The Design Society Seminar Series
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Ilmenau
– one of the Birthplaces of Design Science

Univ.-Prof. Dr.-Ing. habil. Günter Höhne
Univ.-Prof. Dr.-Ing. Christian Weber
Univ.-Prof. Dr.-Ing. Stephan Husung

Technische Universität Ilmenau
Institut für Maschinen- und Gerätekonstruktion (IMGK)
Fachgebiet Produkt- und Systementwicklung /
Product and Systems Engineering Group

guenter.hoehne@tu-ilmenau.de, christian.weber@tu-ilmenau.de, stephan.husung@tu-ilmenau.de

TU Ilmenau – one of the Birthplaces of Design Science
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Where is Ilmenau?

In the state of Thuringia (*Thüringen*):

- Was situated in former Eastern Germany (German Democratic Republic, GDR)
- Since 1990 one of the so-called „new states“
- “The green heart of Germany”
- Ca. 2.15 million inhabitants
- Economically the most successful “new state”
- 4 Universities:
  - Friedrich-Schiller-Universität Jena
  - Technische Universität Ilmenau
  - Universität Erfurt
  - Bauhaus-Universität Weimar
- 5 Polytechnics (*Fachhochschulen*, “Universities of Applied Sciences”):
  - Hochschule für Musik Franz Liszt Weimar
  - Fachhochschule Erfurt
  - Ernst-Abbe-Hochschule Jena
  - Hochschule Schmalkalden
  - Hochschule Nordhausen
  - SRH Hochschule für Gesundheit Gera (private)
- 2 Colleges of Cooperative Education:
  - Duale Hochschule Gera-Eisenach
  - IUBH Duales Studium Erfurt (private)

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Town of Ilmenau and Technische Universität Today

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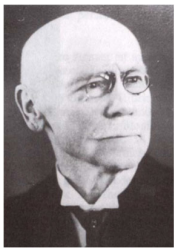
Technische Universität Ilmenau
Brief History (1)

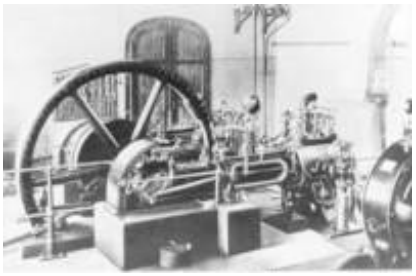


1894 *Thüringisches Technikum Ilmenau* (Thuringia Technical School Ilmenau), founded by Eduard Jentzen

1895 New building in the town centre; still in use today ("Curie-building") ➔↘

1903 Georg Schmidt (1871-1955) becomes Rector ↗

… and remains in this function until 1948 (!)



1926 *Ingenieurschule Ilmenau* (Engineering School Ilmenau)

Additional building; still in use ("Faraday-building") ↘

(1945 American occupation; after 80 days USSR takes over in Thuringia)

1947 School is nationalised

(1949 Formation of German Democratic Republic, GDR)

1950 *Fachschule für Elektrotechnik und Maschinenbau* (Technical School for Electrical and Mechanical Engineering)

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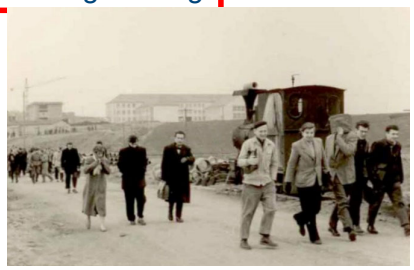
Technische Universität Ilmenau
Brief History (2)

1953 *(Spezial-) Hochschule für Elektrotechnik (HfE)* ([Special] University for Electrical Engineering)

Hans Stamm (1908-1968) appointed as the new Rector ➔

1955 *Fakultät für Feinmechanik und Optik* (Faculty/Department of Precision Mechanics and Optics) – predecessor of today's Faculty/Department of Mechanical Engineering

1956 Start of building the new campus outside the town (today Hans-Stamm-Campus) ➔↘



… which is quite "American-style": institutes, labs, students' homes, sports facilities all on the campus

1957 Right to award doctorate and habilitation degrees

1963 *Technische Hochschule Ilmenau* (Technical University Ilmenau)

1968 3rd reform of universities in GDR: Faculties/Departments replaced by "Sections"

Sektion Konstruktion und Technologie der Feinwerktechnik (KONTEF) (Section for Design and Technology in Precision Engineering)

1972 *Sektion Gerätetechnik* (Section for Instrument Engineering)

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Technische Universität Ilmenau
Brief History (3)

(1990 German reunification: the 5 „new states“ join the Federal Republic of Germany, FRG)

1990 *Fakultät für Maschinenbau und Feinwerktechnik* (Faculty/Department of Mechanical and Precision Engineering)

1991 After only 1 year renamed: *Fakultät für Maschinenbau* (Faculty/Department of Mechanical Engineering)

1991 Commissions of the German National Science Council (*Wissenschaftsrat*) visit and evaluate all former Eastern German Universities

In charge for mechanical engineering in Ilmenau: Prof. Dr.-Ing. Dr. h.c. mult. Gerhard Pahl (1925-2015)

Recommendation: TH Ilmenau to remain university (**not** *Fachhochschule*/polytechnic)

1992 *Technische Universität Ilmenau*

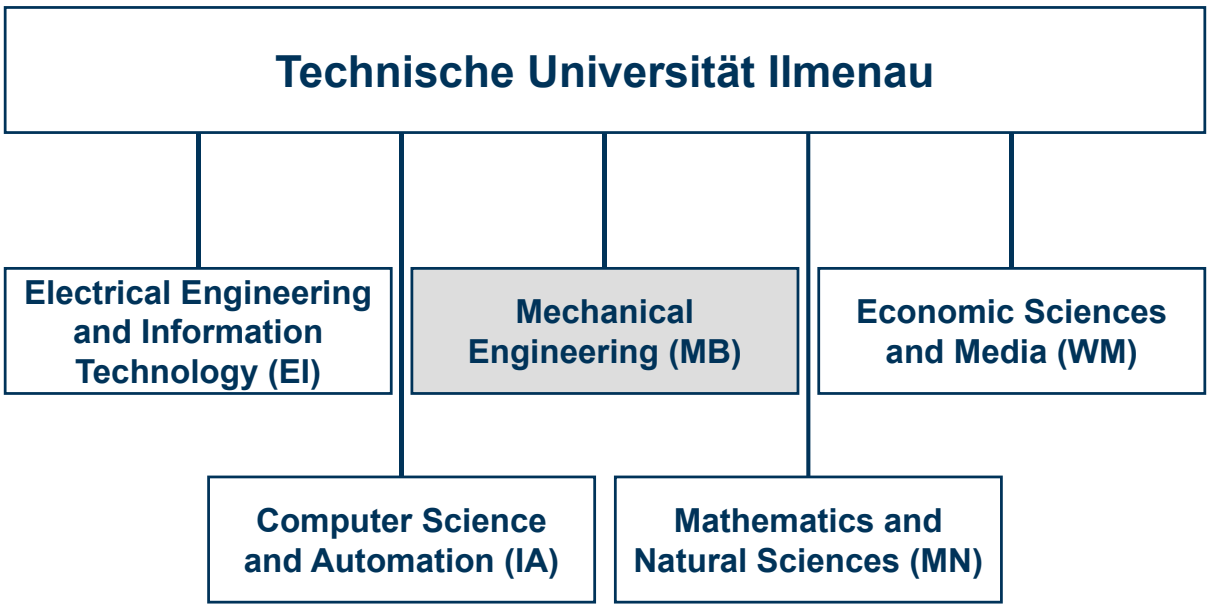
1996 until today:

New buildings and infrastructure established on Hans-Stamm-Campus

04.11.2015: 60 Years – from Precision Engineering and Optics to Mechanical Engineering

- Satellite observation instrument (designed in Ilmenau, built by Zeiss Jena in the early 1960ies) handed over as a technical monument
- Main building of Mechanical Engineering re-named “Werner-Bischoff-building”
- Commemorative event in Audimax (with almost all foreign partners present speaking greetings)
- Exhibition of the groups’ history and of publications
- Festschrift with contributions of all groups of today’s Faculty/Department of Mechanical Engineering

TU Ilmenau today: 5 Faculties/Departments

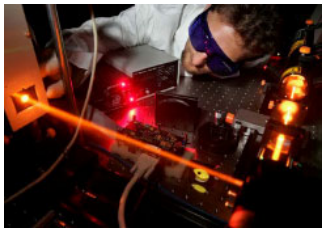


TU Ilmenau: Research and Teaching Areas

Research clusters (fed from different faculties/departments):

- Functional Materials and Technologies
- Intelligent Sensing and Precision Metrology
- Complex Systems and Data-Intensive Engineering

Contributions to all of them by the Faculty/Department of Mechanical Engineering



Teaching areas:

- Engineering and Natural Sciences
- Economics
- Media

Contributions

"Own" courses of studies offered by the Faculty/Department of Mechanical Engineering:

- Mechanical Engineering (MB)
- Automotive Engineering (FZT)
- Mechatronics (MTR)
- Optical Systems Engineering/Optronics (OST)*

* Will be integrated into Mechatronics as an additional branch from 2021/22

History of Engineering Design in Ilmenau

Ilmenau is one of the birth places of Design Science as we know it today.

