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The European Engineer of the 21 Century: "The Unique Tamer of the Exploding Complexity of Technological Systems in the 21 Century"

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Europe has to reclaim Innovation Leadership

- Europe – being a high Cost Continent – can only succeed in the Global Innovation Competition if it manages to reclaim Innovation Leadership

- When looking on Asia´s (China, India, Korea) booming industries, reclaiming innovation leadership (at least in several key technologies) is not a question of options or possible considerations, but a question of survival of Europe

Europe has to reclaim Innovation Leadership

- **Europe´s major weakness - compared to the US - in the global innovation competition is the poor and SLOW TRANSFER of R&D results into BUSINESS SUCCESS.**

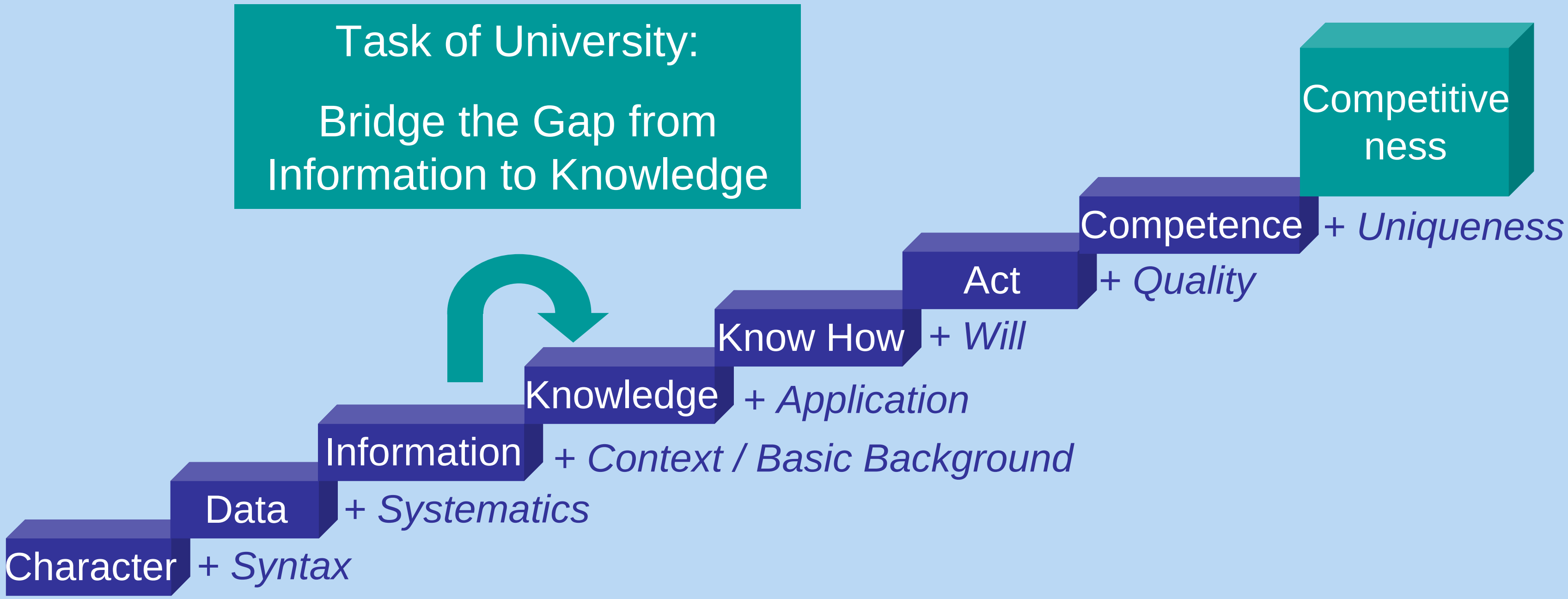
- **Another key success factor for Innovation Leadership is reinforcing Radical Innovations (Technology Push Innovations), in which Europe has lost ground since 1945**

- **Technological Systems are becoming more and more complex. Handling this Exploding Complexity is THE major challenge for the Engineer in the 21 Century**

Challenges for the Engineer in the 21 Century: Managing Complexity and Knowledge

- **The World has become GLOBAL – thus so has education**
- **KNOWLEDGE (and its Fast Dissemination and utilization) is the key element for innovation leadership**
- **Universities have to Bridge the Gap between INFORMATION and KNOWLEDGE**

