

# Integration of a visually supported Function-Embodiment-Synthesis into the Concepts of Model Based Systems Engineering (MBSE)

**Georg Moeser**

IPEK – Institute of Product Engineering at Karlsruhe Institute of Technology (KIT)

## **In which phase of your PhD work are you?:**

I have been a scientific assistant at IPEK for the last one and a half years. The phase of research clarification is done. The next steps are to set up a suitable research design.

## **How does your work refer or contribute to the field of systems engineering?:**

The aim of my work is to increase the acceptance of model based systems engineering (MBSE) in the field of mechanical engineering. This will be done by researching options supporting the modelling of principle solution and embodiment using models. These models have to fit with the overall methodology used by mechanical engineers and must be linked to system models and computer aided design (CAD)-models, which are the main tool to define the final embodiment in mechanical engineering.

## **1.0 Problem Statement**

It was observed that mechanical engineers in some cases struggle with the system context and the requirements of a part or subsystem they are supposed to design. Furthermore it would be helpful, to get information on concepts and working principles that have been chosen during earlier phases of the product development. Another issue is understanding a system design (focus on the embodiment), if changes to a given product should be conducted.[1]

Also the different levels of abstraction between system models (such as SysML models) and CAD models are a major barrier for mechanical engineers to use system models. [2]

The concepts of model based systems engineering (compare [3], [4]) seem to be suitable for information distribution as desired. Adaptions of modeling languages or new model-concepts will be investigated to overcome the missing acceptance of these concepts by mechanical engineers. More than 85 % of the methods described by Pahl/Beitz [5], which are relevant for function-embodiment-synthesis, require or suggest the usage of sketches, pictures and other visualizations [6]. Therefore the focus of this work will be on the usage of visualization within MBSE.

## **2.0 Research Objective, Hypothesis and Research Question**

The objective of this research work is to develop an approach...

- ... to document information (concerning functions, requirements, concepts, working principles, etc.) during concept phases and to offer these information to a designer while modeling with CAD
- ... to achieve traceability of the content of CAD models concerning functions, requirements, working principles of parts and assemblies.

Since mechanical engineers work a lot with sketches made by hand, a hypothesis is:

*Sketches as a main view to system models help mechanical engineers to get comfortable with (digital) system models.*

The main research question is:

*How can the work with sketches used for the modelling of principle solution and embodiment be adapted to get the content linkable in digital model chains?*

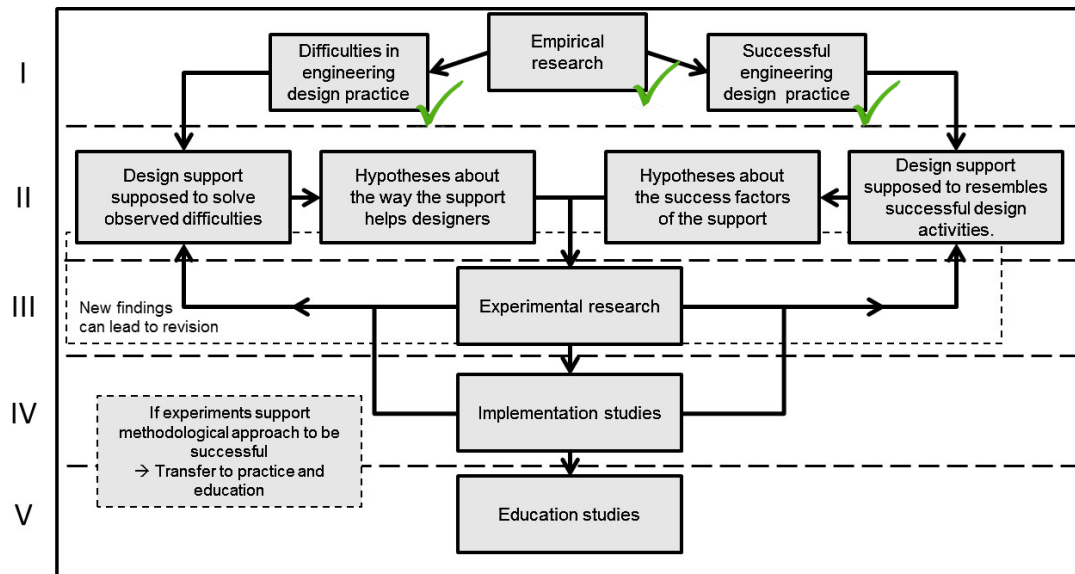
If it is possible to use (hand drawn) sketches within system models - with an acceptable amount of effort - , this will help to increase the acceptance of MBSE.

