Templates, Crash Test Dummies and Digitalization: European Models of Man in the Car Industry

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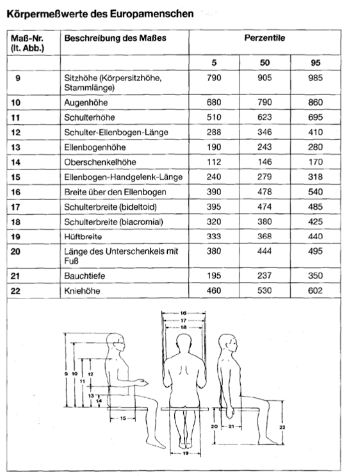
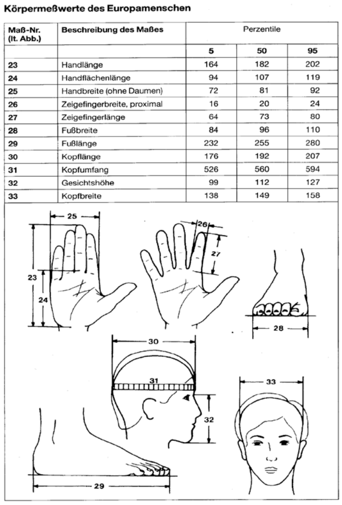
1. Introduction

The *Homo Europaeus* does exist, at least in industrial anthropometry since 1998, at the latest. Based on the standard DIN EN ISO 7250, an abundance of body measurements for the Human Anthropometrics of the European was recorded, the result of which is, obviously, clearly male.[1]



Körpermeßwerte des Europamenschen

Maß-Nr. (lt. Abb.)	Beschreibung des Maßes	Perzentile		
		5	50	95
9	Sitzhöhe (Körpersitzhöhe, Stammlänge)	790	905	985
10	Augenhöhe	680	790	860
11	Schulterhöhe	510	623	695
12	Schulter-Ellenbogen-Länge	288	346	410
13	Ellenbogenhöhe	190	243	280
14	Oberschenkelhöhe	112	146	170
15	Ellenbogen-Handgelenk-Länge	240	279	318
16	Breite über den Ellenbogen	390	478	540
17	Schulterbreite (bideltoid)	395	474	485
18	Schulterbreite (biacromial)	320	380	425
19	Hüftbreite	333	368	440
20	Länge des Unterschenkels mit Fuß	380	444	495
21	Bauchtiefe	195	237	350
22	Kniehöhe	460	530	602



Körpermeßwerte des Europamenschen

Maß-Nr. (lt. Abb.)	Beschreibung des Maßes	Perzentile		
		5	50	95
23	Handlänge	164	182	202
24	Handflächenlänge	94	107	119
25	Handbreite (ohne Daumen)	72	81	92
26	Zeigefingerbreite, proximal	16	20	24
27	Zeigefingerlänge	64	73	80
28	Fußbreite	84	96	110
29	Fußlänge	232	255	280
30	Kopflänge	176	192	207
31	Kopfumfang	526	560	594
32	Gesichtshöhe	99	112	127
33	Kopfbreite	138	149	158

The *Homo Europaeus* does exist, not only as a record and value table, but now also as a three-dimensional, computer-simulated human model, even in competing versions – as

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[1] See H. W. Jürgens et al.., Internationale anthropometrische Daten als Voraussetzung für die Gestaltung von Arbeitsplätzen und Maschinen, in: Arbeitswissenschaftliche Erkenntnisse 108, Dortmund 1998, pp. 1-11.

Humos 2 (Human Model for Safety), or as a RAMSIS (*Rechnergestütztes Anthropometrisch-Mathematisches System* zur *Insassen-Simulation or: computer-supported mathematical-anthropological system for vehicle occupant simulation).* Both "anthropomorphic test devices" are widely used in research, development and construction within the European automotive industry.