The *"Ilmenauer Schule der Konstruktionstechnik"* (Ilmenau School of Engineering Design) was founded in the 1950ies and 1960ies mainly by three people:

- Werner Bischoff (1902-1993)
  Professor for Precision Engineering 1954-1967
- Friedrich Hansen (1905-1991)
  Professor for Systematic Design and Adjustment 1956-1970
- Arthur Bock (1898-1991)
  Professor for Mechanisms and Gears 1956-1964

All three came from the Carl Zeiss Jena company (which contributed significantly to Ilmenau's focus on precision mechanics and optics).

They had already closely co-operated at Zeiss, developing new ideas on design and designing.

This heritage influences the profile of TU Ilmenau to this day.

Werner Bischoff is reported to be the "mastermind";
however, he did not write much.

Therefore, most of the books on Design Theory and Methodology / Design Science were written by Friedrich Hansen.

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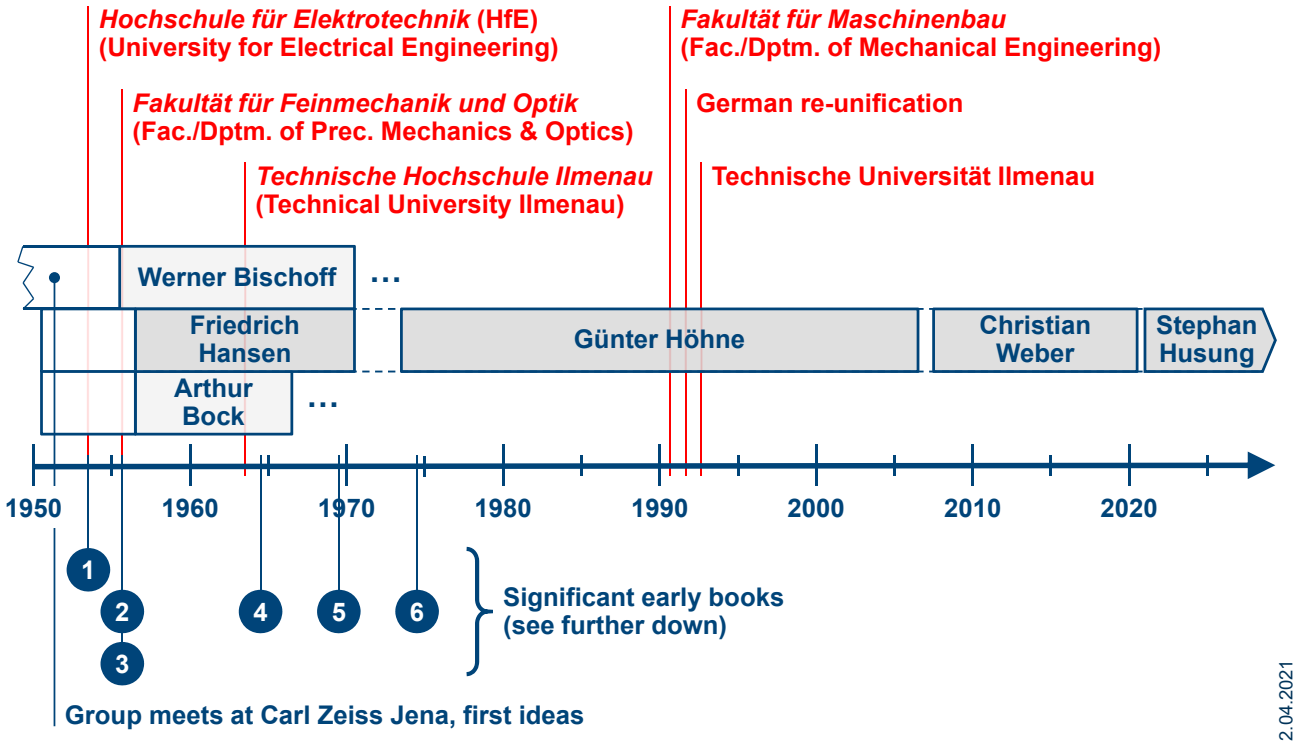
Ilmenau – 60+ Years of Tradition in Design Science Timeline



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Werner Bischoff: Career and Activities at HfE/TH Ilmenau

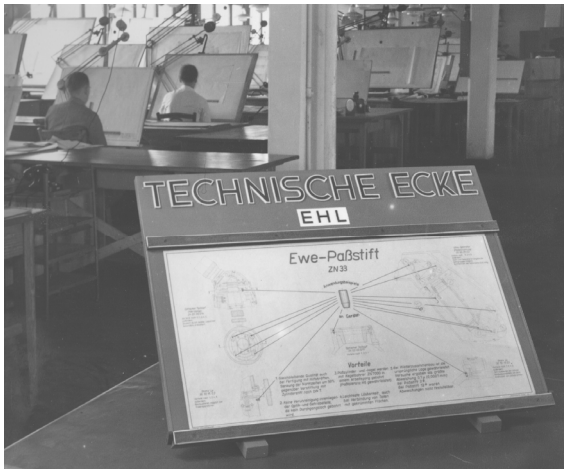
26.07.1902	Born in Ischl, Austria (actually Austria-Hungary)
1920-1925	Studies of Mechanical Engineering at TH Graz
1925-1930	Assistant at TH Graz, Chair of Hydraulic Engines
From 1930	Carl Zeiss Jena, Assistant of CEO W. Bauersfeld, later Head of Design
1939-1944	CEO of *Polskie Zakłady Optyczne (PZO)*, Warsaw
1946	*Entwicklungshauptleiter* (Chief Development Engineer) at Carl Zeiss Jena
1953	Dismissal at Carl Zeiss Jena, allegedly for political reasons in the aftermath of the riots in Eastern Germany on 17.06.1953 (later rehabilitated)
	Main activities at Zeiss: Projection systems, optical and astronomical instruments, before and during WW II also military equipment (sighting and target devices)
1953	Hans Stamm, rector of the newly established HfE Ilmenau had heard of Bischoff's new approach to design/designing and he knew of his dismissal at Zeiss
01.11.1954	Werner Bischoff appointed as professor at HfE Ilmenau; task: develop a concept for teaching and research in the field of Precision Mechanics and Optics
1955	Concept submitted, approval by the Eastern German central government, constitution of the *Fakultät für Feinmechanik und Optik*
01.10.1955	Start of teaching Precision Mechanics and Optics (15 students coaxed away from a higher semester of Electrical Engineering)
1955-1962	Vice-Rector for Research at HfE / TH Ilmenau
01.09.1956	Friedrich Hansen and Arthur Bock follow from Zeiss as professors at HfE
1967	Retired
†28.03.1993	Ilmenau

Zeiss Jena: Origins of Design Science

- The Carl Zeiss Jena company, being an important supplier of military equipment, was severely damaged in World War II
- When WW II came to an end, Thuringia was first occupied by American troops (April-June 1945)
- In exchange for West Berlin, from July 1945 Thuringia was taken over by Soviet troops
- At first, the Americans requisitioned Zeiss patents, drawings and machinery (worth ≈15 Mill. RM), but also ≈100 experts from Zeiss research and development (≈500 persons including their families)
- They were brought to Heidenheim upon Brenz in the American zone (today Baden-Württemberg)
- One year later, *Opton Optische Werke*, later called „Zeiss-Opton" was founded close by in Oberkochen – still the headquarters of the (re-united) Zeiss company today
- After the Russians came in, what was left at Zeiss Jena was brought to the USSR (≈90%!), plus most of the remaining experts (≈300 persons)
- They were sent to Russian optical factories for 5 to 10 years in order to transfer knowledge

Zeiss Jena: First Ideas of Design Science (1)

- When Werner Bischoff was appointed *Entwicklungshauptleiter* (Chief Development Engineer) at Carl Zeiss Jena in 1946, he had virtually nothing left:
  No drawings, no machines, no engineers, no technicians, only skilled workers, …
- The first task was the re-creation of drawings of products – maybe even improvement of designs – in order to get the production running again
- For this Werner Bischoff set up a training programme for unexperienced designers:
  - Analytical training:
    "Why does a design look like it looks?"
  - Examples of good (partial) solutions, design catalogues
- Establishing the concept of "*Technische Ecke*" (Technical Corner) at the EHL = *Entwicklungs-hauptleitung* (Main Development Office) of the Zeiss Jena company in 1951 ➔
- In the process, now well-known terms of Design Theory and Methodology were coined:
  - What are the **principles** behind *Gestalt**?
  - What **functions** are served by principles and *Gestalt*?



