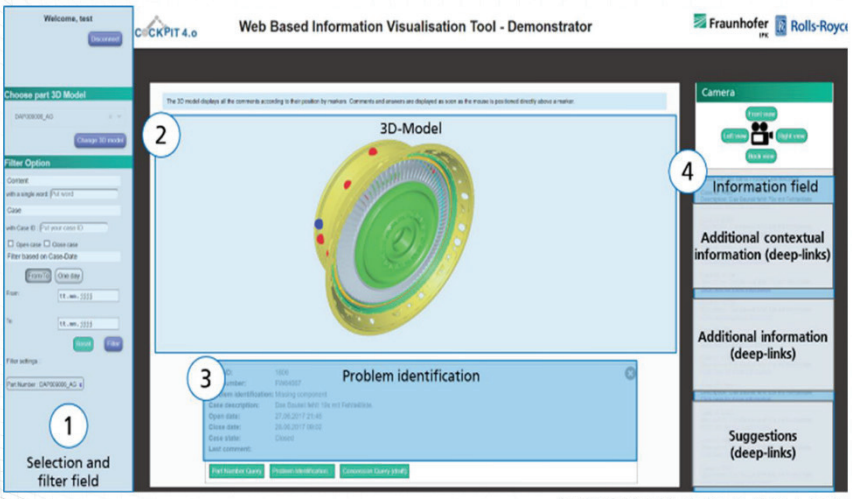


Example: Assistance for direct Engineering Activities: Creating digital fitting Instructions



Source: Stark, Brandenburg, Lindow (2021).

Example: Assistance for direct Engineering Activities: information search, data analysis and decision-making support



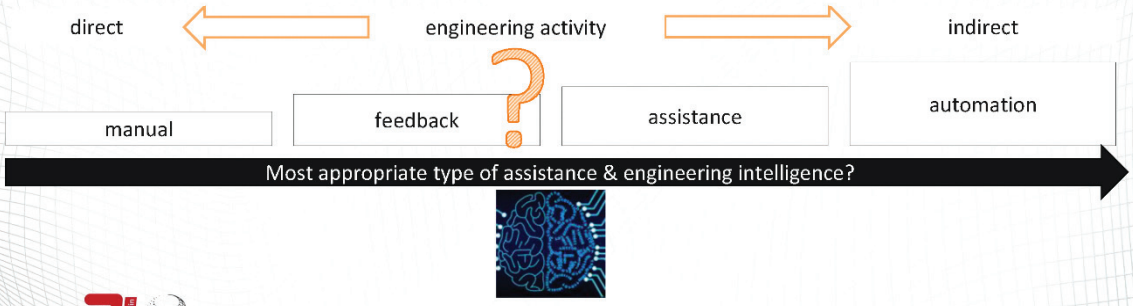
(1) affected parts can be selected via filters
(2) corresponding 3D model is visualized
(3) problem that has occurred is marked and described
(4) context-sensitive information reveals possible solutions to the problem and support the decision-making process

Source: Gogineni S., Lindow K., Nickel J., Stark R. (2020)

Research implications for engineering assistance & intelligence

Future research outlook

- Increasing knowledge about parameters influencing intelligence in engineering
- Level of digitization and virtualization needed to create intelligence
- Number and quality of available and reliable data to guarantee robust intelligence
- Rethinking necessary to generate intelligence for appropriate engineering methods and tools
- How to embrace product life cycle experience and intelligence via Digital Twins?
- New types of engineering tasks might arise



Contact

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Director of the Chair for Industrial Information Technology
at the Technische Universität Berlin

Phone: +49 30 314 25414
E-Mail: rainer.stark@tu-berlin.de

Prof. Dr.-Ing. Sandro Wartzack

Prof. Dr.-Ing. Sandro Wartzack is full professor at the Friedrich-Alexander University of Erlangen-Nuremberg. After completing his studies in production engineering in 1994, he carried out research as a research assistant in virtual product development and awarded his doctorate in 2000. In the subsequent industrial activity in the automotive industry, he held various management positions, most recently as head of simulation and knowledge management. Since 2009 he has the Chair of Engineering Design at Friedrich-Alexander-University Erlangen-Nuremberg. His research focuses on the broad field of Digital Product Development with emphasis on artificial intelligence in product development, design assistance systems, tolerance simulation, and analysis with digital human models. Prof. Wartzack is a member of the board of directors of the Scientific Society for Product Development, a member of the German Academy of Engineering Sciences, and a member of the board of the German Research Foundation in the fields of design, machine elements, and product development. Furthermore, Prof. Wartzack is the scientific editor of the trade journal Konstruktion, guest editor of the Design Science Journal and on the scientific committee of numerous scientific conferences.

✉ wartzack@mfk.fau.de

KTmfk - FAU

The mission statement of the Department of Engineering Design (KTmfk) of the Friedrich-Alexander-Universität Erlangen-Nürnberg is “Design for Environment, Health and Safety”. The KTmfk therefore works on the development of optimal producible, resource efficient and robust systems which address the user’s needs in all research activities at KTmfk. These activities include methods and tools for optimized and shortened CAx processes (CAD, CAE, KBE, DHM), for dimensional management as well as usercentered design. A further focus is on practical examinations on the several test facilities at the institute with emphasis on roller bearings and tribological PVD/PACVD coatings. The KTmfk is eagerly interested in knowledge transfer between university and industrial practice. Opportunities for cooperation can be found in all fields of research of the institute. KTmfk also offers a variety of well-coordinated and modern university courses for the design education of students from engineering degree programs.

Digital Engineering - towards a digital-first and data-driven paradigm in product development

Abstract

This talk will give an overview in product development during the course of time. Starting from empirical studies conducted in product development research, the application of data-driven methods is discussed. It is shown how Data Mining approaches aid modern product design in extracting design principles. Coming from empirical design rules, Data Mining can enhance those rule-based approaches even further. This talk will give insights in how the digital twin is pushing those boundaries in the future. Lastly, possible approaches for a true digital twin based on holistic data integration are presented.

Keywords

Data-driven-engineering; Digital-Twin; Engineering Workbench.

FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG
FACULTY OF ENGINEERING

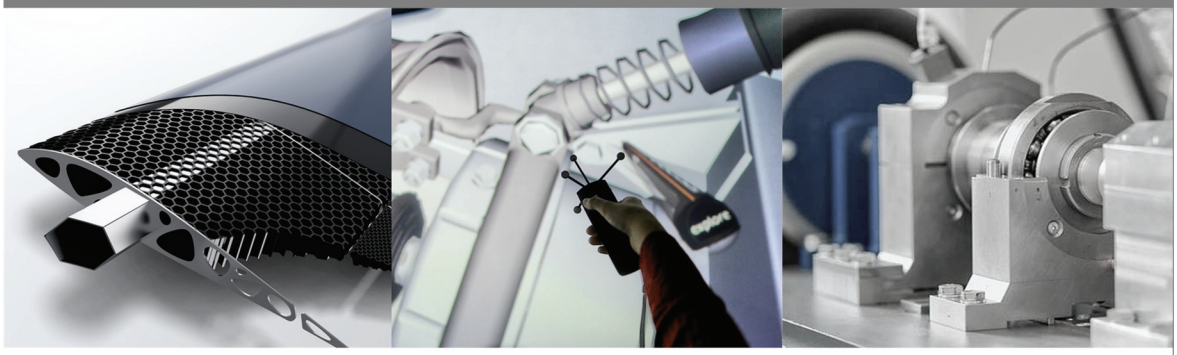
Engineering Design
Prof. Dr.-Ing. Sandro Wartzack

KT mfk

Digital Engineering

towards a digital-first and data-driven paradigm in product development

Prof. Dr.-Ing. Sandro Wartzack



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FACULTY OF ENGINEERING

Engineering Design
Prof. Dr.-Ing. Sandro Wartzack

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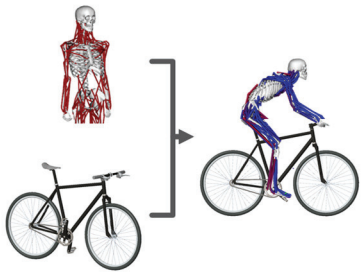
Outline

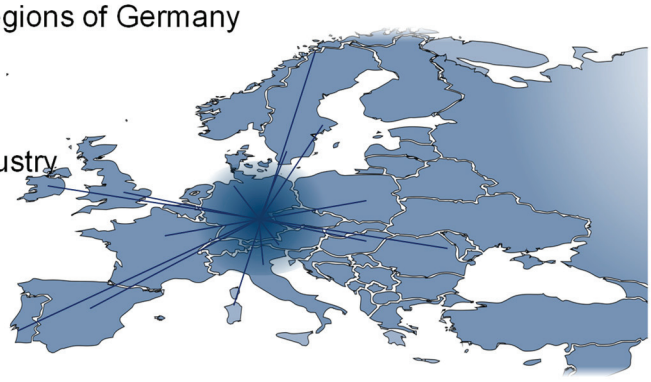


- Chair of Engineering Design
- Digital Engineering and Digital Twin
- The Concept of Digital Twin Couples
- Examples of Digital Engineering in User Centered Design
- Outlook

Engineering Design
Location and focal topics

...in the center of the metropolitan region of Nuremberg
...in one of the industrially strongest regions of Germany
...in one of the most innovative regions of Germany

- Focal topics:
  - Automotive
  - Mechanical Engineering
  - Heart of rolling bearing industry
  - Energy
  - Electrical engineering
  - Medical technology



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Engineering Design
Sites in Erlangen and Nürnberg

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Engineering Design
Our team
Lehrstuhl für
Konstruktionstechnik
Friedrich-Alexander-Universität Erlangen-Nürnberg
Prof. Dr.-Ing. Sandro Wartzack
KT
mfk

7 Degree Courses
2 000 Students
25 Lectures
Engineering Education

Member of important scientific societies
100 B.Sc. / M.Sc. theses
4 Ph.D. theses
30 peer-reviewed publications
Research

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FACULTY OF ENGINEERING
Engineering Design
Prof. Dr.-Ing. Sandro Wartzack
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Chair of Engineering Design
Virtual Product Development and Design Methodology
Machine Elements and Tribology
Lightweight Design
3

Engineering Design

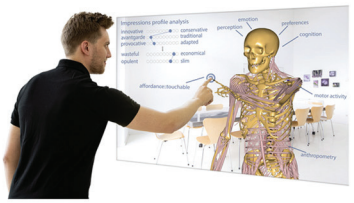
Research group virtual product development and design methodology

Digital Engineering

Holistic use of data from all lifecycle stages for improved engineering by machine learning and data analytic approaches

Dimensional Management

Tolerance analysis and variation simulation as well as tolerance-cost optimization and process-oriented tolerancing



User Centered Design

Integration of digital human models into virtual product engineering

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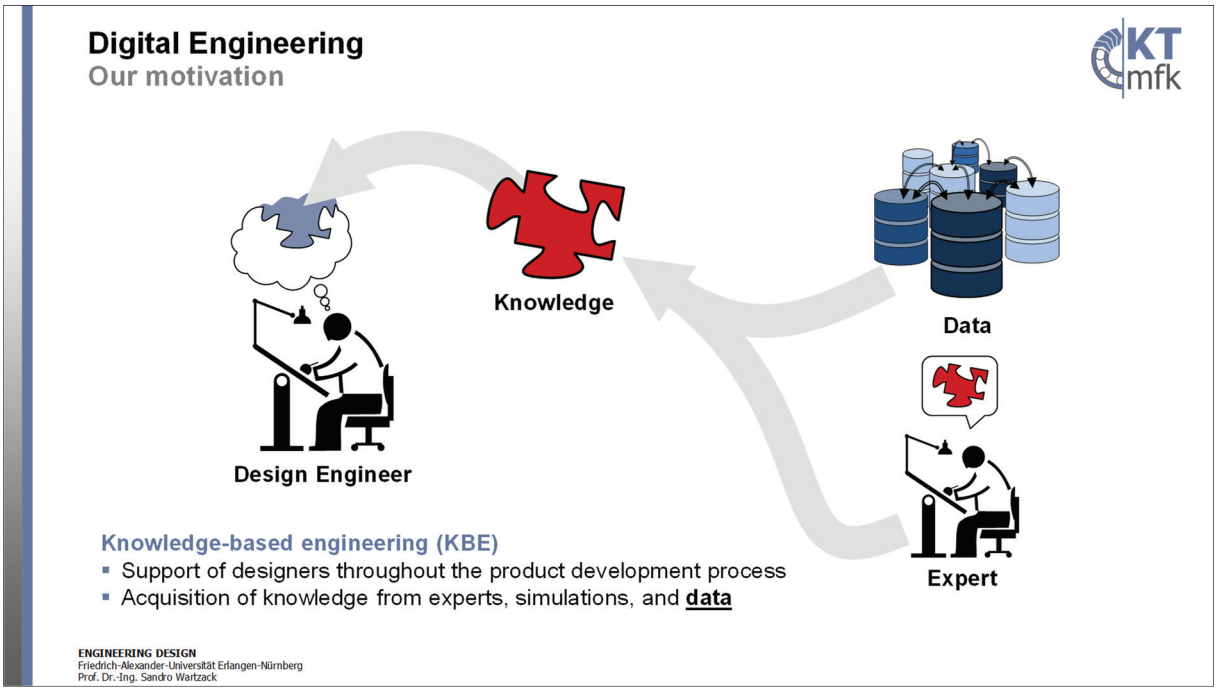
Digital Engineering
Our motivation
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Knowledge
Data
Design Engineer
Expert
Knowledge-based engineering (KBE)
Support of designers throughout the product development process
Acquisition of knowledge from experts, simulations, and data
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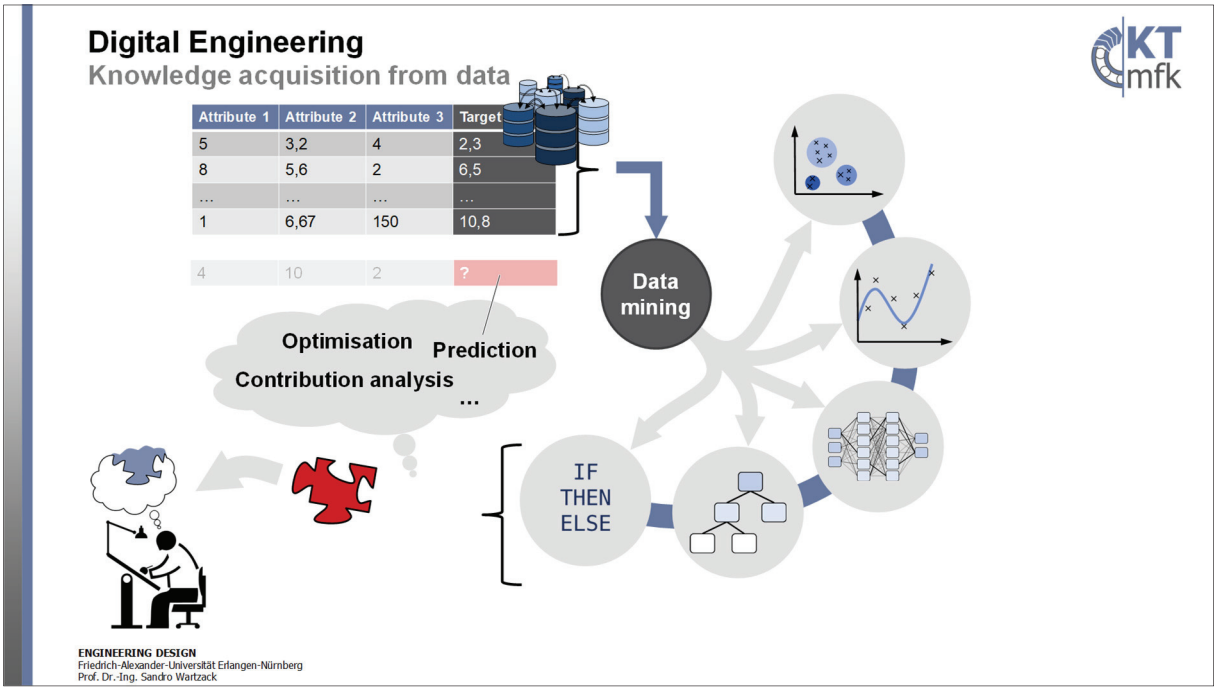
Prof. Dr.-Ing. Sandro Wartzack


Digital Engineering
Knowledge acquisition from data
KT mfk
Attribute 1
Attribute 2
Attribute 3
Target
5
3,2
4
2,3
8
5,6
2
6,5
1
6,67
150
10,8
4
10
2
?
Data mining
Optimisation
Prediction
Contribution analysis
...
IF
THEN
ELSE
ENGINEERING DESIGN
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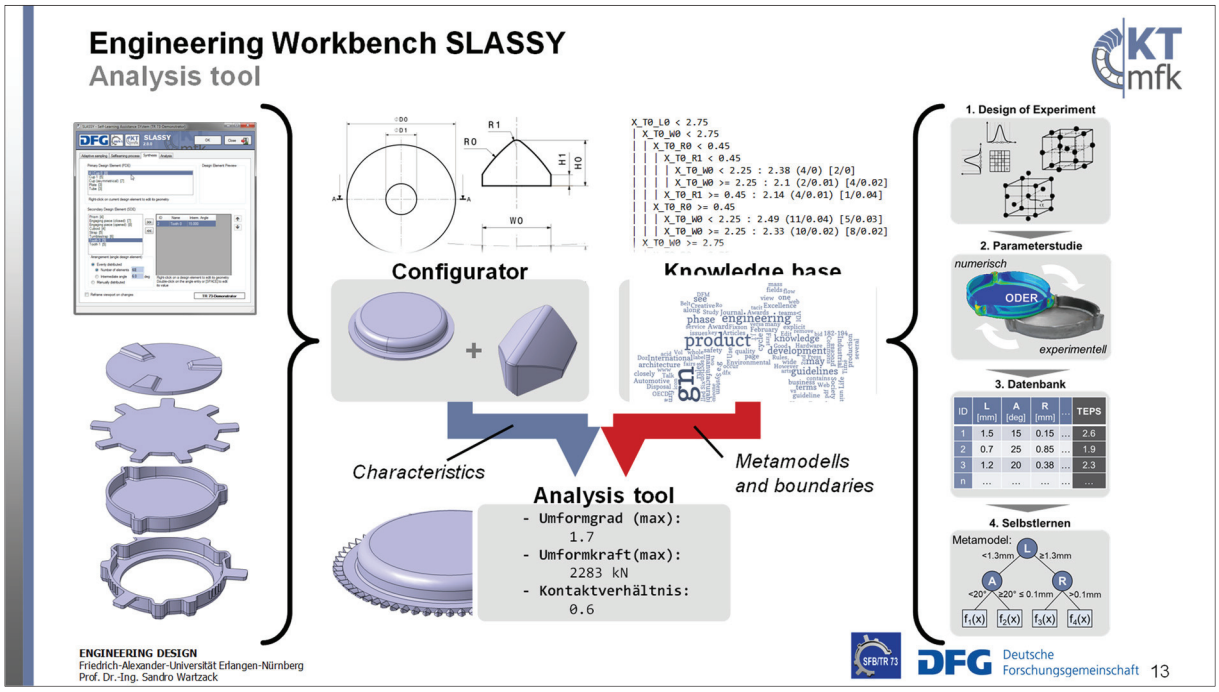
Engineering Workbench SLASSY
Analysis tool
Configurator
Knowledge base
Characteristics
Metamodells and boundaries
Analysis tool
- Umformgrad (max): 1.7
- Umformkraft(max): 2283 kN
- Kontaktverhältnis: 0.6
1. Design of Experiment
2. Parameterstudie
numerisch
ODER
experimentell
3. Datenbank
4. Selbstlernen
Metamodel:
ENGINEERING DESIGN
Friedrich-Alexander-Universität Erlangen-Nürnberg
Prof. Dr.-Ing. Sandro Wartzack
Deutsche Forschungsgemeinschaft
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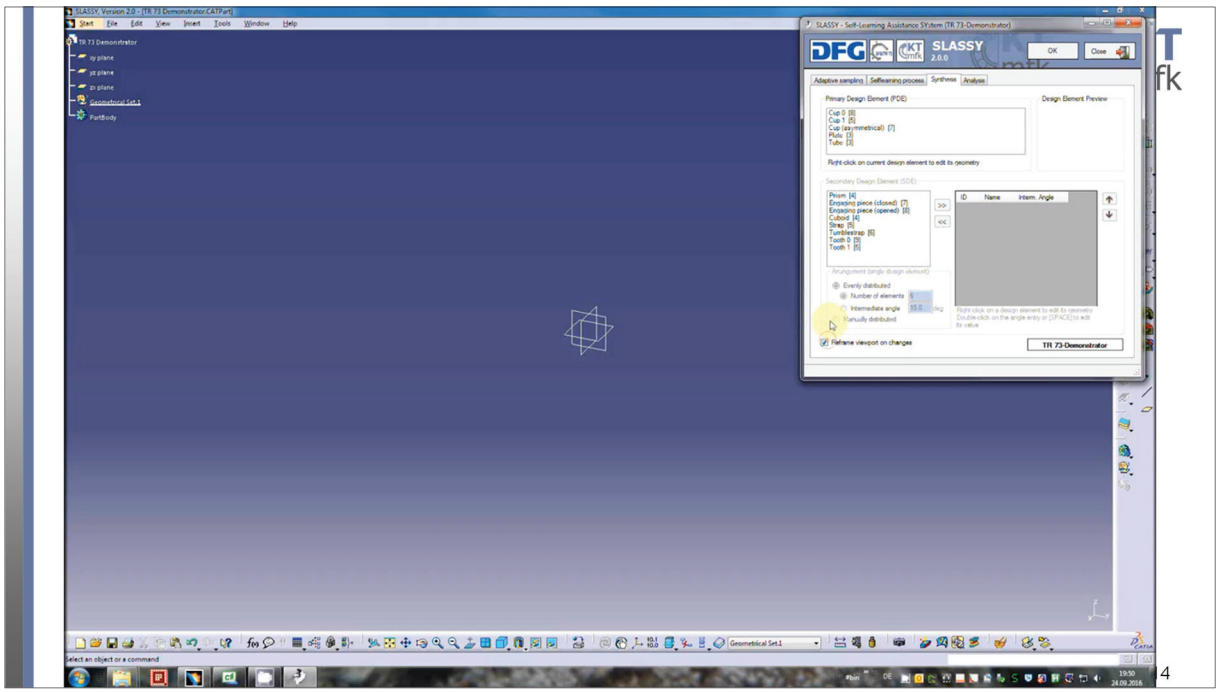
SLASSY
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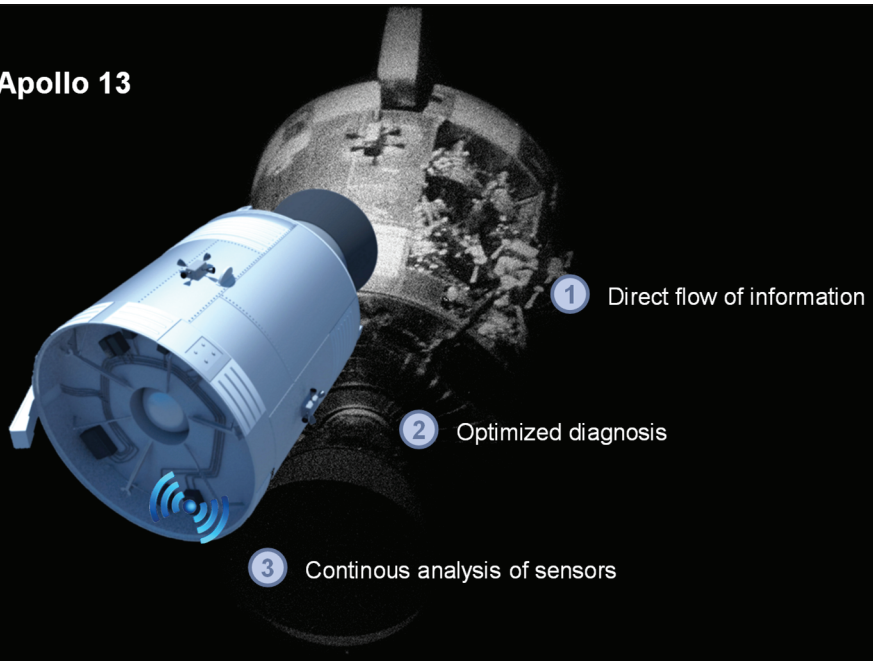
The Digital Twin

