# Introduction to Mechatronic Systems Design

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# Course Assessment

- Student Activities (40%)
  - Progress Reports
  - Quizzes
  - Assignments
- Midterm (20%)
- Project(40%)

- **Policy**
- Topics
- Introduction
- VDI 2206

# Literature

- Gausemeier, J., & Moehringer, S. (2002). VDI 2206-a new guideline for the design of mechatronic systems. IFAC Proceedings Volumes, 35(2), 785-790.
- D. Shettyand R. Kolk, “Mechatronic System Design”, CengageLearning, 2nd Edition, 2011
- SabriCetinkunt, “Mechatronics with Experiments”, Wiley, 2015

# Main Topics

- Introduction to mechatronic systems design
- VDI 2206 guideline for mechatronic design
- Actuator sizing and selection
- Actuator's performance curves and design of control loops
- Software tools for mechatronic systems design

- Policy
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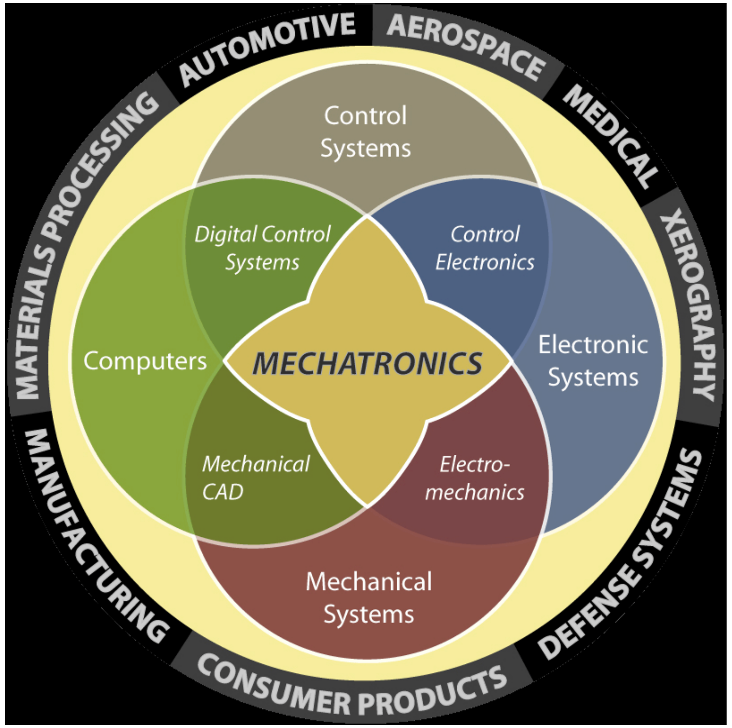
# Definitions

- Mechatronics:




Mechatronics is synergistic integration of mechanical engineering, electronic systems, control systems and intelligent control in design and manufacture of products and processes.

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# Examples

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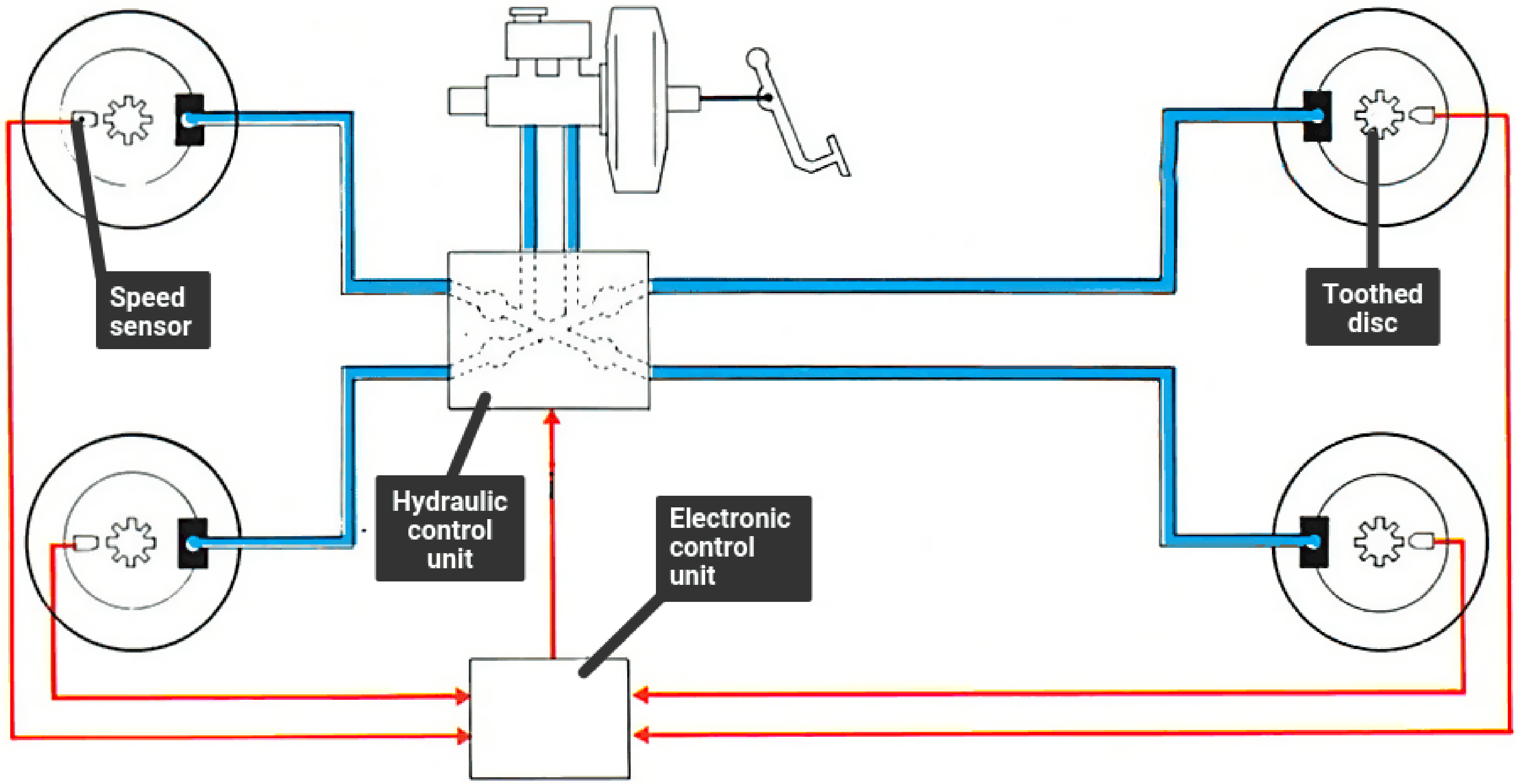
# Examples