* *Gestalt* was later specified by Hansen as: shape + dimension + material + state.
"Layout" or "Geometry" are ***not*** comprehensive translations!

Zeiss Jena: First Ideas of Design Science (2)

- Collaborators from 1950 and 1951, respectively: Friedrich Hansen, Arthur Bock (who both followed Werner Bischoff to HfE Ilmenau later).
- Later Bischoff, Hansen and Bock turned the analytical approach upside down and made it a guide for systematic design (synthesis) ➔
- The first publication stems from 1953: ➔

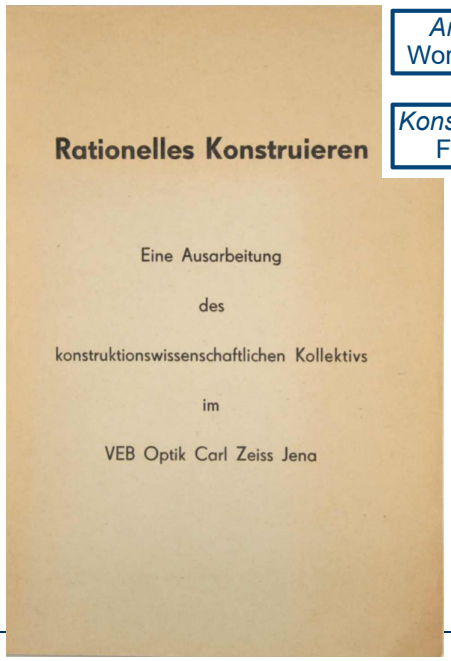
  Bischoff, Werner; Hansen, Friedrich:
  Rationelles Konstruieren (Efficient Designing)

  Published as: *Konstruktionsbücher Bd. 5*
  (Design Books vol. 5),
  VEB Verlag Technik, Berlin 1953 (72 pages)
- The term *"Konstruktionssystematik"* (Systematic Design) was coined by G. Biniek in a journal article (Feingerätetechnik 2 (1953) 3, pp. 286-287)

  This term was taken over by Bischoff and Hansen and used further on
- Note: Systematic Design was developed in and for engineering practice in the first place, came to academia only later!

***Synthese*/Synthesis**

Aufgabe
Task
↓
Grundprinzip
Basic Principle
↓
Arbeitsprinzip
Working Principle
↓
Konstr. Ausführung
Final Design


Rationelles Konstruieren

Eine Ausarbeitung

des

konstruktionswissenschaftlichen Kollektivs

im

VEB Optik Carl Zeiss Jena

Evolution of Early Publications on Design (Books)

First publication:

1. Bischoff W.; Hansen, F.: *Rationelles Konstruieren* (Efficient Designing). *Konstruktionsbücher Bd. 5*, VEB Verlag Technik, Berlin 1953 (72 pages)

A shortened version, aimed at practitioners:

2. Hansen, F.: *Konstruktionssystematik – eine Arbeitsweise für fortschrittliche Konstrukteure* (Systematic Design – a Procedure for Progressive Designers). VEB Verlag Technik, Berlin 1955 (40 pages)

More extensive books that were also published in Western Germany and became well known:

3. Hansen, F.: *Konstruktionssystematik – Grundlagen für eine allgemeine Konstruktionslehre* (Systematic Design – Fundamentals of a General Model of Designing). 1st ed. VEB-Verlag Technik, Berlin 1955; 2nd ed. VEB Verlag Technik, Berlin 1955*; 3rd ed. VEB Verlag Technik, Berlin 1968* ***and*** Hanser, München-Wien 1968 (191 pages)
4. Hansen, F.: *Justierung* (Adjustment). 1st ed. VEB Verlag Technik, Berlin 1964; 2nd ed. VEB Verlag Technik, Berlin 1967*

Was translated and published in English:

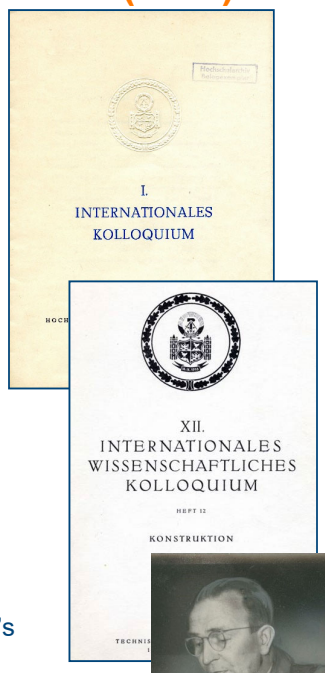
4e. Hansen, F.: Adjustment of Precision Mechanisms. Iliffe Books, London 1970

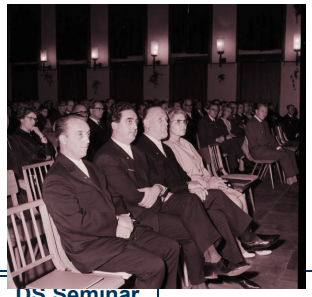
6. Hansen, F.: *Konstruktionswissenschaft – Grundlagen und Methoden* (Design Science – Fundamentals and Methods). 1st ed. Hanser, München-Wien 1974; 2nd ed. Hanser, München-Wien 1976*

* Available online at https://www.tu-ilmenau.de/produkt-und-systementwicklung/tradition/

Internationales Wissenschaftliches Kolloquium (IWK)
International Scientific Colloquium (ISC)

- In 1956 – one year after the founding of the new *Fakultät für Feinmechanik und Optik* (Faculty/Department of Precision Mechanics and Optics) – IWK was launched as a platform of international (East ***and*** West) and interdisciplinary exchange
- It played an important role in presenting and discussing ideas in the field of Design Science in an interdisciplinary atmosphere
- A very significant event was the 12th IWK 1967:
  - Hansen's MAKON group presented their results
  - Transition from Systematic Design to Design Science
  - Two scientists, now well-known and later influential for WDK and, subsequently, the Design Society met for the first time:
    Vladimir Hubka (1924-2006), at that time Prague, CSSR
    W. Ernst Eder (1930-2017), at that time Swansea, UK





← Impressions from IWK 1967, taking place in Ilmenau's *Festhalle* (festival hall)

Werner Bischoff →
at the speaker's desk
(we don't know which IWK/ISC)

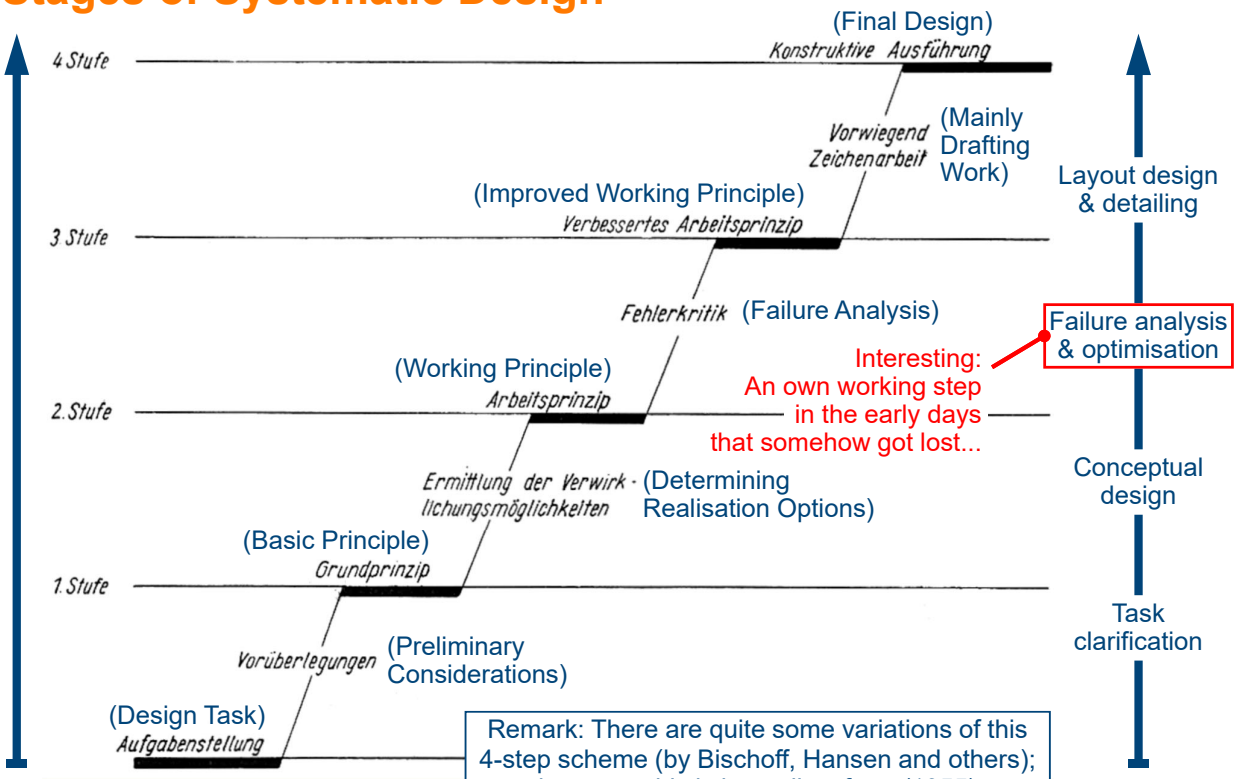
Internationales Wissenschaftliches Kolloquium (IWK)
International Scientific Colloquium (ISC)