A concept which combines **as-built** vehicle components, **as-experienced** loads and environments, and other **vehicle-specific characteristics** to enable ultrahigh fidelity modeling of aircraft and spacecraft or their components throughout their service lives.

National Aeronautics and Space Administration

Apollo 13

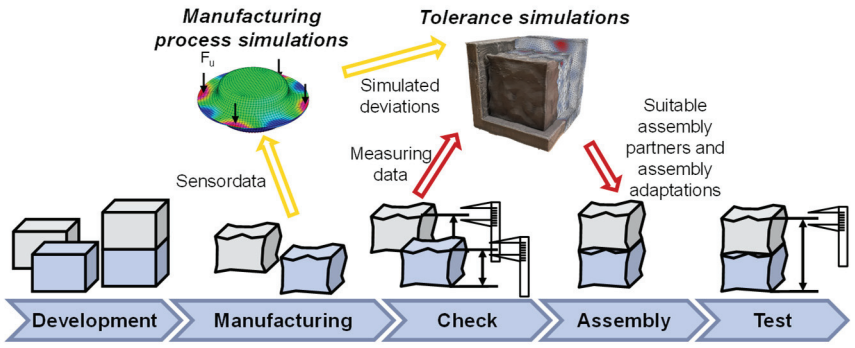


1. Direct flow of information
2. Optimized diagnosis
3. Continous analysis of sensors

Digital Twin for Tolerance Management

Identification of suitable assembly partners and assembly balancing measures

- Sensor data from manufacturing are mirrored to manufacturing process simulations
- From the results, expected geometric deviations can be predicted
- Suitable assembly partners and assembly adjustments can be identified and derived from tolerance simulations



Link to KTmfk paper

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The Future of Digital Engineering

From Digital Product and Process Engineering to Digital Use

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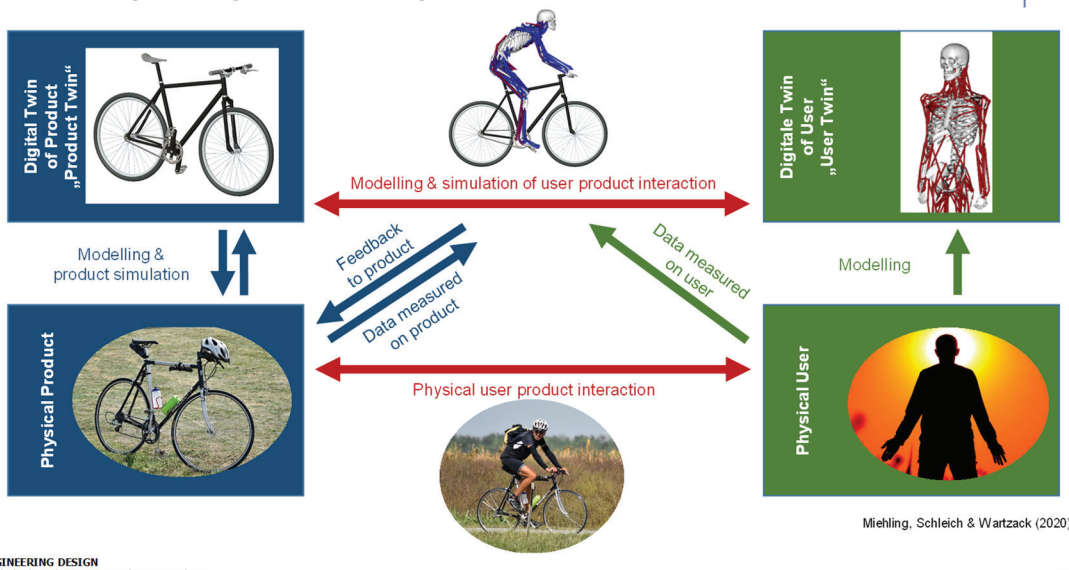
The Future of Digital Engineering
The Concept of Digital Twin Couples



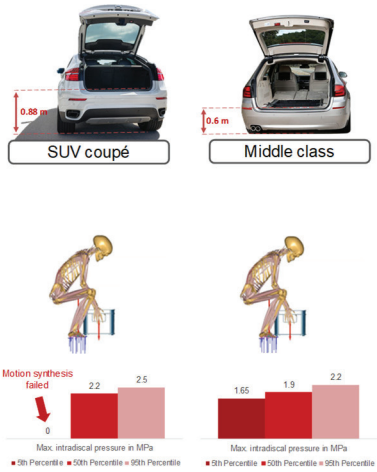
Miehling, Schleich & Wartzack (2020)

Examples of Digital Engineering in User Centered Design
Design of Mobility Products

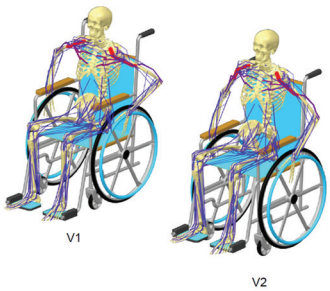
Vehicle Seat Ergonomics

- Optimization of vehicle cockpit layout
- Synthetic creation of user-product interactions

Car Boot Design



Wheelchair Design



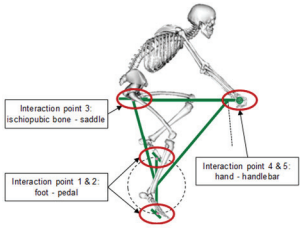
- Optimization of seat height
- Reduction of glenohumeral joint reaction forces

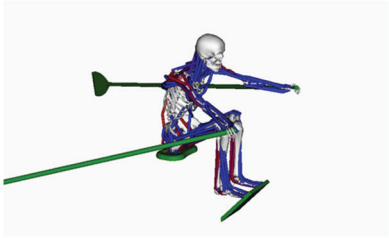
Wolf, Miehling & Wartzack (2018); Krüger (2019)

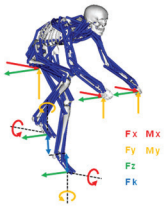
Examples of Digital Engineering in User Centered Design

Design of Sports Equipment

Bicycle & Skiff Geometry Optimization







- Kinematic & dynamic product model
- Synthetic generation of user-product interaction
- Optimization of product geometry for user groups

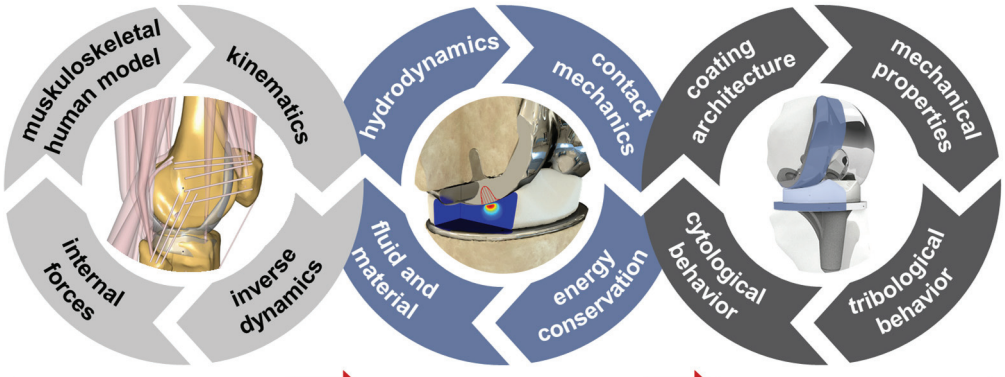
Leg Extension Machine Design

- Reduction of tibiofemoral shear forces for reduced risk of cruciate ligament rupture

Miehling (2018); Krüger (2019)

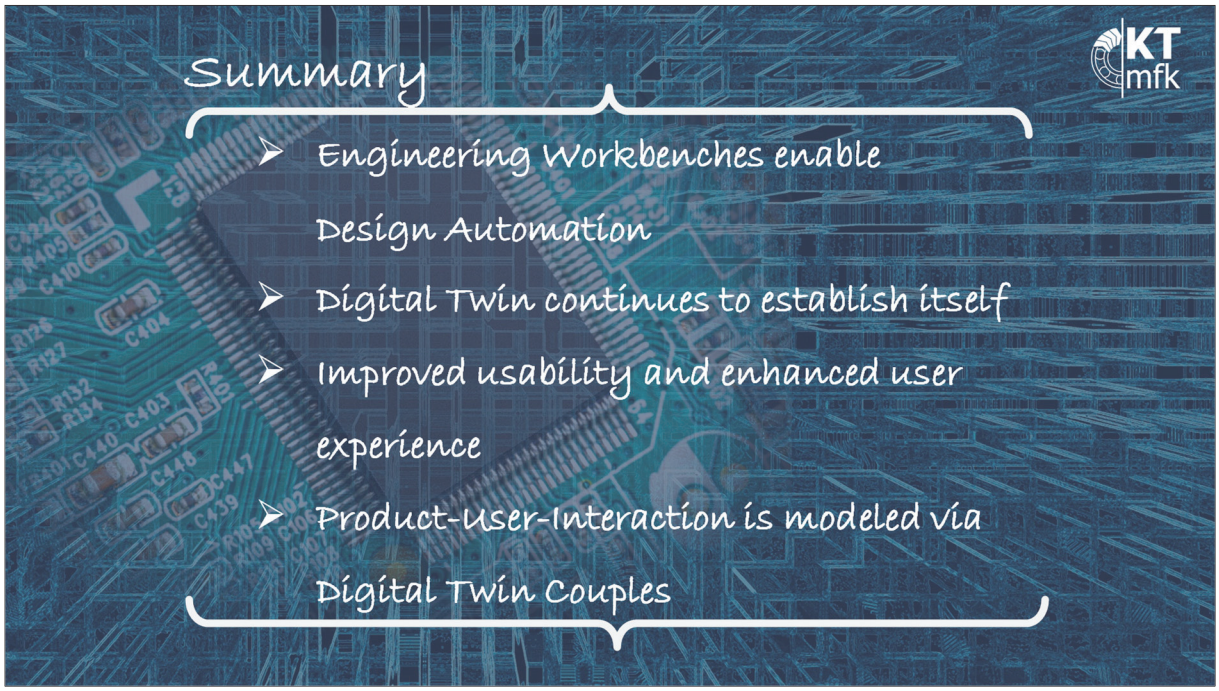
Examples of Digital Engineering in User Centered Design

Design of Amorphous Carbon Layers for Total Knee Endoprostheses



Musculoskeletal simulation ⇄ Soft, transient 3D TEHD simulation ⇄ Development of tribologically effective coating systems

Wartzack et al. (2019)



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E-Mail: wartzack@mfk.fau.de
Web: www.mfk.tf.fau.de

Engineering Design

Prof. Dr.-Ing. Sandro Wartzack

Picture sources:
"Two white chalk on blackboard", Designed by Pressfoto / Freepik
Apollo 13 Service Module NASA Scan, by Kipp Teague
Apollo Service Module, by I14R10 / TurboSquid
"Chip on a circuit board on abstract technology background", Designed by xb100 / Freepik
"Landscape with windmills", Designed by Onlyyouqj / Freepik

Eng. Paulo César R. de Carvalho Alvim

É Engenheiro Civil, formado pela Universidade Federal do Rio de Janeiro, Mestre em Ciência da Informação, formado pela Universidade de Brasília. 1982 a 1984 foi analista de projetos das áreas de transporte e energia. 1985 a 1986, foi analista técnico da Secretaria de Tecnologia Industrial do MIC, atuando nas áreas de energia e tecnologia industrial básica. 1987 a 1989 foi Técnico do CEBRAE, atuando nas áreas de apoio tecnológico aos pequenos negócios e superintendente da área de modernização e cooperação técnica. 1989 a 1990 foi Secretário Geral Adjunto do MEC. 1990 foi técnico da FINEP, atuando na área de apoio a consultoria nacional. 1990 a 1992 Coordenação de modernização tecnológica da Secretaria de Ciência e Tecnologia da PR, atuando as áreas de prospecção tecnológica, PBQP e PACTI. 1992 foi Secretário Adjunto de Governo do Governador do DF/ GDF. 1993 foi Secretário Adjunto de Ciência, Tecnologia e Meio Ambiente do GDF. 1994 a 1995 foi Presidente da FAP-DF. 1995 foi técnico da FINEP, atuando na área de negócios internacionais de tecnologia. 1996 a 1997 foi Vice-Diretor do IBICT. 1998 a 2000 foi Chefe de escritório da FINEP em Brasília. 2000 a 2002 foi Diretor do Departamento de Setores Intensivos em Mão-de-obra da Secretaria de Desenvolvimento da Produção do MDIC. 2002 a 2019, foi analista III do Sebrae Nacional, onde exerceu as funções de Gerente de Acesso a Tecnologia e Inovação, Gerente de Agronegócios, Gerente de Acesso a Mercados, Gerente de Acesso a Mercados e Serviços Financeiros, Coordenador do CRAB, Assessor da Diretoria, analista da Unidade de Cultura Empreendedora, além das participações como Conselheiro dos CDE dos Sebrae PA, AC, RO, RJ e MG e como representante do Sebrae em Conselhos e Fóruns nacionais e internacionais. Atualmente é Secretário Nacional de Empreendedorismo e Inovação do Ministério da Ciência, Tecnologia e Inovações – MCTI.

paulo.alvim@mctic.gov.br

Ministério da Ciência, Tecnologia e Inovações – MCTI

O Ministério da Ciência, Tecnologia e Inovações (MCTI) é um órgão da administração federal direta, visando a consolidação do leque de contribuições do órgão na entrega de serviços públicos relevantes para o desenvolvimento do país. O MCTI tem como missões: produzir conhecimento; produzir riquezas para o Brasil; e contribuir para a qualidade de vida dos brasileiros. Seu objetivo é ser protagonista do desenvolvimento sustentável por meio da ciência, da tecnologia e das inovações. Tem como principais valores: a ética, a transparência, o conhecimento, a integração, a efetividade, a compaixão, a valorização das pessoas, a responsabilidade socioambiental e a inovação. SEMPI - A Secretaria de Empreendedorismo e Inovação do MCTI tem como competência propor, coordenar, supervisionar e acompanhar as políticas nacionais nas áreas de: desenvolvimento tecnológico, empreendedorismo e de inovação; tecnologias estratégicas; tecnologias setoriais; tecnologias habilitadoras; internet das coisas e inteligência artificial; entre outras.

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL

Políticas de apoio à inovação e transformação digital

Resumo

O Ministério da Ciência, Tecnologia e Inovações vem desenvolvendo inúmeras atividades para apoiar programas de fomento ao empreendedorismo e inovação e estimular a transformação digital no Brasil. Com base em seus textos fundantes - a Política Nacional de Inovação, a Estratégia Nacional de Transformação Digital e a Estratégia Brasileira de Inteligência Artificial – aspectos desse esforço serão apresentados e discutidos.

Palavras-chave

Inovação aberta; Startups; Cooperação tecnológica.

MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES

PÁTRIA AMADA BRASIL GOVERNO FEDERAL

INOVAÇÃO ABERTA

SEMPI/MCTI

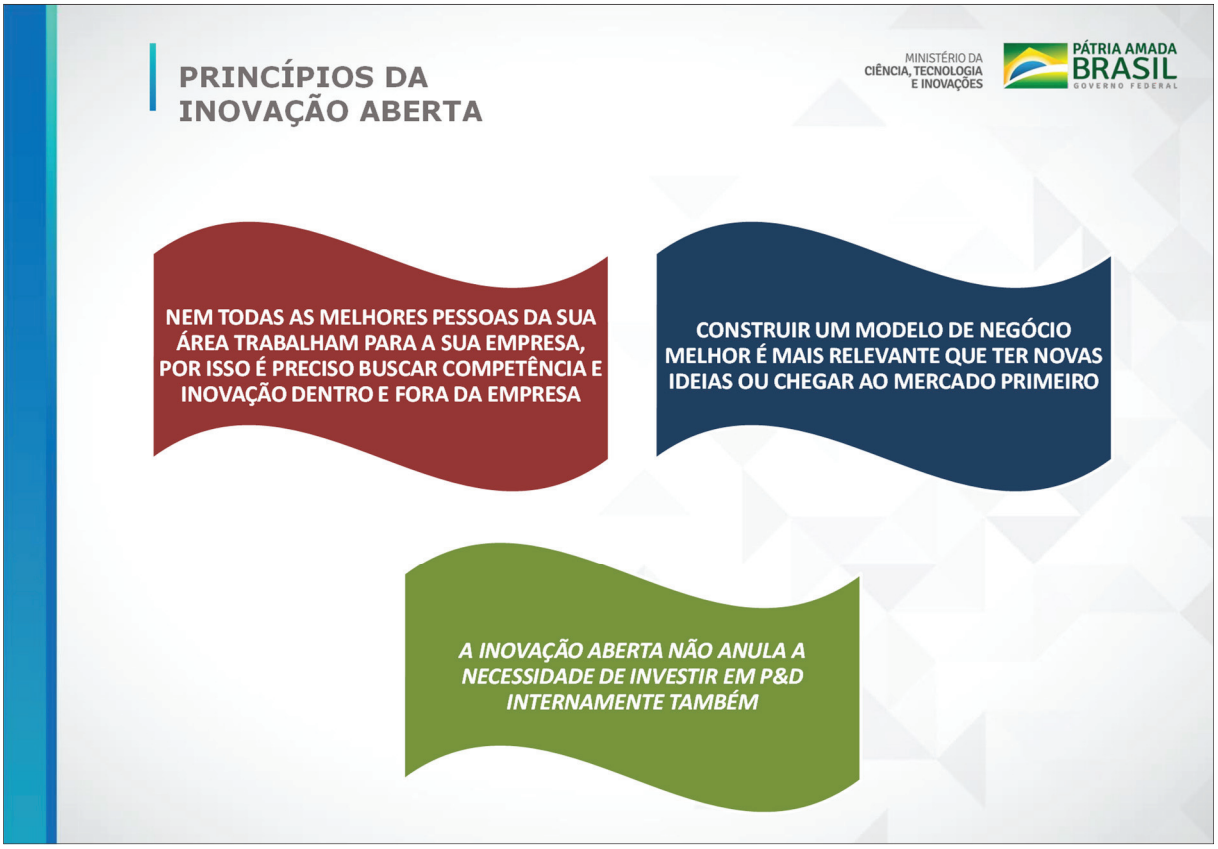
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES

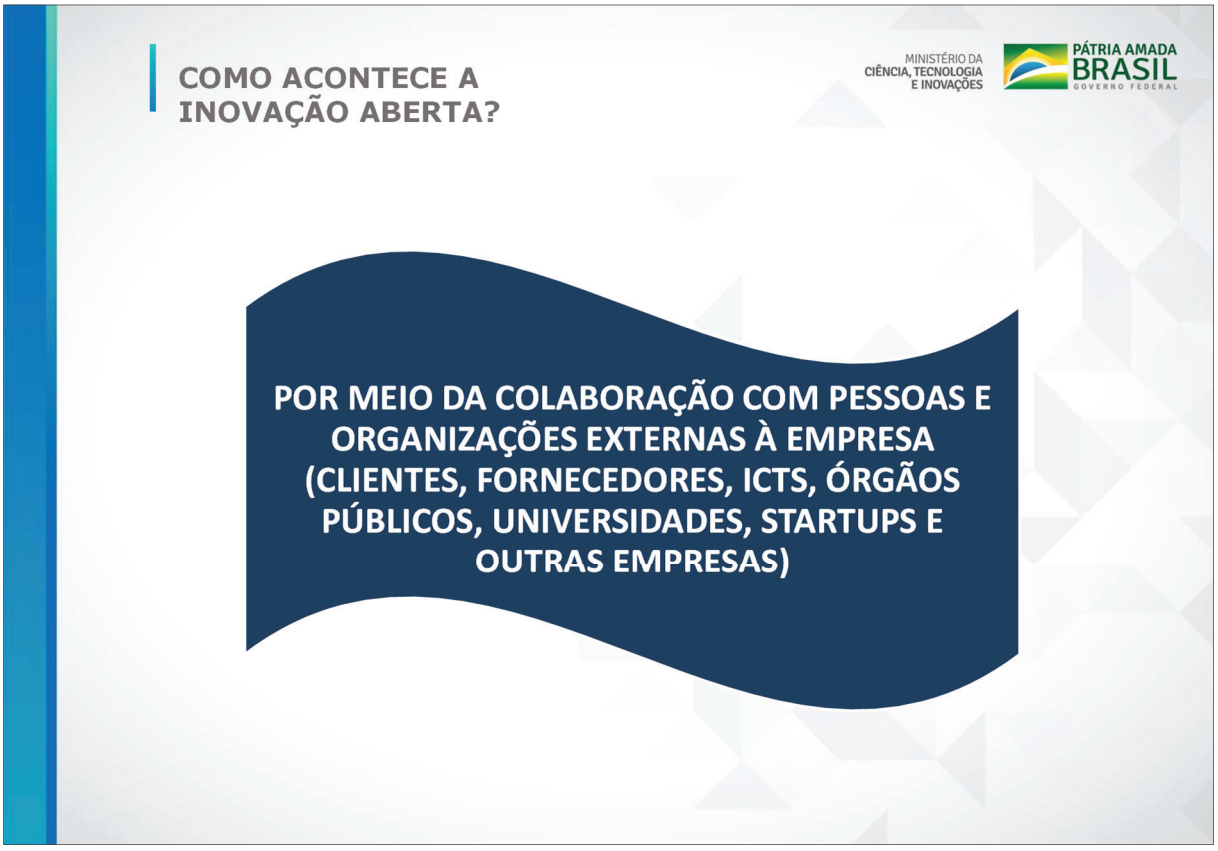
PÁTRIA AMADA BRASIL GOVERNO FEDERAL

O QUE É INOVAÇÃO ABERTA?

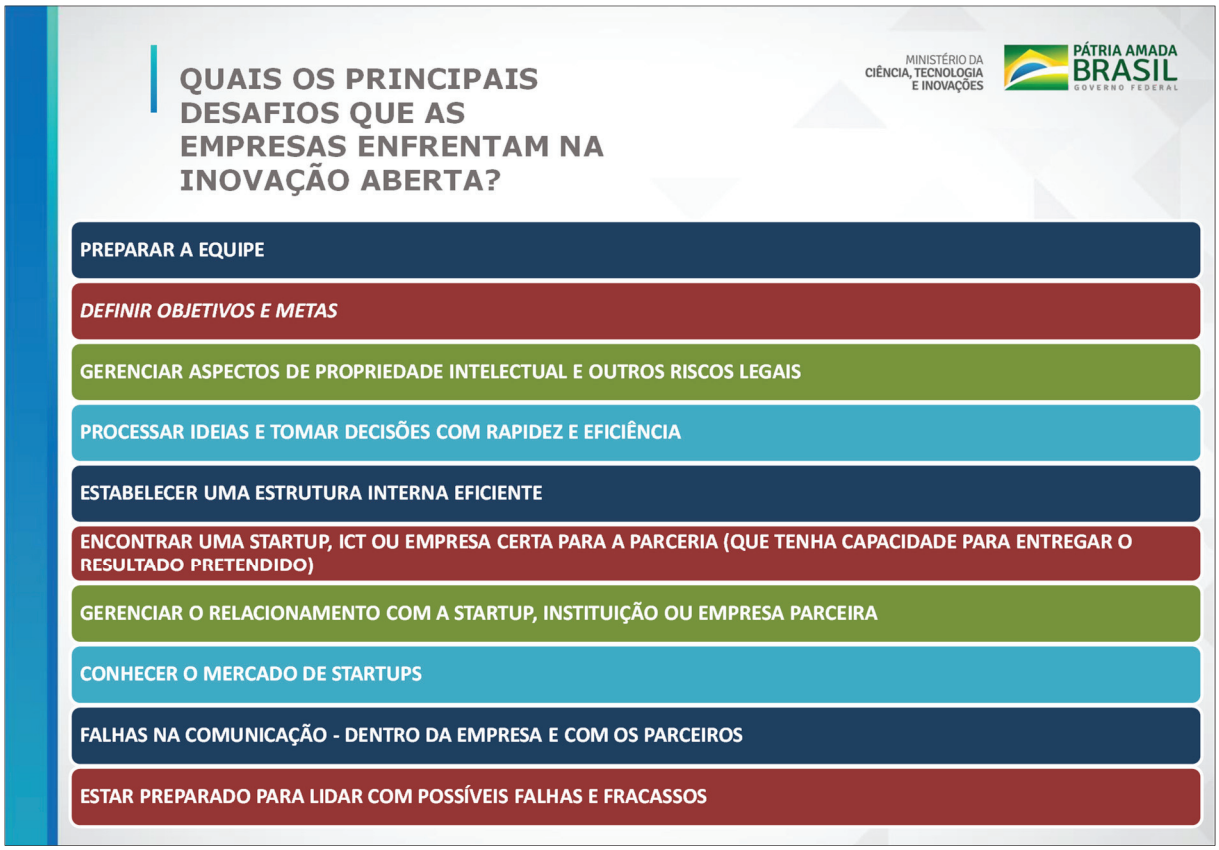
É UMA ABORDAGEM MAIS DISRUPTIVA E MENOS CENTRALIZADA DA INOVAÇÃO

INOVAR COM PARCEIROS, COMPARTILHANDO RISCOS E GANHOS


PRINCÍPIOS DA
INOVAÇÃO ABERTA
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
NEM TODAS AS MELHORES PESSOAS DA SUA ÁREA TRABALHAM PARA A SUA EMPRESA, POR ISSO É PRECISO BUSCAR COMPETÊNCIA E INOVAÇÃO DENTRO E FORA DA EMPRESA
CONSTRUIR UM MODELO DE NEGÓCIO MELHOR É MAIS RELEVANTE QUE TER NOVAS IDEIAS OU CHEGAR AO MERCADO PRIMEIRO
A INOVAÇÃO ABERTA NÃO ANULA A NECESSIDADE DE INVESTIR EM P&D INTERNAMENTE TAMBÉM


COMO ACONTECE A
INOVAÇÃO ABERTA?
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
POR MEIO DA COLABORAÇÃO COM PESSOAS E ORGANIZAÇÕES EXTERNAS À EMPRESA (CLIENTES, FORNECEDORES, ICTS, ÓRGÃOS PÚBLICOS, UNIVERSIDADES, STARTUPS E OUTRAS EMPRESAS)

O QUE NÃO É INOVAÇÃO ABERTA?
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
INOVAÇÃO ABERTA NÃO É TERCEIRIZAÇÃO
INOVAÇÃO ABERTA NÃO É COMPARTILHAR TUDO


QUAIS OS PRINCIPAIS DESAFIOS QUE AS EMPRESAS ENFRENTAM NA INOVAÇÃO ABERTA?
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
PREPARAR A EQUIPE
DEFINIR OBJETIVOS E METAS
GERENCIAR ASPECTOS DE PROPRIEDADE INTELECTUAL E OUTROS RISCOS LEGAIS
PROCESSAR IDEIAS E TOMAR DECISÕES COM RAPIDEZ E EFICIÊNCIA
ESTABELECER UMA ESTRUTURA INTERNA EFICIENTE
ENCONTRAR UMA STARTUP, ICT OU EMPRESA CERTA PARA A PARCERIA (QUE TENHA CAPACIDADE PARA ENTREGAR O RESULTADO PRETENDIDO)
GERENCIAR O RELACIONAMENTO COM A STARTUP, INSTITUIÇÃO OU EMPRESA PARCEIRA
CONHECER O MERCADO DE STARTUPS
FALHAS NA COMUNICAÇÃO - DENTRO DA EMPRESA E COM OS PARCEIROS
ESTAR PREPARADO PARA LIDAR COM POSSÍVEIS FALHAS E FRACASSOS

QUAIS OS RESULTADOS ESPERADOS COM A INOVAÇÃO ABERTA?
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
REDUÇÃO DE CUSTOS
NOVOS FLUXOS DE RECEITA
RESPOSTA ÀS DIFICULDADES DAS EMPRESAS DE INOVAREM SOZINHAS
INOVAÇÃO MAIS COLABORATIVA E DIVERSA

QUAL O CAMINHO? POR ONDE COMEÇAR?
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
COOPERAÇÃO TECNOLÓGICA
ICTS
STARTUPS

BENEFÍCIOS DA COOPERAÇÃO ENTRE ICTS, STARTUPS E COORPORAÇÕES
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E INOVAÇÕES
PÁTRIA AMADA BRASIL GOVERNO FEDERAL
REDUZ O TEMPO ENTRE DESENVOLVIMENTO E COMERCIALIZAÇÃO
CRIA NOVOS MERCADOS
REDUZ RISCOS DO PRODUTO/SERVIÇO SER REJEITADO PELO PÚBLICO
GERA NOVAS IDEIAS E BASE DE CONHECIMENTO
PODE FUNCIONAR COMO UM PONTO DE PARTIDA OU ACELERADOR DA CULTURA DE INOVAÇÃO NA EMPRESA
PROMOVE UMA MUDANÇA DE PERSPECTIVA
REDUZ RISCOS E CUSTOS
PROMOVE O NETWORKING
DEMOCRATIZA O ACESSO ÀS IDEIAS

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Prof. Dr.-Ing. Eckhard Kirchner

Prof. Kirchner, born 1969, studied mechanical engineering and applied mechanics to former Technische Hochschule Darmstadt from 1990 to 1995, where he also received his Ph.D. for a thesis on nonlinear optimization problems in structural mechanics. Between 1999 and 2011 he held various positions at Adam Opel AG and GM Powertrain starting from Analysis Engineer for Structural Integrity up to Head of the Department for Shift System Design and Release with global responsibility within GM, always focusing on combustion powered vehicles. As an intermediate position he was Program Manager for the Concept stage build of G's dry dual clutch DCT program. From 2011 until early 2016 he changed subject and worked in the area of electric mobility with Schaeffler and Siemens. By April 1st he was appointed University Professor for Product Development and Machine Elements and has in the meantime started to build up new research fields and the respective test facilities. He authored a monograph book on vehicle transmissions during his industrial time and holds over 150 patents, mostly on automotive technology.

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pmd - TU Darmstadt

The chair of product development and machine elements at *Technische Universität Darmstadt* is intrinsically linked to methodological research in the area of product development since five decades. Recently, driven by the appointment of Prof. Dr.-Ing Eckhard Kirchner, a re-orientation of the scientific interest has begun focusing on so-called mechatronic machine elements, which enable measurements close to the mechanical or physical process, literally speaking at the skeleton of mechanical engineering. Today, close to 20 people team up at pmd including 15 research associates.

pmd
product development
machine elements

Machine elements with sensory effects – a game changer for digitalization?

Abstract

Current megatrends such as Industrial IoT including Predictive Maintenance or Industry 4.0 and the even more general concept of the digitalization of technology requires an increasing amount of data to be acquired preferably by inexpensive sensor concepts without major changes to future and also existing machinery. In order to foster the digitalization process a series of new sensors is being developed, most of them being designed for special purposes and requiring an adaptation of the system in order to be integrated mechanically and – what is in most cases even more complicated – and into the control system. The question is how to support industry in bringing those machine elements into application. Hence, the industry's requirements for the next generation of machine elements and their implementation need to be clearly defined. Even the most accurate sensors will not be used if they do not meet the requirements of the user. Therefore, the first analysis deals with the user requirements on machine elements with sensory functions and whether current solutions meet those requirements. Literature describes different classes of next generation machine elements, out of which the so-called machine elements with sensory effects are in the focus of this presentation. Sensory effects occur in tribological working surface pairs, the effects can be measured on a component level for a series of different machine elements. However, their influence cannot be exploited on system level without specific design measures and without a deep understanding of the uncertainties associated to these sensory effects. Hence, the presentation shall shed light on sample machine elements with sensory effects, their system integration and a sensitivity assessment of the uncertainties involved. One example to be discussed is the sensory usage of standard rolling bearings, where customer requirements on sensory functions are quite well understood since the bearing can provide information on its loading conditions, the viscosity of the lubricant, bearing failures and potentially its remaining useful life. At the same time, the sensory usage must not harm the regular functions and characteristics of the bearing, hence it is important to assess the sensory rolling bearing against commercially available competitor products, most of them requiring additional build space to the attached sensor modules. The rolling bearing also offers a broad variety of disturbances, which are discussed to explain the scientific challenges to be solved. An outlook will be given on other classes of machine elements offering similar effects as a point of future research topic supporting the digitalization process.

Keywords

Sensory Machine Elements; Digitalization; Sensing Technology.

Machine elements with sensory effects – a game changer for the digitalization?

Univ.-Prof. Dr.-Ing. Eckhard Kirchner
Marcel Neu, M.Sc.
TU Darmstadt, Institute for Product Development and Machine Elements

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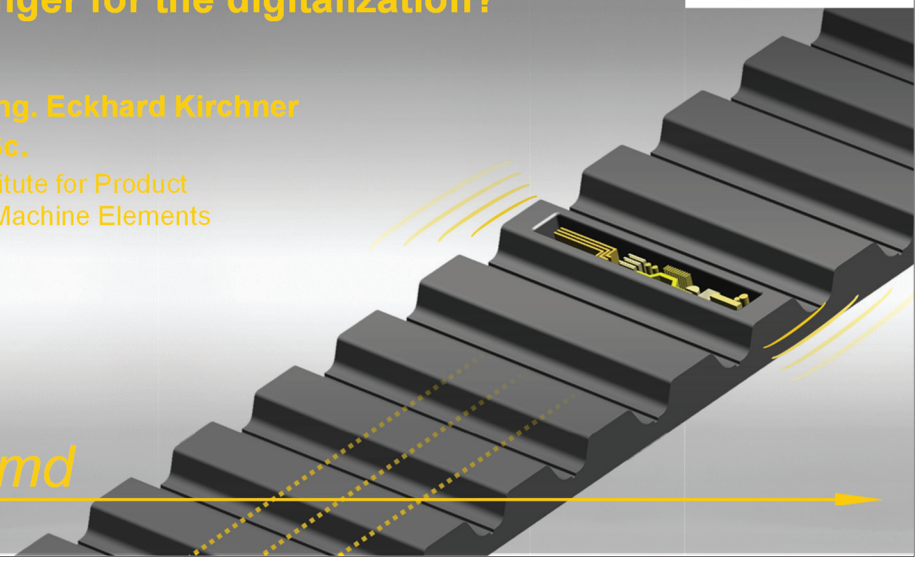

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Motivation – First generation machine elements and their impact

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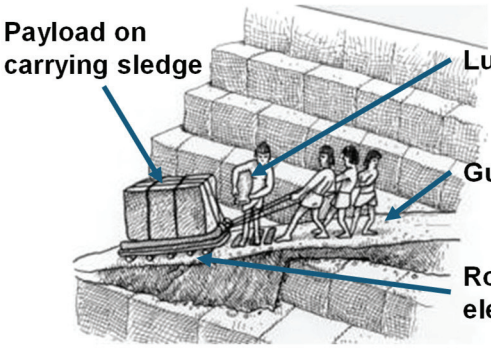
The bearing turned the invention of the wheel into an innovation

Approx. 4000 b.c. in Europe

Building of the pyramids was potentially enabled by rolling bearings



Approx. 2600 b.c. in Egypt

Motivation – Next generation of machine elements is driven by the need for data out of three megatrends

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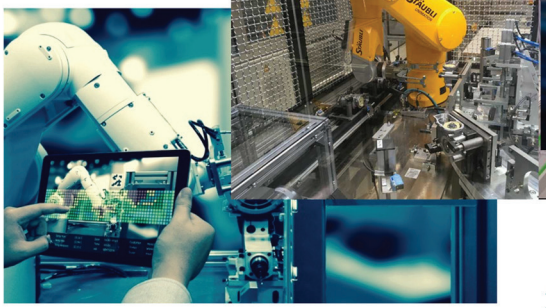
Predictive Maintenance

Digital Twins



Digitalization

https://www.bertrandt.com/#gref, https://www.plastverarbeiter.de/99698/digitaler-zwilling-im-maschinenbau-vision-oder-wirklichkeit/ https://blog.unbelievable-machine.com/en/what-is-predictive-maintenance-definition

Classification of machine elements

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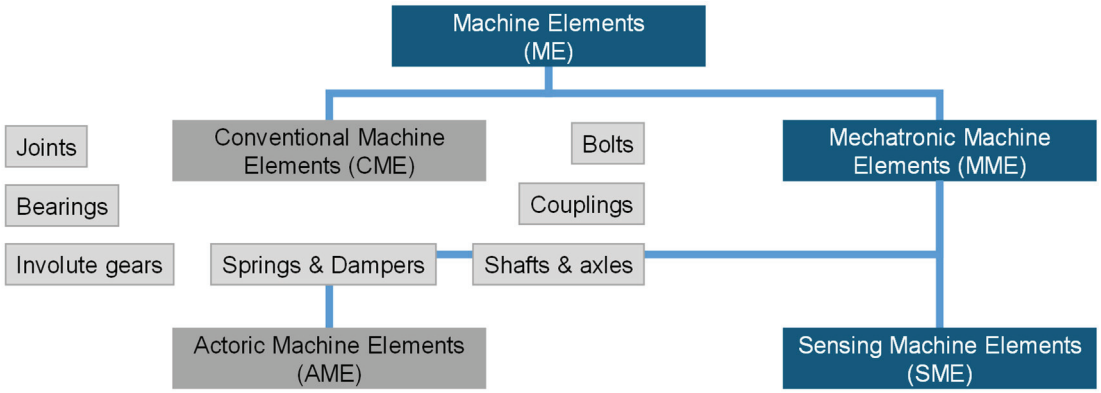

Reference: Vorwerk-Handing et al. (2020): Classification and Examples of Next Generation Machine Elements. In Forschung im Ingenieurwesen, 84. Aufl., S. 21-32.

Classification of machine elements

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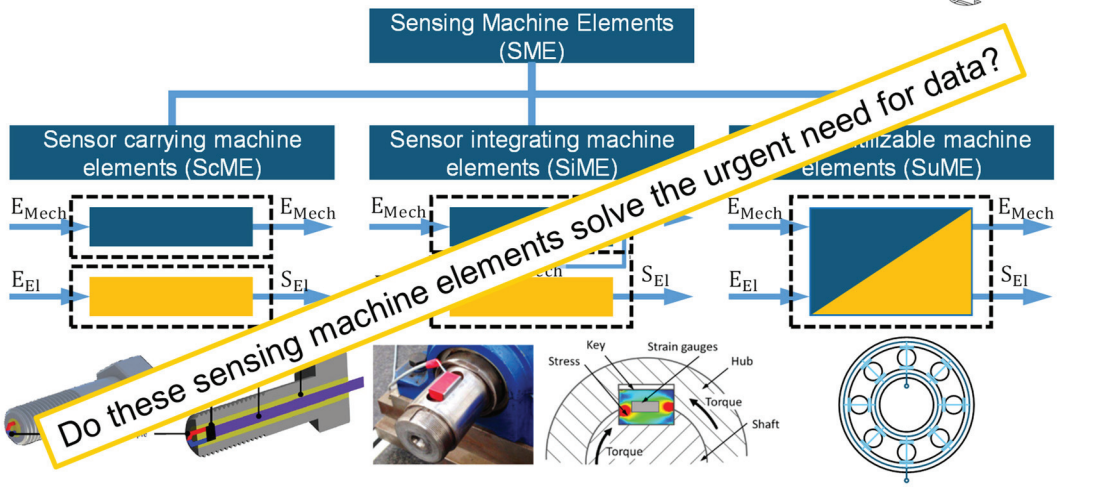

Reference: Vorwerk-Handing et al. (2020): Classification and Examples of Next Generation Machine Elements. In Forschung im Ingenieurwesen, 84. Aufl., S. 21-32.