# Examples

https://www.youtube.com/watch?v=ru4JIZ-x8yo

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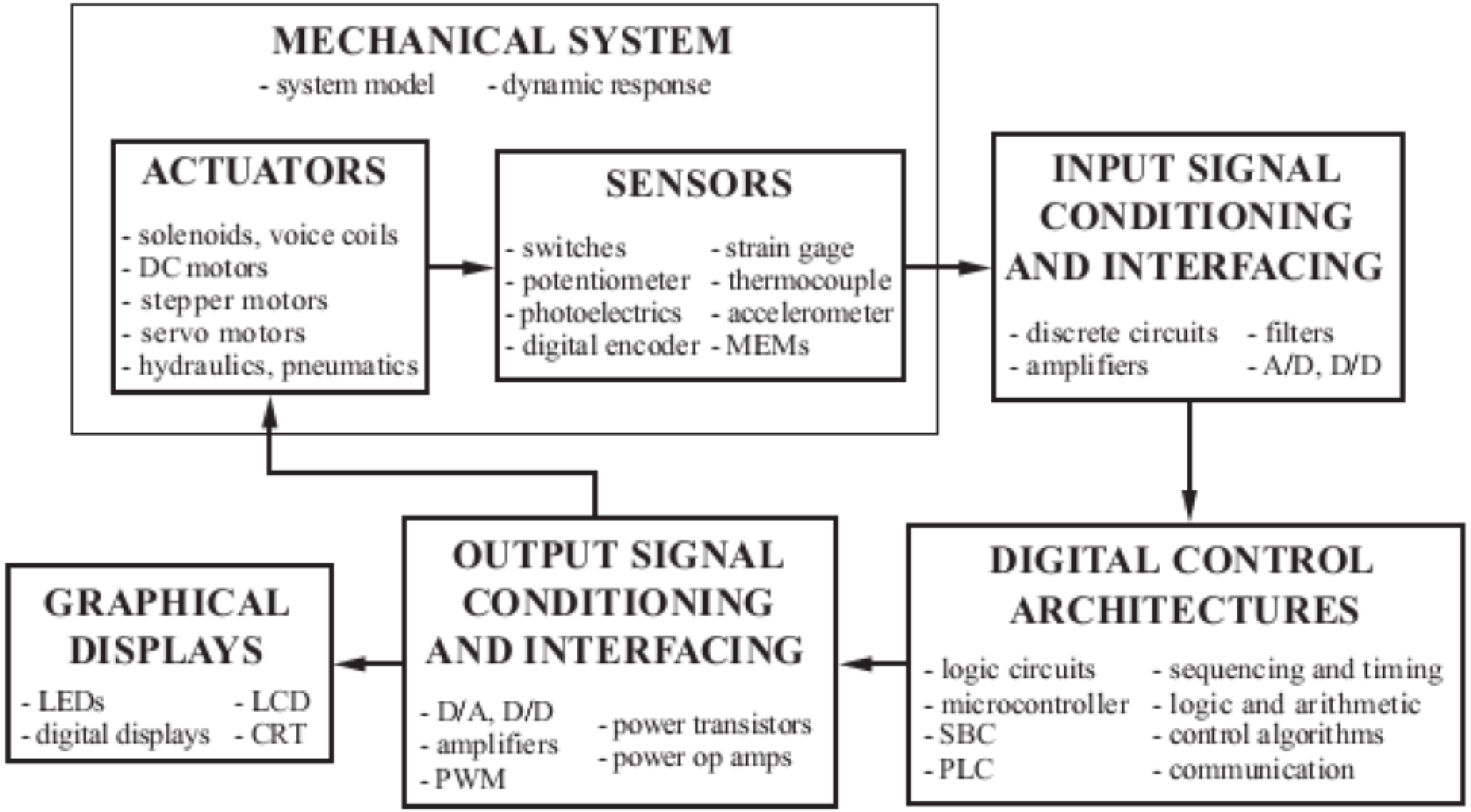
# Mechatronic Systems Components



# Why Mechatronics?

- Mechatronics is a design philosophy: an integrating approach to engineering design
- Mechatronics is a methodology used for the optimal design of inter-disciplinary products.
- The mechatronic design methodology is based on a concurrent (instead of sequential) approach to discipline design, resulting in products with more synergy.

# Why Mechatronics?

- Mechatronics is a synergy in the integration of mechanical, electrical, and computer systems with information systems for the design and manufacturing of products and processes. The synergy is generated by the right combination of parameters; the final product can be better than just the sum of its parts.
- Mechatronic products exhibit performance characteristics that were previously difficult to achieve

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# Why Mechatronics?

