Industrial Engineering and Ergonomics

Professor Doktor-Ingenieur Holger Luczak

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Editor

Industrial Engineering and Ergonomics

Visions, Concepts, Methods and Tools

Festschrift in Honor of Professor Holger Luczak

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Industrial Engineering and Ergonomics – Visions, Concepts, Methods and Tools

A Festschrift in Honor of Professor Doktor-Ingenieur Holger Luczak

Human work is one of the main driving forces in the development of our society, economy and quality of life. Latest statistics of the International Labour Organization (ILO 2007) show that at present there are approximately 1.1 billion so-termed "economically active individuals" in five continents, who spend on average more than half of their daytime hours working. Due to this sheer number, the potential impact of scientific models, methods and tools for the design of human work is tremendous. The ergonomic approach to designing human work goes beyond purely economic and financial criteria and aims at a simultaneous optimization of human well-being and overall system performance (IEA 2009). The corresponding analysis and synthesis of multiple interactions among humans and technical elements of a work system is admittedly not simple, but allows for the sustainable and – in the truest sense of the word – healthy development of companies and organizations in the private and public sectors. The ergonomic approach promises to cope successfully with the grand future challenge of demographic change and to improve the quality of work in different economic cycles. In addition to the classical sphere of human work in private and public institutions, one must also consider the 5.6 billion individuals in the so-called First, Second and Third Worlds who do not regularly participate in work and business processes. One of the most noble tasks of researchers and practitioners dealing with human work is to improve the conditions and possibilities of gaining initial employment, maintaining it and continuously improving the quality of work performed.

Human work in engineering design, manufacturing and service has undergone a significant change in the last decades in terms of both structure and process. This change is especially evident in manufacturing systems in advanced countries, where the bottleneck of human performance (and workload) in a large part of work systems has moved from energetic effectual and sensorimotor levels to high levels of human information processing. This bottleneck shift is not only due to significant changes in customer demands towards informational products bundled

with innovative services, but also to rapid technological progress, which means that predominantly rule-based and skill-based components of human performance are becoming more and more automated. In spite of the rapid diffusion of new technologies in work systems, there are convincing theoretical arguments (DREYFUS 1992, HAREL 2000, BIALEK et al. 2002) that the "ultimate cognitive machine", as a serious alternative to human ingenuity, creativity and proactivity, is not on the horizon – and may never be – and therefore the decisions and actions of the human when planning, monitoring and optimizing complex production processes and the associated product structures are crucial. In particular, a far-reaching and large-scale system optimization that goes beyond assigning degrees of belief and utility values to decision variables and self-adapting the control parameters is not possible without purposeful and goal-directed human intervention. Human decision making and action regulation can be supported by cognitive technical systems which are embedded in ergonomic human-machine interfaces, but the approach should be symbiotic and aimed at "compatibility" (LUCZAK 1998, KARWOWSKI 2005), rather than substitutional. However, it is not only high levels of human information processing that are resistant to automation because they are hard to model and simulate with known scientific methods; the fundamental mechanisms of human sensory and perceptual systems for extracting predictive information from multiple information sources, for estimating and anticipating critical system states, and for resolving "ill-posed" optimization problems on subconscious levels of cognitive control are not well understood. Therefore, the common pragmatic approach of eliciting the implicit knowledge of highly skilled workers and encoding it through formal symbol systems is not likely to yield the intended results and should be substituted by a scientific approach to augmenting human perception, cognition and motor functions in future manufacturing systems.

In addition to these significant changes on the micro-ergonomic level, one also has to consider the dynamic transformation of companies and supply chains on meso- and macro-ergonomic levels. Whilst the dominant share of positions and workplaces in the European Union and North America only a few decades ago were in classic goods production including the associated extractive industry, more and more high-quality jobs have been created in the so-called service sector. In fact, over the past three decades, the service sector has become the largest segment of most industrialized nations' economies (SPORER et al. 2007) and therefore significantly widens the focus of interest of researchers and practitioners dealing with human work. Especially knowledge-based services such as applied research or new product development as well as knowledge-intensive market services such as maintenance of automated plants and machines are developing very fast (AMIL et al. 2007) and demonstrate an urgent need for novel methods of systematic "service engineering" (LUCZAK et al. 2004) including the underlying service customer- and service employee-oriented work system design. However, knowledge-based and knowledge-intensive services are often tightly interwoven with industrial production and systematic service engineering also has to consider

the dynamic interdependencies among products and services (LUCZAK 1999). The companies and organizations designing, developing and managing these advanced product-service systems (MEIER et al. 2008) often need a human-centered work organization to anticipate and stimulate customers' demands and to cope with customer-induced complexity in turbulent markets. One must therefore expect the classic hierarchical and matrix models of industrial management to be more and more substituted by network models of cooperating skilled individuals in multidisciplinary teams, who autonomously coordinate access to shared resources (MALONE 2004). In other words, the old "mechanistic" management methods neglecting multiple external and internal interactions are not expressive enough anymore in the age of value networks (ALLEE 2003). Instead, novel methods and techniques for designing, configuring, and developing open and dynamic socio-technical systems with a large number of individuals who make partially autonomous decisions but also strongly interact in multiply-connected networks have to be invented. Following the holistic approach of LUZCAK et al. (1996), the novel methods and techniques must guide simultaneous systematic interventions for personnel development, organization development and technology development and must be underpinned by proactive project management.

But not only advanced product-service systems and technology-based services are of special interest; the demand for personal services, e.g. in health care, is growing in many countries and suggest that steps need to be taken to reinvigorate classical research in ergonomics concerning stress and strain of service employees and their clients in a dynamically evolving service situation (cf. CARAYON 2007). The superimposition of components of stress and their impact on physical, mental and emotional strain of the involved persons is an especially interesting research subject, which can greatly benefit from the classical works in industrial production (LUCZAK 1979, GFA 2000). In the majority of advanced countries one must expect an accelerated growth in personal services due to the cited demographic change. This is characterized by a rapidly increasing average age in the population as a result of longer life expectancies and lower birth rates. In the United States, for instance, there were approximately 37 million citizens aged 65 and over in 2006, or 12.5 percent of the total population. This number is expected to grow to about 72 million by the year 2030, or 19.3 percent of the total population (US CENSUS BUREAU 2007). Demographic change is also having a big impact in the European Union. The proportion of the working population between the ages of 55 and 64 is expected to increase from 56 million in 2006 (11.4 percent of the total population) to 70 million in 2030 (13.5 percent). Furthermore, the number of people in the European Union aged 65 and older is expected to increase from 82 million in 2006 (16.8 percent) to 122 million in 2030 (23.5 percent) (EC 2006). This societal change is historically unique and will increase the need for novel methods and tools concerning an individualized and age-differentiated design of work systems in engineering design, manufacturing and service to support "healthy aging". These methods and tools are already under development in German priority research programs (FRIELING 2006).