This closer look at the development, scientific design, technical configuration, and industrial application of this average European or "standardized Euro-Man" in the context of the project "Imagined Europeans" is guided by a number of different paths of access and aspects of problems. The spectrum of the relevant man-machine concepts and (later) views on this was and is huge. They range from specific engineering perspectives, to medical, technology history and critical cultural approaches. Thus, at first glance it is an approach done by studying the history of scientific disciplines (the history of biomechanics), especially in view of the history of anthropometrics and ergonomics that are no longer only used for economic history (research of the history of industrialization), but also for the history of technology, meaning the emergence and development of applied ergonomics and industrial anthropology. German scientists and researchers in the development of European standards and conspicuous models have played a prominent role including Hans W. Jürgens and his Anthropological Institute at the University of Kiel, Professor Henry Dupuis at the Max Planck Institute for Work Physiology in Dortmund, researchers from the Technical University of Munich, the automotive industry and the engineering company Human Solutions GmbH for the development of the digital human model RAMSIS. It is here that a history of the European Re-conquering of anthropometric standards is made, as all human models and anthropometric data used in the automotive industry were subject to quasi Americanization. German automobile companies developed, designed and tested their vehicles in the 1950s, 1960s and 1970s according to American passenger and driver data.

One can gain access to the matter at hand by studying the history of specific industries, which means path dependencies and economic as well as technical developments in the European automotive industry, both in the context of identifying specific European developments of this industry and in terms of the history of passive safety. In the late 1960s the European automotive industry began to call for scientific body data on the European. The starting point and the central problem was the car seat. The diversity of not yet standardized seats in the various European nations has been increasingly replaced by a standard Euro-seat.

However, ergonomics also expanded broadly in other parts of car production, particularly in all areas of safety. The man moved to the center of development and production through a combination of precise measurements, accurate simulation, and continuous integration into existing processes. That this was not always the case is made clear by three brief, interesting (especially in view of gender history) stories from the 1950s, the 1980s and the 1990s, one of which is Borgward.

In 1954, the Bremen car constructor, Borgward, developed a car, "Isabella," which did not fit the average German body. Most buyers, especially women, sank in the car seat.

Almost every normal driver could barely see the road from the seat. A little background explains the situation: Borgward himself was only 1.66 meters tall but had a giant seat. Despite this fault, the car model did not sell poorly, but in 1961 Borgward went bankrupt. The other example is from the British car industry: In a book edited in1986, *Bodyspace, Anthropometry, Ergonomics and Design*,[2] Stephen Pheasant questioned, "Can the application of ergonomics to the design of the driver's workstation help reduce the safety problem?" "Hard evidence is scant" and so the answer was as follows:

> *But at least one influential consumer is convinced. Attending an exhibition at the Design Centre in London, the Prime Minister, Mrs. Margaret Thatcher, sat at the wheel of a prototype motor car and said 'I don't like it, I cannot see the front. Redesign it for me. I like to see where the front of the car is so I don't bang into the back of a bus. If I was in insurance I would put up the premium'. Mrs. Thatcher is 1600 mm in statue – the 44th percentile for British women.*[3]

The last story comes from the United States:

> *Most of the airbag deaths involve infants, children, and females of small stature. This has led to speculation that, because the government's airbag compliance tests require the use of 50th percentile male dummies, the bags are designed to protect adult males but not smaller occupants. This is not correct. Serious airbag inflation injuries occur primarily because of occupants' positions when the bags begin to inflate – not because of people's sizes. Anyone on top of, or very close to, an airbag when it begins to inflate is at risk of serious inflation injury.*[4]

It was with these remarks that Brian O'Neill, president of the Insurance Institute for Highway Safety, tried to disperse public concerns about the safety of airbags at a Senate hearing in 1997. Even if the statement was factually correct, that the conclusion could be reversed: drivers with short legs are at an increased security risk of the airbag because in order to reach the pedals, they unavoidably must sit close to the airbags, which are primarily installed in the steering wheel.