User requirements for sensing machine elements (SME)

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User survey:
Why are sensor bearings available on the market not yet suited for application?
What are the requirements for a load-sensing rolling bearing?

No structural weakness	Structural deformations or stress concentrations caused by design modifications (e.g. holes) increase failure risk
No additional design effort	Additional effort increases cost. Minimal design effort creates the possibility of implementation in existing machinery by retrofitting
No additional assembly effort	Additional effort increases cost. Costs of the assembly process are variable costs occurring for each individual part

Additional design rules for design **with** sensing machine elements mean additional effort for the product developer applying SME, preventing the widespread application of SME

- Developer **of** SME must make additional effort to develop SME that can be applied without additional effort.

Comparison of the different technologies

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	Displacement	Strain	Ultrasonic Waves	Electric Impedance
No structural weakness	Drill holes in the unloaded area 0	Drill holes in the unloaded area 0	Drill holes in the loaded area -	Drill holes in the unloaded area 0
No additional design effort	Additional installation space in axial direction -	No additional installation space +	No additional installation space +	No additional installation space +
No additional assembly effort	Measuring ring can obstruct the assembly -	Do not damage sensors during installation 0	Insert sensor in hole +	Contact the shaft and outer ring +

+ Technology likely to meet requirements;
0 Low risk technology does not meet requirements;
- High risk technology probably does not meet requirements

Result:

- Measurement of the electric impedance is a promising concept
- Additional efforts in design and assembly are low
- Structural weaknesses are not expected

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Technologies for sensing rolling bearings

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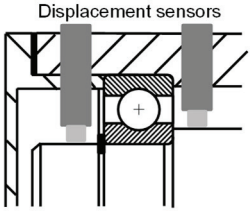
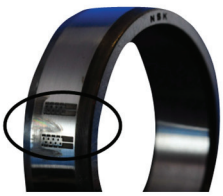
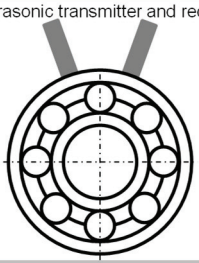
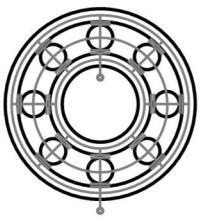
Displacement	Strain	Ultrasonic Waves	Electric Impedance
Displacement sensors 		Ultrasonic transmitter and receive 	
Relation of load, bearing stiffness and displacement	Bearings loads lead to deformation of the outer ring	Bearing frequencies and their dependency to axial load are measured	Bearing impedance depends on deformation and lubrication

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Concept of sensing rolling bearing

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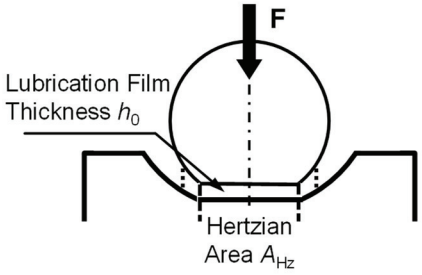

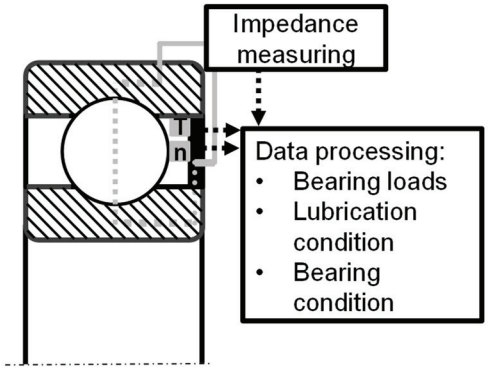

Influencing factors and/or measurands:

- Geometry
- Lubricant
- Hertzian Area
- Surface properties e.g. damages

Functional structure of the sensor rolling bearing

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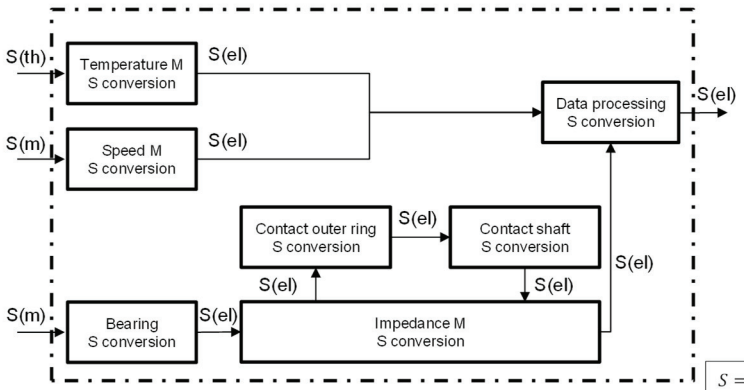

QFD method GM4

- Comparing functions and customer requirements
- Structural weakness, design effort & assembly effort are influenced mainly by contact of outer and inner ring

→ Focus of technical development:

- Contact of outer ring
- Contact of inner ring

S = Signal M = Measurement
th = thermal m = mechanic el = electric

Prototype in industrial gearbox

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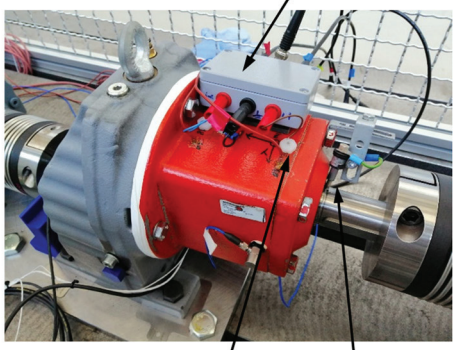

Comparison of prototype to user requirements

No structural weakness	
	Need of a drill hole (for contact of outer ring) out of loaded zone ➔ no structural weakness issue
No additional design effort	
	Need of a drill hole ➔ minimal design effort
No additional assembly effort	
	Bearing mounting process remains, additional parts without mounting issues ➔ minimal additional effort

Measurement results in industrial gearbox

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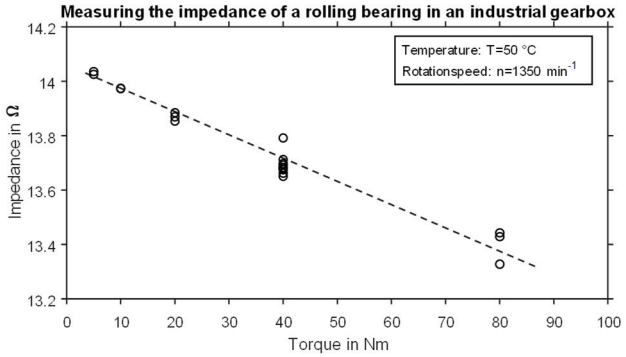

Observations:

- Clear correlation of impedance and torque
- Proof of concept achieved on test bench
- Possible real-world disturbances were not investigated
  - Aging of lubricant
  - Wear of components
  - Contamination of lubricant

Design rules for sensing machine elements

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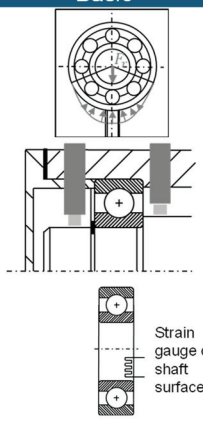
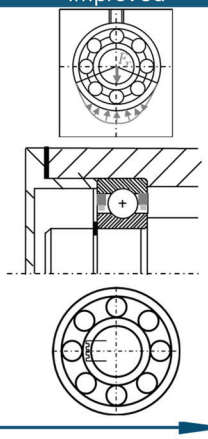
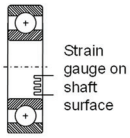
Design rule	Effect	Example from case study: Basic	Example from case study: Improved
Confine the changes to unloaded areas	Reduce effort to reinforce areas of the design weakened by the integration of sensor		
Maintain installation space	Maintain compatibility to standard components to enable drop-in solutions for reduced integration effort		
Stick to standard mechanical interfaces	Maintain assembly process and enable retrofit of sensors during product life cycle for better sustainability		

Design of next generation machine elements – Toothed belt with integrated sensor

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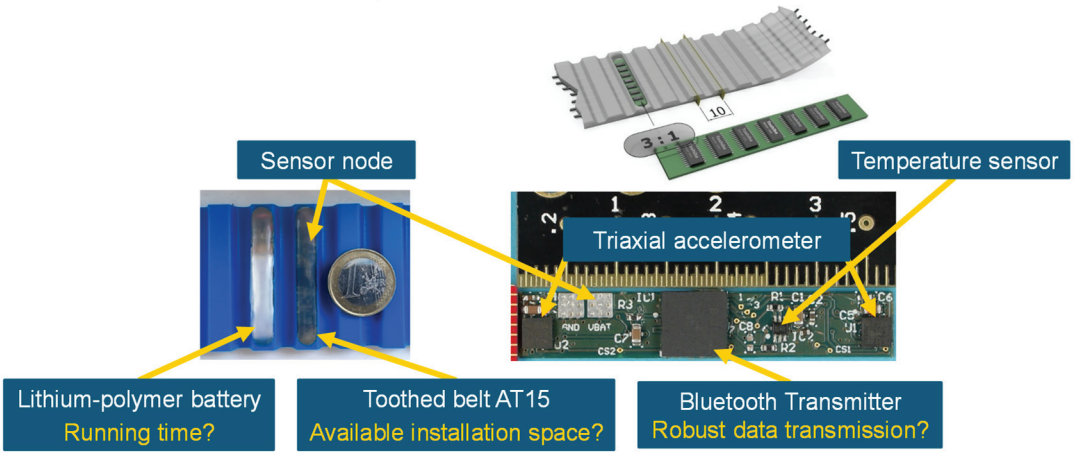

Design of next generation machine elements – Challenge for a consumer product micro-sensor

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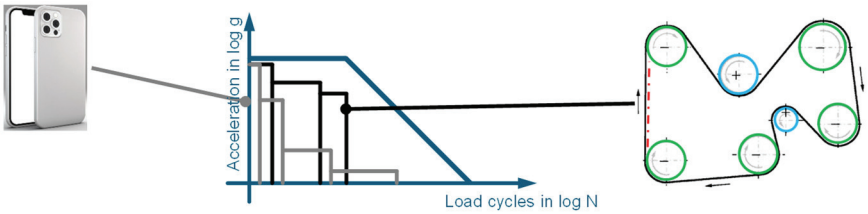
Falling of a mobile phone from a desk: $a \approx 500\ \mathrm{g}$

Centrifugal acceleration of a belt drive with $d = 100\ [\mathrm{mm}]$ at $n = 3000\ [\mathrm{min}^{-1}]$ causes $a \approx 500\ \mathrm{g}$



Extreme but not unrealistic example: Operation of a toothed belt at $n = 9500\ [\mathrm{min}^{-1}]$ leads to a centrifugal acceleration of $5000\ \mathrm{g}$ (!) when passing a disc with $d = 100\ [\mathrm{mm}]$

Design of next generation machine elements – Disturbance variables, uncertainty, robustness

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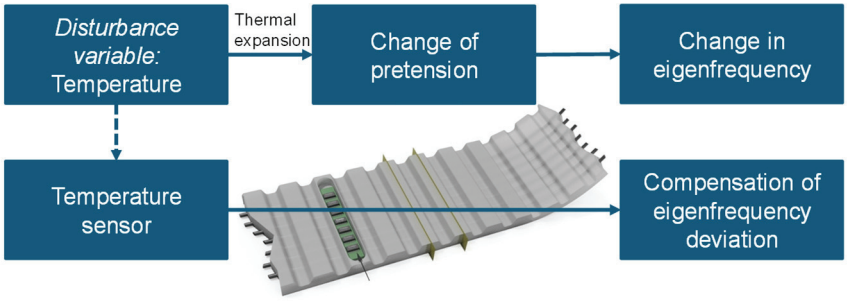
- ***Uncertainty*** (based on ISO Guide 73:2009-11):
  "Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequence, or likelihood."



Future research questions in engineering design

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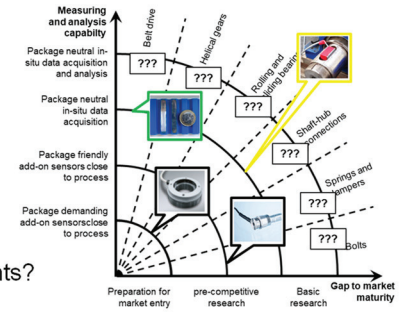
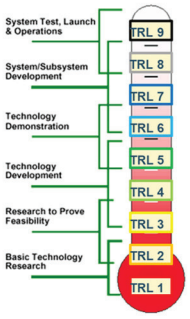
- How can we design SME with maximum autonomy of their energy balance?
- What design opportunities exist for the data transfer from a shielded in-situ located sensor to the system controller?
- Does modularization support the design of sensor modules that can be used across different machine elements out of a limited choice of microelectronic components?





- How can we achieve a unique signal transfer path when using mechanical components for the signal transfer path exploiting the three basic rules of engineering design?
- …

Thank you for your attention!

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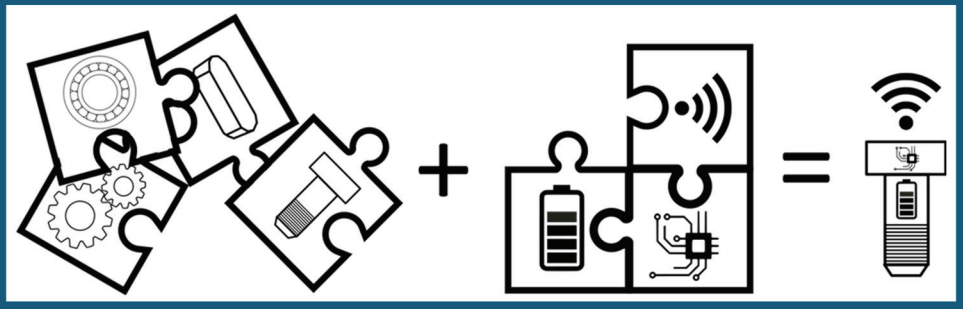

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Eng. Josias Leal

Josias L. Leal, Diretor de Engenharia e Desenvolvimento da Vulkan do Brasil é Engenheiro Mecatrônico com MBA em Logística & Supply Chain management pela Fundação Getúlio Vargas, com mais de 20 anos de experiência no segmento industrial em Sistema de Transmissão de Potência e Freios industriais. Atualmente é responsável pelo desenvolvimento global da divisão industrial Vulkan, DPPA (Desenvolvimento de Produto, Processo e Aplicação), liderando Inovação, Propriedades intelectuais, certificação de produtos e processos, engenharia de aplicação e projetos com foco em processos Lean e digitalização de processos.

✉ josias.leal@vulkan.com

Vulkan do Brasil

Fundado na cidade de Dortmund, Alemanha, em 1889, o Grupo VULKAN é dirigido por Die Hackforth Holding GmbH & Co. KG. A matriz do grupo é localizada em Herne, Alemanha. Reconhecida no mercado por ser uma empresa tradicional, sólida e com know-how em tecnologia e engenharia. A VULKAN está presente em mais de 50 países, com fábricas, filiais e escritórios de representação. Suas fábricas estão localizadas na Alemanha, Brasil, China, Índia e Estados Unidos. A empresa atua mundialmente com 3 unidades estratégicas de negócios: VULKAN Couplings, VULKAN Drive Tech e VULKAN Lokring. No Brasil, desde 1974, possui fábricas em Itatiba, certificadas pelo Sistema de Gestão da Qualidade ISO 9001:2015 e de Meio Ambiente ISO 14001:2015. Possui Filial no Rio de Janeiro. É responsável também pelo mercado industrial da América Latina com filiais na Colômbia e México.

VULKAN

VConnect – *Smart Solution* para sistemas de freios industriais

Resumo

A Vulkan Drive Tech, divisão do Grupo Alemão Vulkan, investe continuamente em pesquisa e desenvolvimento, com base não somente nas tendências tecnológicas, como digitalização, internet das coisas, entre outras inovações, mas principalmente em soluções que traga benefícios reais e tangíveis aos usuários finais dos seus produtos. Seguindo este princípio, a empresa acaba de lançar um Aplicativo para Freios Eletromagnéticos, o VConnect, em linha e totalmente conectado a sua outra recente inovação que é o Novo Conversor Eletrônico V317. Facilidade na parametrização inicial do freio com o equipamento, manual online, acompanhamento remoto, alarme de falhas, análise online das correntes, tensões e tempos de abertura e fechamento do freio, são apenas algumas das vantagens do novo aplicativo da Vulkan, VConnect!

Palavras-chave

Manutenção ágil; Disponibilidade; Conectividade; Smart Solution; Digitalização; IoT.

APP VCONNECT

SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN

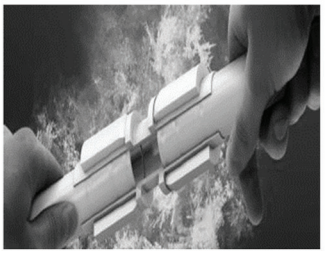
VULKAN DRIVE TECH

Mobile and Stationary
Drive Technology

VULKAN COUPLINGS

Marine Propulsion/
Gensets

VULKAN LOKRING



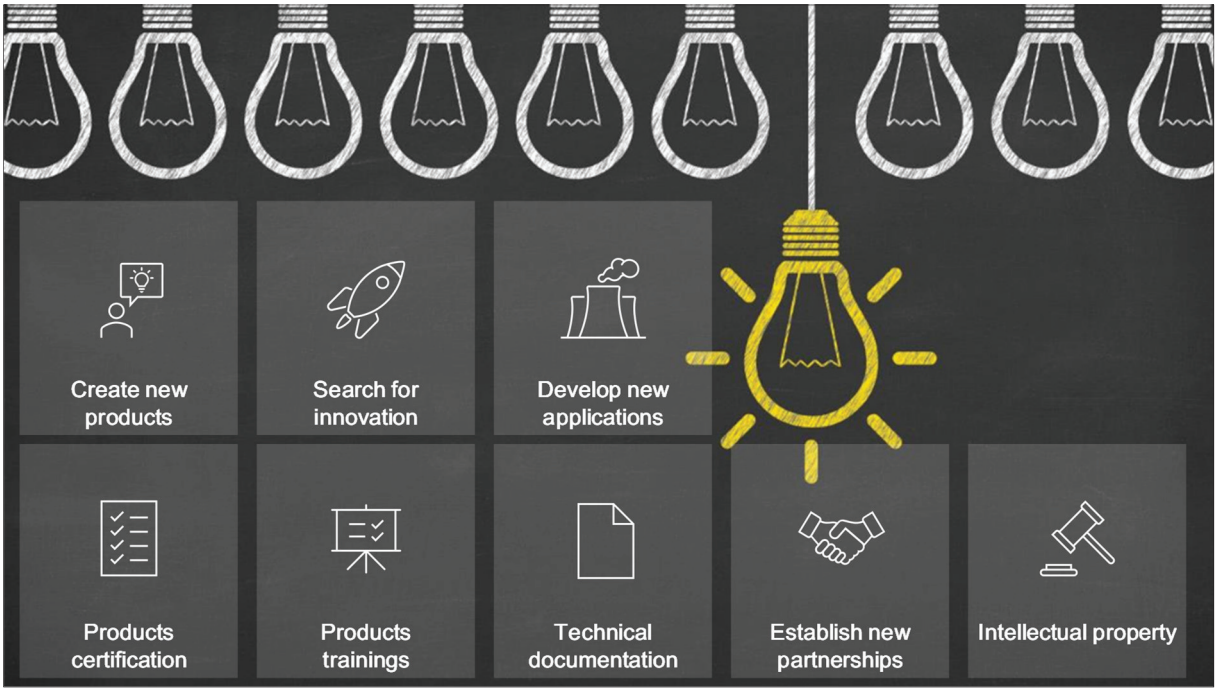
Solder Free Connection
HVAC, Refrigeration & Automotive

Missão:
Recuperar rapidamente, melhoria contínua e ampliação do know-how da Vulkan do Brasil para viabilizar a expansão do mercado global de nossa divisão industrial Vulkan Drive Tech

Simplesmente o melhor:

Engenheiros altamente experientes
Designers de produto excepcionais
Organização autônoma
Completamente separado de nossa fábrica e de seu dia-a-dia

O GRUPO VULKAN
VULKAN COUPLINGS | VULKAN DRIVE TECH | VULKAN LOKRING
O Grupo VULKAN foi fundado em 1889 e a matriz é localizada em Herne, Alemanha. Sua linha de produtos se diversificou no decorrer da sua história devido principalmente a sua política de investimento em Pesquisa e Desenvolvimento. Atualmente a empresa possui 3 divisões de negócios.
13,801 CLIENTES
1,260 EMPREGADOS
Herne Alemanha
183 PATENTES
1 GRUPO
Itatiba Brasil
DPPA
DESENVOLVIMENTO DE PRODUTOS PROCESSOS E APLICAÇÕES
20 SUBSIDIÁRIAS
O centro de competência técnica da divisão global Vulkan Drive Tech
Matriz
Fábricas
Subsidiárias