Due to these clear international trends a high-dimensional approach to work system analysis, design and optimization is required. In many interesting application domains the work system (meta-)model will be fairly complex and must not only represent the working persons with their skills, knowledge and abilities, but also the following entities: the team structures and processes, the structure and process organization of the company, the customers and clients, the norms, values, motives, agreements and competencies, the goals, tasks, activities and actions, the work objects, documents and artifacts, the technology, techniques, tools and means for input-output transformation, the formal/informal information and material flows, the chances, risks and possible human errors, the boundary conditions, invariants, state variables, task couplings and fluctuations of the work system as well as the environmental factors. Furthermore, the objective function for work system design and optimization must cover multiple criteria such as customer and client satisfaction, productivity, cost effectiveness, quality, flexibility, energy and resource efficiency, workload, safety, health, self-development, participation etc., which are partially conflicting. One cannot deny that such a high-dimensional and multi-criteria approach is quite challenging for *Arbeitswissenschaftler* in engineering faculties (industrial engineers and ergonomists), as profound knowledge and excellent skills in the classical disciplines – anthropometrics, biomechanics, physiology, control theory, information theory, environmental ergonomics, to name just a few – are still necessary but no longer sufficient. In order to be qualified and competent, the industrial engineer and ergonomist has to consider a vast array of additional sources of scientific (and practical) knowledge in new neighboring disciplines such as cognitive science (LUGER 1994), or even contribute to building up the new community of service science (SPORER et al. 2007), in order to study so-termed interactive work in dedicated research programs in detail. In fact, a work organization with multi-functional and closely interacting teams also increases the frequency and intensity of cooperation between (distributed) working persons and therefore models and methods of communication sciences or social software engineering must also be taken into account. The perfect industrial engineer and ergonomist must consequently be a true modern Gottfried Wilhelm Leibniz, who is widely considered to have been the last universal genius and whose contributions are scattered in numerous scientific journals and in tens of thousands of letters and unpublished manuscripts. Although a second Leibniz has not come of age in industrial engineering and ergonomics so far, there is a small but fine group of outstanding persons in the scientific community who have been able to deliver important contributions to an impressively large variety of classical and novel areas over many decades and therefore come quite close to the Leibnizian ideal.

One of these outstanding persons is Professor Doktor-Ingenieur Holger Luczak. According to his colleagues and friends, he is a man with a brilliant mind, broad and deep knowledge, great communication skills and a person of highest integrity. According to his students, he is a gifted university teacher and a critical, but

friendly and open supervisor. Furthermore, he is a man of extraordinary creativity and productivity who has authored and co-authored more than 95 scientific articles in peer-reviewed international and national journals as well as more than 140 peer-reviewed conference proceedings. His publications cover an impressively wide array of scientific subjects such as workload measurement/analysis/assessment, stress and strain, superimposition of stressor variables, analysis and prediction of recovery times for informational-mental and energetic effectual work, ergonomic design and evaluation of human-machine systems and human-computer interfaces, ergonomics of electronic information displays, cognitive engineering, task analysis and modeling, design and evaluation of group and team work, computer-supported cooperative work, production planning and control, service engineering and management, logistics and information management as well as the especially exciting and rarely considered scientific subject of ergonomics and ethics. Selected research lines of Professor Luczak are analyzed in detail in the next section.[1] Professor Luczak has authored, co-authored and edited an almost unbelievable total of 91 books. Among these books are bestsellers such as the first and second editions of the standard German textbook on industrial engineering and ergonomics (*Arbeitswissenschaft* [151, 268a]) as well as the corresponding handbook (*Handbuch Arbeitswissenschaft* [238]), which are frequently used by scientists and engineers all over Germany, Austria and Switzerland. He has also authored and co-authored the equally impressive total of 191 book chapters. His "classic" book chapters were published in the *Handbook of Human Factors and Ergonomics* [365, 555], the *Handbook of Human-Computer Interaction* [219], the *Human-Computer Interaction Handbook* [446, 573] and the *International Encyclopedia of Ergonomics and Human Factors* [552, 553, 554].

The scientist – career path, research lines and research approach

One cannot completely understand the collective works of an ingenious scientist and gifted university teacher without shedding some light on his curriculum vitae and scientific career. Holger Luczak was born on 30 November 1943 in the city of Leipzig, Germany. World War II was raging and many major German cities were under heavy attack by allied air forces. On 4 December 1943 Leipzig suffered its most severe air raids and the baby Holger Luczak was badly wounded. This incident had a lifelong effect on his health and left a characteristic mark on his face. It may also have shaped his peaceful, even pacifist attitude. His family later moved to the western part of Germany where he grew up in a small Westphalian village in a rural community atmosphere, though with severe restraints after World War II. He gained his *Abitur* (German university entrance qualification) at the

[1] The interested reader can find a complete list of Professor Luczak's publications in the publications section. To simplify citation, only the chronological identification numbers of his publications are hereafter given in parentheses.

Paulinum/Schillergymnasium in Münster, which were Latin grammar schools following the ideal of a humanistic education. In 1963, he began his dual studies in mechanical and industrial engineering at Darmstadt University of Technology, Germany. He received the internationally respected German *Diplom-Ingenieur* degree (master's degree) in 1969. From 1969 to 1974, he was a research assistant at the Institute of Ergonomics at Darmstadt University of Technology, where he carried out his doctoral research under the supervision of the famous Professor Walter Rohmert. In 1974, he received his doctorate in engineering. The title of his thesis was "Untersuchung informatorischer Belastung and Beanspruchung des Menschen" (investigation of informational stress and strain on the human [17]). After completing his doctorate, he was appointed assistant professor (*Oberingenieur*) at the same institute and was able to develop his first own research lines. In 1977, he completed his *Habilitation* (the highest academic qualification a person can achieve by their own pursuit in Germany) and was granted the desired venia legendi. His habilitation thesis was titled "Arbeitswissenschaftliche Untersuchungen von maximaler Arbeitsdauer und Erholungszeiten bei informatorisch-mentaler Arbeit nach dem Kanal- und Regler-Mensch-Modell sowie superponierten Belastungen am Beispiel Hitzearbeit" (ergonomic investigations of maximum working and recovery times for informational-mental work on the basis of information-theoretic and control-theoretic models of the human as well as for muscular work with superimposition of heat stress [36]). While in Darmstadt he and his colleagues developed the famous stress-strain concept and later enhanced this important theoretical foundation of ergonomics [17]. The stress-strain concept combines job analysis, stress definition, observation and measurement, with measurement of human strain on the basis of aggregated stressor variables concerning different resources, capacities and abilities. A collection of variables can accordingly be considered as a meaningful entity in terms of the design and evaluation of work processes. At Darmstadt University, Professor Luczak was also involved in several practical research projects in different domains, e.g. air traffic control [29], the postal service [32], the police force [55], and disseminated knowledge into industry [37].