### 3.0 Research Approach

In order to achieved the research objectives, an approach based on best practices and scientific findings will be used. Studies on the needs of mechanical engineers will be done. Furthermore the processes in industry will be considered to design the new approach appropriate for industry use and to achieve user acceptance.

### 4.0 Methodology

As stated above the next steps are to set up a detailed research design. The research methodology will be based on MARXEN [7] (compare Figure 1).



**Figure 1: Development path of design support [7]  
(check marks added to display research progress)**

### 5.0 Research Contribution and Practical Implications

A successful implementation of the aimed approach will increase the efficiency and acceptance of systems engineering. The distributed up-to-date information will help engineers to save time to clarify system context and requirements of “their” part of the system. It will help to reduce iteration loops by having important information present. Furthermore the analysis of systems will get more effective, if changes or further developments are planned.

The connection of CAD-Systems to MBSE-models with a methodical approach will raise the return of invest of MBSE. Companies, that do invest in model based systems engineering, will get a more effective development process by using the model information from systems engineering with more disciplines - like mechanical engineering in this case.

## References

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- [2] Zingel, Johannes Christian (2013): Basis definition of a common language of product engineering in the context of modeling of technical systems and a modeling technique for the systems of objectives and objects of technical systems on the basis of the ZHO-principle, Karlsruhe, , IPEK - Institut für Produktentwicklung am Karlsruher Institut für Technologie
- [3] INCOSE (2014): A world in motion – systems engineering vision 2025; <http://incose.org/ProductsPubs/products/sevision2025.aspx>, reviewed January 2015
- [4] Friedenthal, Sanford; Moore, Alan; Steiner, Rick (2011): A Practical Guide to SysML: The Systems Modeling Language, Second Edition, Waltham, Morgan Kaufmann
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- [7] Marxen, Leif (2014): A Framework for Design Support Development based on the integrated Product Engineering Model iPeM, Karlsruhe, IPEK - Institut für Produktentwicklung am Karlsruher Institut für Technologie

## Contact

Dipl.-Ing. Georg Moeser

IPEK – Institute of Product Engineering at KIT  
Kaiserstraße 10; 76131 Karlsruhe; Germany

Phone: +49 721 608-47176

Fax: +49 721 608-46051

E-Mail: [georg.moeser@kit.edu](mailto:georg.moeser@kit.edu)

URL: [www.ipek.kit.edu/21\\_2568.php](http://www.ipek.kit.edu/21_2568.php)

# Integration of a visually supported Function-Embodiment-Synthesis into the Concepts of MBSE

Georg Moeser<sup>1</sup>

<sup>1</sup>IPEK – Institute of Product Engineering  
at Karlsruhe Institute of Technology (KIT)