- Concurrent engineering is a design approach in which the design and manufacture of a product are merged in a special way. It is the idea that people can do a better job if they cooperate to achieve a common goal. It has been influenced partly by the recognition that many of the high costs in manufacturing are decided at the product design stage itself.

# Why Mechatronics?

- The characteristics of concurrent engineering are:

1. Better definition of the product without late changes.
2. Design for manufacturing and assembly undertaken in the early design stage.
3. Process on how the product development is well defined.
4. Better cost estimates.
5. Decrease in the barriers between design and manufacturing.

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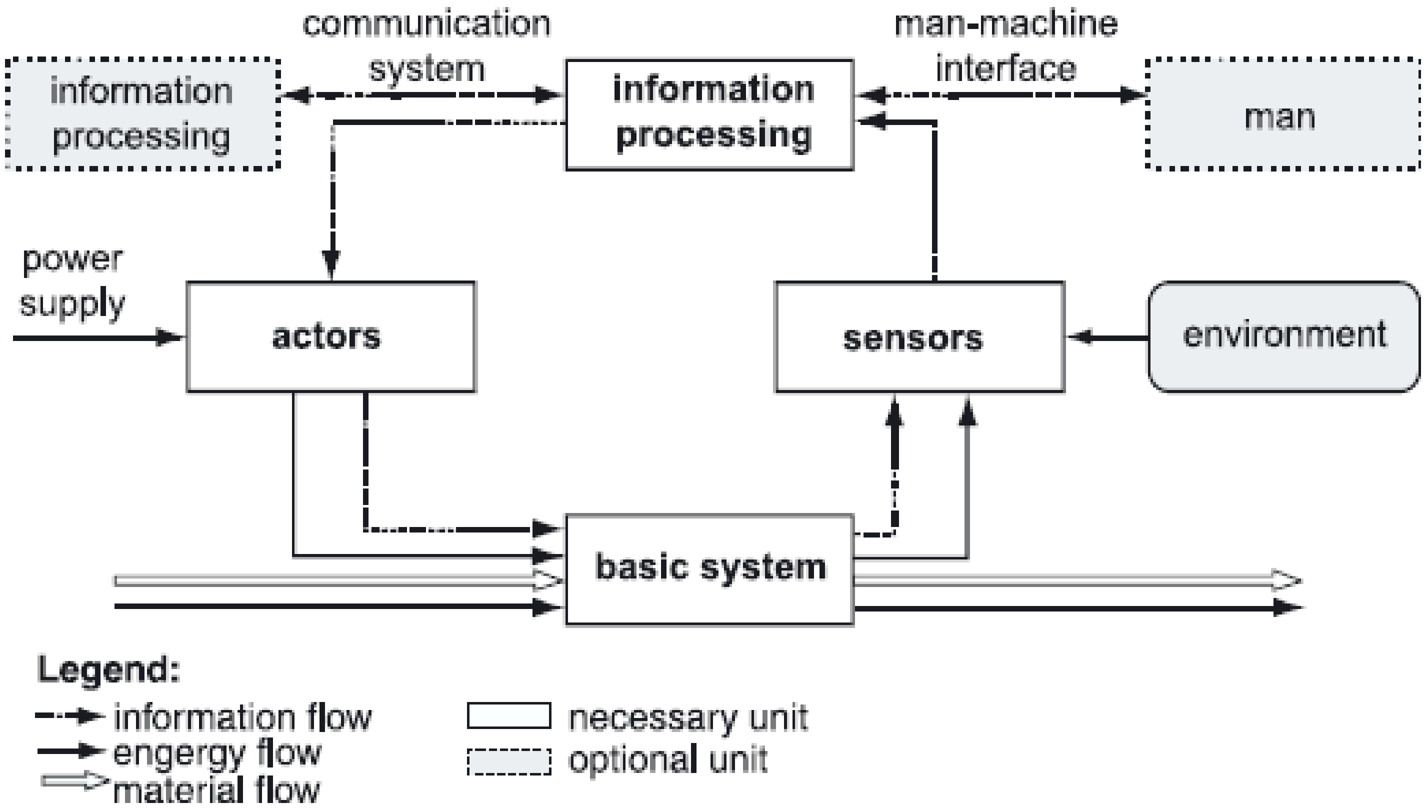
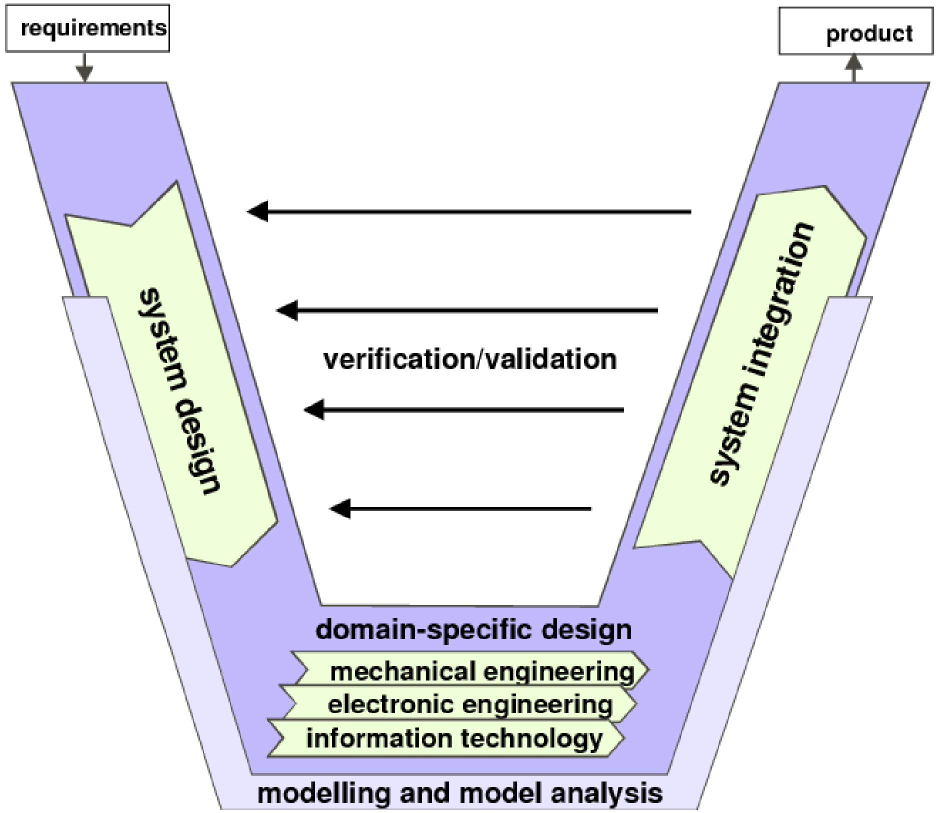
## Basic Structure of a Mechatronic System