In 1976, he was appointed full professor for Production Technology with a focus on industrial engineering and ergonomics at Bremen University, Germany. Although this was a very important promotion and a highly visible recognition of his academic achievements, it was also an unexpected challenge in terms of severely limited research possibilities. The change from Darmstadt to Bremen was a true jump into cold water. The labs in Bremen were poorly equipped and there was a painful shortage of research funds. He also had to lead a centralized service unit and not an independent research institute, which was rather dysfunctional for natural science-based research. This change from a metaphorical "richly laid table" to a "tabula rasa" had to do with the concept of an *Eckprofessor* (founding professorship), who had to plan and build up a fully equipped engineering faculty with its buildings, labs and services for future colleagues, students and co-workers. In other words, an *Eckprofessor* had to focus on service and not on

research in the first years of the faculty. This was not an ideal situation for a young and very ambitious scientist. In spite of these unfavorable conditions, Professor Luczak successfully tracked down research project funds in industry and ministries and founded the renowned Bremen Institute for Industrial Technology and Applied Ergonomics (BIBA) in 1980. Among his research projects was the "Modellversuch Produktionstechnik" (pilot project production engineering [57]) and several humanization projects on "Arbeitsstrukturierung in der Teilefertigung und Montage" (work structuring in manufacturing and assembly) with AEG production units in Northern Germany [50, 68, 71, 80, 100] as well as selected foundries [69, 70]. Moreover, a huge research project with a total budget of more than 9 million German marks was established dealing with the human technology and organizational development of a "ship of the future" [63, 64, 65, 66, 67, 89, 90, 95, 96, 97, 98, 107, 115, 116, 117]. In fact, the focal point of his work shifted from basic research in the lab towards application studies. The industrial context dominated the research goals which focused on concrete demands and effective solutions rather than on theoretical or methodological gaps. However, the adaptation of laboratory and simulation methods to the respective application area guaranteed a science-based system improvement [82, 83, 95]. The shift from the methodological focus in Darmstadt to the forefront of technology in Bremen was coupled to the basic problem of not hindering technological progress through a corrective ergonomics approach, but to anticipate micro- and macro-ergonomics problems in a technology development line and to solve them conceptually [179]. His works in Bremen were complemented by his activities in (co-)authoring a *Denkschrift* [44, 45, 46, 47, 81], some literature surveys and application studies on recovery periods [48, 49, 51, 53], which were complementary to his habilitation thesis. Some theoretical studies regarding the superimposition of stressor variables were also conducted [41, 56]. The famous book *Praktische Arbeitsphysiologie* by G. Lehmann was re-edited by Professor Rohmert and Professor Rutenfranz with the help of Professor Luczak, who contributed no less than five chapters [58, 59, 60, 61, 62].

When the situation in Bremen became uncertain in terms of the development of the Faculty of Production Engineering to its planned full size, Professor Luczak decided to accept a "call" to the Berlin University of Technology in 1982, where the Faculty of Engineering Design and Manufacturing had an open position as head of the Institute of Industrial Engineering and Ergonomics. Following an overlap strategy, the BIBA leadership remained in Professor Luczak's hands for two more years while in parallel he started his first research activities in Berlin. The research lines were adjusted or newly developed in accordance with the focus of the faculty in Berlin. The research line focusing on humanization and human technology of production was pursued [100, 101, 102, 122, 129, 136, 138, 140, 142] and enriched by time scheduling [92, 93, 110, 135] and topics on planning and organization [108, 118, 132, 134]. The research line on disciplinary structures and methods continued to be highly significant [99, 103, 104, 106, 109]. It led to some remarkable surveys [119, 120, 123, 132, 138, 143, 144, 145, 150] and a textbook [151].

Furthermore, a novel research line dealing with engineering design and computer-aided design was established. The focus was on the assessment of stress and strain in engineering design work [91, 94, 111, 112, 121, 125, 126, 127, 128, 130, 133, 137, 139, 149, 153] as well as organizational modeling and simulation. Finally, the new research line of human-computer interaction (or "work with display units", WWDU) was created in addition to the ergonomic design of CAD systems [105, 113, 114, 141]. The research in this area culminated in the hosting of the WWDU 1992 Congress in Berlin, which won international acclaim and was attended by more than 800 participants [147].

In 1992, Professor Holger Luczak was appointed full professor at the famous Faculty of Mechanical Engineering of RWTH Aachen University and became head of the renowned Institute of Industrial Engineering and Ergonomics (IAW – Institut für Arbeitswissenschaft). Simultaneously, he was appointed director of the highly reputed Research Institute for Operations Management (FIR – Forschungsinstitut für Rationalisierung) at RWTH Aachen University and was therefore able to significantly sharpen his profile in industrial engineering and production management. The faculty in Aachen was a fully developed mechanical engineering faculty with more than 45 full professors and one of the best and largest of its kind in the world. It incorporated, for example, chemical engineering and materials engineering in addition to the classic goods production sphere plus advanced application technologies such as textile engineering, automotive engineering, plastics engineering, aerospace engineering etc. His "Institut für Arbeitswissenschaft" already had a good organizational structure with three leading scientists plus research assistants. The university institute was complemented by a federal research institute with three assistant professors and one leading administrator. However, the situation was not comfortable as 60–80% of the research budget had to be brought in through project-oriented research funded by different authorities for basic and applied research (German National Research Foundation DFG, German Federal Ministry of Education and Research BMBF etc.) or directly by industry. Two large institutes with more than 45 research assistants pursuing their doctorates and a corresponding breadth of research areas coupled with financial and leadership responsibility were a suitable challenge for Professor Luczak. The wealth of opportunities and possibilities at RWTH Aachen University also led to an explosion of his publication list from about 150 references before he came to Aachen to about 600 references 13 years later. Because it is not possible to provide a detailed analysis of these publications, only selected contributions are cited below.