Create new products
Search for innovation
Develop new applications
Products certification
Products trainings
Technical documentation
Establish new partnerships
Intellectual property

APP VCONNECT

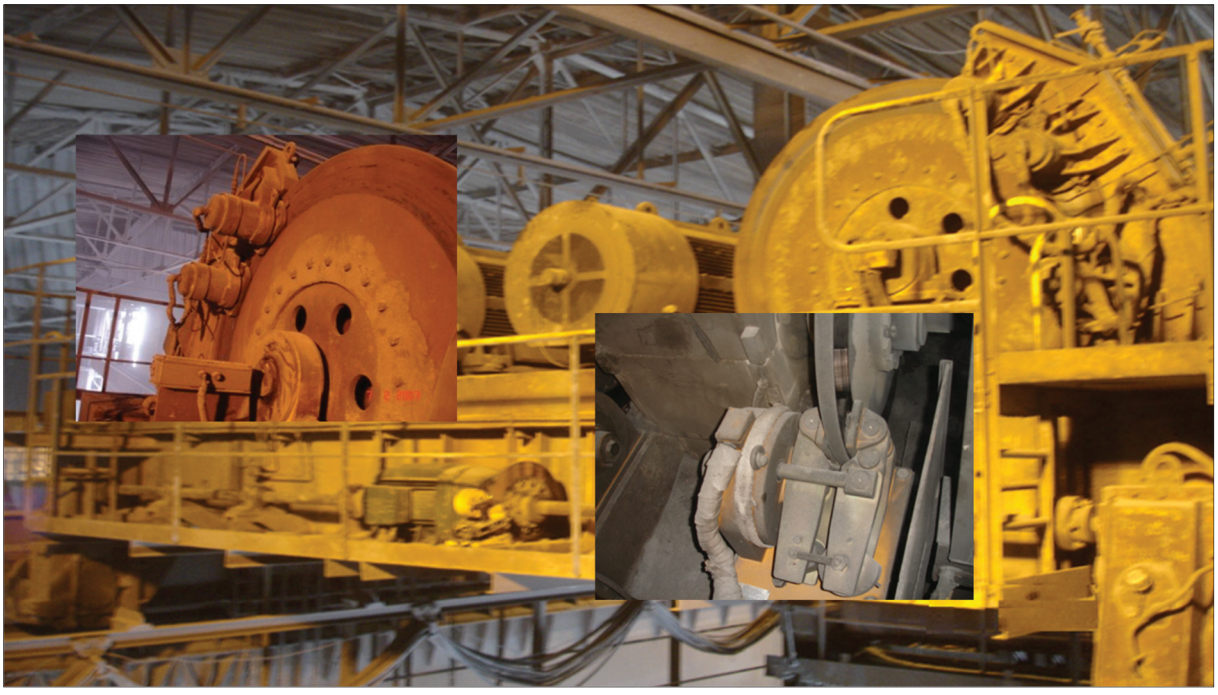
SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

FREIOS INDUSTRIAIS ELETROMAGNÉTICOS

2021 | Josias Leal - 25 Seminário de Alta Tecnologia 6 - 24

BARBELLA

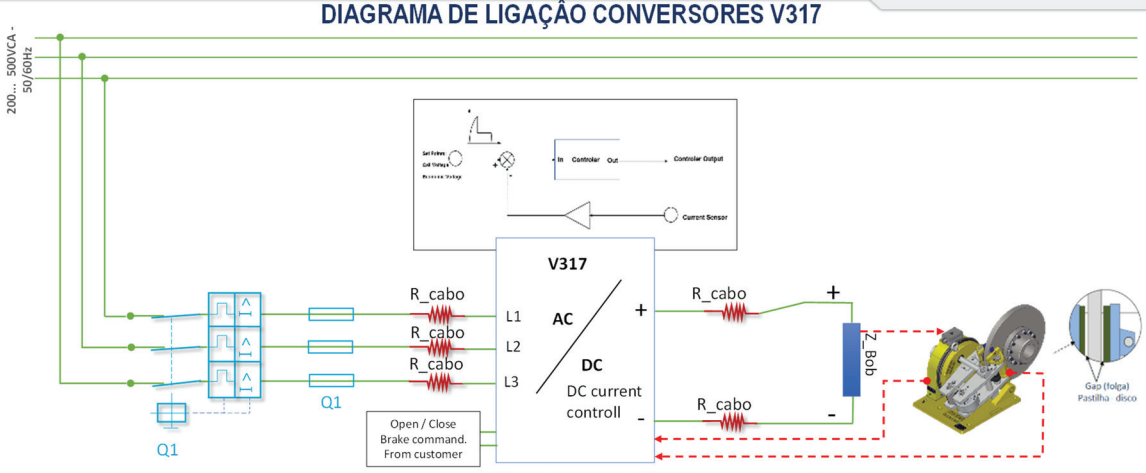


APP VCONNECT

SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

DIAGRAMA DE LIGAÇÂO CONVERSORES V317

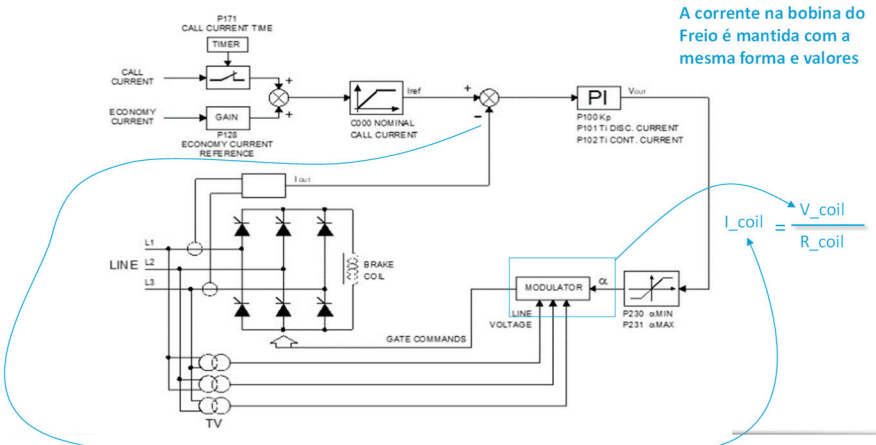


APP VCONNECT

SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

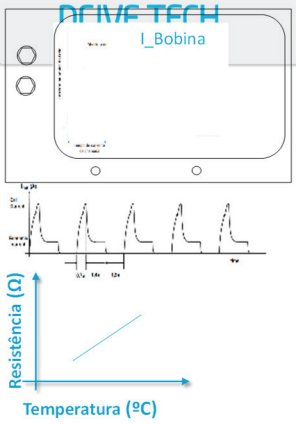
VULKAN DRIVE TECH

DIAGRAMA DE BLOCO DE CONTROLE DE CORRENTE ELÉTRICA



A corrente na bobina do Freio é mantida com a mesma forma e valores

$$I_coil = \frac{V_coil}{R_coil}$$



Aumento na temperatura e na resistência da bobina do Freio

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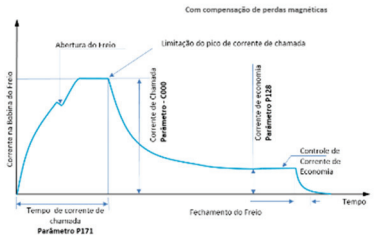
VULKAN DRIVE TECH

PARAMETRIZAÇÃO DA CORRENTE CC

Configuração conforme o modelo de Freio

Modo de controle de corrente de saída



C000 - Corrente de chamada

P128 - Corrente de economia

P171 - Tempo de corrente de chamada

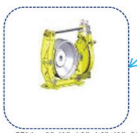
P177 - Tempo de confirmação de Freio aberto

APP VCONNECT

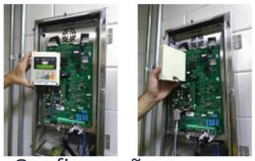
SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

POSSIBILIDADES DE CONFIGURAÇÃO E MONITORAMENTOS



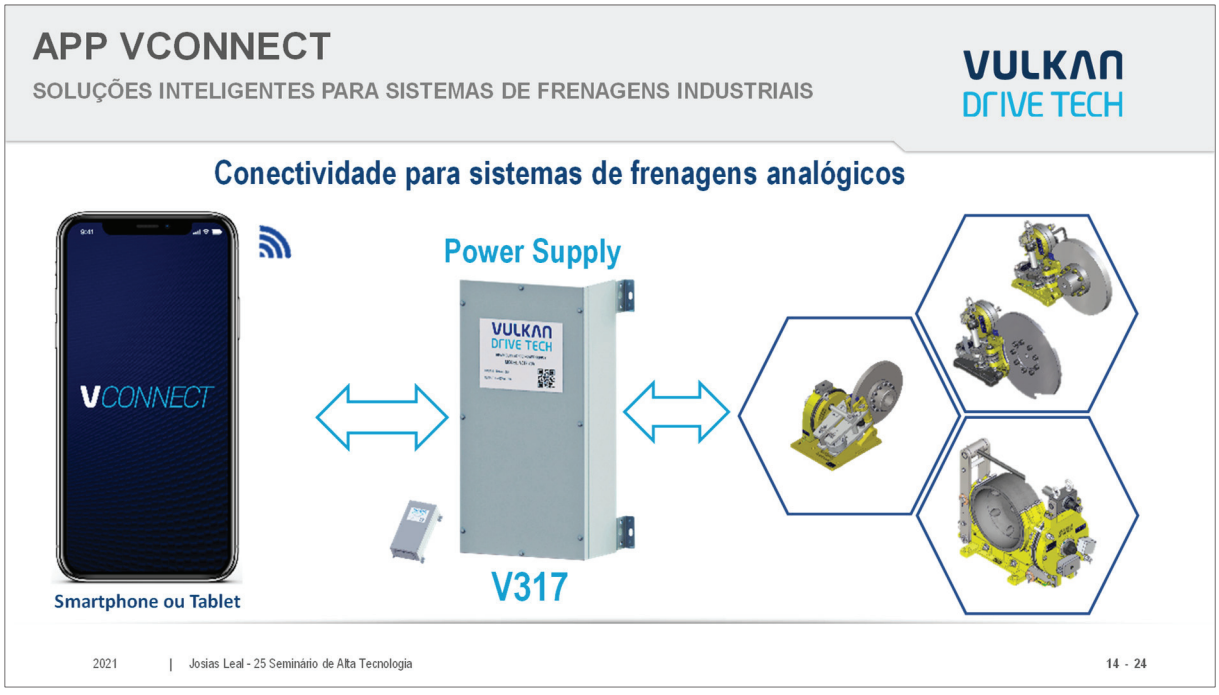
FESA = 8", 0", 13", 16", 9", 23", 30
FESSF = 200, 250, 350, 530, 600, 750



Configuração e monitoramento via Teclado

Configuração e monitoramento via Software

VCONNECT
SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS


APP VCONNECT
SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS
VULKAN DRIVE TECH
Conectividade para sistemas de frenagens analógicos
Power Supply
VCONNECT
Smartphone ou Tablet
V317
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SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

VULKAN CONNECT – MODOS DE UTILIZAÇÃO

Parâmetros

Permite a configuração de parâmetros conforme o modelo de Freio em operação.

Monitoramento

Demonstra variáveis do sistema em tempo real. Formatos números ou Gráficos.

Alarmes

Demonstra Alarmes em tempo Real. Fornece informações sobre o alarme e como solucioná-lo.

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SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

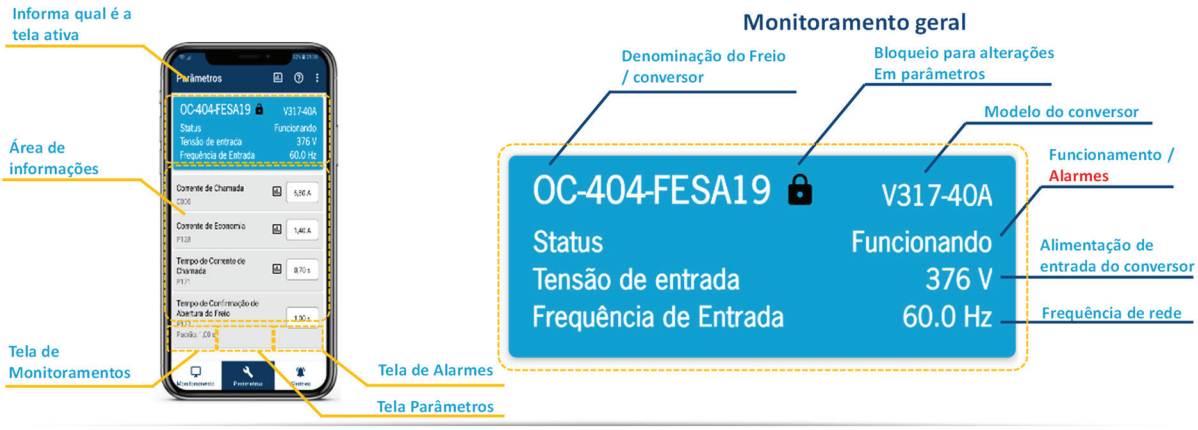
INSTALAÇÃO DO KIT VULKAN CONNECT

2020 | APP – V317 16 - 26

APP VCONNECT

SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH



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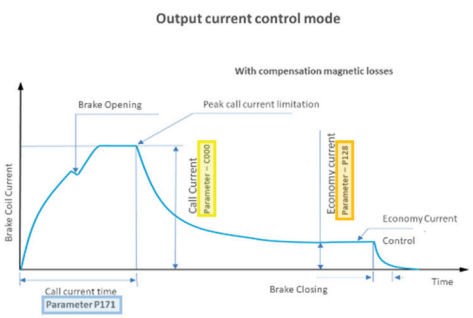
SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

FÁCIL PARAMETRIZAÇÃO



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SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

FÁCIL PARAMETRIZAÇÃO

Parameters

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SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS

VULKAN DRIVE TECH

GRÁFICOS EM TEMPO REAL

Monitoring

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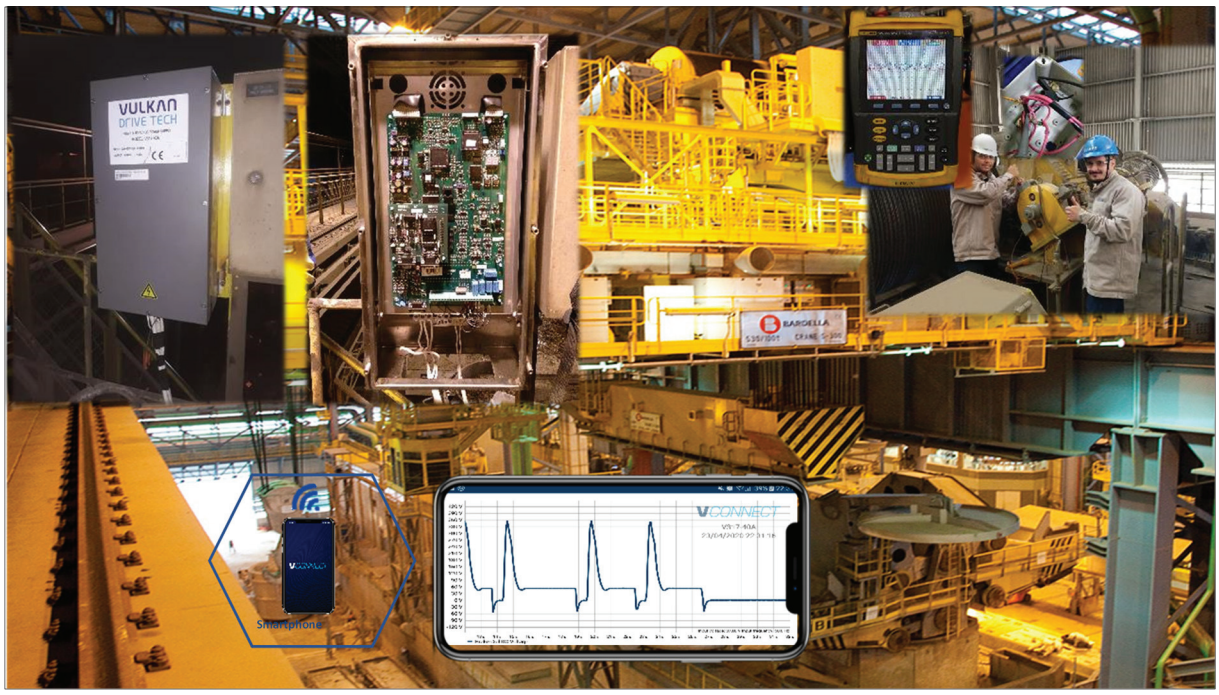
SOLUÇÕES INTELIGENTES PARA SISTEMAS DE FRENAGENS INDUSTRIAIS
VULKAN
DRIVE TECH
DIAGNÓSTICO DE FALHAS EM TEMPO REAL
Alarms
Active Alarms
Inactive Alarms
Alarms


VULKAN
DRIVE TECH
Smartphone
VCONNECT

VCONNECT
✓ Conectividade ao nosso produto
✓ Aumento da disponibilidade do equipamento
✓ Praticidade na analise e identificação de falhas
✓ Informação a mão para tomada de decisão
✓ Elimina a necessidade de outros dispositivos de medição
✓ Aumenta a vida útil e confiabilidade do nosso produto
Google Play
V

Eng. Bruno Castellani

Bruno Castellani é Gerente de Marketing e Serviços na empresa Balluff, é formado em engenharia mecatrônica, pós-graduado em Marketing e Vendas e Especialização de Gerenciamento de Produtos. Possui 15 anos de atuação na área de Serviços em automação Industrial, com foco na gestão de engenharia de aplicação, Treinamentos, reparos e pós-vendas. Atualmente responsável no desenvolvimento de estratégia de desenvolvimento de negócios com tecnologia IO link. É atual diretor técnico do IOLINK na associação Profibus.

✉ bruno.castellani@balluff.com.br

Balluff Brasil

A Balluff é uma empresa de médio porte – com gestão familiar há quatro gerações, fundada em 1921 na cidade de Neuhausen auf den Fildern, próximo de Stuttgart. Cresceu como uma empresa globalizada, aberta e referência no segmento. Com sua rede de 38 filiais de vendas, produção e desenvolvimento, bem como representações, está presente em 68 países em todo o mundo. No Brasil, a marca está presente desde 1983. Sua forma de atuação tem como objetivo compreender e colaborar melhor os seus clientes e poder assim dar a eles aquilo que precisam: soluções de alta qualidade em sensoriamento, identificação e rede, bem como software para soluções globais de sistemas para todos os setores da automação industrial, como os setores: Automotivo, Indústria de Embalagens, Alimentos e Bebidas, Indústria Siderúrgica, Energia, Plásticos, Borracha e Pneus, Indústria de Semicondutores, Metalurgia e outros.

Como sensores SMART, favorecem o serviço de pós-venda de máquinas

Resumo

Com o aquecimento da economia, as empresas estão voltando a aumentar a produtividade, disponibilizando as máquinas a operarem em sua plenitude. Aspectos importantes como otimização, ganho de produtividade e redução de custos, sempre são pautas importantes, tanto em momentos de baixa com em alta produtividade. A automação industrial, atrelado a conceito de IIOT está cada vez mais alinhado a digitalização de máquinas, focando diretamente em soluções que apoiam ao ganho de produtividade e aumento de OEE de máquinas. O sensoriamento é a base da automação de máquinas. Não é possível realizar nenhuma automação sem possuir dados gerados pelos sensores, ou seja, sensores são fundamentais para que isto aconteça. Porém para que sensores tenha uma relevância importantes da aquisição de dados, é necessária avançar em SMART DEVICES, utilizando tecnologia de sensores que tragam além da detecção ou medição, muito mais informações, como diagnósticos, tempo de vida útil, tensão de alimentação, corrente, temperatura, danos externos, falhas, etc., está tecnologia se chama IO LINK. Iremos abordar, quais os benefícios desta tecnologia para a utilização em máquinas e processos.

Palavras-chave

Iiot; IOLINK; Pós-vendas; Agilidade; Manutenção preventiva; Manutenção Preditiva.

BALLUFF

Como Sensores SMART, favorecem o serviço de Pós vendas

Balluff Controles Elétricos Ltda

BALLUFF

- Gerente de Marketing e Serviços na empresa Balluff, é formado em engenharia mecatrônica, pós-graduado em Marketing e Vendas e Especialização de Gerenciamento de Produtos. -
- Possui 15 anos de atuação na área de Serviços em automação Industrial, com foco na gestão de engenharia de aplicação, Treinamentos, reparos e pós-vendas. Atualmente responsável no desenvolvimento de estratégia de desenvolvimento de negócios com tecnologia IO link. É atual diretor técnico do IOLINK na associação Profibus.