# V-Shaped Model for Design of Mechatronic Systems

**Requirements:** Starting point is an individual design task. The task has been clarified/defined and described with the help of requirements. These requirements represent at the same time the measure for the evaluation of the later product.

**System design:** The object is to define a cross-domain solution concept which describes the essential physical and logical characteristics of the future product. The overall function of a system will be divided into sub-functions. Suitable working principles and/or solution elements are assigned to these sub-functions and the fulfilling of the functions regarding the overall system context is evaluated. In mechanical engineering this phase is called “conceptualisation”, but this term has not the same meaning within software and electronic engineering. Therefore “system design” has been chosen as a cross-domain term.



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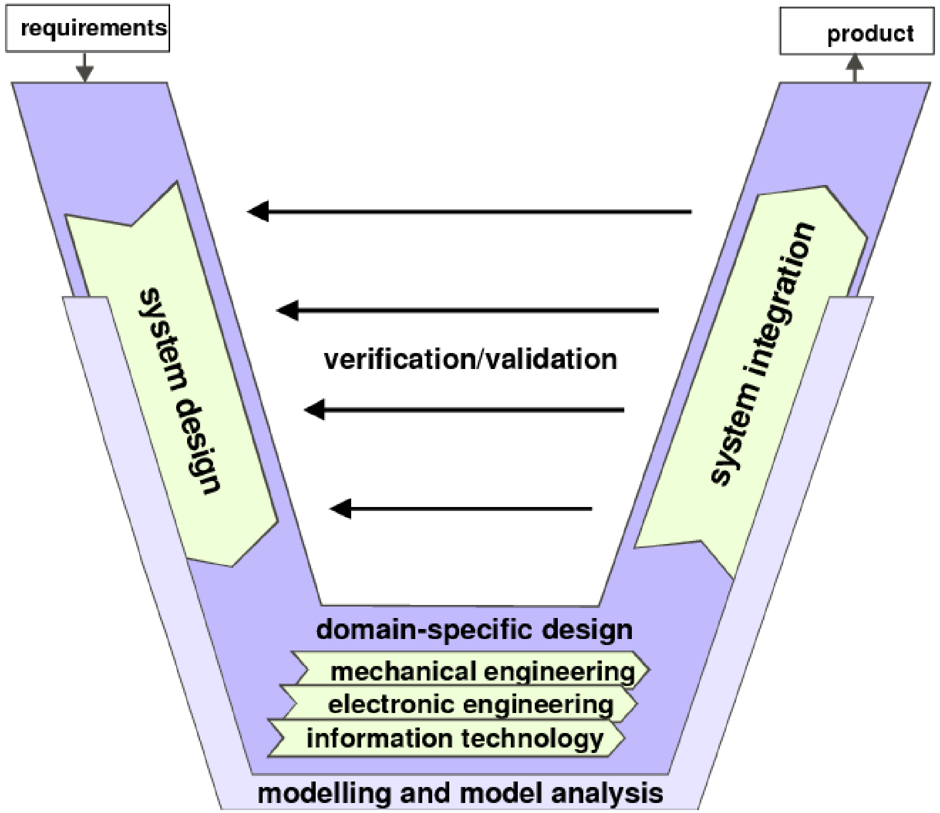
# V-Shaped Model for Design of Mechatronic Systems

**Domain-specific design:** The solution concept which has been developed conjointly by the involved domains will be worked out in detail mostly separately in the concerned domains. Elaborate design and calculations are necessary in order to guarantee the functional performance, in particular that with critical functions.

**System integration:** The results from the specific domains are integrated to an overall system in order to analyse the interrelations.

**Verification/validation:** The design progress has to be checked continuously by means of the specified solution concept and the requirements. It is to be assured that the actual system characteristics match with those wanted.

**Modelling and model analysis:** The described phases are flanked by the modelling and analysis of the system characteristics with the aid of models and computer-aided tools for simulation.