When he joined RWTH Aachen University, Professor Luczak restructured the research lines to a certain degree, but their substance was preserved. However, some novelties were introduced. First, the research line in humanization [171] and human technology of production was shifted towards aspects and types of work organization [168, 175, 184], for example so-termed "product islands" [148, 161, 170, 172, 230], "user teams" [152] and other participatory approaches [170, 177, 193, 209, 214, 217, 220, 225, 226, 247]. These topics also required an extensive discussion

on human models and design criteria [198, 229, 232, 255, 307, 308, 352, 372, 373, 391, 469] being used for a humanistic organizational development [260, 262, 286, 332, 349, 364, 426, 492]. As the funding for the humanization research program came to an end, this research line ended in 2000 with several surveys [363, 474], but was followed by research on inter-company cooperation [246, 289, 303, 331, 358, 402, 411, 448, 461, 462, 463, 470]. Second, the research line dealing with disciplinary structure was developed further, but with lower intensity: it comprised some renewed surveys carried out on invitation of conference organizers [159, 164, 165, 180, 203, 221, 274] or handbook/encyclopedia editors [205, 210, 234, 238, 239, 240, 241, 242, 279, 296, 309, 328, 365, 369, 432, 521] and also included original works [176, 278, 294, 317, 347, 367, 383, 384, 385, 386, 389, 390, 396, 440, 456, 481, 493, 496]. In recent years, the development of "service engineering" into an academic discipline in its own right, though considerably overlapping with ergonomics, has gained increasing acceptance [314, 321, 424, 433, 441, 482, 489, 494, 508, 514, 520]. Today, there is a lively worldwide debate on service engineering that was initiated and matured to a considerable degree by Professor Luczak and his co-workers. Third, the research line centered around engineering design and computer-aided design was also a continual challenge [162, 178, 183, 188, 189, 199, 207, 219, 250, 256, 298, 324, 333, 345, 380, 522]. However, it was modified and modernized by novel methods of telecooperation in new product development [228, 266, 292, 318, 406, 408, 413, 507] and computer-supported cooperative work in general [247, 257, 262, 306, 326, 353, 366, 403, 425, 430, 442, 459, 479, 488]. Furthermore, a change of the research focus from classical engineering design work to concurrent engineering [222, 251, 267, 277, 293, 319, 404, 428, 447] and chemical process engineering [305, 341, 346, 354, 399, 409, 452, 457, 487] occurred. Fourth, human-computer interaction became a major component of laboratory and empirical research with different focuses. The research covered the complete cycle comprising electronic information displays and human perception [181, 187, 208, 212, 231, 265, 371, 401, 420, 444, 446, 455], central information processing [169, 213, 218, 223, 224, 253, 338, 375, 379, 381, 382, 405, 416, 431, 471, 484, 485, 506, 511] as well as motor processes and input devices [158, 186, 190, 192, 197, 237, 323]. Various application areas were also covered [157, 377, 443, 454, 472, 483, 490, 516, 517, 518, 519]. The wealth of innovations in this field can only be outlined: scientific studies and design solutions for stereoscopic displays in air traffic control [231] and advanced manufacturing systems [224], see-through head-mounted displays for supervisory control of machine tools [265], virtual retinal displays for mobile augmented vision systems [401] etc. A mouse with tactile feedback was also developed [197], the effectiveness of which was proven by experimental variables derived from sensorimotor models. Through the integration of novel displays and input devices into concepts of cognitive engineering, several innovative user interfaces were designed and developed which significantly enhanced human performance [326, 341]. Predictive user models [382] covering the whole range from novice to expert and from the disabled to the proficient worker were a prerequisite of design proposals with a sound theoretical

background which were investigated in a hypothesis-driven experimental validation process according to their design gradient. Application areas comprise manual work processes in automotive and aircraft assembly [483], manufacturing with CNC milling machine tools or 3D laser welding cells [213, 223] and also work processes in engineering design and industrial service [305, 341, 409], all backed by the cited novel concepts and techniques. The progress in this still very active research area was substantially influenced by institutes of RWTH Aachen University, especially the ergonomics branch of the Institute of Industrial Engineering and Ergonomics under the leadership of Professor Luczak, as is proven by his clusters of publications. Fifth, a new research line at his institute was the development of concepts for occupational safety and health as well as labor protection according to the new paradigm of health improvement, "good" working conditions as well as individual emotional appreciation of the work situation through positive feelings like the "pleasure of work". These components play a considerable role in new company-wide concepts of *Gesundheitsförderung* (health promotion) [233, 235, 275, 311, 316, 348, 359, 387, 388, 410, 456, 480, 497, 498, 499, 500, 501, 510, 536]. The concept also underpinned the popular approach of "healthy aging" in terms of reducing absenteeism and contributing to the stability and robustness of work and business processes. In fact, occupational safety and health with its ultimate goal of prevention and the introduction of positive design concepts is still a fruitful research domain, where Professor Luczak opened new doors for the growth and prosperity of his institute. One should also not forget the "bread and butter" tasks in ergonomic analysis and design with methodological studies and developments [252], with application-oriented adaptation of methods and measurement techniques [244] and with comparative investigations of design variants [261, 268]. In this context, driving tasks as well as postal video coding [513] came into focus [185, 236, 335, 336, 350, 486], while workplaces at blast cabins required the development of anthropometrical methods [191]. Mobile workplaces found special consideration [468], and the anthropomorphization of tools and technical means were also analyzed [368, 397, 478]. All in all, the demand-driven applied research which is a regular part of most university institutes. However, the work on anthropomorphization attracted the special interest of the scientific community in ergonomics, as it simplifies the transition from rational to emotional design. This is a promising strategy with various future research opportunities.

Concurrently to the research agenda of his university institute, Professor Luczak developed the complementary agenda of the Research Institute for Operations Management. Here, he "inherited" three research groups. The first group dealt with production planning and control (PPC), the second group with logistics, and the third group with "indirect" functions in a company such as maintenance, design etc. The PPC group was restructured according to a trend analysis [154]. The core competencies were extended towards Computer Integrated Manufacturing (CIM) [160] and decision support systems for make-or-buy decisions [173]. The research in advanced planning and scheduling was

strengthened [204] and the complexity of CIM put into question [211]. This was the basis for the development of the famous Aachen PPC reference model [269, 270, 271, 282, 287] that includes different types of order processing and respective company types [245], tasks and operations [285] for organizational development [273, 288] and a section for managing software functions and enterprise data [254, 280, 290]. The complete body of knowledge was published in a leading technical textbook [272]. Furthermore, already existing market surveys of PPC software on the basis of more than 1000 differentiation criteria were extended towards Supply Chain Management (SCM) [304] in intercompany cooperation and towards Enterprise Resource Planning (ERP) comprising more organizational units within the company [327, 339]. Here, the organization and management aspects came more and more into focus [356, 376, 417, 437, 466, 467, 502, 512]. Workflow management systems for PPC were studied, too [398]. These studies resulted in a textbook for practitioners [449]. In 2004 and 2005, Professor Luczak handed over the PPC concepts to his FIR successor. They were published in a textbook one year later (SCHUH 2006).