**Motivation**  
**→2 Use Cases**

**State of Research**

**Research Objective**

**Research Question**

**Research Design**

**First Findings: My Approach**

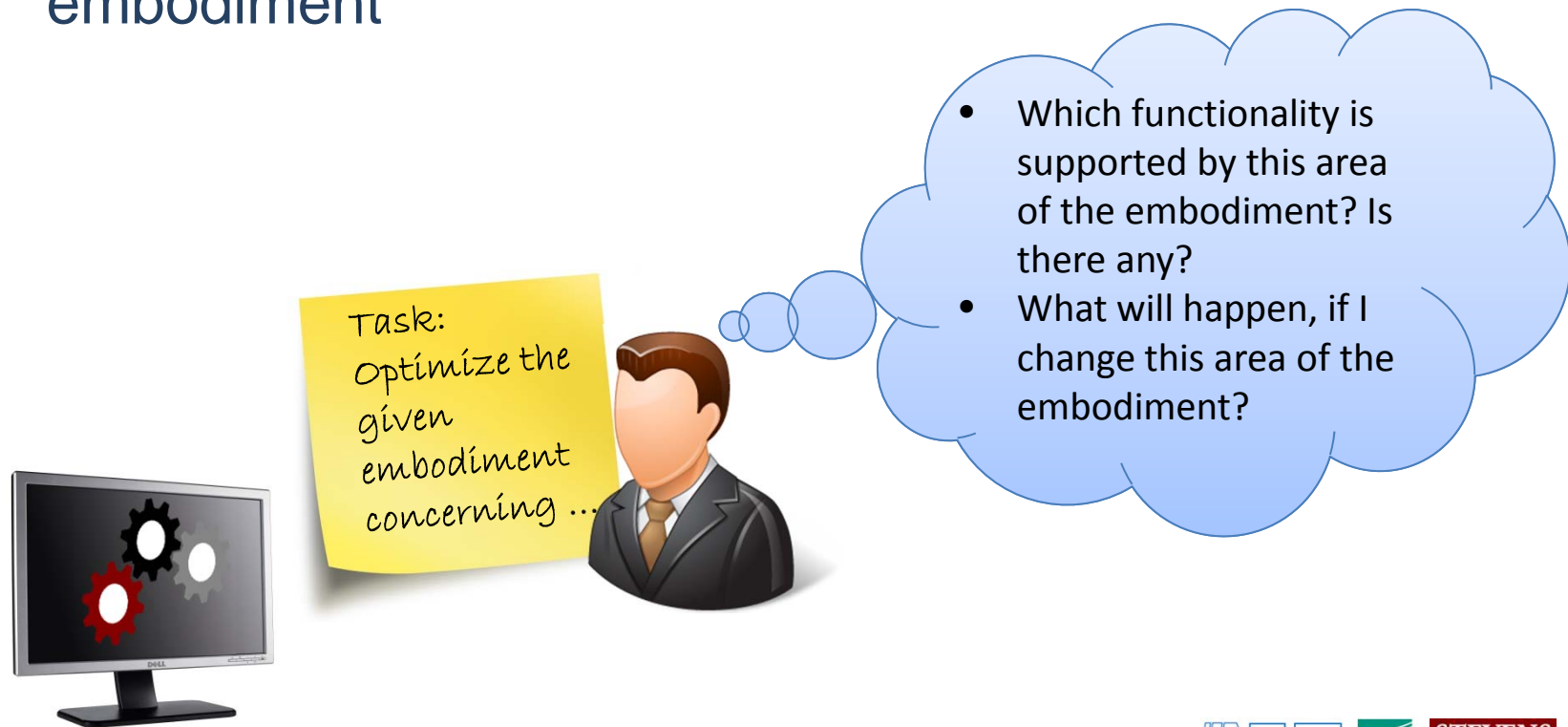
**Outlook**

**Summary**

- During Function-Embodiment-Synthesis (FES)
  - Different **illustrations are used** by engineers
  - Option to link the content of illustrations, showing important developed objects, is requested
  - **Not all relevant information** generated during the concept phase is **communicated** to CAD designers



- In development of product generations
  - Engineers **have to gain a detailed understanding** of the functions, achieved by the given reference embodiment