The Steps to Knowledge and Competitiveness



Source: North

Essential Tasks of Technical Universities

- **Strategic and deep alliance of Research & Teaching**

- **Teaching the sound theoretical principles of the engineering sciences (knowledge with a long half-life period)**

- **Mediation of the skills and competences „how to transfer information into knowledge and knowledge into products“**

- **Providing the basis for Radical Innovations (“Technology Push Innovations”)**

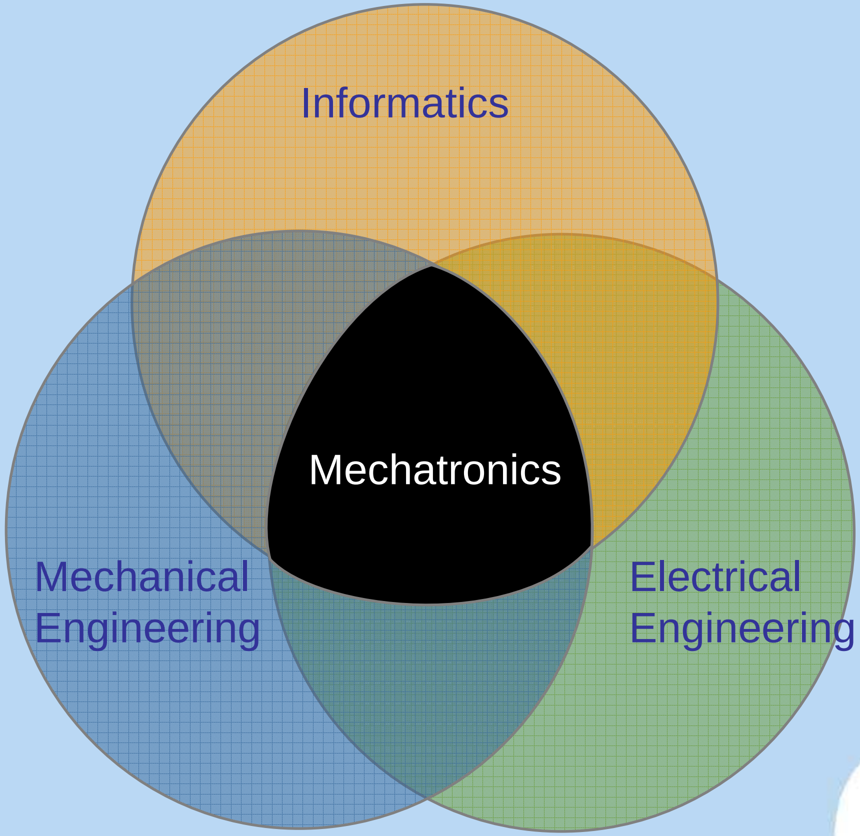
Challenge “Complexity”

- Technological Systems are becoming more and more complex
- Technological Systems are much higher integrated and interrelated
- The best example for this is the Discipline of “MECHATRONICS”, which is the spatial and functional full integration of mechanics, actuators, automation and control systems and software
- Thus "Mechatronics" is the ultimate engineering discipline, which could also be called the "Kings Discipline of Engineering" or "Jewel in the Crown of Engineering".

"Mechatronics" the "Kings Discipline of Engineering" or "Jewel in the Crown of Engineering”

Mechatronics:
Simultaneous, full integration and interrelation of three disciplines

- Software
- Automatisation



- Mechanics
- Fluid technology

- Mikro electronics
- Power electronics

Definition of Complexity

- What is Complexity ?

- A large number of Scientists has dealt with complexity.
- Some definitions are given below:

- D. Adam und U. Johannwille define complexity:

  "Complexity is the sum of all features of an object"

Definition of Complexity

- W. Eversheim, F. B. Schenke and L. Warnke:
-

“In general complexity increases with the number of elements and with the level of interrelations between these elements“

Definition of Complexity

- There are Various Characteristics of Complexity:
  - “Complexity of a Technical System and its Subsystems“
  - “Complexity of Manufacturing”
  - “Complexity of the Functionality”
  - “Complexity of the various States of Matter“
  - “Complexity as perceived by the User („Complexity of Handling“

Mathematical Definition of Complexity

- **The FUNCTIONAL PRODUCT COMPLEXITY (FPCI)**
  Calculation of the Information-Content as function of the existing couplings

$$I_{\kappa_{F_i}} = lb\left(\frac{1}{1-\kappa_{F_i}\cdot\frac{N_{EF_i}}{N_{EF_{ges}}}\cdot\left(1-\varepsilon_{I_{100\%}}\right)}\right)$$