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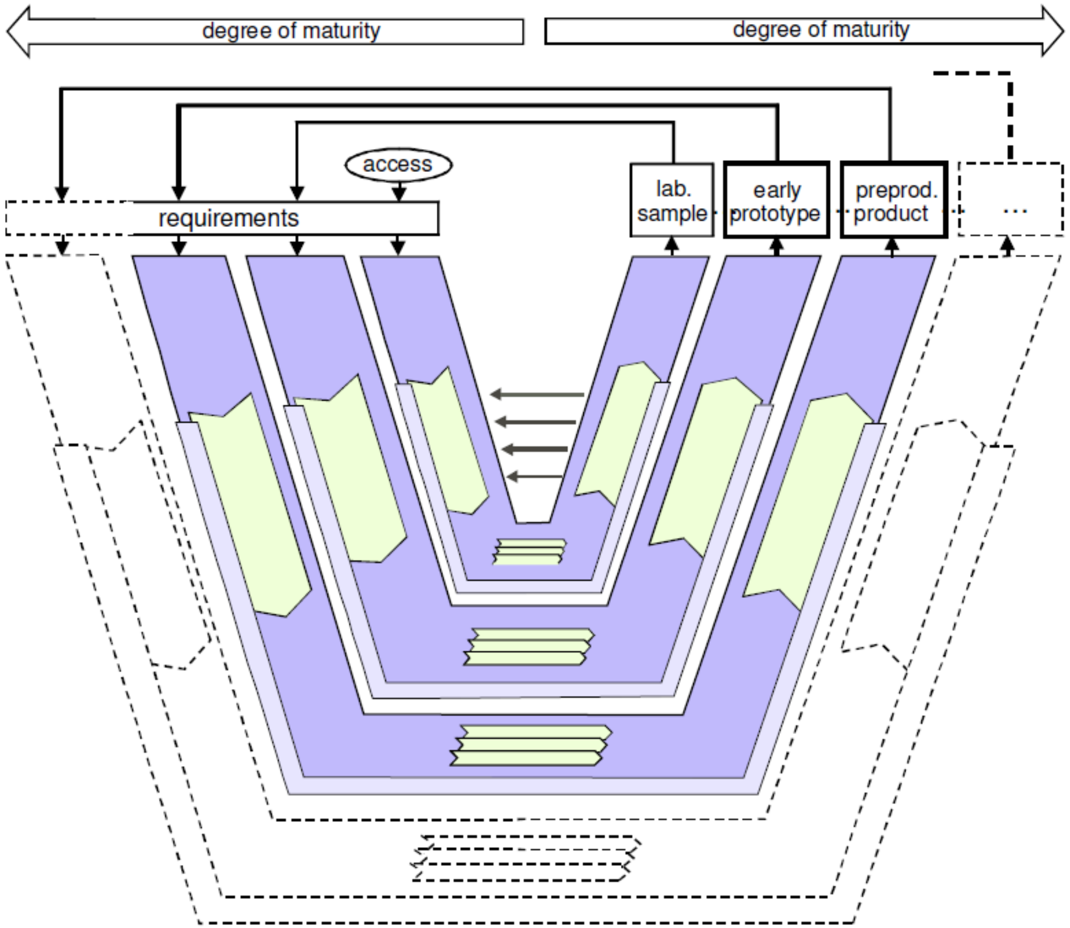
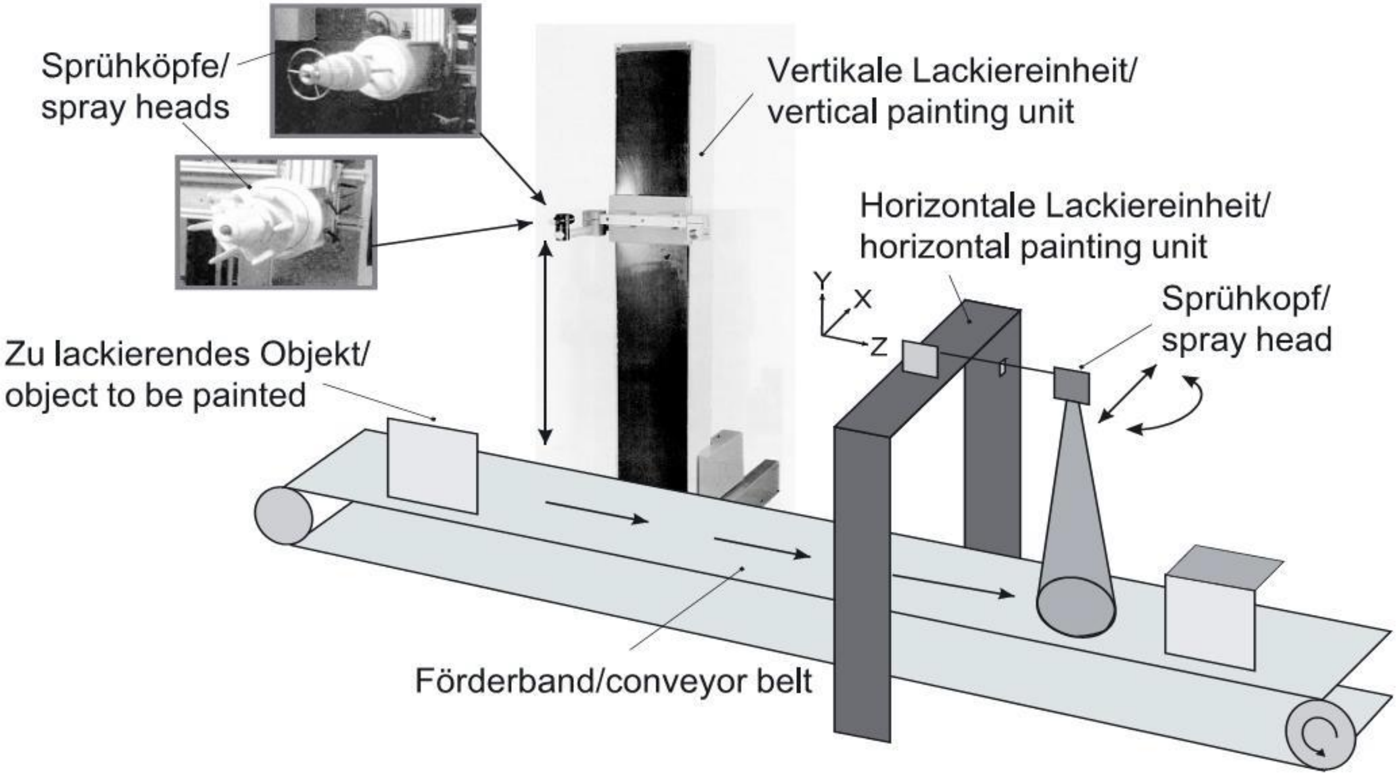
## V-Shaped Model for Design of Mechatronic Systems