- In 1956 – one year after the founding of the new *Fakultät für Feinmechanik und Optik* (Faculty/Department of Precision Mechanics and Optics) – IWK was launched as a platform of international and interdisciplinary exchange
- It plays an important role in presenting and discussing ideas in the field of Design Science in an interdisciplinary atmosphere
- IWK/ISC still exists today (albeit now in a 3-year rhythm) – maybe the oldest colloquium of its kind in existence:
  - Reviewed by an international board
  - All contributions in English
  - Permanent, cost-free open-access publication of all contributions at *Digitale Bibliothek Thüringen* (dbt, Digital Library Thuringia)
- The last event (59th IWK/ISC) took place in 2017: "Engineering for a Changing World":

  4 days, > 300 participants, > 150 contributions
- The event scheduled for 2020 (60th IWK/ISC) had to be postponed due to the Covid-19 pandemic; now:

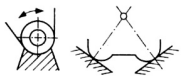
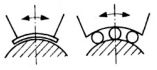
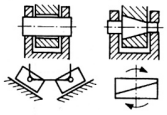
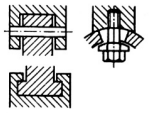
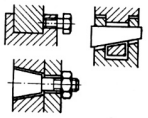
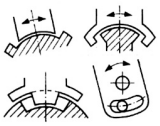
  12.-16.09.2022 (www.tu-ilmenau.de/60-iwk/)
- **Looking forward to your contributions!**

Entwicklungsstufen der Konstruktionssystematik (1955)
Stages of Systematic Design

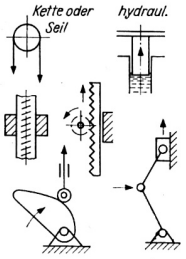
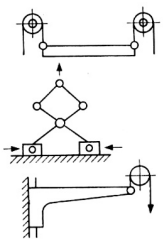


Leitblätter (Guide Sheets): Early Design Catalogues
(Examples Taken from Hansen, *Konstruktionssystematik*, 1955)

Leitblatt: Winkelbewegliche Paarung

Nr.	Ordnende Gesichtspunkte	Unterscheidende Merkmale	Beispiele
1.	Art der Winkelbewegung	Drehung um raumfeste Achse Bewegung mit veränderlicher Drehachse	
2.	Art der Paarung	Flächenberührung Linien- oder Punktberührung	
3.	Form der Lastaufnahmefläche (bei Flächenberührung)	Zylinder Kegel geneigte Ebenen	
4.	Sicherung gegen seitliches Kippen	Achse Führungsleiste Schraube	
5.	Spannelemente	Schraube Keil Kegel	
6.	Begrenzung der Winkelbewegung	Begrenzungskraft Begrenzungsform	

Leitblatt: Hubgetriebe für Plattformen

Nr.	Ordnende Gesichtspunkte	Unterscheidende Merkmale	Beispiele
1.	Art des Grundgetriebes	1.1. Zugorgangetriebe 1.2. Druckorgangetriebe 1.3. Schraubengetriebe 1.4. Zahnstangengetriebe 1.5. Gelenkgetriebe 1.6. Kurvengetriebe	
2.	Sicherung der Parallelführung	2.1. Form des Grundgetriebes 2.2. Mehrfachanordnung 2.3. Zusätzliche Führung	z. B. gleicharmige Doppelkurbel 

Hansen: *Konstruktionswissenschaft* (Design Science), 1974

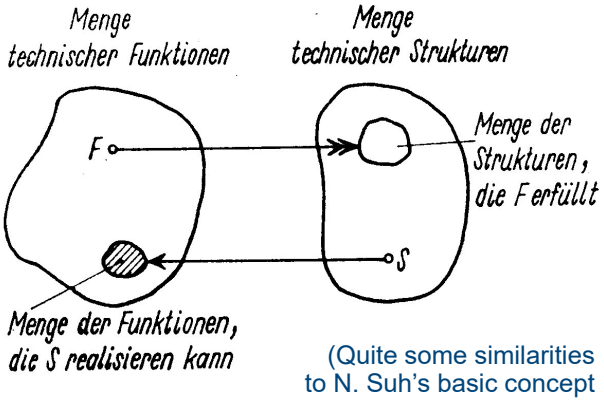
- Comprehensive considerations on products and processes and their relations
- Introduction of the “system” concept:

  A “system” is generally defined as a clearly delimited part of reality which
  - has relations to its environment (U),
  - has a structure (S) and
  - has a function (F).
- “There is a meaningful relation between these three system properties.
  Always the function is determined by the structure and depending on the environment.”
- The properties of a system (vector P) can be formally expressed by: **P = { U, F, S }**
- Distinction between technical and other systems by defining and describing environments (U), structures (S) and functions (F) specific for them
- Core issue for engineering design:

  Relations between structures (S) and functions (F):

  Analysis: **S ⟶ F**

  Synthesis: **F ⟶ S**



(Quite some similarities to N. Suh’s basic concept of Axiomatic Design!)

Role of Systematic Design in Industry, Science, Politics

In the 1950ies and 1960ies Systematic Design became an important issue in Eastern Germany:

- A new scientific approach
- A new teaching and training concept for engineers
- A means to perform design more efficiently and to produce better designs in industry (thus promising an advantage over “the West”)

Several activities were launched in order to spread the approach in industry:

- Doctoral candidates were sent into industry (before completing the doctorate) or went into R&D in industry (after the doctorate) as *“methodische Berater”* (method advisor)
  Example: After his doctorate Günter Höhne went to ROBOTRON in Karl-Marx-Stadt (today Chemnitz) in order to advise on and introduce task clarification, development of solutions and their variants, evaluation
- Introduction of – sometimes large – industrial projects with and for industry (see example in next slides)
- There were links to the philosopher Johannes Müller at Technische Hochschule Karl-Marx-Stadt (Chemnitz): In the 1960ies he developed the concept of *Systematische Heuristik* as a “technology of brain work” and a “system of methods for accomplishing problem solving tasks”
  By intervention of Walter Ulbricht, head of the dominant Socialist Party and of the state in GDR, in 1969 *Systematische Heuristik* became the guiding concept of improving the efficiency in engineering and science; however, this remained an intermezzo because in 1971 Ulbricht was disempowered and most of his economic reforms were brought to an end by his successor Erich Honecker

Industrial Co-operation

- In the German Democratic Republic (GDR) a large industrial research project was founded – in several branches of industry:
  AUTEVO – *Automatisierung der Technischen Vorbereitung der Produktion* (Automation of the Technical Preparation of Production)
- Responsible for precision mechanics and optics: Dr. Klaus-Dieter Gattnar, at that time chief designer at Carl Zeiss Jena (later CEO, promoting the re-unification of Zeiss East & West)
- As a part of the AUTEVO programme, from 1965 until 1972 a project between Zeiss and TH Ilmenau was granted under the leadership of Friedrich Hansen:
  MAKON – *Maschinelle Simulation konstruktiver Tätigkeiten* (Automated Simulation of Design Activities) – goal was investigating computer applications in design (CAx)
  Focus in Ilmenau was on early phases (in co-operation with Johannes Müller, Karl-Marx-Stadt / Chemnitz)
- Scientific output:
  5 Joint doctoral thesis 1969: Anschütz, F.; Fritsch, M.; Höhne; G.; Langbein, P.; Mehlberg, H.; Otte, V.: *Beiträge zum konstruktiven Entwicklungsprozess* (Contributions to the Engineering Design Process)

The interdisciplinary MAKON research group at TH Ilmenau (left to right): Fritz Anschütz, Helmut Mehlberg, Peter Langbein, Viktor Otte, Friedrich Hansen, Manfred Fritsch, Günter Höhne; Günter Frank, first group leader, is missing on this photograph

Konstrukteurinformationen (KOIN) (Information for Designers)

- Providing catalogues and guidelines for designers in practice always was (and is) an important task in Ilmenau's design research activities
- In the 1970ies, together with Carl Zeiss Jena, the concept of *Konstrukteurinformationen* (KOIN, information for designers) was developed and realised
  - Internal know-how of Carl Zeiss Jena: ***not*** publically available
  - KOIN from research projects (TH Ilmenau): publically available, also for teaching ↓