Balluff Controles Elétricos Ltda

BALLUFF

IMPACTOS DAS OCORRÊNCIAS

- Altos Custos de Deslocamento
- Pressão para resolução
- Equipe técnica desmotivada
- Cegueira técnica

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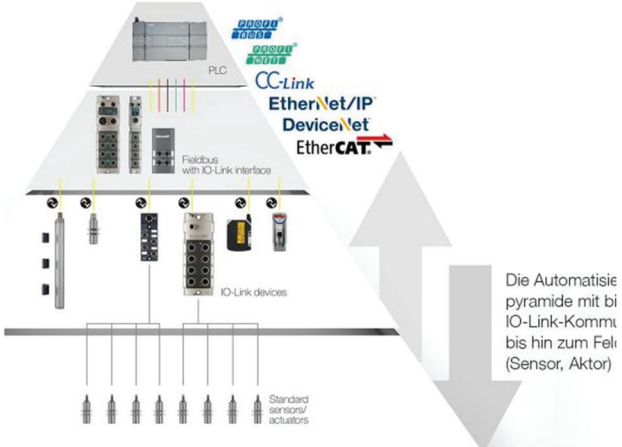
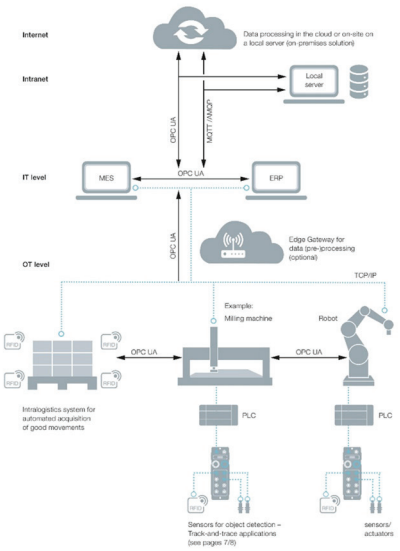
BALLUFF

Use IO-Link

Universal · Smart · Easy



Die Automatisie
pyramide mit bi
IO-Link-Kommu
bis hin zum Fel
(Sensor, Aktor)



BALLUFF

Use IO-Link

Universal · Smart · Easy

- **Universal** – o IO-Link é padrão internacional (IEC 61131-9)
- **Inteligente** – o IO-Link possibilita diagnóstico e parametrização de equipamentos
- **Fácil** – o IO-Link proporciona significativa simplificação e redução de custos

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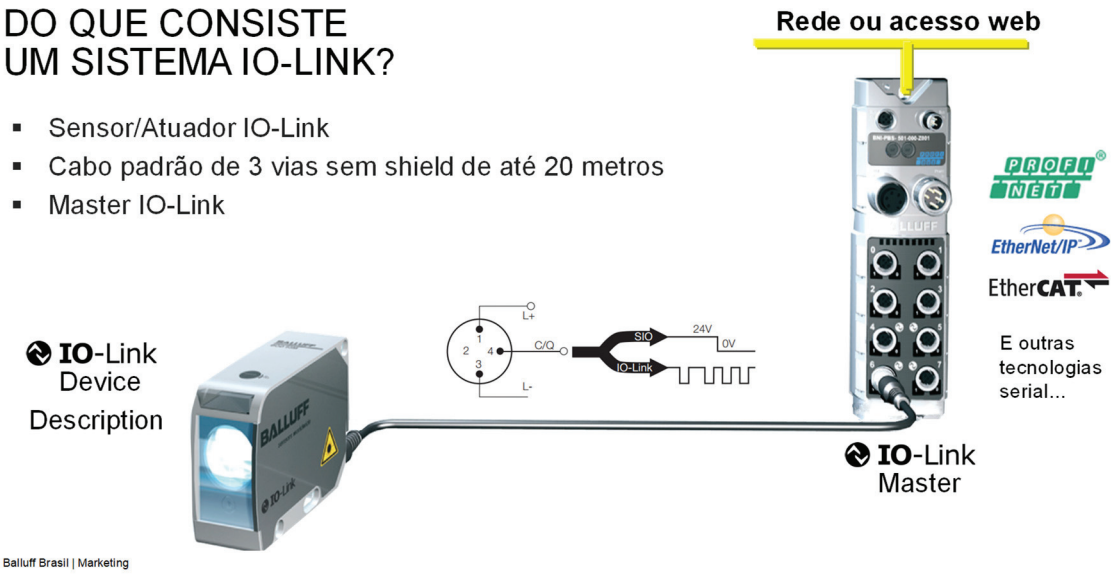
DO QUE CONSISTE UM SISTEMA IO-LINK?

- Sensor/Atuador IO-Link
- Cabo padrão de 3 vias sem shield de até 20 metros
- Master IO-Link



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AS 5 RAZÕES PELAS QUAIS O IO-LINK TRAZ TANTAS VANTAGENS

- Padronizado
- Reduz tempo de parada
- Manutenção programada
- Reduz drasticamente o cabeamento
- Parametrização remota

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Padronizado

IO-Link

IO-Link é suportado por uma grande Comunidade Corporativa

Para mais informações www.io-link.com

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Manutenção programada

- **Coletar**- Dados, informações, relatórios
- **Definir**- defeitos, Causas
- **Agir**- Técnicas, Aplicações

BALLUFF

Parametrização remota

Identification | Parameters | Monitoring | Diagnostics

Parameter	Value		Unit	Status
Parameters				
Parameter Data				
Operating system functions				
index131 - Group diagnostics	enabled			
index131 - Group error diagnos...	enabled			
index131 - Local threshold cha...	enabled			
index131 - Local parameter ch...	enabled			
index131 - Local reset	enabled			changed
index131 - Retentive error mem...	enabled			changed
index131 - Analog value coding	Tmin [°C] (4)			changed
Temperature monitoring				
index131 - Temperature monito...	Overshoot			
index131 - Temperature unit	°C			changed
index131 - ON-delay time (at P...	enabled			
index131 - ON-delay time (at m...	enabled			
index131 - ON-delay time	0.0		s	
index131 - Tripping delay time (...	0.0		s	
index131 - Temperature sensor...	PT1000			changed
index131 - Hysteresis	5			
index131 - Relay switching res...	Closed-circuit principle (NC)			
Thresholds				
index131 - Threshold ϑ1	100			changed
index131 - Threshold ϑ2	40			changed
index131 - Warning threshold f...	90			changed
index131 - Warning threshold f...	43			changed

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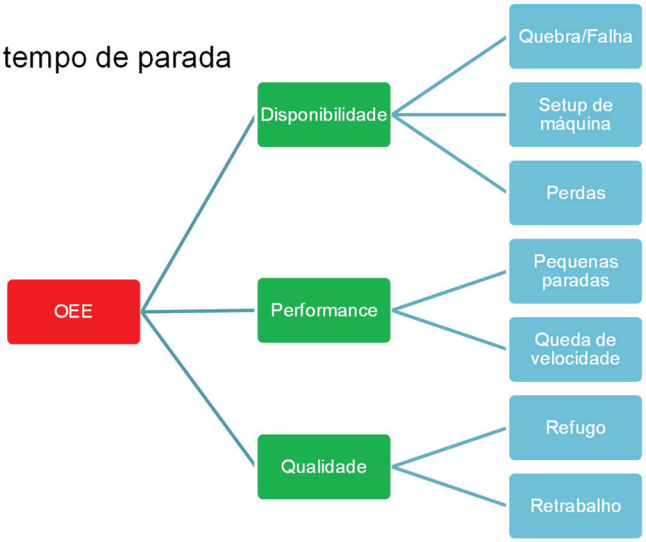
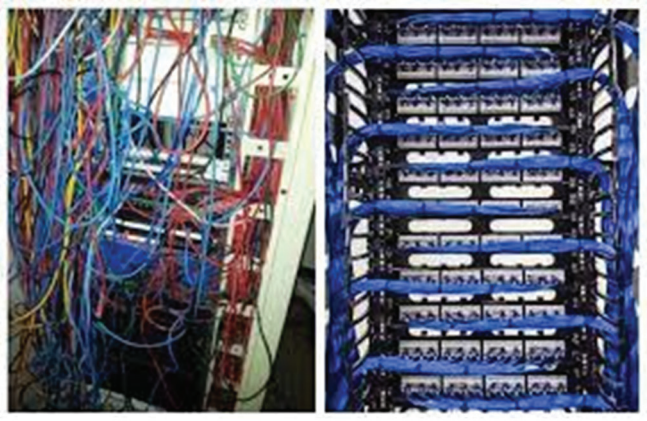
BALLUFF

Reduz tempo de parada



BALLUFF

Reduz drasticamente o cabeamento



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BALLUFF

CONCLUSÃO

Use IO-Link
Universal · Smart · Easy

- Agilidade no suporte.
- Satisfação do cliente
- Reduzir Maquina parada
- Manutenção preventiva
- Cliente e fornecedor satisfeito

Balluff Brasil | Marketing

Eng. Cassio Luiz Francisco de Andrade

Cassio Luiz Francisco de Andrade, graduado em Engenharia Mecânica pela Universidade São Paulo-USP (1987) e Mestre em Engenharia Mecânica pela Universidade Federal de Santa Catarina (UFSC). Possui MBA em Gestão Empresarial pela Fundação Getúlio Vargas (FGV), especialização em Técnicas de Engenharia de Produção pela Universidade de Campinas (UNICAMP), especialização em Engenharia de Fundição pela Universidade Sociedade de Ensino de Santa Catarina (UniSociesc) e especialização em Estudo do Trabalho pelo REFA. Em uma trajetória definida com mais de 20 anos na Tupy S.A., onde atualmente encontra-se como Diretor Técnico de Usinagem Corporativo, possui experiência na área de Engenharia Mecânica, com ênfase em processos, fabricação e desenvolvimento de produtos, P&D de tecnologias de usinagem e fundição, e, mentoria no processo de transformação digital da Usinagem Tupy.

✉ cassio@tupy.com.br

Tupy S.A.

A Tupy S.A é uma companhia multinacional presente em vários países com mais de 80 anos de história. Sua jornada evolutiva abrange 3 importantes fases a serem destacadas: inovações e conquistas, presença no desenvolvimento sustentável e futuro habilitador. Juntamente com as pessoas, que é o seu principal valor, a empresa tem atuado fortemente rumo a um futuro tecnológico habilitador através de iniciativas em P&D Disruptivo, Transformação Digital e Inovação. Com o propósito de estabelecer valor ao uso de dados, a palestra abordará um case da transformação digital aplicado na empresa através de uma engenharia de sistema inteligente estruturada para inspeção de peças automotivas com inteligência artificial.

Transformação Digital Tupy – Um case da jornada de valor com dados

Resumo

A Tupy S.A é uma companhia multinacional presente em vários países com mais de 80 anos de história. Sua jornada evolutiva abrange 3 importantes fases a serem destacadas: inovações e conquistas, presença no desenvolvimento sustentável e futuro habilitador. Juntamente com as pessoas, que é o seu principal valor, a empresa tem atuado fortemente rumo a um futuro tecnológico habilitador através de iniciativas em P&D Disruptivo, Transformação Digital e Inovação. Com o propósito de estabelecer valor ao uso de dados, a palestra abordará um case da transformação digital aplicado na empresa através de uma engenharia de sistema inteligente estruturada para inspeção de peças automotivas com inteligência artificial.

Palavras-chave

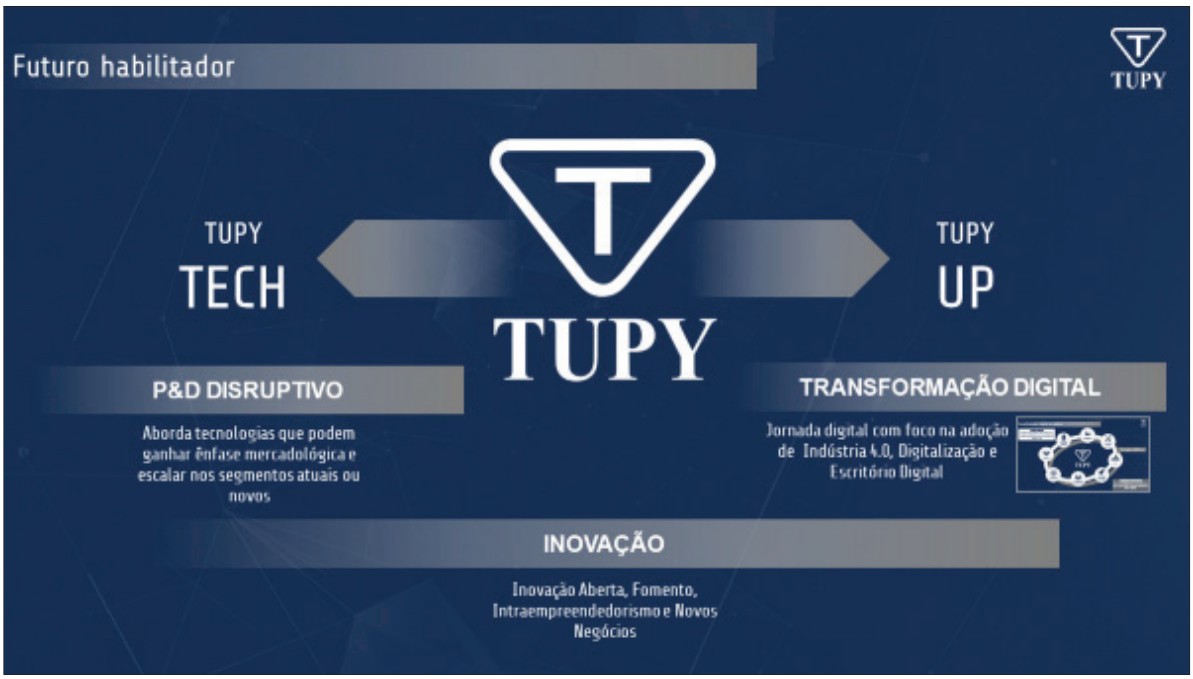
Transformação digital; sistema de visão; inteligência artificial.

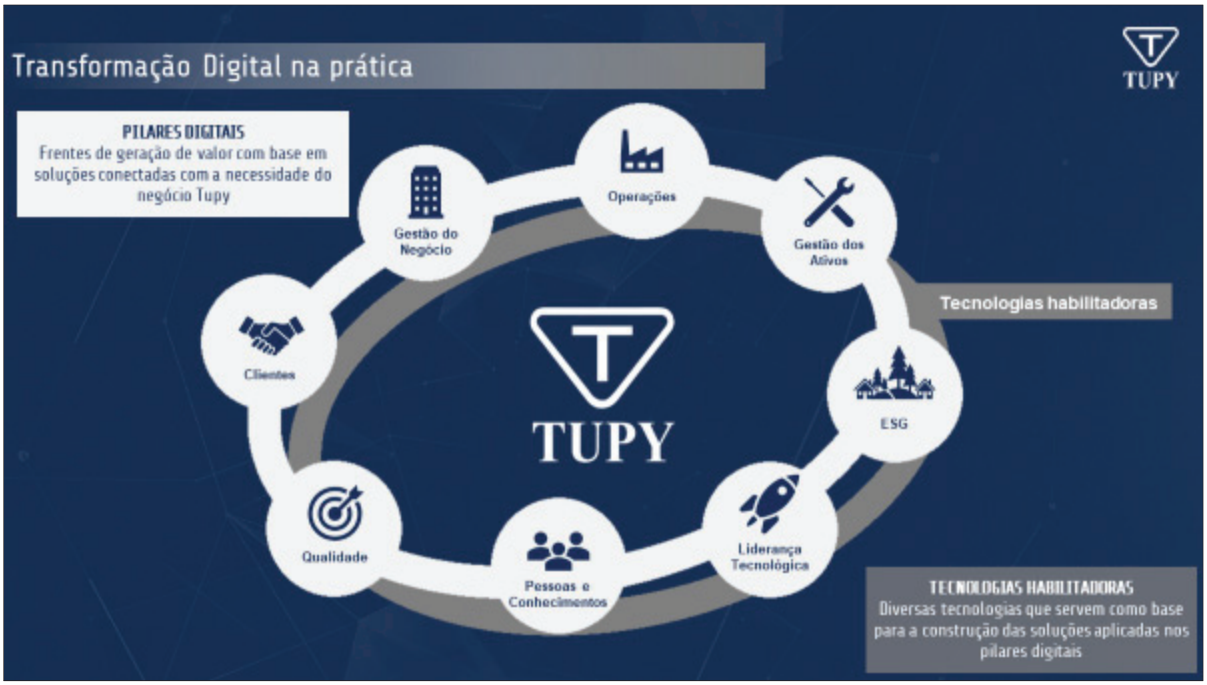
Transformação digital Tupy
Um case da jornada de valor com dados
25º Seminário Internacional de Alta Tecnologia
Setembro/2021
TUPY
TUPY3
NOVO
MERCADO

QUEM
SOMOS ?
TUPY

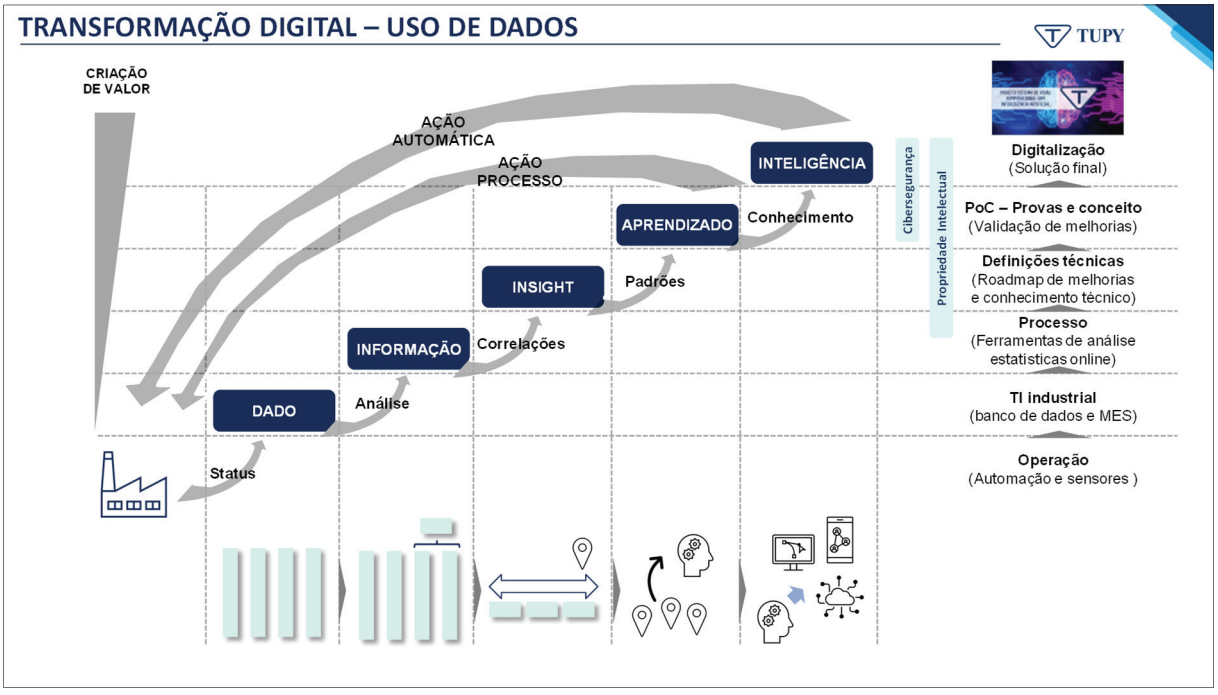
Presente com desenvolvimento sustentável
TUPY
Presença em diversos setores
Agricultura
Transporte de carga
Infraestrutura
Geração Energia
Impacto direto na saúde, saneamento, alimentação = expectativa de vida
Resultados consistentes
4,2B
Receita líquida anual em reais (base 2020)
$$$$
Um dos maiores pagadores de dividendos do Brasil
18k
Investidores pessoas físicas, 7% do capital total
Pessoas motivadas
+ 14k
Colaboradores distribuídos na unidades do Brasil, México e escritórios nos Estados Unidos e Europa
Atuação consciente
+ 80k
Pessoas da comunidade atendidas no Centro de Triagem e Testagem COVID 19
47M
de metros quadrados destinados à conservação da biodiversidade

Mais de 80 anos de história
TUPY
Metalurgia Complexa
cinzento
vermicular
nodular
Geometrias Complexas
P&D e Inovação Tecnológica
Concepção e design
Metalurgia
Fundição
Usinagem
Cultura
Pioneirismo
Relações de longo prazo
Educação
Inovação
TUPY
OS ALICERCES DOS ÚLTIMOS 83 ANOS SE MANTÊM INTACTOS


Futuro habilitador
TUPY
TUPY
TECH
TUPY
TUPY
UP
P&D DISRUPTIVO
Aborda tecnologias que podem ganhar ênfase mercadológica e escalar nos segmentos atuais ou novos
TRANSFORMAÇÃO DIGITAL
Jornada digital com foco na adoção de Indústria 4.0, Digitalização e Escritório Digital
INOVAÇÃO
Inovação Aberta, Fomento, Intraempreendedorismo e Novos Negócios


Transformação Digital na prática
TUPY
PILARES DIGITAIS
Frentes de geração de valor com base em soluções conectadas com a necessidade do negócio Tupy
Gestão do Negócio
Operações
Gestão dos Ativos
Tecnologias habilitadoras
Clientes
ESG
TUPY
Qualidade
Pessoas e Conhecimentos
Liderança Tecnológica
TECNOLOGIAS HABILITADORAS
Diversas tecnologias que servem como base para a construção das soluções aplicadas nos pilares digitais