N_{EF_i} ... number of all elementary functions EF, which are part of the function F_i

$N_{EF_{ges}}$ ... whole number of EF of the considered overall system

with the limitation factor $\varepsilon_{I_{100\%}} = \frac{1}{2^{I_{100\%}}}$

$N_{x_{EF_i}}$ ... number of EF, which are coupled with EF_i

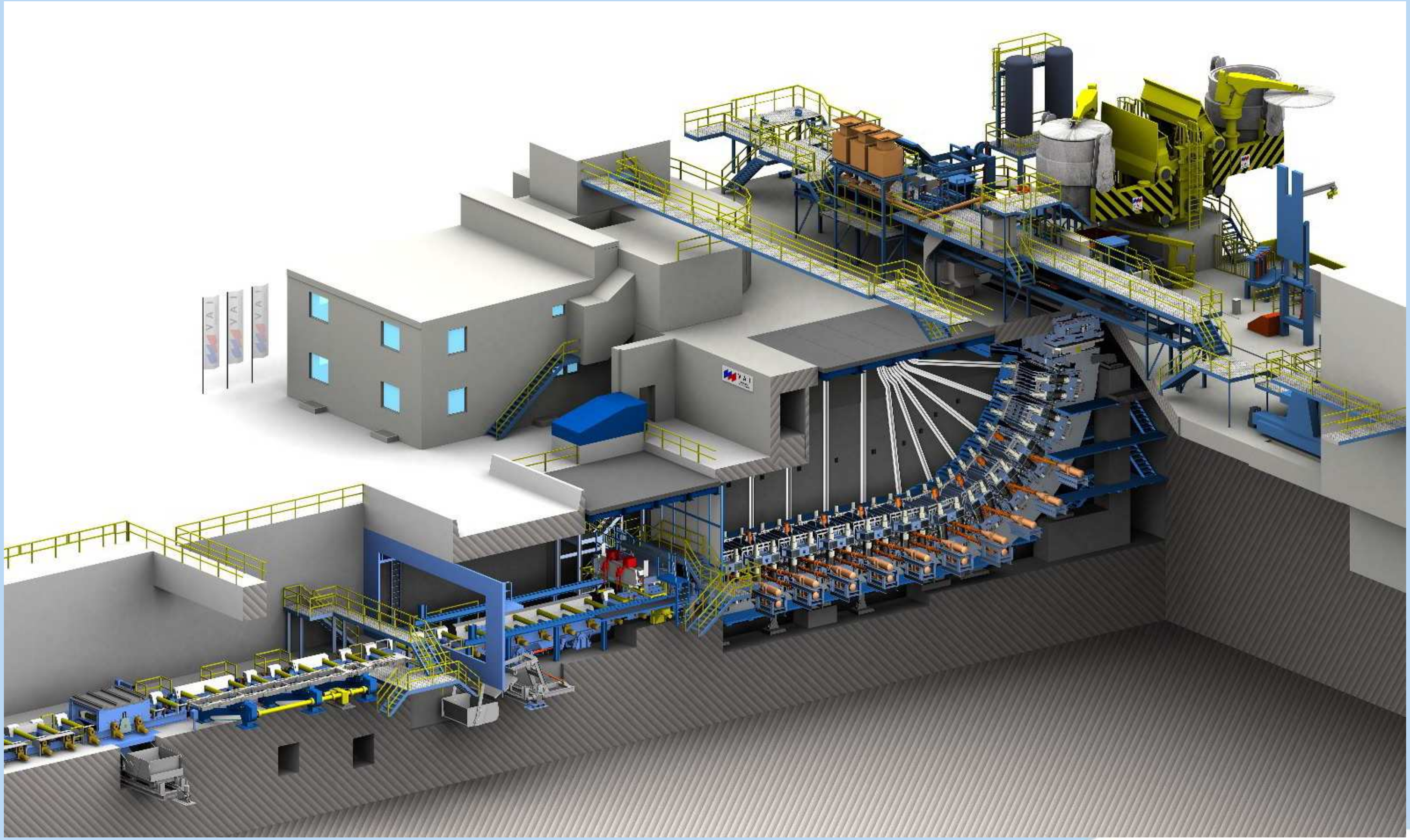
$N_{x_{F_i}}$ ... number of functions, coupled with the father-function F_i