1 Frank, G.: Konstruktionsregeln für die Vereinheitlichung
2 Frielinghaus, R.: Rollengeradführungen (Fehlereinflüsse, Hinweise zur konstruktiven Gestaltung)
3 Nönnig, R.: Federführungen (Berechnung, Hinweise zur Konstruktion)
4 Schilling, M.: Konstruktionsprinzipien
5 Sperlich, H.: Gestaltungsrichtlinien zum kraftgerechten Konstruieren
6 Sperlich, H.: Methodische Richtlinie zur Konstruktionskritik
7 Merbach, P.-M.: Lösungssammlung berührungsloser Antastverfahren
8 Höhne, G.; Kalinowski, H.-R.: Fehlerkritik (Methodik der Fehlerkritik im KEP, Methoden der Fehlerapproximation)
9 Tänzer, W.; Unbehaun, E.: Membranfedern als Bauelemente für Federführungen
10 Riegel, W.-U.; Schilling, M.: Kennlinienbeeinflussung von Federführungen
11 Kallenbach, E.; Hermann, R.: Gleichstrommagnete – Entwurf, Berechnung
12 Just, E.; Felscher, H.: Schwingungen
13 Arlt, B.: Bauelementedimensionierung mittels Spannungsoptik
14 Meissner, M.: Gestaltungsrichtlinie für Plastteilverschraubungen
15 Sperlich, H.: Vermeiden oder Beseitigen von Spiel
16 Heiderich, Th.: Tolerierung von Reflexionsprismen
17 Bochnia, A.; Heiderich, Th.: Grundsätze zur Gestaltung eines definierten Justierablaufes
18 Heiderich, Th.: Invarianz, Sensitiv- und Innocenzachsen bei Planoptik; Empfindlichkeiten und Gültigkeitsgrenzen
19 Bochnia, A.: Berechnung der Lageempfindlichkteiten von Linsen und Linsengruppen mittels Empfindlichkeitsfaktoren
20 Pech, W.: Starrkörpermodelle zur Berechnung von Schwingungen an Geräten auf der Basis des Programmsystems BEKOS
21 Just, E.; Sänger, Th.: Schwingungsberechnung feinmechanisch/optisch/elektronischer Geräte
22 Just, E.: Dimensionierung von Dämpfern für den Gerätebau
23 Schüller, U.: Nullpunkt- und Lastverhalten von Blattfedern der Gerätetechnik

Konstrukteurinformationen (KOIN) (Information for Designers)

Example: Excerpt of KOIN 4,
Manfred Schilling: *Konstruktionsprinzipien*
(Design Principles), 1981

2. Erst wenn die Belastungen nicht weiter verkleinert werden können, ist zu versuchen, die Wirkungen, also die Spannungen und Deformationen, zu verringern (Bilder 9, 10, 11).

Bild 9 Die große Flächenpressung an einer Kugel-Ebene-Paarung (a) kann vermieden werden durch ein Zwischenteil 1, ohne die Zahl der Freiheiten der Paarung (hier 5) einzuschränken.

Bild 10 Durch Aufteilung der Kräfte (b) wird die Druckbeanspruchung (a) der Führungsleiste 1 einer Wälzführung zu einer Biegebeanspruchung, die zu einer Vergrößerung der Berührungsfläche zwischen den Kugeln und der Führungsleiste führt, so daß die Belastbarkeit z. B. 3mal und die Lebensdauer 27mal so groß werden können.

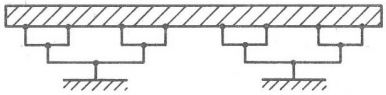


Bild 11 Die gleichmäßige Verteilung der Auflagekraft auf möglichst viele Auflagepunkte führt zu einem Minimum an Biegespannungen.

3. Die Verminderung der Spannungen und Deformationen in einem Bauteil ist nicht durch ein großes Werkstoffvolumen, sondern durch eine zweckmäßige Anordnung des Werkstoffes anzustreben (Bilder 12, 13).

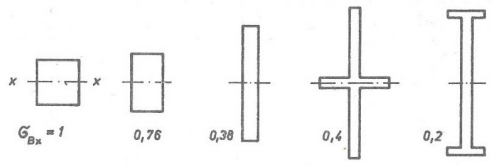


Bild 12 Bei gleichem Werkstoffvolumen und gleichem Biegemoment variieren die Biegespannungen für die dargestellten Querschnittsformen etwa von 5 bis 1.

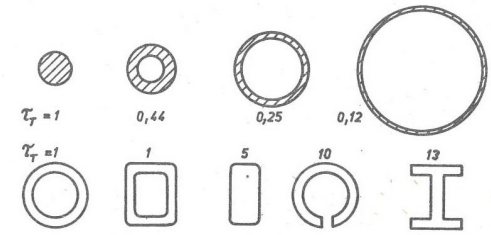


Bild 13 Bei gleichem Werkstoffvolumen und gleichem Torsionsmoment ergeben größere polare Trägheitsmomente (oben) und geschlossene Querschnitte (unten) kleinere Torsionsspannungen.

4. Es ist zu beachten, daß die Art der Spannung die Belastbarkeit oder/und das notwendige Werkstoffvolumen wesentlich beeinflußt (Bilder 14, 15, 16, 17, 18).

- Gußwerkstoffe ertragen höhere Druck- als Zugspannungen
  GGL 4 : 1 Mg-Gußlegierungen 2:1
  GT 3 : 1 Al-Gußlegierungen 1,5 : 1.

Zur optimalen Ausnutzung des Werkstoffvolumens ist deshalb für die Zugseite ein stärkerer Querschnitt vorzusehen.
- Druck- und Zugbeanspruchung erfordert bei gleicher Belastbarkeit des Bauteils einen geringeren Werkstoffaufwand als Biege- oder Torsionsbeanspruchung (Bilder 14, 15).
- Bei großen Kraftleitungswegen (Bild 17, Strecke $\overline{AB}$) wird durch Zugbeanspruchung eine Querschnittserhöhung vermieden, wie sie wegen der Knickgefahr bei Druckbeanspruchung notwendig wäre.

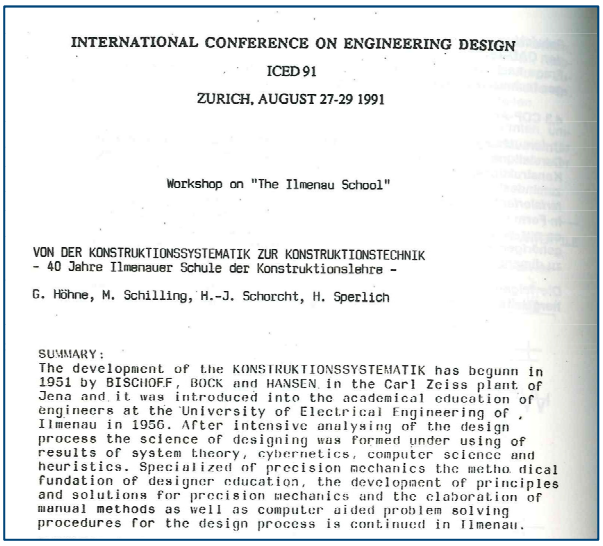
Recognition of the “Ilmenau School of Engineering Design”

- At the 8th International Conference on Engineering Design (ICED ‘91) in Zurich a workshop was organised on “40 Years Ilmenau School of Engineering Design” (*Ilmenauer Schule der Konstruktionslehre*) ➔

  Attendees: Vladimir Hubka, W. Ernst Eder, Wolfgang Beitz, Gerhard Pahl, Karlheinz Roth, Klaus Ehrlenspiel, Christian Weber, ...

  On behalf of TU Ilmenau: Günter Höhne, Manfred Schilling, Hans-Jürgen Schorcht, Horst Sperlich ➘
- In 1994 VDI (*Verein Deutscher Ingenieure*, German Association of Engineers) awarded the Fritz Kesselring Medal of Honour

  “in commemoration of the founders of the ‘Ilmenau School’, Werner Bischoff, Arthur Bock and Friedrich Hansen ➔



INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN

ICED 91

ZURICH, AUGUST 27-29 1991

Workshop on "The Ilmenau School"

VON DER KONSTRUKTIONSSYSTEMATIK ZUR KONSTRUKTIONSTECHNIK
- 40 Jahre Ilmenauer Schule der Konstruktionslehre -

G. Höhne, M. Schilling, H.-J. Schorcht, H. Sperlich

SUMMARY:
The development of the KONSTRUKTIONSSYSTEMATIK has begunn in 1951 by BISCHOFF, BOCK and HANSEN in the Carl Zeiss plant of Jena and it was introduced into the academical education of engineers at the University of Electrical Engineering of Ilmenau in 1956. After intensive analysing of the design process the science of designing was formed under using of results of system theory, cybernetics, computer science and heuristics. Specialized of precision mechanics the metho dical fundation of designer education, the development of principles and solutions for precision mechanics and the elaboration of manual methods as well as computer aided problem solving procedures for the design process is continued in Ilmenau.