TRANSFORMAÇÃO DIGITAL – USO DE DADOS



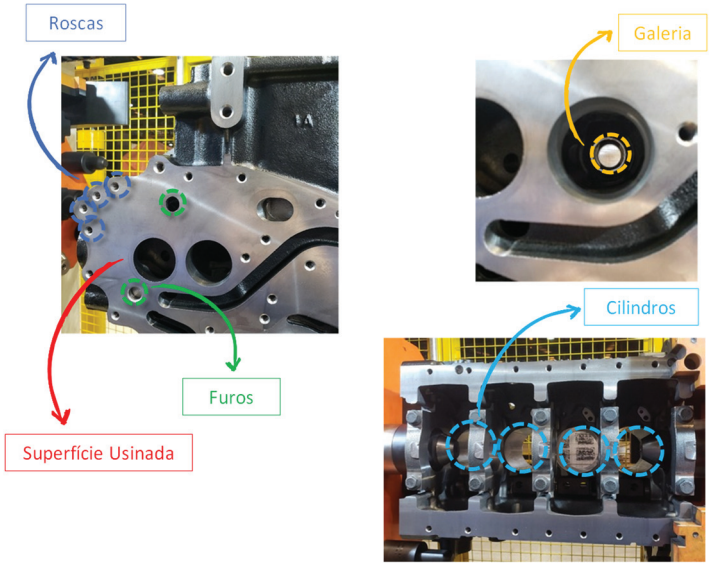
SISTEMA DE VISÃO
COMPUTACIONAL COM
INTERLIGÊNCIA ARTIFICIAL

SISTEMA DE VISÃO COMPUTACIONAL COM INTELIGÊNCIA ARTIFICIAL
TUPY
Conceito
Aplicação de um sistema de visão computacional com inteligência artificial para automatização no processo de inspeção final visando melhoria na inspeção da qualidade do produto.
Objetivos
Inspeção de peças com inteligência artificial para evitar erro humano na tomada de decisões;
Padronizar o tempo de ciclo de inspeção;
Aumentar qualidade da inspeção;
Redução de custos de não qualidade.
Detalhamento
INSPEÇÃO DE PEÇAS COM INTELIGÊNCIA ARTIFICAL
Exemplos de regiões a serem analisadas
Roscas
Galeria
Cilindros
Furos
Superfície Usinada
Defeitos a serem analisados
Falta de operação;
Rosca incompleta;
Inclusões;
Falta de material;
Obstruções;
Pontos de oxidação;
Riscos;
Amassados;
Quebra de borda;
Análise Dimensional;
Conceito em estudo.
Motivador
Automatização do processo
QUALIDADE
Qualidade na inspeção de peças
Custos elevados por não qualidade
Conexão com os pilares digitais
Operações
Gestão dos Ativos
Gestão do Negócio
ESG
Clientes
TUPY
Liderança Tecnológica
Qualidade
Pessoas e Conhecimento

INSPEÇÃO DE PEÇAS COM INTELIGÊNCIA ARTIFICAL

TUPY

Exemplos de regiões a serem analisadas



Defeitos a serem analisados

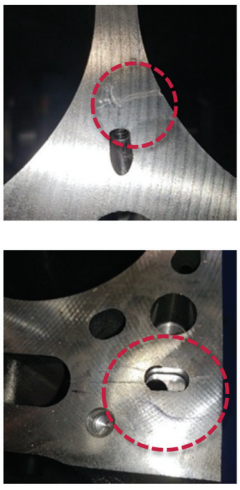
- Falta de operação;
- Rosca incompleta;
- Inclusões;
- Falta de material;
- Obstruções;
- Pontos de oxidação;
- Riscos;
- Amassados;
- Quebra de borda;
- Análise Dimensional;

INSPEÇÃO DE PEÇAS COM INTELIGÊNCIA ARTIFICAL

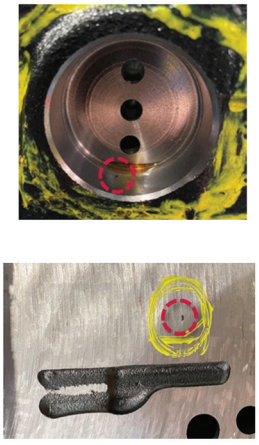
TUPY

Exemplos de defeitos a serem inspecionados

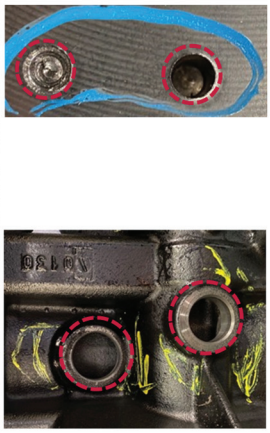
Riscos



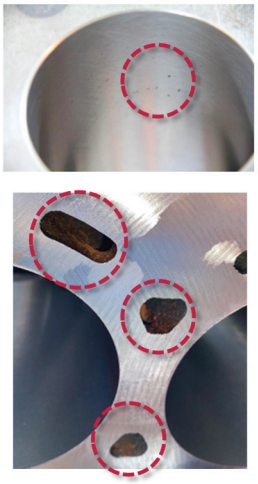
Inclusões



Falta de Operação/Material



Pontos de oxidação



PROVA DE CONCEITO DA TECNOLOGIA

TUPY

Prova de Conceito

Objetivo

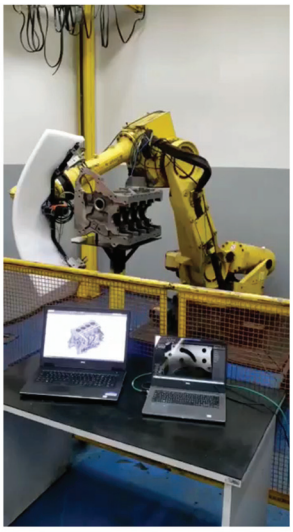
Avaliar a eficácia da tecnologia do sistema de visão computacional para na identificação de defeitos presentes em faces usinadas.

Método

- Instalação do sistema de visão;
- Realizar PoC;
- Coleta de imagens com defeitos mais recorrentes;
- Parametrização do sistema analítico de imagens;
- Resultados.

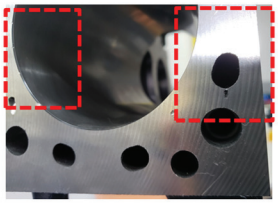
Sistema de Visão com defletor para iluminação direta

Testes

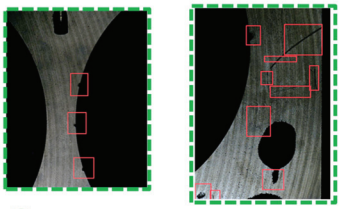


Resultados

Imagem capturada com celular



Imagens Sistema de Visão

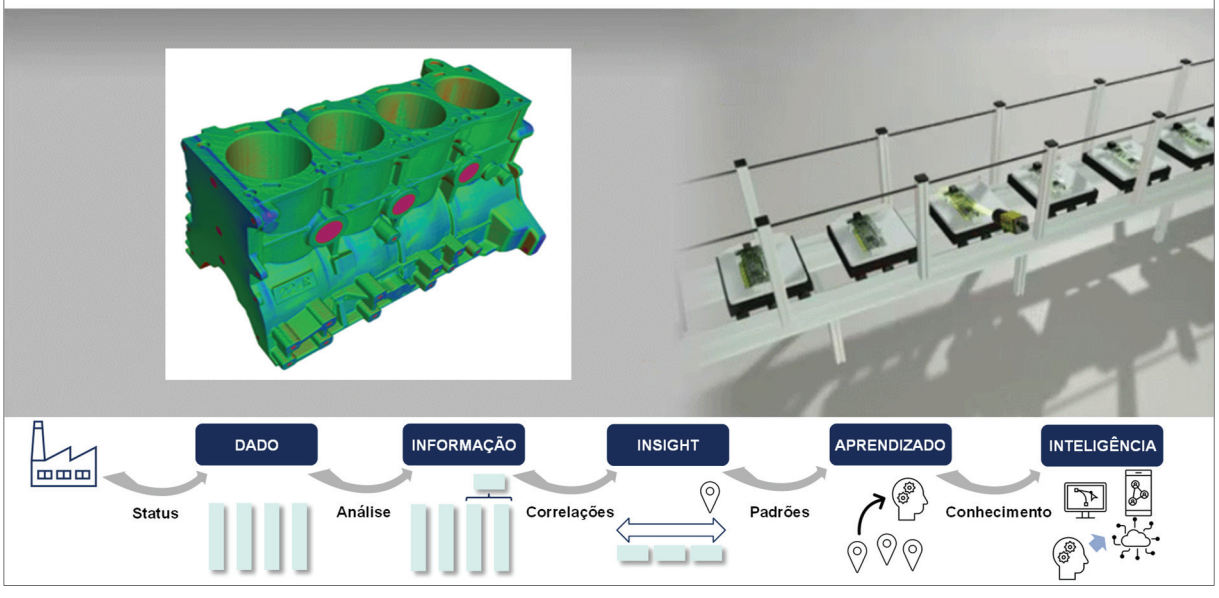


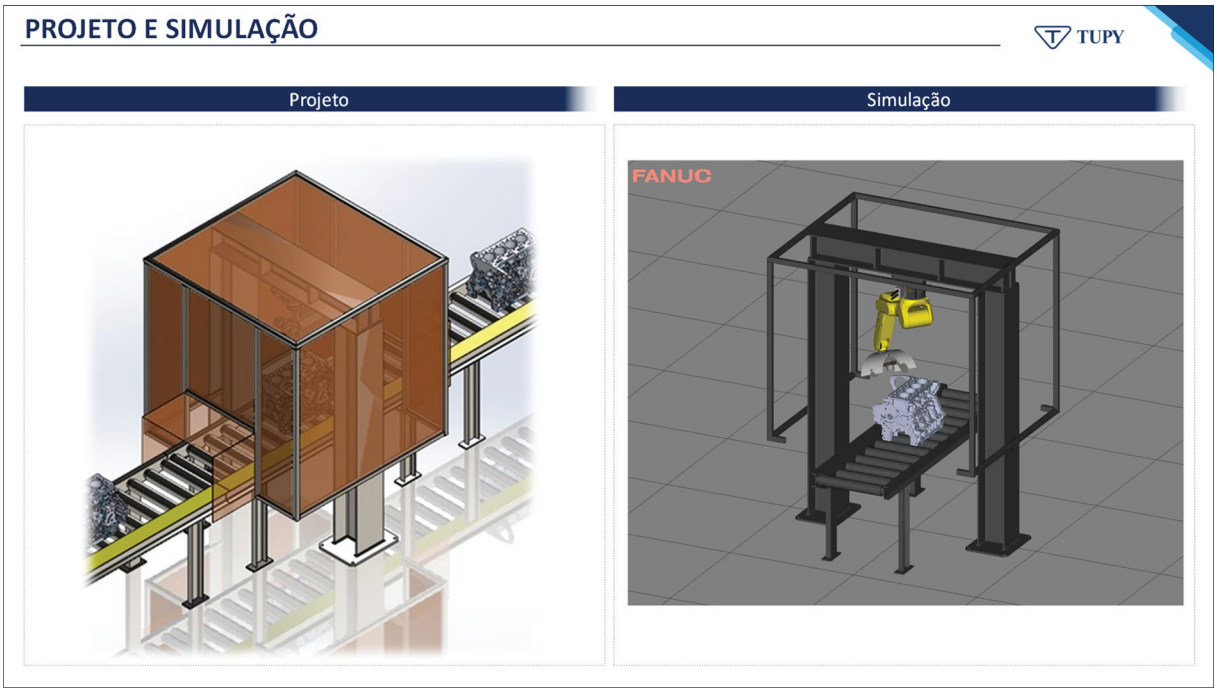
PoC Aprovado.

INTELIGÊNCIA ARTIFICIAL

TUPY

Conceito




PROJETO E SIMULAÇÃO
TUPY
Projeto
Simulação
FANUC

TUPY
Tupy, trabalhando na transformação
de um mundo melhor e mais sustentável.
TUPY

OBRIGADO!
Cassio Luiz Francisco de Andrade
Diretor Usinagem Corporativo
cassio@tupy.com.br
www.tupy.com.br

Dr.-Ing. Alain Pfouga

Dr.-Ing. Alain Pfouga, born in 1975, studied mechanical engineering and received the Dr.-Ing. degree in 2006 from the Technical University of Darmstadt, Germany. He began his professional career as a consultant in product lifecycle management at PROSTEP AG and has been continuously assigned to management positions since 2008. In 2009, he served as head of the Toulouse office of PROSTEP France Sarl and site coordinator for DMU integration A380 at Airbus. From 2010 to 2014, he was assigned to establish an international distribution channel for PROSTEP with partners from South Korea, Japan, USA, and Nordics. As of July 01, 2017, he was appointed as the general manager of the prostep ivip Association - a community of interest with over 190 organizations joined together to define solutions for industrial digital transformation. He also actively serves in international standardization and as an advisory board member of the research association Smart Engineering.

✉ alain.pfouga@prostep.com

prostep ivip Association

prostep ivip is a leading, globally active, independent network of industry, IT and research. The industry-driven non-profit association focuses on the digital transformation in product creation and production. Collaboration, Systems Engineering and Digital Twin among other topics play decisive roles. For enabling the digital transformation in the manufacturing industry, prostep ivip defines and aggregates the requirements of manufacturers and suppliers from different branches. Goal is the digitalization of the entire product creation process – from idea to implementation. Therefore, standards are set, and related implementations are fostered. The headquarters of prostep ivip is in Darmstadt, Germany, and the Association was founded in October 1993 by 38 industrial companies and several system vendors as part of the German STEP initiative. Members of prostep ivip currently include almost 200 companies and organizations from more than 20 nations.

prostep IVIP

Strategic options for industrial digital transformation

Abstract

Many industrial companies are searching for individual approaches to ways in which they can use digital tools to transform their development, manufacturing, service operations, etc. and develop new data-driven business models. Based on our observations of the context in which such companies act, we want to fine-tune our vision of the future and offer collaborative concepts that could help them get to grips with the digital future. It isn't clear what specific impact our constantly changing world will have on the classic value chains, but this presentation discusses key drivers and options for change, based on our observation of the surrounding environment.

Keywords

VUCA; CASE; Product IT; Lifelong Learning; CO2-Footprint; Digital Transformation.

prostep ivip
Strategic options for industrial digital transformation
reflected on needs and challenges in the industry
International Seminar on High Technology
30 September 2021
SCPM
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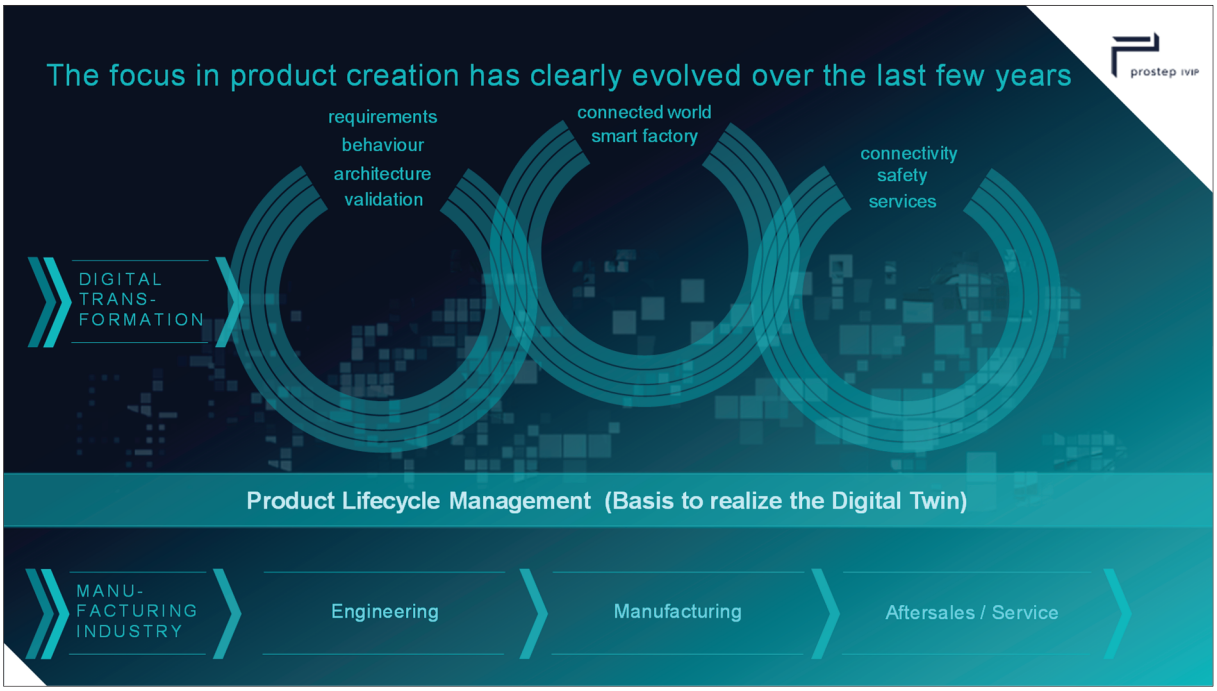
The focus in product creation has clearly evolved over the last few years
prostep ivip
MANU-
FACTURING
INDUSTRY
Engineering
Manufacturing
Aftersales / Service
Product Lifecycle Management (Basis to realize the Digital Twin)


The focus in product creation has clearly evolved over the last few years
prostep ivip
requirements
behaviour
architecture
validation
connected world
smart factory
connectivity
safety
services
DIGITAL
TRANS-
FORMATION
Product Lifecycle Management (Basis to realize the Digital Twin)
MANU-
FACTURING
INDUSTRY
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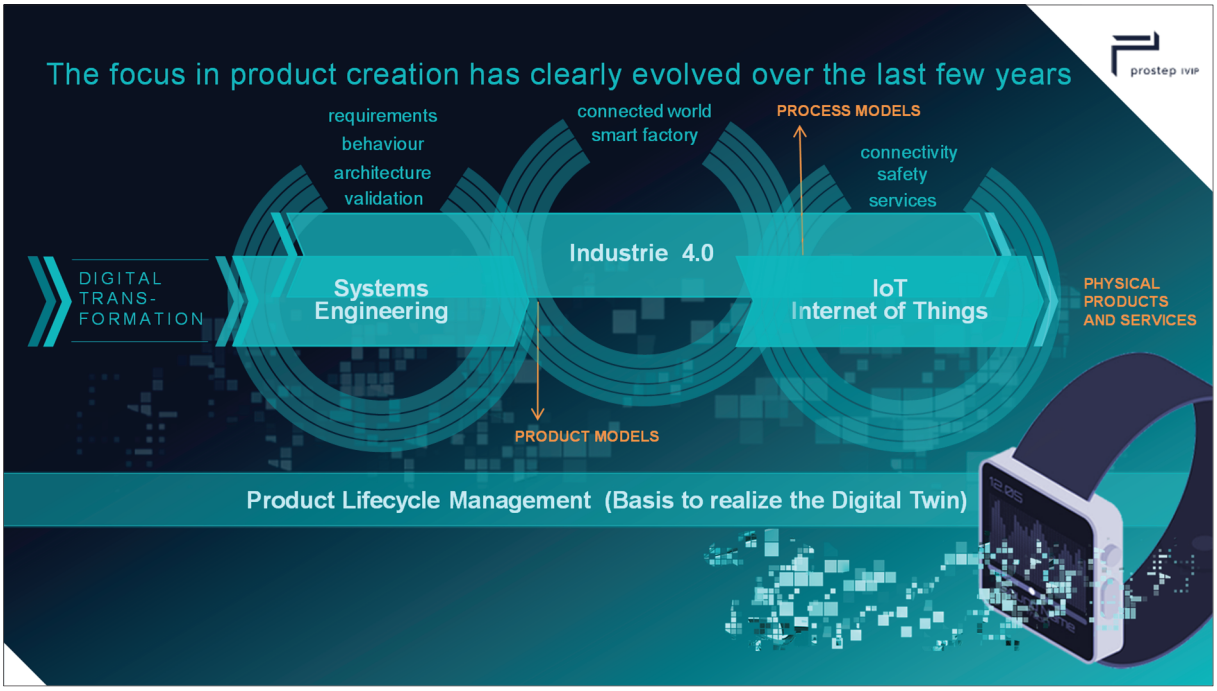
Aftersales / Service