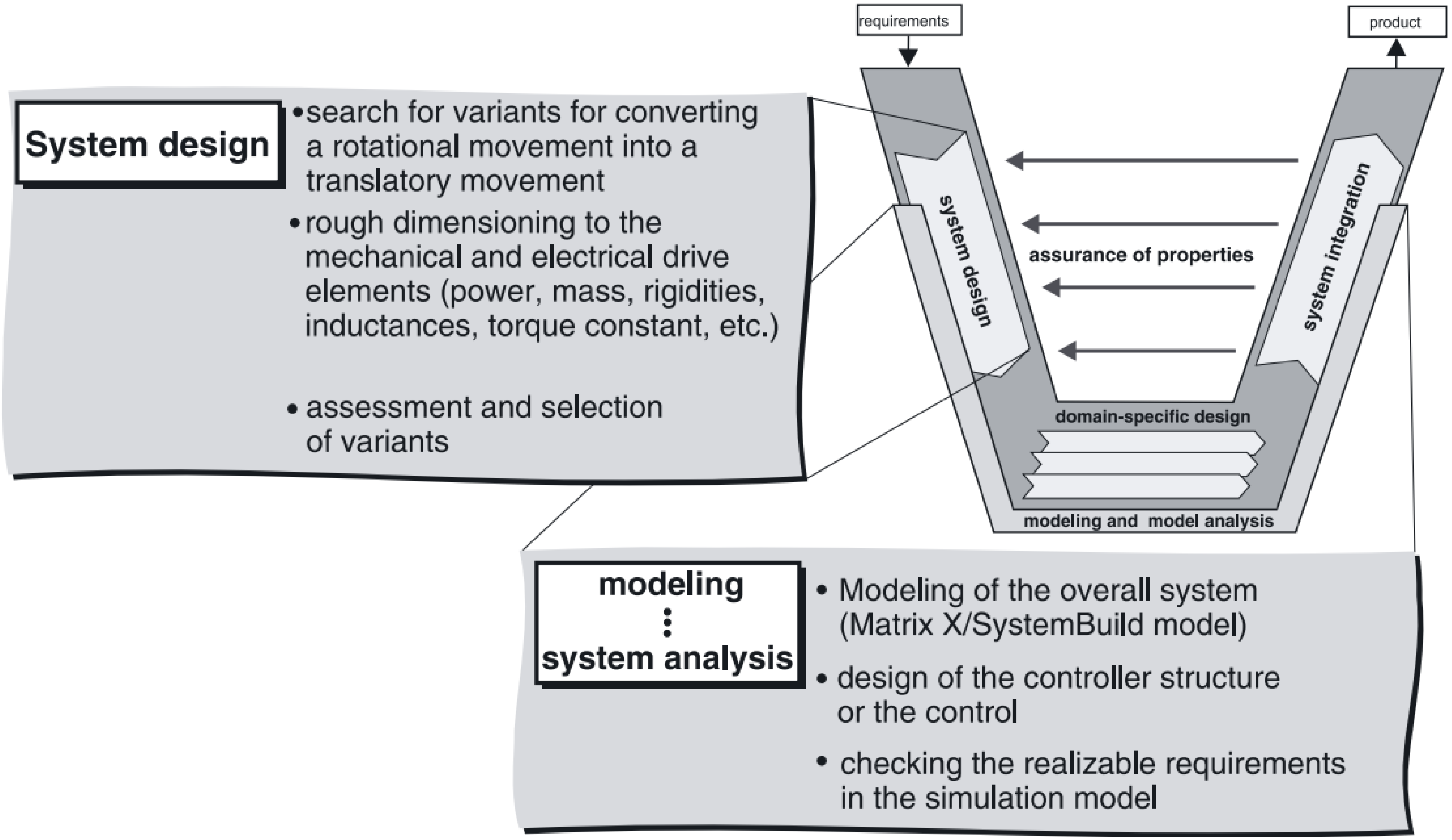
# Assurance of Properties

| Verification | Validation |
| --- | --- |
| • Verification means checking whether the way in which something is realized and whether it coincides with the specification.<br>• Verification is the answer to the question : Is a correct product being developed? For example, does a software program coincide with the specs of algorithms. | • Validation means testing whether the product is suitable for its intended purpose or achieves the desired value.<br>• Validation is the answer to the question : Is a right product being developed? |

# Example – Horizontal Painting Unit Drive



# Example


requirements
product
System design
•search for variants for converting a rotational movement into a translatory movement
•rough dimensioning to the mechanical and electrical drive elements (power, mass, rigidities, inductances, torque constant, etc.)
• assessment and selection of variants
system design
assurance of properties
system integration
domain-specific design
modeling and model analysis
modeling
system analysis
• Modeling of the overall system (Matrix X/SystemBuild model)
• design of the controller structure or the control
• checking the realizable requirements in the simulation model