and the degrees of coupling

$$\kappa_{F_{i,j}} = \begin{cases} \text{falls } \kappa_{EF_i} \text{ noch unbekannt} & \dfrac{N_{x_{F_i}}}{\left(N_{F_j}+N_{TR_j}-1\right)} \\ \text{sonst} & \dfrac{1}{N_{EF_{F_{i,j}}}}\cdot\displaystyle\sum_{k=1}^{N_{FF_{i,(j+1)}}}\left(\kappa_{F_{k,(j+1)}}\cdot N_{EF_{k,(j+1)}}\right) \quad \text{mit } \kappa_{EF_i} = \dfrac{N_{x_{EF_i}}}{N_{EF_{ges}}-1} \end{cases}$$

Quelle: Prof. Dr. R. Scheidl, DI. Dr Stefan Dierneder, Johannes Kepler Universität, Linz/Österreich

Standard 8m Slab Caster for Steel Width 1650 mm



21 Slides until EoS (End of Show)

Complexity in Metallurgical Plant Engineering - Definition “Ex-ante”

- Number of engineering departments / engineers involved
- Number of sub-components involved per machine/ industrial plant
- Number of different sub suppliers per machine/ industrial plant
- Number of design alternatives (e. g. 500 different roller schemes per year for continuous casting machines)
- Number of (strongly coupled) technical domains involved
- Number of interfaces

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Complexity in Metallurgical Plant Engineering - “Ex-Post”

- Number of (substantial) design modifications throughout the engineering phase, the manufacturing phase and the start up phase (i. e. high NCC-costs)
- Problems and duration of the start up phase of the machine / Plant
- Sensitivity of the machine for misfunction / unplanned machine down times
- Expensiveness of maintainance of the machine / plant
- Overburdening of machine operators
- (Short) Product life cyle

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Challenges for the Mechatronical Engineering of Metallurgical Plants (1/2)

- Metallurgical Plants and Machines typically are very large (hight 80 m and more, typically > 20 Mio € per machine) and are very complex but with very low lot sizes (typically less than 10 /year) =>
  - No prototypes can be built in the tech center of the developer
  - Due to the low lot sizes the designers/vendors cannot really make profit from the learning curve
- Each Metallurgical Plants and Machines typically consists of more than 50 sub-components and more than 50 sub-suppliers

Availability Total System

$$P = p^n$$

P Probability, the system works correct
p Probability, the component works correct
n Number of components in system

Components	Correctness of each component 0.99	0.95	0.9
1	0.99	0.95	0.9
10	0.90	0.60	0.35
50	0.61	0.08	0.01
100	0.37	0.01	0.00

Challenges for the Mechatronical Engineering of Metallurgical Plants (2/2)

- Metallurgical plants (e. g. a blast furnace) have to run 24hours 365 d/y x 24h. An unplanned down time in a steel plant costs a tremendous amount of money.
- Safety is a very big issue in steel plants handling steel ladles with more than 200 tons of liquid steel (1600 ℃)
  ➔ Robust, fail safe design
- Metallurgical Plants and Machines typically life times of 30 years and more. Thus the design has to be future proof and flexible (➔ Modular Design and „Upgradability“)

The European Engineer of the 21 Century

- The Answer against this increasing complexity of mechatronical systems is the consequent application of an integrated model based mechatronical CAE process !

- The only expert able and skilled enough to handle this is the well **Educated Engineer of the 21 Century**