The focus in product creation has clearly evolved over the last few years
prostep ivip
requirements
behaviour
architecture
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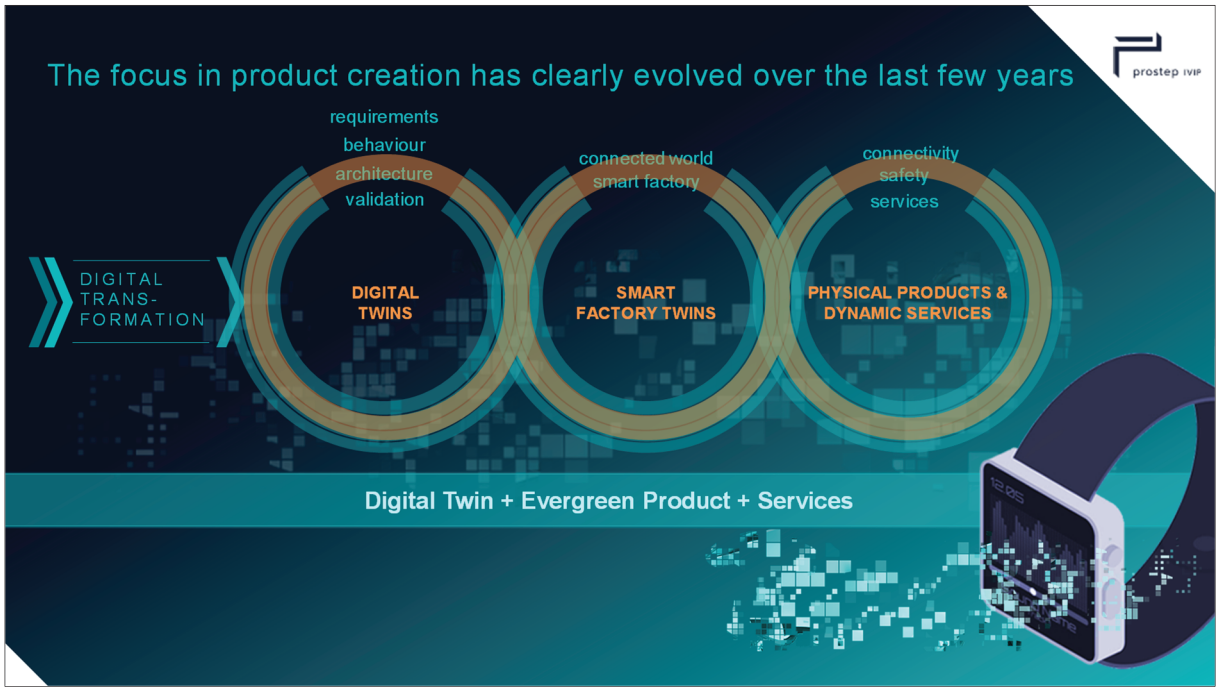
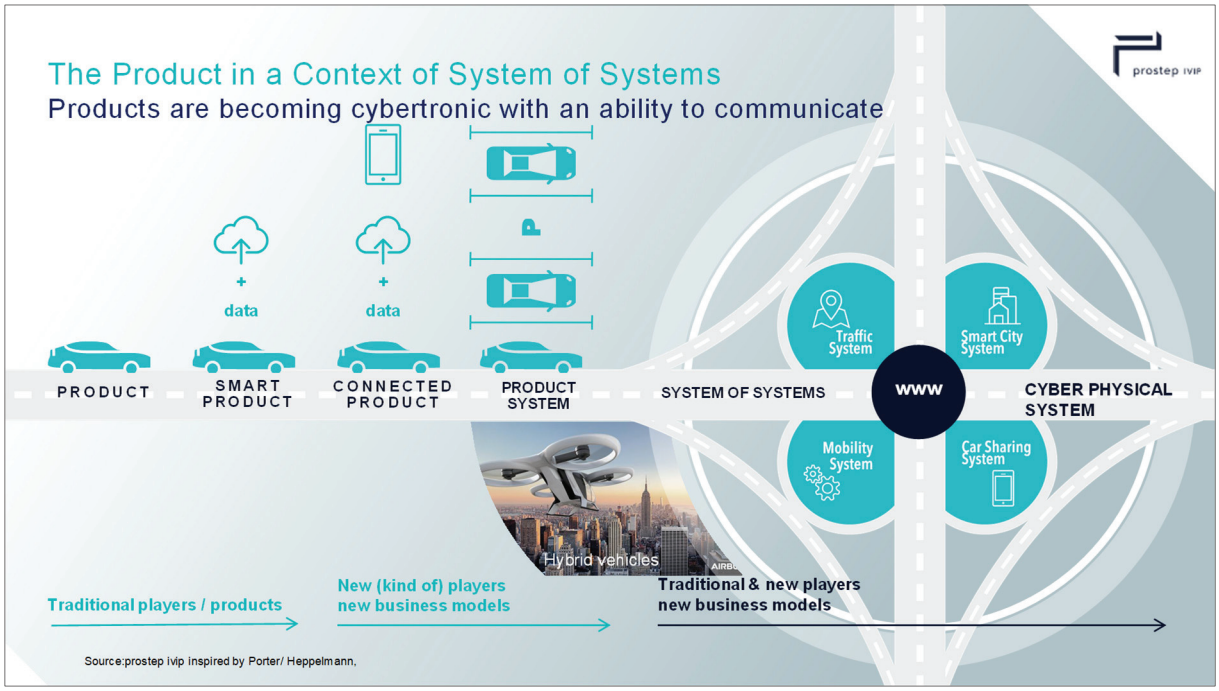
connected world
smart factory
PROCESS MODELS
connectivity
safety
services
Industrie 4.0
DIGITAL
TRANS-
FORMATION
Systems
Engineering
IoT
Internet of Things
PHYSICAL
PRODUCTS
AND SERVICES
PRODUCT MODELS
Product Lifecycle Management (Basis to realize the Digital Twin)


The focus in product creation has clearly evolved over the last few years
prostep ivip
requirements
behaviour
architecture
validation
connected world
smart factory
connectivity
safety
services
DIGITAL TRANS-FORMATION
DIGITAL TWINS
SMART FACTORY TWINS
PHYSICAL PRODUCTS & DYNAMIC SERVICES
Digital Twin + Evergreen Product + Services


The Product in a Context of System of Systems
Products are becoming cybertronic with an ability to communicate
prostep ivip
+ data
+ data
PRODUCT
SMART PRODUCT
CONNECTED PRODUCT
PRODUCT SYSTEM
SYSTEM OF SYSTEMS
www
CYBER PHYSICAL SYSTEM
Traffic System
Smart City System
Mobility System
Car Sharing System
Hybrid vehicles
Traditional players / products
New (kind of) players new business models
Traditional & new players new business models
Source:prostep ivip inspired by Porter/ Heppelmann,

The Product in a Context of System of Systems
Products are becoming cybertronic with an ability to communicate
prostep ivip
+
data
+
data
IT IN THE DEVELOPMENT
IT IN THE PRODUCT
IT
WORLDS
Hybrid vehicles
Traditional players / products
New (kind of) players
new business models
Source:prostep ivip inspired by Porter/ Heppelmann,

prostep ivip
Key drivers for transformations
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The world that surrounds us
Issues, technologies and solutions

Volatility Uncertainty Complexity Ambiguity	Connected Autonomous Sharing Economy Electric	Development Cost Program lead-time Agile & MUCH Faster	**Lifelong learning** Just-in time knowledge - online
Sustainability Customer & Consumer Oriented Interdisciplinary Engineering Accelerated Half-Life Cycles Data-Centric	Production and Supply Chain, Support and Services, Engineering	"We are in the deepest transformation since the creation of our industry" - *Toyota.*	Engineering tackles challenges beyond economics, with implications on mankind's very existence
	Digitalization		**New technologies emerging at huge speed:** AI & Machine Learning IOT & Digital Twin Blockchain, Hyperledger, RPA Quantum Computing
Decarbonization	Half-life of engineering knowledge is down to 3-5 years	"The winner takes all!" "Competition is for losers"	

Speed, speed, speed & Adaptability — Multi-Discipline Approach

Value-Opportunities

Data-Driven Businesses & Processes

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Key drivers of transformation

CO_2 / Ecological Footprint

Digitalization

Future markets and customer needs

People and Skills

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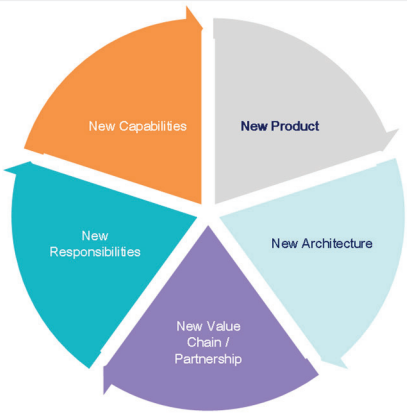
New Business Paradigms require new development processes

- CO_2 / Ecological Footprint
- Future markets and customer needs
- Digitalization
- People and Skills



Measures and capabilities for success

- **Maturity of Capabilities vs. Maturity of Integration**
- **Digital Thread / Continuity**
  Traceability is a fundamental capability (e.g. for ecological footprint)
- **Value-Chain Positioning**
  Business Focus
- **Variability of the Development Objectives**
  Time to Market vs. Maturity vs. Quality vs. Shareability vs. …

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Data driven engineering collaboration

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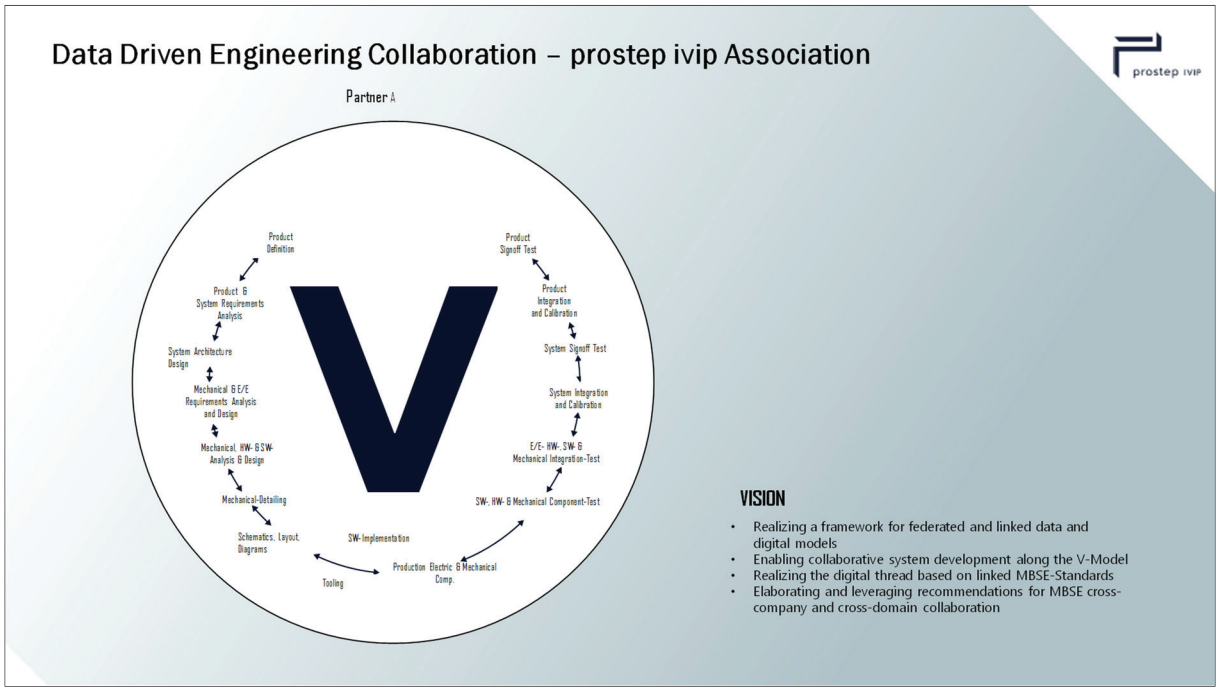
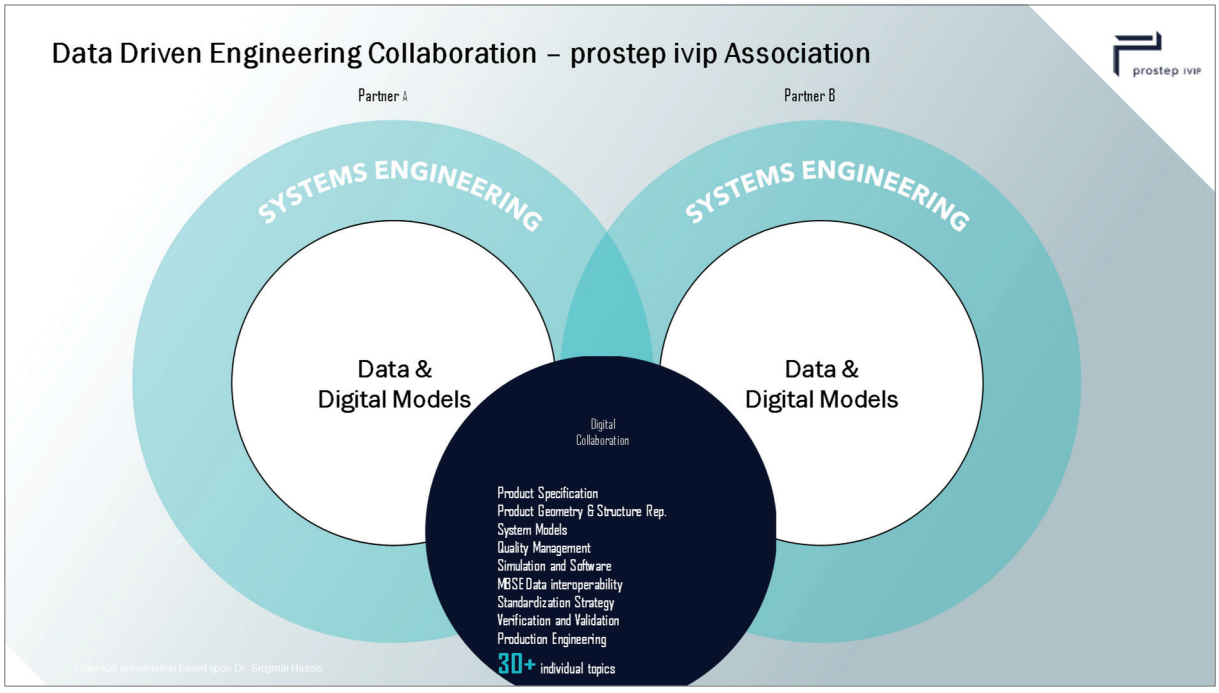
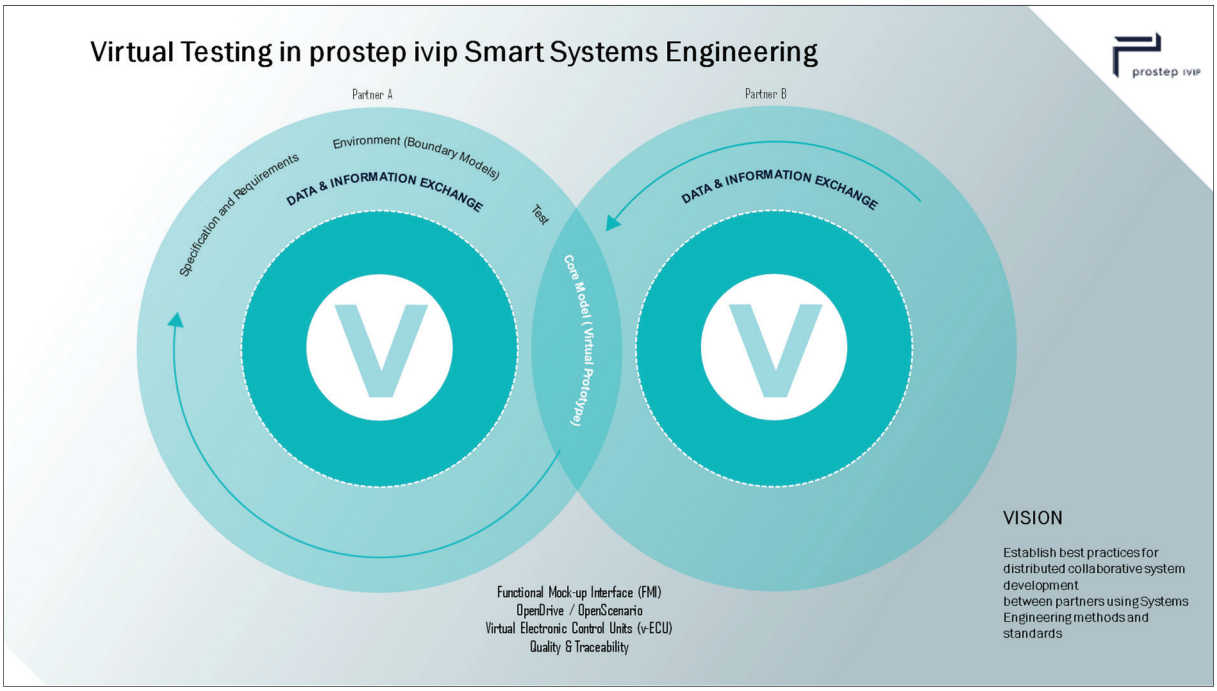

Data Driven Engineering Collaboration – prostep ivip Association
prostep ivip
Partner A
Product Definition
Product & System Requirements Analysis
System Architecture Design
Mechanical & E/E Requirements Analysis and Design
Mechanical, HW- & SW- Analysis & Design
Mechanical-Detailing
Schematics, Layout, Diagrams
SW-Implementation
Tooling
Production Electric & Mechanical Comp.
SW-, HW- & Mechanical Component-Test
E/E-, HW-, SW- & Mechanical Integration-Test
System Integration and Calibration
System Signoff Test
Product Integration and Calibration
Product Signoff Test
VISION
Realizing a framework for federated and linked data and digital models
Enabling collaborative system development along the V-Model
Realizing the digital thread based on linked MBSE-Standards
Elaborating and leveraging recommendations for MBSE cross-company and cross-domain collaboration


Data Driven Engineering Collaboration – prostep ivip Association
prostep ivip
Partner A
Partner B
SYSTEMS ENGINEERING
SYSTEMS ENGINEERING
Data & Digital Models
Data & Digital Models
Digital Collaboration
Product Specification
Product Geometry & Structure Rep.
System Models
Quality Management
Simulation and Software
MBSE Data interoperability
Standardization Strategy
Verification and Validation
Production Engineering
30+ individual topics
Graphical presentation based upon Dr. Siegmar Haasis


Virtual Testing in prostep ivip Smart Systems Engineering
prostep ivip
Partner A
Partner B
Environment (Boundary Models)
Specification and Requirements
DATA & INFORMATION EXCHANGE
Test
DATA & INFORMATION EXCHANGE
Core Model (Virtual Prototype)
V
V
Functional Mock-up Interface (FMI)
OpenDrive / OpenScenario
Virtual Electronic Control Units (v-ECU)
Quality & Traceability
VISION
Establish best practices for distributed collaborative system development between partners using Systems Engineering methods and standards

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Strategic considerations for transformation
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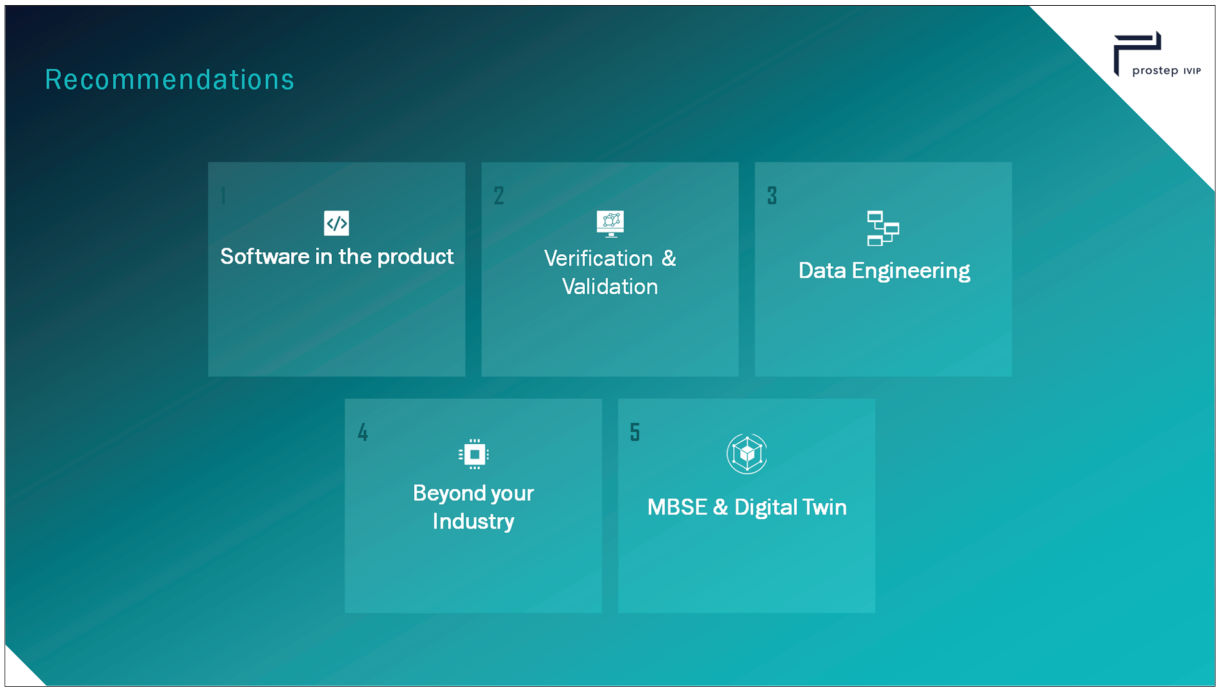
Recommendations
prostep ivip
1
Software in the product
2
Verification & Validation
3
Data Engineering
4
Beyond your Industry
5
MBSE & Digital Twin

prostep ivip
Networking People
Thank You!
Success for you – and your company

Patrocínio

EMAG

DMG MORI

VULKAN

FESTO

SANDVIK Coromant

THERMAL MANAGEMENT SOLUTIONS

SIEMENS

Apoio

TECHNISCHE UNIVERSITÄT DARMSTADT

TU berlin

UFABC

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