The rationalization approach to indirect company functions was pursued and refined. It was based on time consumption considerations [156, 196] and prognosis of technical and organizational possibilities in foundries [155], in printing industries [262], in after-sales functions of manufacturing industries [276] and especially in synchronization of manufacturing and maintenance [295, 299, 310, 310, 360, 500]. Maintenance Planning Systems were developed following the well-known approach of reliability centered maintenance [419]. However, the logical bridge from indirect company functions to industrial service is rather short. For this reason – partly driven by the Quality Movement [200, 227, 249, 301, 302, 330, 392, 393, 418, 477] – service design, service engineering and service management were incorporated more and more in research and application studies [201, 259, 284, 297, 300, 313, 314, 315, 322, 325, 334, 340, 342, 343, 355, 362, 429, 434, 460, 465, 503, 504, 509, 523]. Later the group was renamed “service management” and drove the development of the cited novel disciplines of “service science” and “service engineering” to a large extent. With this perspective and the generated scientific basis, the transformation from the design and management of classical industrial services – close to engineering concepts – to other types and other aspects (mentality, culture etc.) of service work was carried out successfully.

Research in the logistics group was cultivated via the development of operations research algorithms [202, 281, 414, 464] and via aspects of network organization [215, 216, 258, 263]. Nevertheless, the logistics group came under pressure from two sides. First, the neighboring PPC group incorporated more and more aspects of material and information flows according to MRP I and II concepts into production planning and techniques for the management of procurement, stock and distribution were more and more integrated into ERP and SCM software systems. Second, the “information logistics” approach reshaped the classical works to a large extent and created new competition. In order to cope with these challenges, the group was renamed “Information Management” in 2002

and focused on this aspect of modern companies and company networks. The rapid development of the Internet, in particular, contributed to the development of new and fruitful research areas in Electronic Business [400, 427, 476, 515].

One cannot deny that the *Zeitgeist* and major methodological trends shaped the agenda of the Research Institute for Operations Management to a certain extent. However, Professor Luczak anticipated new and fruitful research areas early and orientated the development of his research lines accordingly. This strategy turned out to be highly successful [489, 493]. Under his leadership and guidance both the Institute of Industrial Engineering and Ergonomics and the Research Institute for Operations Management grew quickly and prospered. When he officially retired in 2005 about 70 research assistants and six assistant professors were employed, making this institution one of the largest and most respected in the world.

In his works throughout the decades Professor Luczak preferred a research approach which his colleagues termed "theory-driven". In ergonomics, theory-driven means that first a concise research question is defined on the basis of an engineering design problem or a gap of knowledge in the scientific literature. Second, a set of hypotheses concerning the work system under study is formed and a preferably quantitative model of the human, the task, the tools, the work objects and the environmental variables including their interactions is developed. Third, the developed model is checked, simulated, verified and validated so that the experimenter can make precise predictions about stress and strain of the human in the work system, the upper bounds of executability of tasks, the limits of human endurance etc. under different experimental conditions. Fourth, experiments are carried out in the laboratory or in the field and the data are collected through measurements, observations or interviews. Fifth, the data are analyzed and interpreted in order to draw conclusions about the model-based predictions, to cross-validate the model and to verify the previously stated hypotheses (to be precise: the negation of the hypotheses is falsified in the sense of Karl Popper). Sixth, the findings serve as a starting point for forming a new set of hypotheses to be tested in follow-up studies. This approach is demonstrated at its best in Luczak's classic scientific articles on heart rate variability as a psychophysiological measure of strain [1, 4, 5, 34, 43] and his studies of recovery times for informational-mental work as well as heat work [39, 42, 75]. Especially his control-theoretic models of the cardiovascular and cardiorespiratory system as well as the human thermoregulation system and its coupling with the cardiorespiratory system have set an extraordinary high scientific standard for a younger generation of ergonomists [39a]. Furthermore, he recognized the power of advanced mathematical methods for time series analysis very early on and used them to correlate and fuse large data streams from psychophysiological measurements. Through these works he demonstrated standing in the tradition of the "Max Planck Institut für Arbeitsphysiologie", a former basic research institute of international renown. For his excellent research contributions and his important services for the scientific community (see below), Professor Luczak received the highest international honors and was appointed Fellow of the International

Ergonomics Association in 2000. One year later he also received the famous Distinguished International Colleague Award of the Human Factors and Ergonomics Society of the United States in recognition of "a non-U.S. citizen who has made outstanding scientific contributions to the human factors and ergonomics field".

The teacher

Professor Luczak's excellence in research is the natural nutrient medium for his excellence in teaching. He developed a unique concept for teaching the fundamentals of industrial engineering and ergonomics including selected application areas. This concept was continuously improved to satisfy the demands of his students. From the very beginning of his academic career in 1969 he had been extensively involved in the preparation and support of lectures and exercises in ergonomics at Darmstadt University of Technology under the supervision of Professor Rohmert. Furthermore, from 1972 to 1976 he was the *Prüfungsassistent* (examination assistant) and had to record every one of his professor's oral examinations in writing. Professor Rohmert held several hundred examinations per year and Professor Luczak therefore had access to a very large empirical base with which to reformulate and restructure the chapters of the lecture notes in continuous cycles. This knowledge about the preconditions, process and outcome of university teaching was very helpful when Professor Luczak was appointed full professor at Bremen University. In Bremen he taught the fundamentals of *Arbeitswissenschaft* in compulsory courses for mechanical and industrial engineers, and variants of advanced methods and tools in elective courses for students of all faculties. He understood teaching as a service for his students that has to be continually improved in accordance with innovation concepts.

When he was in Bremen as member of a faculty of production technology in foundation, he preferred an industry-oriented teaching concept [57] that bound variants of work analysis and work design to clusters of production technologies and company profiles, respectively (SCHWIER 1982). During his time at the Berlin University of Technology, the teaching concept was revised and oriented towards a discipline-structuring approach [79] – in accordance with the possibilities and limitations of a classical faculty of mechanical engineering design and manufacturing. This approach included "methods", "basic knowledge components" in terms of objective working conditions (work forms and work types), "working persons" and "application areas". The catalogue of core elements (*Gegenstandskatalog* [104]) became a widely-known and accepted conceptual framework for teaching purposes. His lecture notes – edited privately and sold on a net cost basis in more than 10,000 copies to students, practitioners and colleagues – became a de facto standard in industrial engineering and ergonomics (LUCZAK 1985–1992). This de facto standard was the basis of the first edition of the cited textbook *Arbeitswissenschaft*, which was published in the renowned

engineering textbook series by the Springer publishing house and was sold many thousand times [151]. His scores in student evaluations of lectures were excellent and an impressive demonstration of how a "supplementary" discipline – as it was seen by the majority of his technology-oriented colleagues – can gain recognition and acceptance in an engineering curriculum.