The European Engineer of the 21 Century

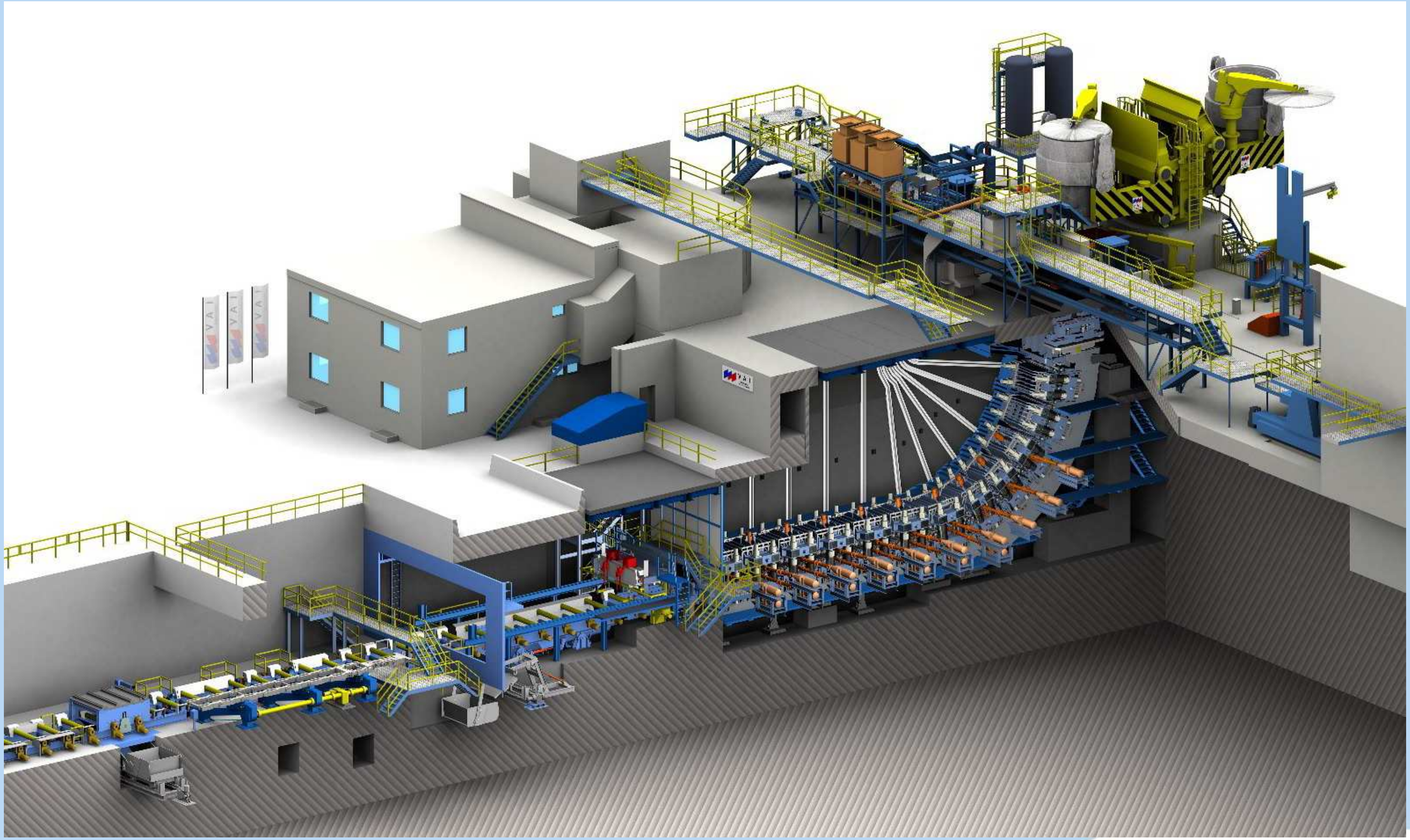
The European Engineer of the 21 Century:

"The Unique Tamer of the Exploding Complexity of Technological Systems in the 21 Century"

Mechatronical design- and Engineering-Concepts of The European Engineer of the 21 Century