Vehicle engineers like Prof. Dr. Hans-Jürgen Förster from Daimler-Benz dealt with the driver under the perspective of man as an integral component function of the automobile, as a "control person" upon whose conduct the effect of the technical product, the Automotive, depends: the driver as *Homo instrumentalis*.[5] This conception of the driver influenced the development of computer-simulated driver models, such as VEHUN-

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[2] See S. Pheasant, Bodyspace. Anthropometry, Ergonomics and Design, London 1986, esp. chapter 13, p. 198 sq.: The driver´s workstation.

[3] Ibid., p. 198, report in the Daily Telegraph, 27 March 1984.

[4] Quoted in J. M. Wetmore, Redefining Risks and Redistributing Responsibilities. Building Networks to Increase Automobile Safety, in: Science, Technology, & Human Values 29 (2004) 3, pp. 377-405, here p. 396.

[5] See H-J. Förster, Der Stellenwert der Verkehrssicherheit im Straßenverkehr der 80er Jahre aus der Sicht der Fahrzeugtechnik und Automobilindustrie, 23 pages manuscript 1983, in: Historisches Archiv Daimler-Benz sowie Idem., Der Fahrzeugführer, ein Homo Instrumentalis, in: VDI-Gesellschaft für Fahrzeugtechnik (ed.), Das Mensch-Maschine-System im Verkehr, Düsseldorf 1992, pp. 379-425.

CULUS, being developed in the mid-1980s at the Institute for Vehicle Technology of the TU Berlin. The aim was less about body measurements and more about making predictions regarding senso-motoric information processing and the resulting actions of the driver.[6] The "Design Driver," "Human Factors in Vehicle Design", as well as the "Anthropometry in the Design of the Driver's Workspace" and "the integration of man-machine-environment components into a cohesive unit or system" – these and similar aspects have already been in play for a long time – at least since the famous study of McFarland and Stoudt from 1961 for the American Society of Automobile Engineers (SAE) – as central in the thinking and working of the automotive engineers.

The perspective of historians of technology is, on the other hand, quite different. The man-machine relationship in its historical dimension is, for example, a theme of a new history of the body or a history of the changing relationships between technology and the physical human body. Hybrid techno bodies, dissolving boundaries between body and technology, symbolic and visual representations of the body, the historical approach to the question of how man was measured and the necessary gear and mutual influence of tools, procedures, discourses, actors and media as well as the "opening of the body for biometric and biopolitical interventions" (Theile), have all been and are being historicized.[7] On the other hand, the historical debate about the changing relationship between technology and users, in order to investigate the "consumption junction" and a complex, multiple feedback process, influenced innovation history to play a role in which users are involved as co-producers of technology. The design of the passenger compartment of the automobile can be considered a description of the negotiation process, including cultural traditions that demonstrated considerable persistence.[8]

Whatever the perspective, at least the scientific construction of the driver resulted in the development of standards, mannequins, templates, and anthropomorphic test devices as dummies and digital human models. To be able to coordinate man and machine, developers need the most accurate data of the user. Knowledge in the field of anthropology and ergonomics is transformed in the field of production. How, and in which way did this process happen? Which anthropometric data were and are introduced in the automotive development? How have these standards and models been developed and used? There are, therefore, three important types of human models, which in turn can be subdivided into several types: templates, dummies and digital human models.

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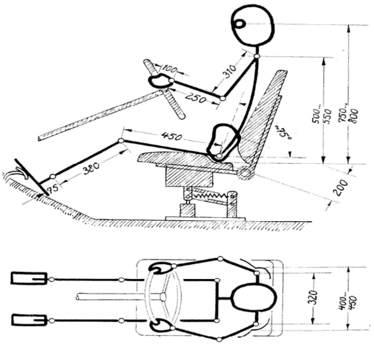
[6] See particularily Ibid, p. 227.