When Professor Luczak joined the huge Faculty of Mechanical Engineering of RWTH Aachen University with more than 1000 students per year in compulsory diploma courses, his teaching concept had to be revised and innovated again to satisfy the new requirements. The lecture structure was therefore developed towards a "problem-oriented" approach. This approach is reflected in the second edition of his *Arbeitswissenschaft* textbook [268a]. Principles of work organization and company-structuring were elaborated and several application examples as well as best practices were included. The paper-based lecture notes were reduced more and more in favor of electronic course material published over the Internet. In the year 2000 the complete body of lectures including all figures, tables and text annotations was made available for free public access. This "courseware" was not only used by students of RWTH Aachen University but also by many foreign students as well as the scientific and practitioners' communities. A special service for students at RWTH Aachen University was to put all written examination questions and tasks on the Internet, so that the standards were made clear. The vision of an "eLearning System in Industrial Engineering and Ergonomics" became reality at RWTH Aachen University in 2003 and later throughout Germany [526, 527, 529, 548]. Furthermore, the Institute of Industrial Engineering and Ergonomics became one of the first teaching units with certified teaching quality according to the EFQM model. The certification process was prepared and evaluated by a doctoral dissertation (KORSMEIER 2002).

Today, the third edition of his standard textbook is in the process of being published. The third edition has been substantially revised by his successor, who took over primary responsibility as both editor and author (SCHLICK, BRUDER, LUCZAK 2009). However, when the "senior scientist" is asked what excellence in teaching means according to his experience and standards, he still has a concise answer [see 564]. Just in numerical terms the facts speak for themselves: more than 10,000 students in compulsory courses, more than 1,000 students in advanced courses, about 100 successful doctoral students and three successful habilitation candidates give an idea of the impact of Professors Luczak's teaching over 30 years as a highly dedicated and innovative university professor. His special way of scientific reasoning as well as his theory-driven approach to the development of concepts, models and methods have thus influenced a significant fraction of university-educated industrial engineers and ergonomists in Germany. Four of his former students have been appointed full professors at international research universities and teach the fundamentals of his school of thought to younger generations of students and practitioners. He regarded teaching as a "service task" involving producers and consumers (quality and co-ordination aspect), technology (media and e-learning) and organization (discipline- and value-oriented), which

should be a subject of ergonomical research in itself and must be practiced in never-ending cycles of innovation. There is no doubt that he truly lived this philosophy.

His services for the scientific community

Throughout his academic career Professor Luczak delivered important services for the scientific community. His activities started in 1973, when he was asked to do the preparatory work for an invited speech by Professor Rohmert at the World Congress of the International Ergonomics Association (IEA) in Amsterdam. This was helpful for Luczak as he was thus drawn as scientific co-worker into a group of peers (RUTENFRANZ, LUCZAK, LEHNERT, ROHMERT, SZADKOWSKI 1980), who were preparing a "Denkschrift Arbeitsmedizin und Ergonomie" for the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG). The *Denkschrift* was a natural science-based response to the rather politics-driven "Humanisierung der Arbeit" approach (humanization of work) and stimulated a vivid discussion about the role of social sciences in the discipline and the priorities of paradigms.

In Bremen he held one of only three *Eckprofessuren* (founding professorships) and was responsible for shaping the faculty of production technology at the university. Bremen University was regarded as a kind of antithesis to the classical university model, which had come under significant pressure in the 1968 student revolution. The result of his efforts to involve about 40 leading partners from industry as well as the most progressive professors in production technology into the development of a *Leitbild* was a highly successful model of faculty organization and curriculum development. The novel paradigm left behind the traditional product-oriented boundaries between different sub-disciplines in mechanical engineering and favored a production process-oriented concept for organizational (faculty structure) and personal development (election committees). Today, the Faculty of Production Engineering of Bremen University is one of the most renowned engineering faculties among young scientists in Germany. In Berlin he accepted the task assignment of the "Gesellschaft für Arbeitswissenschaft" (GfA) to overcome the schism between the social- and natural science-based approaches to *Arbeitswissenschaft* in Germany. The result of the project, which was pursued jointly with critical social scientists, became a core definition of the discipline and an ordering model for structuring it [104]. Later he edited the cited *Handbuch der Arbeitswissenschaft* [238]. This handbook provided a place for selected scientific contributions to the discipline and has been supporting peace and harmony between different approaches and paradigms for over 10 years now. It included contributions from approximately 200 German-speaking authors and was the first complete handbook in the German language since the first incomplete attempt by Professor Giese in the 1930s. It can be regarded as a landmark publication. As GfA president, Professor Luczak had to

cope in the early 1990s with many aspects of German Reunification. He tried to stabilize the discipline by writing comments and recommendations to the point of exhaustion for scientists and research institutions in the former German Democratic Republic (GDR) that had come under significant political and social pressure in the newly formed Federal Republic of Germany (FRG). An additional challenge was to incorporate excellent and interested researchers and scientists from among the 1300 members of the East German "Gesellschaft für Arbeitshygiene" into the GfA, which had 700 members at the time. This integration process was carried out by mutual consensus and the 1993 president of the GfA was a leading scientist from the former GDR. At the same time Luczak became increasingly involved in IEA affairs (1990-1997). Alongside a position on the IEA council (from the mid 80s until now) he held the "publications chair" and the "science and technology chair" on the IEA executive committee, where he developed the number and structure of Technical Groups/Special Interest Groups to more than two dozen according to the future domains of the discipline. He was also extensively involved in the preparation and structuring of IEA congresses as well as in the formulation of priorities in ergonomics education and curricula in terms of a worldwide quality standard for certification and accreditation bodies (BCPE, CREE etc.). In Aachen he was not only devoted to the cited handbook project but also contributed to GfA memoranda about "Future Research Directions" (2000-2002). He was elected GfA president for a second time in 2003 – an honor that is only very rarely bestowed on a scientist in Germany. He used this demonstration of trust to substantially increase the GfA services for its members and fostered the cooperation between scientific societies dealing with human work in Germany. Some years ago he was admitted to "acatech" and is one of only 282 highly respected members of this German Academy of Science and Engineering. The academy represents Germany in the European Council of Applied Sciences, Technologies and Engineering and in the International Council of Academies of Engineering and Technological Sciences – the global union of academies for technical sciences. He also played an active role on the board of the German Group of University Professors in Work and Enterprise Organization ("Hochschulgruppe für Arbeits- und Betriebsorganization"). At the end of his academic career, Professor Luczak was dean of the Faculty of Mechanical Engineering of RWTH Aachen University for several years. Today, he still chairs the "Club of Professors" of GfA ("Hochschulgruppe Arbeitswissenschaft").