- In both use cases aspects of knowledge management are requested
- Interconnected models seem to be suitable solving the challenges

**MBSE concepts are investigated concerning their capabilities to support FES and the review of reference embodiments**



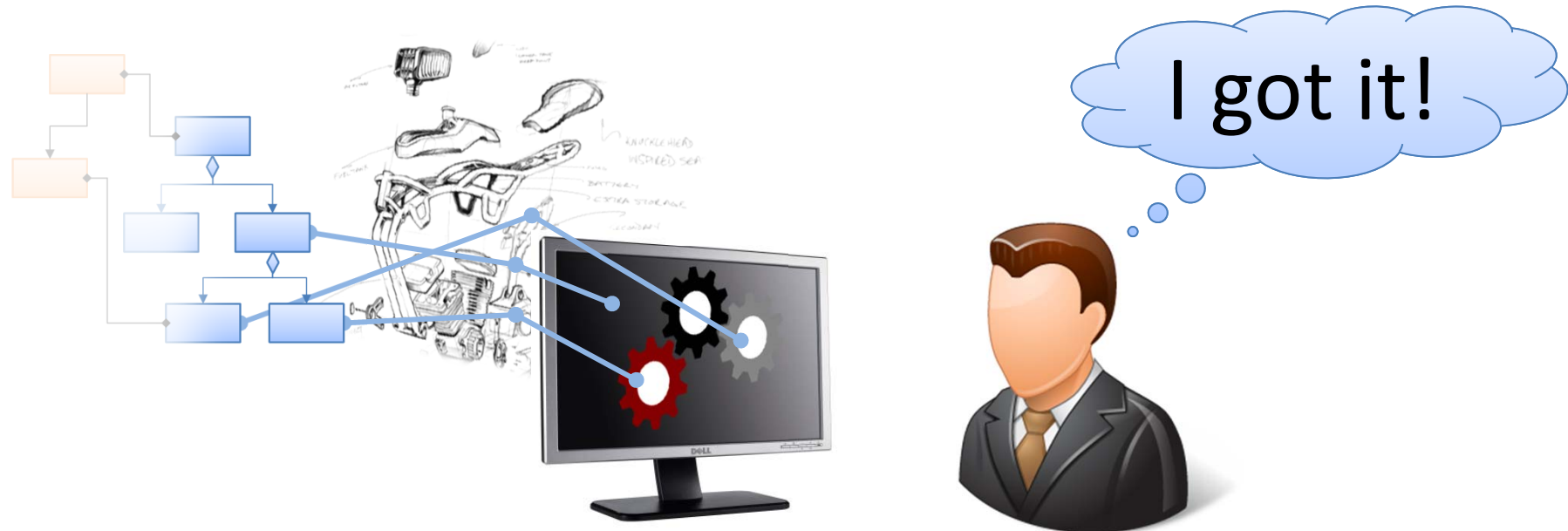
- Free sketches are **commonly used**
  - See Pahl/Beitz & Koller/Kastrup
- Usage of visualization, such as **free sketches**, is **supporting FES** activities
  - cognitive psychology
- Interdisciplinary modeling languages like **SysML** are **not capable** to link the content of free sketches to other model elements