[7] See B. Orland (ed.), Artifizielle Körper – Lebendige Technik. Technische Modellierungen des Körpers in historischer Perspektive, Zürich 2005, p. 9sq.. and G. Theile (ed.), Anthropometrie. Vermessung des Menschen von Lavater bis Avater, München 2005, especially p. 12. From a gender perspective: H. J. Schmidt, Menschengeschlecht als normatives Ziel politisch gesteuerter Inkorporierung des Technischen, Manuskript für das AGT-Kolleg der Hans Böckler Stiftung am MZWTG. See also P. Sarasin, Reizbare Maschinen. Eine Geschichte des Körpers 1765–1914, Frankfurt a. M. 2001 and more recently the literature review by D. Siemens, Von Marmorleibern und Maschinenmenschen. Neue Literatur zur Körpergeschichte in Deutschland zwischen 1900 und 1936, in: AfS 47(2007), pp. 639-682.

[8] See K. Möser, The driver in the machine: changing interiors of the car, in: H. Trischler and S. Zeilinger (eds.), Tackling Transport, London 2003, pp. 61-80.

2. The beginnings of anthropometric thinking in the automotive industry and the long road to templates (Kiel Dummy)

Six trends and issues should be taken into consideration:
First, the beginnings of anthropometric thinking in the automotive industry reach back to the second half of the 1950s. In a way, the annual meeting of the Section Vehicle Technology of the VDI held in March 1957 signaled a starting point, which dealt with the problem of adapting the vehicle to the people. It was the design of the seats, which developed with the intention to optimize the passenger area on the basis of different seat-mass data (mass-leg length, thigh-length mass, shoulder-width mass, *etc.*) from which a "key figure for the convenience" has been elaborated. Dieter Dieckmann from the Max-Planck-Institute for Work Physiology in Dortmund presented research findings on "The effect of vibrations on man," which later resulted in an extensive research project for VW ("investigations and improvement of a Volkswagen front seat model 1957/58").
The work of physiologist Henry Dupuis, who headed the former Max Planck Institute for Agriculture and Agricultural Labor, who had his own working group about *Anthropotechnik* and who had delivered a paper on the "The situation of work physiology in the drivers cab" at the VDI session, finally brought things to a head when he demanded that the "previous practice in the industry, first to build a vehicle and finally to squeeze in the driver" must be replaced by a fundamental rethinking.[9]
With the development of the American Standard SAE J 826 (1962), on the one hand, and the "Kiel Dummy" from 1975, on the other, one finds something of a history of the German / European-American competition in the development and use of body-shape templates in the automotive industry.



The creator of the Kiel Dummy, Professor Jürgens, was soon encouraged to note that the templates according to DIN 33408 had been developed for the design of seats of all

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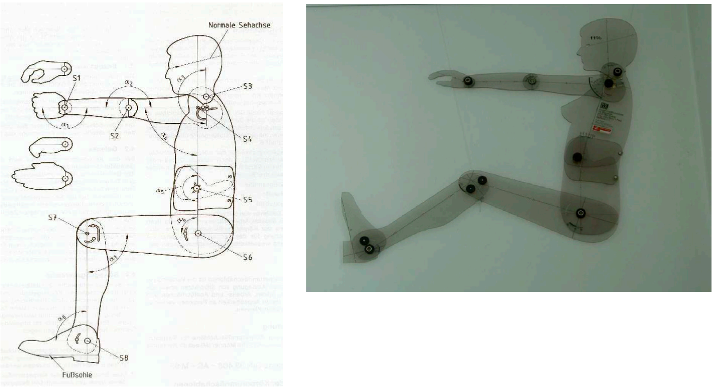
[9] See VDI-Tagungsbericht in: BTÜ (Betrieb und Technische Überwachung) 2 (1957), p. 150.

kinds, not just specifically for automotive seats. In fact, it was primarily the automotive industry that "has for some years been working successfully with the templates according to DIN 33408 Part 1." Thus, in the templates, development experience had been incorporated particularly from the automotive industry, but also from the Federal Bureau for Defense Technology and Procurement. Some representatives of other industries, notably from Bosch and Bayer, had criticized this. The suitability of the Kiel puppet for the design requirements in their companies was firmly denied.[10] The design of seats with only a two-dimensional template, or in fact a total of eighteen templates (six each for the front, side and top view), was regarded as too expensive and indeed seen possible only in special cases.[11]