From the very beginning of his career as a university professor he was elected and later reelected several times by his professor colleagues, other scientists and funding authorities as referee/reviewer for the German Research Foundation (DFG). He is elected referee of the Association of Industrial Research Funding (Arbeitsgemeinschaft Industrieller Forschungsvereinigungen, AiF) and was also referee in several governmental research programs of the German Federal Ministry of Education and Research, the Federal Ministry of Economics and Technology, the Federal Ministry of Labor and Social Affairs and various German federal state ministries. For many years he was "curator" (advisory board member)

at several research institutes (Fraunhofer and others), faculties and companies. He reviewed the strategic research plans, profiles and works of these institutions and advised on administrative or economical decisions.

Professor Holger Luczak was a longstanding member of numerous editorial boards of peer-reviewed scientific journals (*Ergonomics*, *Applied Ergonomics*, *International Journal of Human-Computer Interaction*, *Theoretical Issues in Ergonomics Science*, *International Journal of Occupational Safety and Ergonomics*, *International Journal of Product Development*, *Zeitschrift für Arbeitswissenschaft* etc.). As GfA president he was responsible for two conferences per year – the Spring Meeting with a scientific focus and around 140 to 450 participants and the Autumn Meeting with application-specific topics relating to companies. Alongside his strong IEA commitment, in his capacity as president of the WWDU Group (Work With Display Units, later Work With Computing Systems WWCS), he organized the Berlin 1992 conference [147] and the Berchtesgaden 2002 conference [407]. Jointly with Professor Zink he organized the ODAM 2003 conference in Aachen [463]. He was an influential and longstanding member of the scientific advisory boards of numerous congresses: HCI, ASEAN Ergonomics, OHS, Production Technology and others. Furthermore, he worked as a referee, reviewer and consultant for scientific establishments and institutions in Austria, Switzerland, Italy, France, Scandinavia, USA, East Asia etc., evaluating research programs, research proposals and restructuring research departments. He also participated in several election committees. The number of reports, manuscripts, CVs, programs, proposals, abstracts, papers and plans that required his qualified comment ran to thousands over the decades. The influential and powerful peer position he held is made clear by the diversity and sheer number of Professor Luczak's commitments and the hard, highly detailed work that justifies the collective "trust". In fact, trust seems to be the dominant success factor in his service to the scientific community: trust in his scientific standing and overview of the discipline, trust in his independent judgment and competent advice, and trust in his management abilities and great leadership.

The Festschrift – structure and contents

There can be no doubt that such an internationally outstanding and influential scientist, teacher and colleague deserves a very special recognition of his lifetime achievements in academia, science and technology. It only remained to find the right opportunity and a dignified framework. Following an old German academic tradition, his colleagues and alumni decided to celebrate Professor Holger Luczak's 65th birthday by gathering and publishing a collection of scientific articles in industrial engineering and ergonomics as well as neighboring disciplines written by a group of internationally recognized researchers. The decision to publish this Festschrift was made during a past GfA Congress and

within a few weeks the “critical mass” of committed authors had been reached. In order to present the full spectrum of models, methods and tools in engineering design, production and service, no additional constraints were set on contributions. However, the German academic tradition leaves many degrees of freedom regarding the publication format of a Festschrift and one can find very different approaches – from a loose collection of handwritten articles to printed hardcover books. Knowing that Professor Luczak prefers scientific books and considers other print media to be comparably inferior, the editor decided to aim at the highest honor and to publish this high-quality book. Because of Professor Luczak’s excellent reputation the renowned Springer publisher supported this ambitious publication project from the very beginning and deserves special acknowledgement. Special thanks go to Dipl.-Ing. Dipl.-Wirt.Ing. T. Jeske who spent a lot of effort and time getting the festschrift in shape. The result is quite impressive: 93 authors from 12 countries have contributed 46 scientific articles and there were more than 700 book pages to be printed.

The structure of the Festschrift follows the famous ordering model of work processes which was developed by LUCZAK and VOLPERT [104] as a unifying framework for the manifold aspects of the *Arbeitswissenschaft* discipline. The ordering model distinguishes seven structural and six procedural levels resulting when human work is studied by different analytical approaches on different time scales. The hierarchy of levels is shown in Fig. 1.

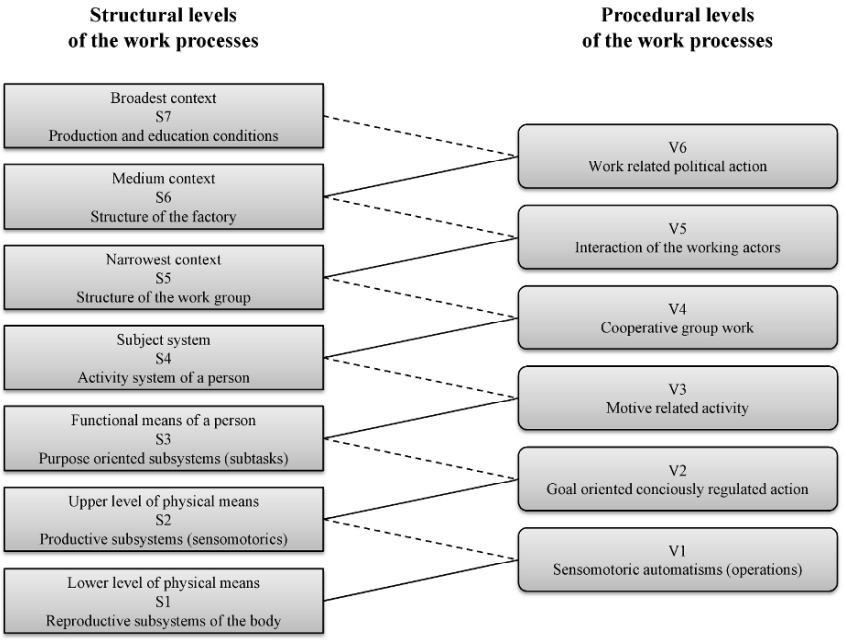

Fig. 1: Structural and procedural levels of work processes [104, 365]

To structure the Festschrift, only the structural levels of the ordering model were considered (Fig. 1, left hand side) and the 46 articles were unambiguously mapped onto one of seven parts. In some cases the clearly broader scope of the article had to be disregarded in favor of providing a clear structure.

On structural level 7 – the highest level of structural abstraction of the ordering model – the societal, social and political aspects of human and work are considered. In accordance with a later minor revision of the ordering model [489], the editor decided to assign contributions dealing with overarching frameworks for industrial sectors, value networks or communities to this level too. The first article on Level 7 and the first in the associated Part 1 of the Festschrift was written by Professor Hans-Jörg Bullinger and his colleague Professor Joachim Warschat. Professor Bullinger is the president of the Fraunhofer Society in Germany and a professor at Stuttgart University. Professor Warschat is a member of the management board of the Fraunhofer Institute for Industrial Engineering (IAO) in Stuttgart. This impulse-giving article is titled "Innovation through New Technologies" and deals with technology development as a driver of innovation in modern companies. Different types of technology development are distinguished and their effects on new products are discussed. Furthermore, four types of innovation are introduced and explained through examples from industry. Finally, typical innovation patterns in organizations are identified.