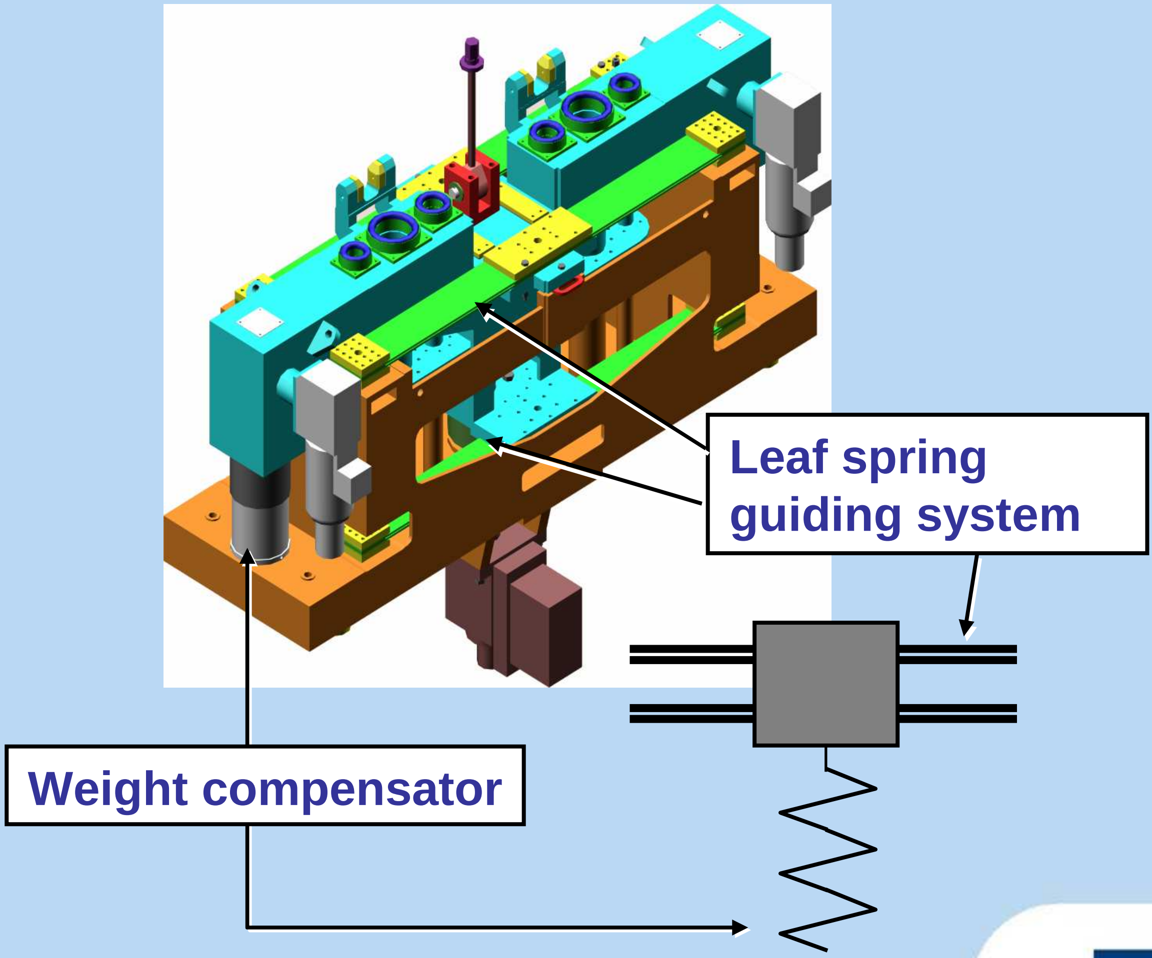
- Modulares, Parametric Design
- Functional Decomposition
- Robust Design
- Dependency Inversion