- ... is to develop an approach for **knowledge management on FES** by **integrating free sketches in MBSE** in order to support the introduced use cases

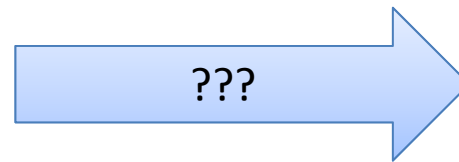
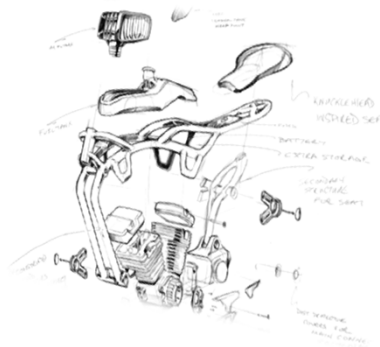


*„Free Sketches as a main view to system models help mechanical engineers to get comfortable with system models“*

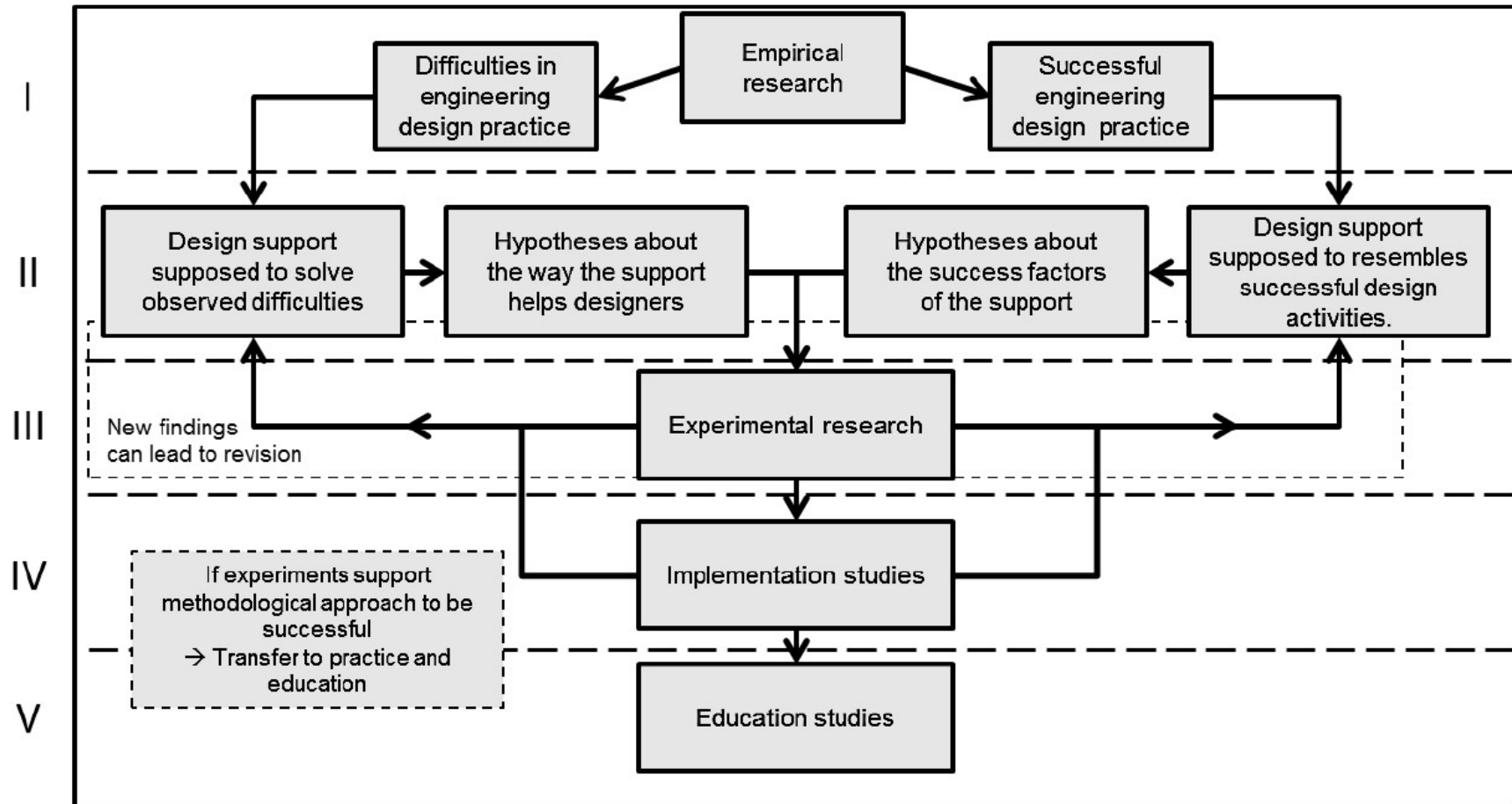


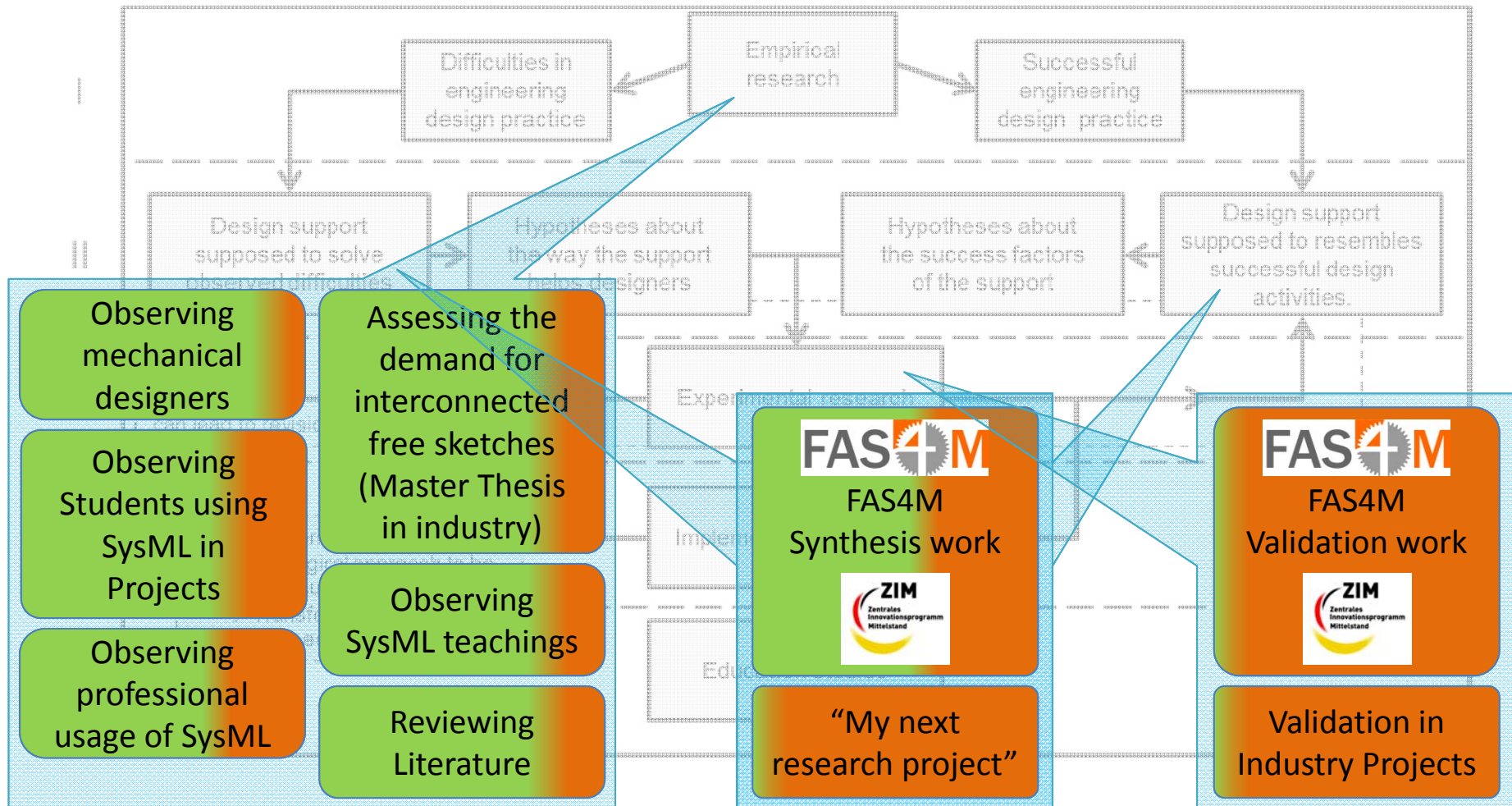
## Main question:

- How can the **work with free sketches**, used to model principle solution and embodiment, be **adapted**, to get their **content linkable** in digital model chains?



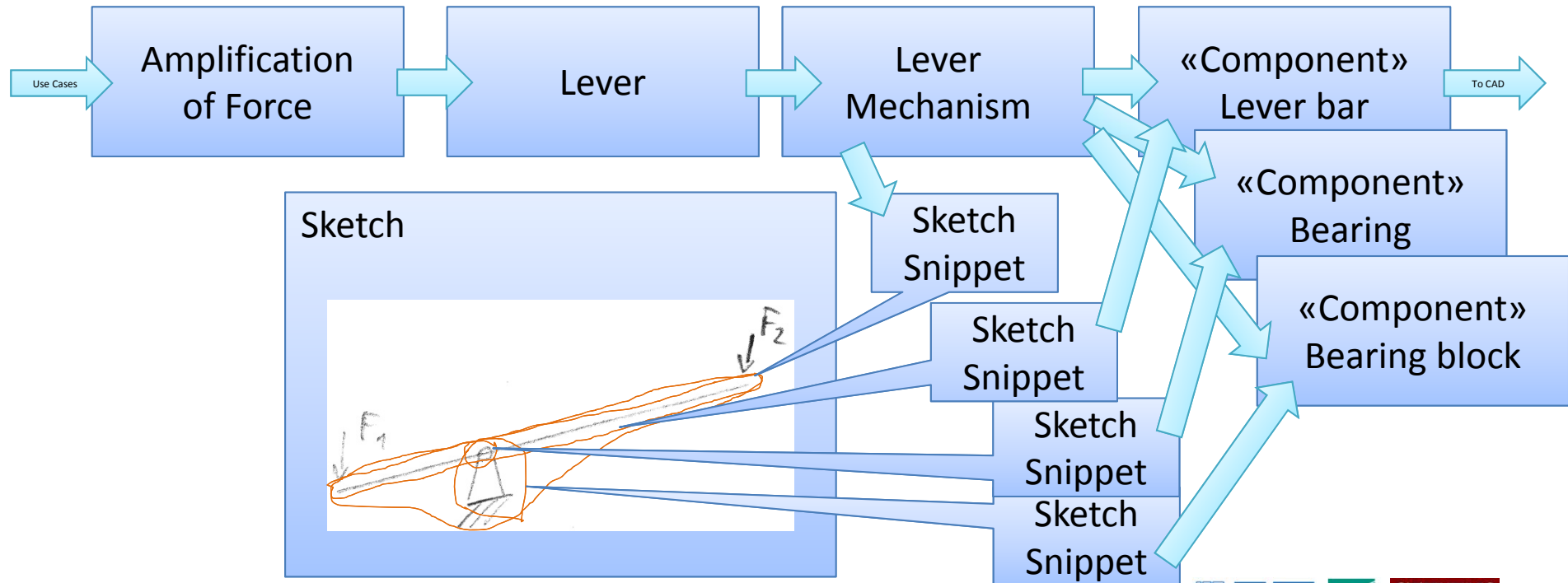
- Additionally more detailed questions



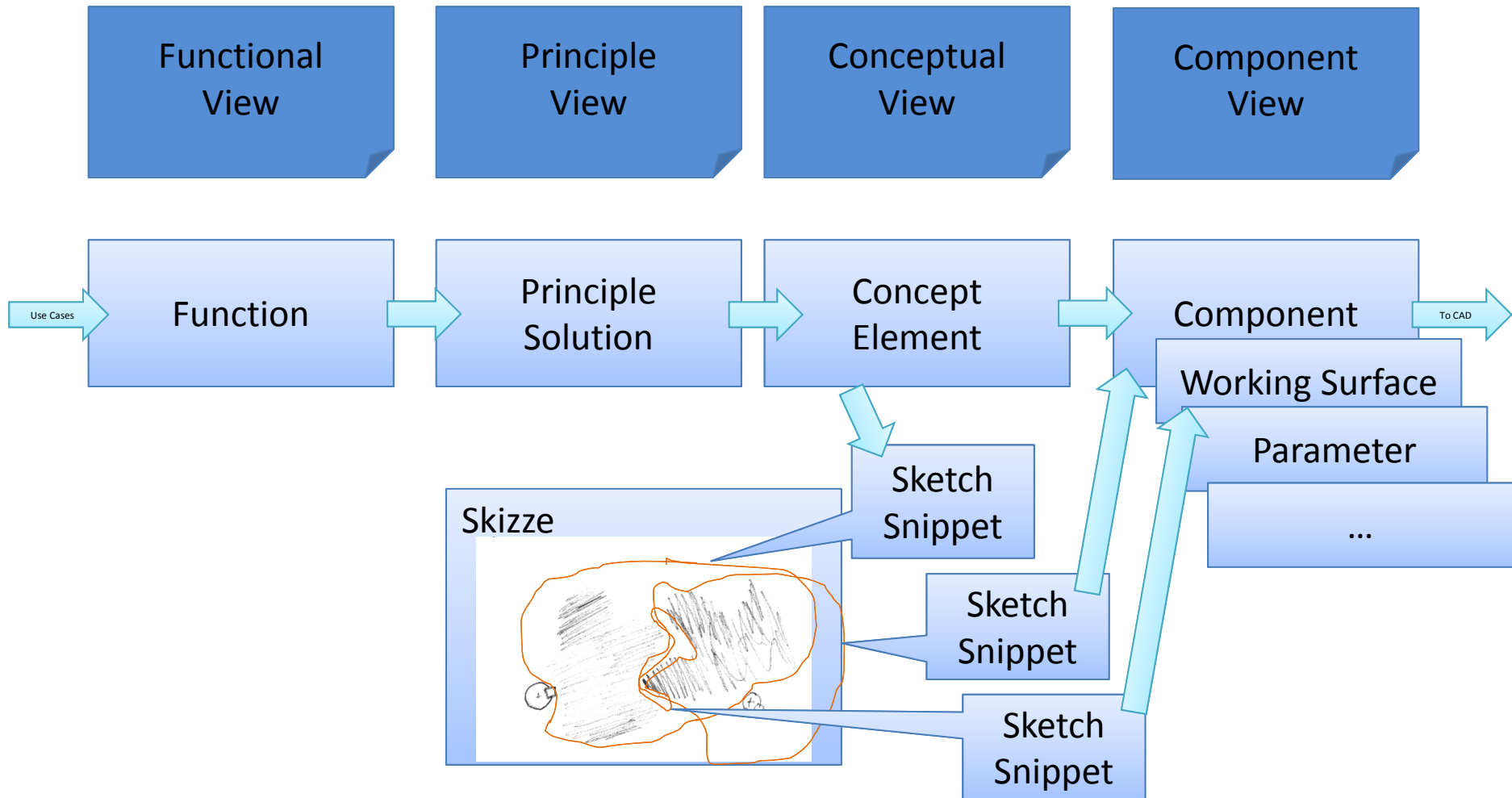




# My Approach – an example

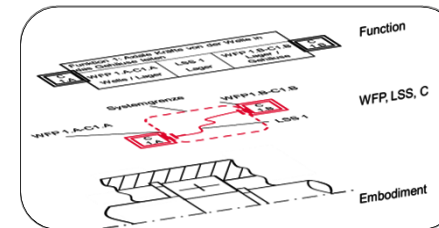


# My Approach

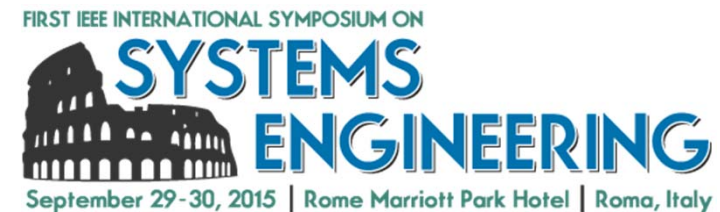




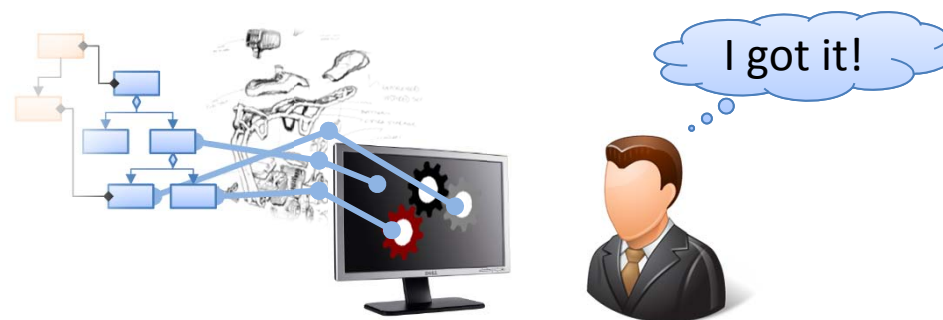
- **Develop a software tool** to support the new approach
- **Validate the new approach** in development projects
- **Integrate the Contact & Channel Approach (C&C<sup>2</sup>-A)**



- **Publicize at**