TU Ilmenau: Policy of Teaching Engineering Design

- **Sound fundament:** Fundamentals of mathematics, natural sciences, computer science and technology, adapted and balanced with view to engineering applications.
- **Continuity:** Integration of engineering design projects throughout the whole course of studies, with increasing challenges.
- **Individual support:** Effective project work in small teams (2-6 students), each tutored by one research assistant; encouragement of individual approaches and inventive solutions.
- **Interdisciplinary and practice-oriented tasks:** Different engineering disciplines combined in projects (mechanical and electrical engineering, optical and precision engineering, computer science, measurement technology, manufacturing technology, economics); enabling students to work on and design opto-mechatronic systems; confrontation with complex tasks in practical projects in industry.
- **Team-work:** Team-work increasing with progress in studies; involvement of (senior) students into current research projects of the institute.
- **Methodical and systematic work:** Exercising conceptual work as well as systematic detailing; using up-to-date methods and tools (heuristic approaches, creativity techniques, systematic fault analysis, design by configuration of supplied components, later complemented by 2D- and 3D-CAD applications, simulation techniques and tools, Simultaneous Engineering, Virtual Reality, Model-based Systems Engineering, ...).

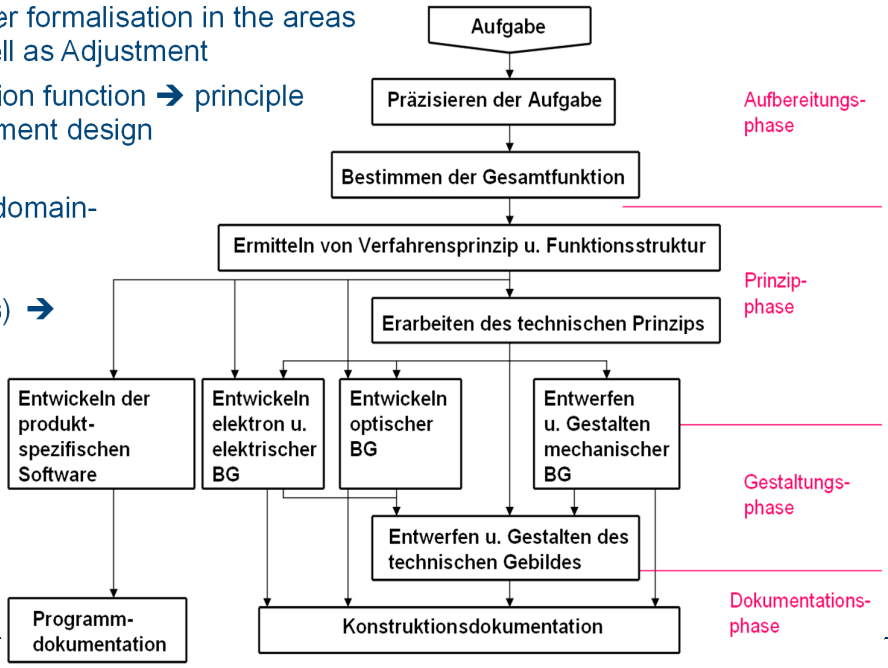
Still maintained today!

Engineering Design Group 1973-2006

- After Friedrich Hansen had retired (1970), in 1973 Günter Höhne was appointed as his successor (coming from industry: ROBOTRON, Karl-Marx-Stadt/Chemnitz)

Brief description of research and teaching 1973-2006 (1):

- Continuation and stronger formalisation in the areas of Design Science as well as Adjustment
- New focus on the transition function ➔ principle development ➔ embodiment design (*Gestaltungslehre*)
- Even stronger focus on domain-spanning considerations (i.e. “mechatronics”, here also implying optics) ➔



[Höhne/Schilling/Sperlich, 34th IWK 1983]

Engineering Design Group 1973-2006

- After Friedrich Hansen had retired (1970), in 1973 Günter Höhne was appointed as his successor (coming from industry: ROBOTRON, Karl-Marx-Stadt/Chemnitz)

Brief description of research and teaching 1973-2006 (2):

- “Building bridges” to West-German scientists:
  - First meetings between East and West German design researchers in the late 1980ies, among them G. Pahl (Darmstadt), W. Beitz (West-Berlin), K. Ehrlenspiel (Munich), J. Franke (Braunschweig), J. Müller (Karl-Marx-Stadt/Chemnitz), G. Höhne (Ilmenau)
  - In the early 1990ies *“Ladenburger Diskurs”,* organised by Gerhard Pahl (Darmstadt), funded by the Daimler foundation
  - After this the workshop series *“Bild und Begriff”* (Image and Concept) was organised by Klaus Ehrlenspiel und Johannes Müller
- These activities ultimately led to “Human Behaviour in Design” – still alive as a Special Interest Group (SIG) of the Design Society

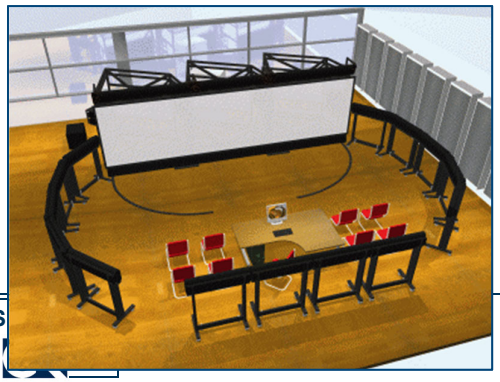
“Bild und Begriff” meeting 1994, Naupoldsmühle/Thuringia ➔

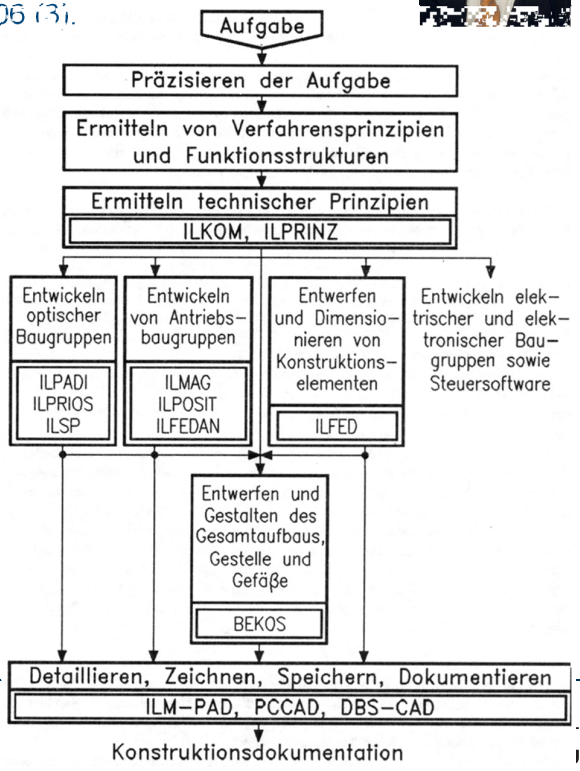
Engineering Design Group 1973-2006

- After Friedrich Hansen had retired (1970), in 1973 Günter Höhne was appointed as his successor (coming from industry: ROBOTRON, Karl-Marx-Stadt/Chemnitz)

Brief description of research and teaching 1973-2006 (3):

- **ILKON (ILmenauer KONstruktionssystem):** Comprehensive computer support system for precision engineering, based on results of the MAKON project, developed in co-operation with other groups at TH Ilmenau ➔
- **Flexible Audio-visual Stereo Projection Device (FASP):** VR visualisation combined with 3D acoustics using the wave-field synthesis algorithm (developed at IDMT Ilmenau), opened 07.02.2007 ➔





Engineering Design Group 1973-2006

- After Friedrich Hansen had retired (1970), in 1973 Günter Höhne was appointed as his successor (coming from industry: ROBOTRON, Karl-Marx-Stadt/Chemnitz)

Brief description of research and teaching 1973-2006 (4):

- **Digital Mechanism and Gear Library (DMG-Lib)*:** New ways of providing engineering knowledge via
  - Scanned books and articles, searchable (> 36,000)
  - Mechanism descriptions, most incl. videos (> 3,100)
  - Interactive animations (> 2,800)
  - Biographies (> 5,800)
  - Pictures of persons, mechanisms, models (> 45,000)

Please visit:
www.dmg-lib.org

Model provided by University "Politehnica", Timisoara, Romania; animated by DMG-Lib

Übertragungsmechanismus von Bonjour. 9

wesenheit singulärer Glieder die Kette eine geschlossene sein müßte. Vor allem muß auch untersucht werden, ob alle Glieder gegen das ruhende Glied des Mechanismus ebene Bewegungen ausführen oder nicht, da im ersteren Falle die Kette eine ebene, im letzteren eine räumliche wäre. Endlich muß die Anzahl der sich gegeneinander bewegenden Glieder ermittelt werden, wobei das ruhende Glied (das Maschinengestell) mitzuzählen ist. Es empfiehlt sich, auf Grund dieser Feststellungen die erhaltene kinematische Kette schematisch aufzuzeichnen, d. h. ohne Rücksicht auf die Ausführungsform der Elementenpaare und der einzelnen Glieder, weil erst hierdurch der rechte Einblick in die Art der Kette gewonnen wird. Auf welche Weise man aus gegebenen Mechanismen die schematische Darstellung der entsprechenden kinematischen Ketten erhält, soll an zwei Beispielen erläutert werden.