Standard 8m Slab Caster for Steel Width 1650 mm

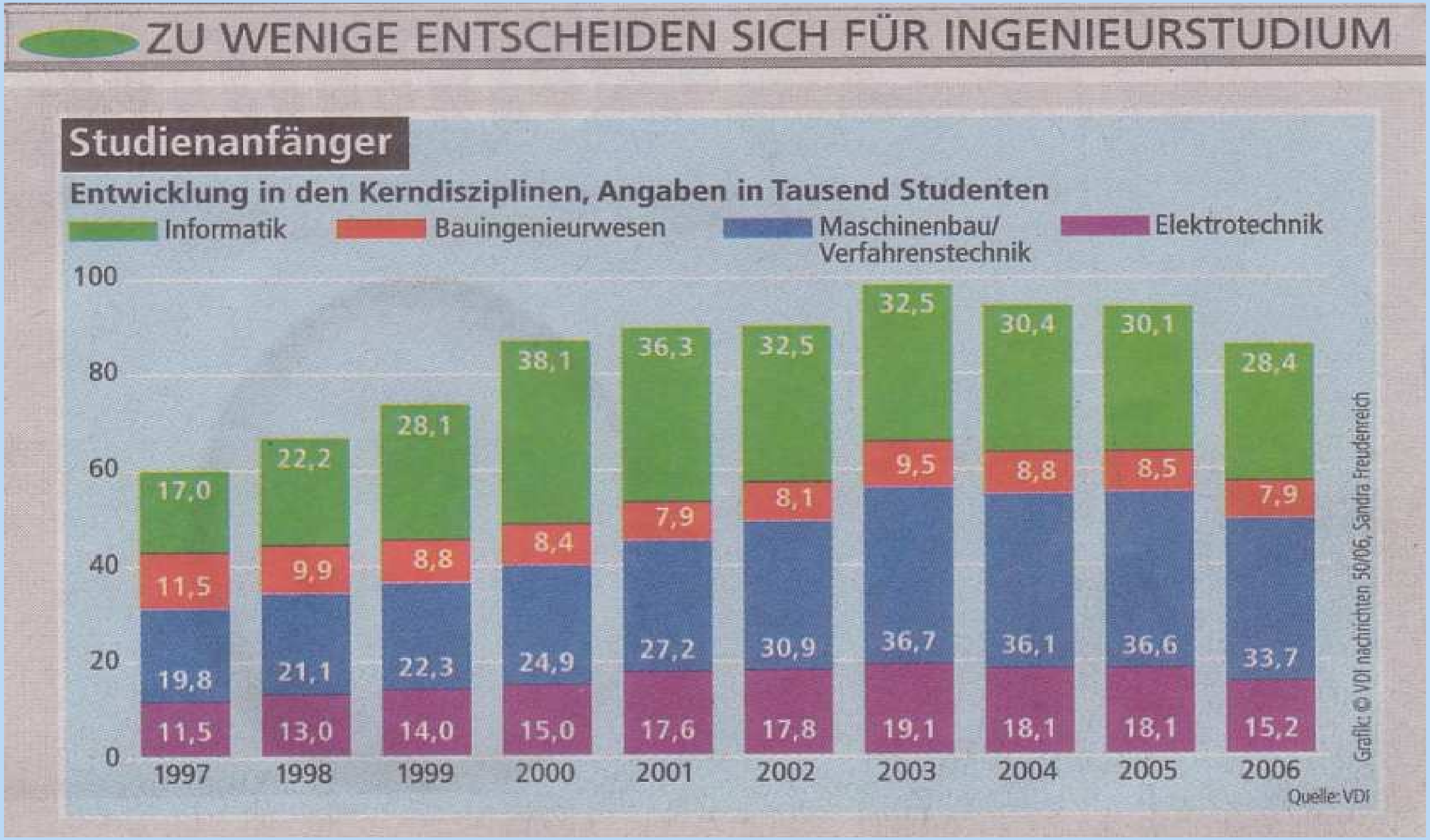


12 Slides until EoS (End of Show)

Functional Decomposition for Mold Guidance and Weight Compensation



"Production" of Engineers in Germany



Quelle: VDI-Nachrichten, 2006

Education of Engineers in China

- China has invested heavily in the education of its engineers in the last decade
- In 2005 approx. 50 % of the 14 million university students are enrolled in a technical or engineering curriculum.
  In Germany the respective figure is just 15%.

Europe has to at least “hold” its position in Engineering Intelligence

- “Engineering Intelligence” (EI) has always been a key to Technological, Industrial and Economical Leadership
- If Europe wants to continue to make money with technology, Europe needs „Do-ers“
- Europe needs „Do-ers“ not „Talkers“
- Engineers are „Do-ers“ not „Talkers“
- Europe needs to keep and reinforce its “Engineering Intelligence”

Europe has to at least “hold” its position in Engineering Intelligence

- Europe is doing nothing to “hold” its Engineering Intelligence – on the contrary since EI is always closely related to production and manufacturing and since Europe is loosing production to Asia on a large sustainable scale Europe is continuousely loosing Engineering Intelligence
- Europe is publicly funding almost all trades and jobs except engineering:
  - The EC funds the olive oil farmers with 2366 Mill € in 2004 (by the way: This is 8 times higher as all money spent for NMP p.a. within the 6. EC FP)
  - The EC funds the tobacco and wine farmers with 2374 Mill € in 2004 (by the way: This is 8 times higher as all money spent for NMP p.a. within the 6. EC FP)
- But Europe does not fund its Engineering Intelligence

Europe has to at least "hold" its position in Engineering Intelligence

- High tech is becoming more and more sophisticated and complex => Intelligent simplification is extremely important
- Intelligent Simplification is the art (*ref. Michelangelo*) of identifying and disregarding those physical phenomena, which are not decisive /determinative for the behavior /performance of a complex technical system
- Intelligent Simplification can obviously only be based on a deep understanding of the theoretical basics => therefore the return to a sound education of engineers in the theoretical basics (knowledge with a long half-life period instead of short term shicky-micky subjects) is of utmost importance
- Intelligent simplification has always been and must remain the USP of engineering education
  However there is valid concern that this "art" is being lost