  - IEEE ISSE – IEEE International Symposium on Systems Engineering
  - TdSE – Tag des Systems Engineering



- Successful implementation of the approach will...
  - ... increase efficiency in SE (e.g. less of cost intensive iterations)
  - ... raise the RoI of MBSE by more efficient engineering, due to using the model information from SE in more disciplines



# Georg Moeser

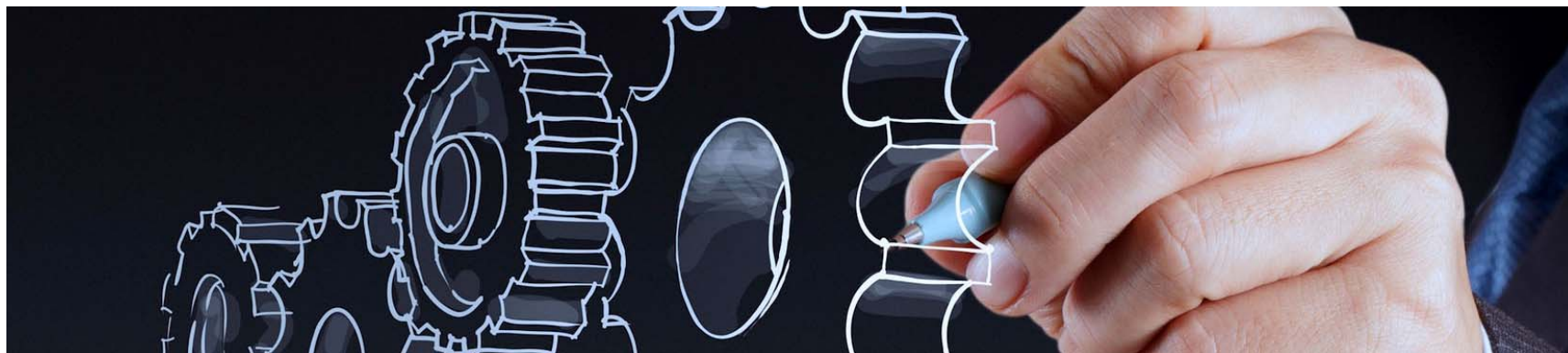
Scientific Assistant

IPEK – Institute of Product Engineering  
at Karlsruhe Institute of Technology (KIT)

Tel.: +49 721 608-47176

Fax: +49 721 608-46051

[georg.moeser@kit.edu](mailto:georg.moeser@kit.edu)



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