12. Übertragungsmechanismus von Bonjour.

Der Zweck dieses in Fig. 15 dargestellten Mechanismus ist die Änderung der Expansion einer Dampfmaschine mit Schiebersteuerung vom Regulator aus. Er wird dadurch erreicht, daß die nach der Reguliatorhülse führende Stange z den Hebel 2 in drehende Bewegung gegen das Maschinengestell 1 bringt und die mit 2 gelenkig verbundene Stange 3 die Kurbel 4 in Bewegung setzt, die durch die Stange 5 die im Schieberkasten der Dampfmaschine drehbar gelagerte Kurbel 6 dreht. Mit der Kurbel 6 ist die Regulierwelle starr verbunden, die mittels Schraubengewinden die Expansionsschieberplatten gegeneinander verschiebt. Dieser Mechanismus kann unabhängig von der Art, wie der Hebel 2 in Bewegung gesetzt wird, also ohne Hinzunahme der zum Regulator führenden Stange z und ohne Hinzunahme der Expansionsschieberplatten angesehen und demgemäß aus 6 Gliedern bestehend betrachtet werden, die untereinander nur durch Drehpaare mit parallelen Achsen verbunden sind. Die Kette ist demnach eine ebene Drehpaarkette von 6 Gliedern und 7 Drehpaaren. Vier von den Gliedern sind binär,

Fig. 15.

[Grübler, M.: Getriebelehre, Springer, Berlin 1917]; integrated animation by DMG-Lib

* Principal investigator: Dr.-Ing. Torsten Brix

Engineering Design Group 1973-2006

- After Friedrich Hansen had retired (1970), in 1973 Günter Höhne was appointed as his successor (coming from industry: ROBOTRON, Karl-Marx-Stadt/Chemnitz)

Brief description of research and teaching 1973-2006 (5):

- Establishing and deepening international contacts, first in teaching, later also in research
- "Exporting" teaching concepts in the field of engineering design and precision engineering:
  - University of Niš, Yugoslavia (today Serbia, 1972-1986)
  - University of Setif, Algeria (1979-1983)
  - Universidade Federal de Santa Catarina (UFSC), Florianópolis, Brazil (1989-1991)
  - Universidade Federal de Minas Gerais (UFMG), Belo Horizonte, Brazil (2003-2007)
  - Universidade Federal de Bahia (UFBA), Salvador, Brazil
  - Universidade de Sao Paulo (USP), Sao Paulo, Brazil
- 11.12.2008: Prof. Höhne receives the honorary doctorate of the Universidade Federal de Santa Catarina (UFSC), Florianópolis, Brazil, by rector Prof. Alvaro T. Prata ➔

- Introducing tele-teaching for a joint course in Engineering Design for students of Material Science at TU Ilmenau and Friedrich-Schiller University Jena as early as 1998

Engineering Design Group 2007-2020

- After Günter Höhne had retired (2006), in 2007 Christian Weber was appointed as his successor (coming from Saarland University, Saarbrücken)

Brief description of research and teaching 2007-2020 (1):

- Continuation of the work on the application of (audio-visual) VR techniques in product development in several projects – often together with partner institutions[1]
- Basic methods:
  - Integration of directional characteristics of sound sources
  - Digital Mock-up including acoustical behaviour,
    - Integration of different acoustical simulations (measured data, pre-simulated data, real-time)
    - Integration of models for structure-born sound transmission[2] (based on four-pole models)
  - Exchange of acoustical data (integration into the STEP standard)
- Digitalisation and enhancement of car noise emissions using Artificial Neural Networks (ANN)
- Audio-visual traffic simulation
- New ways to build and re-use VR scenes:
  - Controlled by MBSE/SysML models
  - Separation between product, actor(s) and environment
  - Integration of physical behaviour by physics engines
  - Transfer to different VR-systems (CAVE, HMD sVR)

[1] Fraunhofer Institute of Digital Media Technologies (IDMT), Ilmenau, Prof. Karlheinz Brandenburg; Institute for Product Development (IPEK) at Karlsruhe Institute of Technology (KIT), Prof. Albert Albers; Media Production Group at TU Ilmenau, Prof. H. Krömker.

[2] Air-borne sound transmission is already realised by the wave-field synthesis algorithm of IDMT Ilmenau

Engineering Design Group 2007-2020

- After Günter Höhne had retired (2006), in 2007 Christian Weber was appointed as his successor (coming from Saarland University, Saarbrücken)

Brief description of research and teaching 2007-2020 (2):

- Continuation of the work on the application of (audio-visual) VR techniques in product development in several projects – some examples:

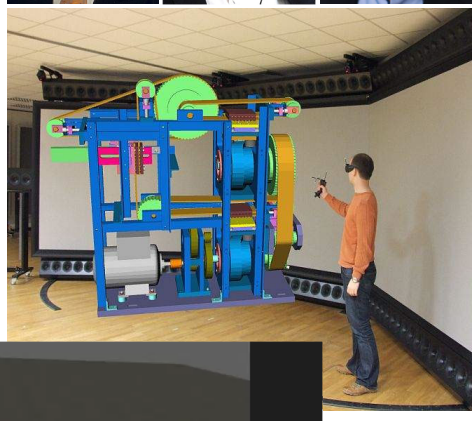
← Fly around a vehicle to test the representation of directional characteristics

↓ Traffic situation; acoustic simulation via Artificial Neural Network (ANN) based on measurement data

12.04.2021

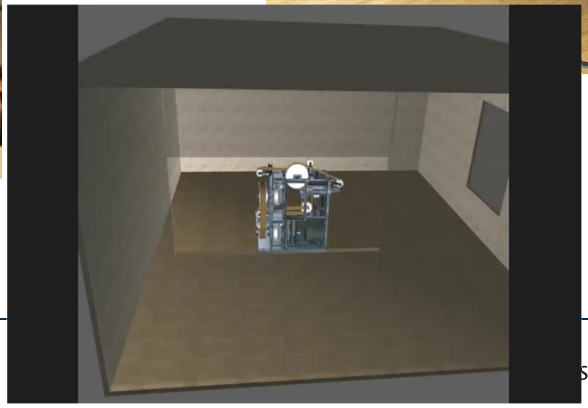
Award for (audio-visual) VR Techniques in Product Development

- Stephan Husung as a research assistant and doctoral candidate of Günter Höhne was the main actor in setting up the Flexible Audiovisual Stereo Projection Device (FASP) at TU Ilmenau ↘
- Stephan Husung's doctoral thesis (2012) on **"Simulation of Acoustic Product Properties Using Virtual Reality during Product Development"** received the Scientific Award 2012 of prostep ivip e.V.



↑ Award ceremony at prostep ivip symposium 2012

Investigation of acoustic properties of a pick&place unit in VR →



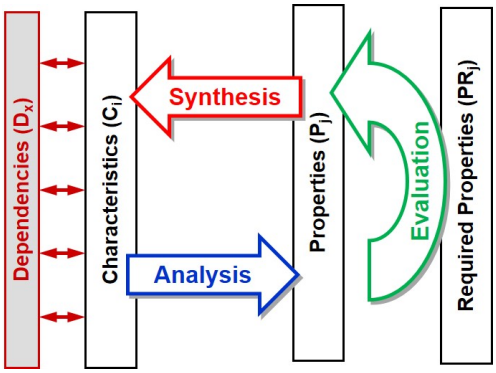
12.04.2021

Engineering Design Group 2007-2020

- After Günter Höhne had retired (2006), in 2007 Christian Weber was appointed as his successor (coming from Saarland University, Saarbrücken)

Brief description of research and teaching 2007-2020 (4):

- Continuation of the project Digital Mechanism and Gear Library (DMG-Lib):
  - European project “ThinkMotion”*
  - Please visit: www.dmg-lib.org
- Contribution to Design Science: New approach to model products and product development processes:
  - Characteristics-Properties Modelling (CPM)
  - Property-Driven Development (PDD) ➔