# Example – Horizontal Painting Unit Drive

### 4.2.1 Selected requirements

Desired speed in $x$ direction:
  1 m/s

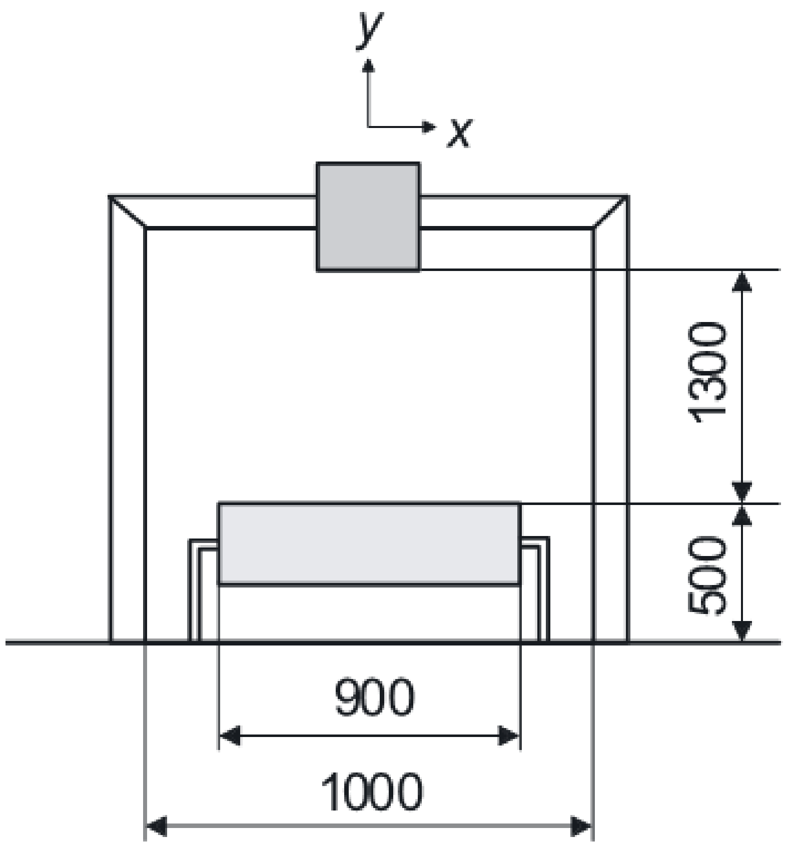
Distance at constant desired speed in $x$ direction over the belt:
  700 mm (ideally: 900 mm)

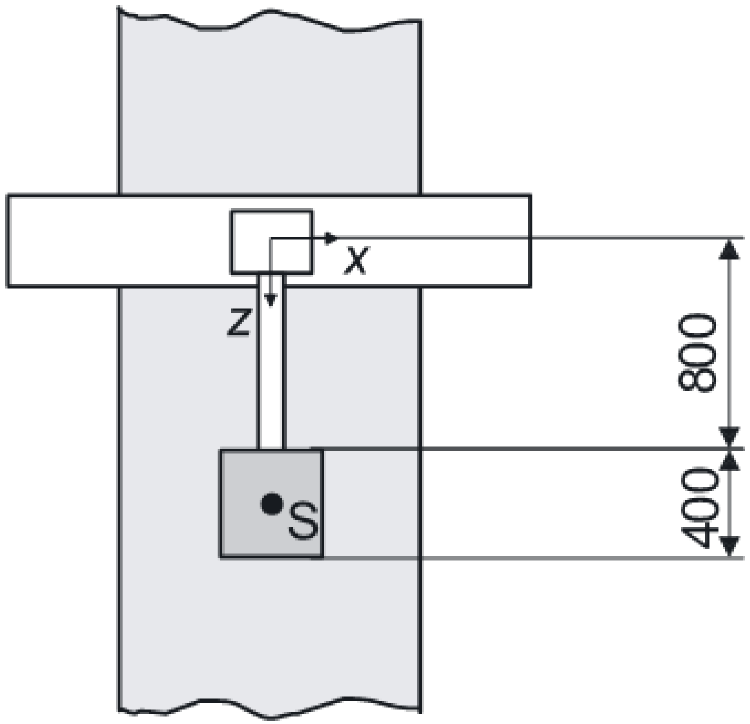
Maximum oscillating amplitudes in $x$ direction in the range of constant desired speed:
  ±3 mm (ideally: ±2 mm)