The second article on level 7 was written by Professor Fritz Klocke and is about "Production Technology in High-Wage Countries – From Ideas of Today to Products of Tomorrow". Professor Klocke is one of the directors of the Laboratory for Machine Tools and Production Engineering (WZL) and holds the chair of Manufacturing Technology at RWTH Aachen University. Professor Klocke is also head of the Fraunhofer Institute of Production Technology (IPT) in Aachen. In his article, the conceptual foundations and selected research fields of the so-termed Cluster of Excellence on "Integrative Production Technologies for High-Wage Countries" of our Faculty of Mechanical Engineering are presented. This cluster of basic research projects is part of the Excellence Initiative of the German federal and state governments and aims at promoting excellent research in German universities. The article also describes innovative concepts and systems for production planning and integrated production processes.

The third contribution which can be assigned to the seventh level of abstraction was written by Professor Klaus Henning and Andrea Huson. Professor Henning is the head of the Center for Learning and Knowledge Management and holds the chair of Information Management in Mechanical Engineering at RWTH Aachen University, Germany. In their paper with the programmatic title "Innovation Champions – Or How to Achieve (Global) Competitiveness!", they take a look into the far future by outlining conditions for working, learning and competency development in the year 2020. They argue that there is a need for further research to analyze worldwide trends in these fields and to identify best practices of innovation processes to cope with future challenges.

The fourth article was written by Professor Emerita Gunilla Bradley from the School of Information and Communication Technology of the Royal Institute of Technology (KTH), Stockholm, Sweden. The article is titled "The Convergence Theory and the Good ICT Society – Trends and Visions" and analyzes ongoing social changes related to the rapidly growing use of information and communication technology and its impacts on the structure of work, organizational design, communication processes and work content.

The fifth article was contributed by Professor Michael J. Smith and Professor Pascale Carayon from the United States of America. Professor Smith is a Professor Emeritus of Ergonomics and Industrial Psychology at the Department of Industrial and Systems Engineering of the University of Wisconsin-Madison. Professor Carayon is the Procter & Gamble Bascom Professor in Total Quality and director of the Center for Quality and Productivity Improvement at the same department. Their article is titled "Community Ergonomics and Globalization: A Conceptual Model of Social Awareness" and presents a set of eight so-termed community ergonomics principles in an international and multicultural context. These principles focus on the goals of social responsibility, fairness and social justice, in support of prosperity of an organization or society. With their contribution the authors not only want to honor Professor Luczak, but also the work of Professor Antoinette Derjani-Bayeh (second author), who died in a tragic accident 10 years ago.

"Car Mechatronic" is the title of the sixth article, in which Professor Georg Spöttl presents an approach for designing and developing a new European core occupational profile. Following the objective of educating a broadly and excellently trained as well as customer-oriented technician for future service work in the automotive sector, he describes the structure of a novel curriculum and its development within a European research project. Georg Spöttl is a professor at the University of Bremen and Director of the Institute of Technology and Education (ITB), Germany. His article concludes structural level 7.

Level 6 of the ordering model focuses on the structure of enterprises and companies. Different forms of industrial relations and organization are analyzed as well as managerial decisions which impact on the entire company. The associated Part 2 of the Festschrift starts with an article by Professor Klaus J. Zink and Sven Seibert. They analyze "Performance Measurement from a Macro-Ergonomics Perspective" and give examples of so-called ergonomics performance indicators to be used for an extended corporate performance measurement and management system, which considers the demands of stakeholders both inside and outside the company. Professor Zink holds the chair of Industrial Management and Human Factors (LIA) of the University of Kaiserslautern, Germany, and is head of the Research Institute of Technology and Work (ITA).

The second article, entitled "Technology Management" and written by Professor Dieter Spath, Dr. Karl-Christof Renz, and Klaus Seidenstricker, is closely linked to Professor Bullinger's article. The authors present the foundations

of technology management in leading enterprises on different levels of abstraction and how the transition from theory to practice can be successfully achieved. Professor Spath is head of the Institute for Human Factors and Technology Management (IAT) of Stuttgart University and head of the Fraunhofer Institute for Industrial Engineering (IAO). He is the successor of Professor Bullinger in both positions.

This article is followed by a series of three papers contributed by colleagues from our Faculty of Mechanical Engineering of RWTH Aachen University. The first article in the series and third article in Part 2 of the Festschrift deals with quality management in modern companies and was written by Professor Robert Schmitt and Professor Tilo Pfeifer from the Laboratory for Machine Tools and Production Engineering (WZL). Professor Schmitt holds the chair of Metrology and Quality Management at RWTH Aachen University. He is one of the directors of WZL as well as of the Fraunhofer Institute of Production Technology (IPT). Professor Pfeifer is his predecessor and professor emeritus. The article is about "Success with Customer Inspiring Products – Monitoring, Assessment and Design of Perceived Product Quality". The authors introduce the novel concept of the "perceived quality" of a product which is shaped by all the customer's visual, tactile, acoustic and olfactory impressions when using the product and therefore adds subjective perceptible characteristics to the classic concept of product quality.

The fourth article was contributed by Professor Jörg Feldhusen and Frederik Bungert. Professor Feldhusen is head of the Institute for Engineering Design of RWTH Aachen University. The contribution is titled "Pattern Languages to Create a Holistic Methodology for Product Development and to Derive Enterprise-Specific Engineering Guidelines" and gives insights into a novel pattern-based methodology for product lifecycle management.

The fifth article was written by Professor Günther Schuh, Dr. Volker Stich, and Gerhard Gudergan. Professor Schuh is one of the directors of the Laboratory for Machine Tools and Production Engineering (WZL) and holds the chair of Production Engineering at RWTH Aachen University. He is one of the directors of the Fraunhofer Institute of Production Technology (IPT) and director of the Research Institute for Operations Management (FIR). Dr. Volker Stich is the leading administrator of FIR and a former co-worker of Professor Luczak. The article is about "Reference Models – A Basis for Designing Efficient Technical Services" and deals with service management through the embodiment of basic goals. A reference model for technical services is presented and its validity is discussed.

The sixth article dealing with organization at enterprise level is also rooted in the service sector and was written by Priv.-Doz. Dr. Johannes Springer and Karl-Gerhard Freyer. It is titled "Service Modeling and Engineering in the Telematics Industry – The View from the Perspective of a Toll Service Provider". Dr. Springer was a former assistant professor (*Oberingenieur*) at the Institute of Industrial Engineering and Ergonomics of RWTH Aachen University and pursued