- Based on this approach: Additions to the transition function ➔ principle development ➔ embodiment (*Gestaltungslehre*)
- Modelling of machine elements as components of mechatronic systems, based on the four-pole/multi-pole theory
- Representation and processing of tolerance information in 3D-CAD (as a contribution to “Robust Design”)

* Principal investigator: Dr.-Ing. Torsten Brix

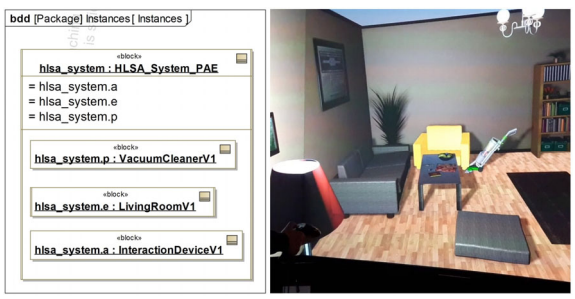
12.04.2021

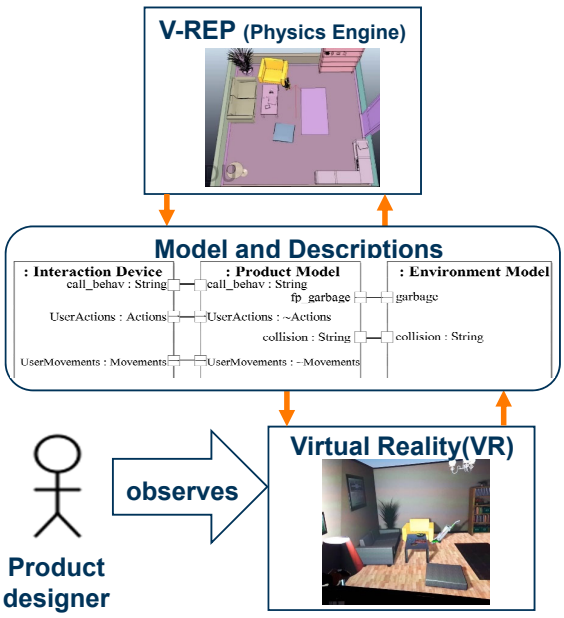
Engineering Design Group 2007-2020

- After Günter Höhne had retired (2006), in 2007 Christian Weber was appointed as his successor (coming from Saarland University, Saarbrücken)

Brief description of research and teaching 2007-2020 (3):

- Contribution to Integrated Virtual Product Development
  - Description of technical products with different variants of product and environment using Model-Based Systems Engineering (MBSE) approaches (a.o. SysML language)
  - Coupling of SysML models with behavioural simulations
  - Generation of interactive Virtual Reality scenarios based on SysML and simulation models for different output devices





12.04.2021

Institut für Maschinen- und Gerätekonstruktion
Institute of Design and Precision Engineering

(Re-) founded 26.05.2008, consisting of:

- Machine Element Group,
  Prof. Dr.-Ing. Ulf Kletzin
- Engineering Design Group,
  Prof. Dr.-Ing. Christian Weber
  Now
  Product and Systems Engineering,
  Prof. Dr.-Ing. Stephan Husung
- Precision Engineering Group,
  Prof. Dr.-Ing. René Theska

Aims:

- Improve visibility in the scientific community and in industry
- Co-ordinate research and teaching
- Acquire joint research projects
- Combine resources
- Maintain and enhance the “Ilmenau School of Engineering Design”
- Support a common identity
- Contribute to the profile of the Faculty/Department

Engineering Design Group 2007-2020

- After Günter Höhne had retired (2006), in 2007 Christian Weber was appointed as his successor (coming from Saarland University, Saarbrücken)

Throughout the whole career:
Closely involved in the Design Society and its predecessor WDK

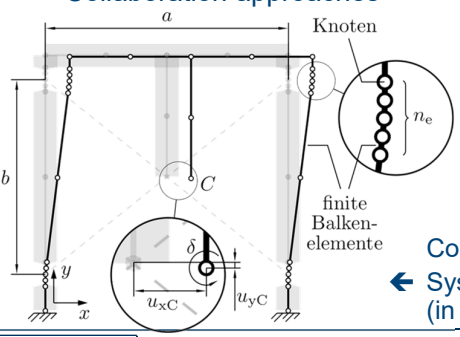
1985-2000	Participant of WDK (Workshop – Design – Konstruktion)
2000	Founding member of the Design Society
2000-today	Involved in the Summer School on Engineering Design Research (with international colleagues: M.M. Andreasen [DTU], L. Blessing [Singapore University of Science and Technology], D. Pigosso [DTU], G. Cascini [Politecnico di Milano])
2001-2005	Member of the Advisory Board
2005-2013	Member of the Board of Management (Secretary)
2015	Programme Chair of the 20th International Conference on Engineering Design (ICED ‘15), Milano 27.-30.07.2015 – together with Stephan Husung as Assistant Programme Chair →
2015	Fellow of the Design Society →

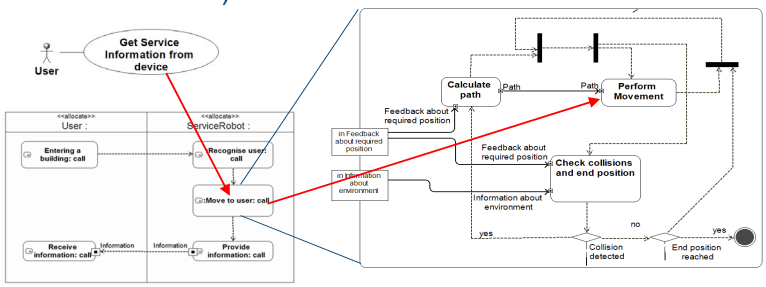
Product and Systems Engineering Group (2021+)

- After Christian Weber had retired (01.10.2020), on 01.01.2021 Stephan Husung was appointed as his successor (coming back from industry, having acquired his doctorate/PhD 2012 at TU Ilmenau)

Brief description of research and teaching plans (1):

- New/extended name of the research group: **Product and Systems Engineering**
- The research activities focus on
  - Holistic product development process from requirements elicitation and analysis, via function-oriented product development to systematic verification/validation (V&V)
  - User- and goal-oriented methods (e.g. DfX, Design Review, Robust Design, V&V)
  - Appropriate modelling of the product (informal, semi-formal and formal – e.g. solution principles, SysML, simulation models)
  - Tools (e.g. CAx)
  - Collaboration approaches





Continuous system modelling ↑

← Systematic design of mechanisms (in cooperation with the Compliant Systems Group)

12.04.2021

Product and Systems Engineering Group (2021+)

- After Christian Weber had retired (01.10.2020), on 01.01.2021 Stephan Husung was appointed as his successor (coming back from industry, having acquired his doctorate/PhD 2012 at TU Ilmenau)

Brief description of research and teaching plans (2):

- Teaching shall continue in the good tradition of Ilmenau interdisciplinary engineering design education (“Ilmenau School of Engineering Design”) with plenty of practical application
- Current and future challenges in the field of
  - Mechatronic System Development,
  - Application of new Technologies in Product Development as well as
  - Integrated Virtual Product Development

  will be addressed.

12.04.2021

TU Ilmenau – one of the Birthplaces of Design Science
Summary / Conclusions

- The history of Design Theory and Methodology at HfE / TH / TU Ilmenau was influenced by political implications and also by chance in a remarkable way
- In spite of this (because of this?), HfE / TH / TU Ilmenau could make some contributions to the evolution of Design Science
- The origins of Design Science in Ilmenau are in industrial practice (Zeiss), it came to academia only later (and, partly, by accident)
- We are trying to continue on this path in present and future – both for driving research and evaluating results
- Precision engineering (which always was “mechatronic”) has been the main application focus then and now
- Interdisciplinary co-operation was and is an extremely important issue
- However, Ilmenau’s holistic concept of teaching design is challenged
  - because students have changed – we have to cope with starting conditions quite different from the past
  - by some consequences of the so-called Bologna process (“modularisation”, tightening and increasingly inflexible regulations)
- What we try to do: Find the best scientists and teachers, let them develop their ideas in a peaceful, highly interdisciplinary and world-open atmosphere!

The Design Society Seminar Series
14.04.2021

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a worldwide community

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– one of the Birthplaces of Design Science

Thank you for your attention!
We’re looking forward to your questions and comments!

Univ.-Prof. Dr.-Ing. habil. Günter Höhne
Univ.-Prof. Dr.-Ing. Christian Weber
Univ.-Prof. Dr.-Ing. Stephan Husung

Technische Universität Ilmenau
Institut für Maschinen- und Gerätekonstruktion (IMGK)
Fachgebiet Produkt- und Systementwicklung /
Product and Systems Engineering Group

guenter.hoehne@tu-ilmenau.de, christian.weber@tu-ilmenau.de, stephan.husung@tu-ilmenau.de