Electric drive

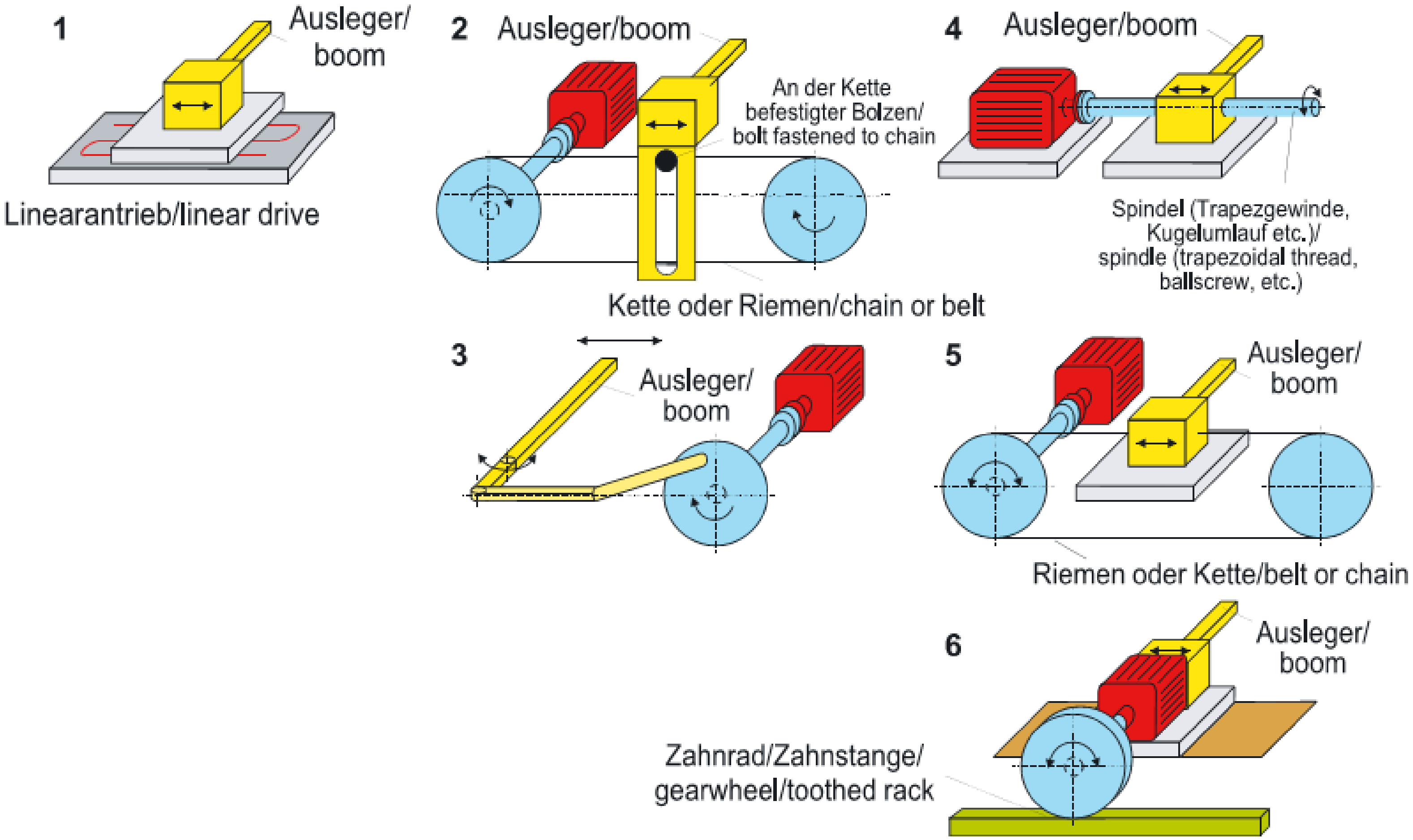
The geometrical requirements are summarized in Figure 4-12.

# Example – Horizontal Unit

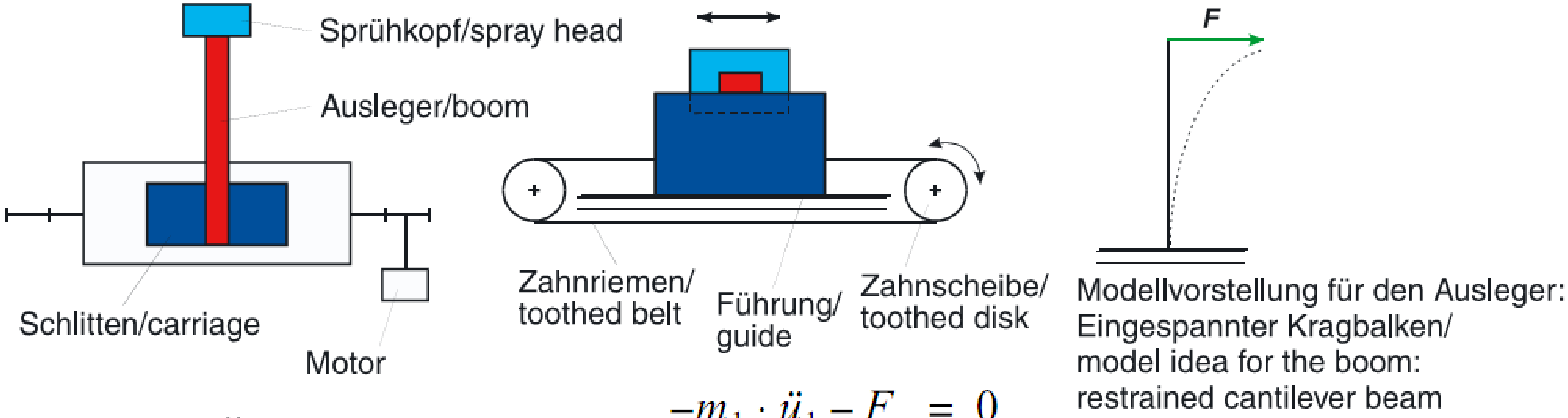


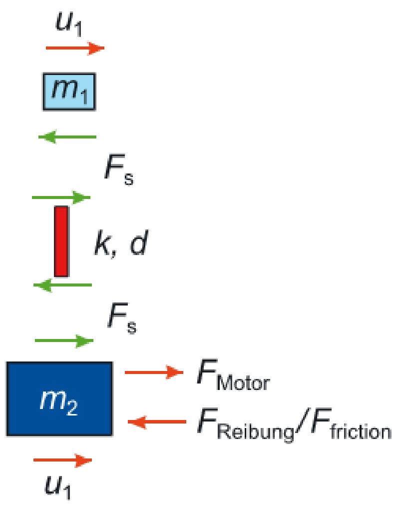



# Example – Horizontal Unit



# Example – Horizontal Unit




$$-m_1 \cdot \ddot{u}_1 - F_s = 0$$

$$F_s = F_k + F_d = k \cdot (u_1 - u_2) + d \cdot (\dot{u}_1 - \dot{u}_2)$$

$$u = \frac{F \cdot 1^3}{3EI}$$

$$-m_2 \cdot \ddot{u}_2 + F_s + F_{Motor} - F_{Reibung} = 0$$

$$F_{Motor} = 2 \cdot M_{el} / d_{Zahnscheibe}$$

# Example – Horizontal Unit