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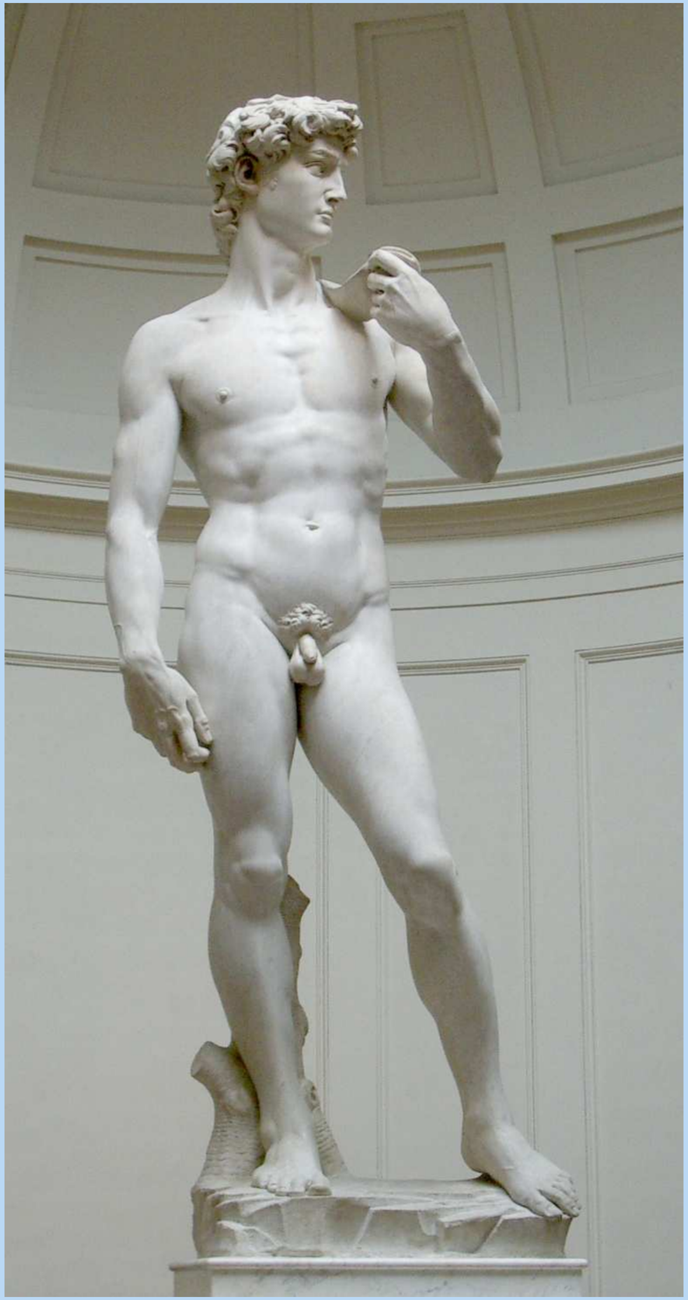

- Michelangelo Buonarroti:
- An Artist in Omitting every material, which does not belong to the skulptur.

Summary
Educating the European Engineer for 21th Century

Essential Tasks of Technical Universities:

- **Strategic and deep alliance of Research & Teaching**
- **Teaching the sound theoretical principles of the engineering sciences**
  (knowledge with a long half-life period)
- **Mediation of the skills and competences „how to transfer information into knowledge and knowledge into products“**
  - **Intelligent Simplification**
  - **Engineering Intelligence**
- **Providing the basis for**
  TECHNOLOGY PUSH INNOVATIONS

Summary

- **The EU has a sustainable problem in continuously loosing ground regarding its engineering intelligence – especially against Asia.**
- **Recent Studies in Germany have identified – among others – that "Technical Disciplines" are continuously loosing its fascination among young man (girls)**
  (Nota Bene: Laptop and i-phone are deemed sexy by the youngsters, but they don't care any longer how this items function internally)

Summary

Several studies suggest – among others - the following reasons for this problem in Europe:

- **The Adverseness of most teachers against technic in general on elementary and high school level**
- **In spite of the fact, that in modern life technical products and applications (mobility, communication, etc.) play THE dominant role, the creater of these technical products, the engineer, is not at all being seen as the "hero" in the media.**
  On the opposite: Medical doctors and lawyers are the heroes of hundreds of TV soaps, but there is no single TV series in which an engineer is the hero.
  (In the US high tech military movies and games are taking over this part)

Another Lesson which we can learn from the Chinese

- ***If you have to provide for one year ahead, then seed rice,***
- ***If you have to provide for a decade ahead, then plant trees,***
- ***If you have to provide for a century ahead, then educate people !***

Tschunag-Tse

Many Thanks for your Attention