The so-called "Kieler Puppe" for men and women. (DIN 33408-1:1981, Privat)

At last, in September 1981, they presented a separate proposal for the standard "representation scheme of the human figure."[12]

Regarding the collection of whole body measurements, the main task then was to grasp body measurements for foreign workers in the Federal Republic. In June 1984, finally a revised standard of DIN 33402 was submitted, "Part 5: Dimensions of the Human Body; values of Italian, Yugoslav and Turkish workers in the Federal Republic of Germany presented." There were also other complementary volumes to DIN 33402, and from all this arose the need for the "further development of the templates" and especially of the Kiel Dummy. Therefore, in May 1982, tested models of the side view, top view and front view were finally presented. It was, however, also clear that as a working tool, templates now clearly showed their limits. The intention to simulate a variety of body

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[10] See Brief Bayer an den FNErg vom 13.5.1981 sowie auch Brief Bosch vom 30.6.1981, in: ebd.

[11] See Protokoll vom 29.9.1981, S. 3.

[12] On that discussion see: Bericht über die Einspruchsverhandlungen zu den Norm-Entwürfen Körpermaße des Menschen und Körperumrißschablonen für Sitzplätze, 9 December 1980, p. 5sq.

positions had led to increasingly complex patterns, and the high number of stacked stencil parts made handling increasingly difficult.[13]

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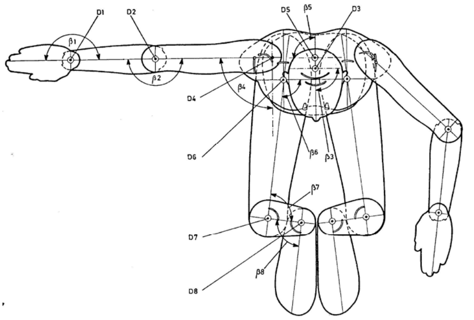

Bild 2. Gelenkwinkel nach dem funktionstechnischgen Meßsystem (Draufsicht)

Fifth, in the various expert groups and working committees of DIN, CEN and ISO, a multitude of (sometimes differing) standards have developed. As in all these areas, from the form and execution of the driver placement, grip force, visibility and seat heights, universal standards only sporadically were available, so “these definitions are based on a variety of scientific, more or less secure documents and consequently differ from or are sometimes even contradictory.”[14] In September 1981, Germans put together a 95-page synopsis of “Design of the driver seats: Compilation and comparative examination of the currently present standards and regulations in this area.” With this document, they led, in some ways, the transnational harmonization efforts for ergonomic standards. The leading role that Germany played here was already demonstrated by the fact that the formation of the international ergonomics committee of ISO (with 33 member countries) on April 3-4, 1975 had been held in the German capital, Bonn.[15] Additionally, these examples demonstrate how long and difficult – not only in the field of ergonomics, but especially in body measurements – the way to overcome the “competitive norm” and to find a single standard or norm in Europe had been.

Sixth, as far as the international data collection was concerned, in 1979 Jürgens presented for the first time body mass data, namely from France, Poland, Italy and the USA, and one year later he added data from Belgium, Germany, Britain, Canada and the Netherlands. Jürgens’ International Body Mass Database increased rapidly in size and

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[13] See Besprechungsprotokoll, 7 May 1982.

[14] Attachment 4 to the Report for 1980.

[15] See Tätigkeitsbericht FNErg für die internationale Normungsarbeit im Jahre 1975, p. 1.

complexity. “In this context it is to recognize,”said the anthropometric expert, that “export-oriented countries make major efforts to gain an early knowledge of body size data from foreign countries.”[16] In 1982, he proudly stated that the German rules and technical regulations in (Ergonomics-) standards were by far the largest and the only ones that cover all areas of engineering.[17] The Kiel Dummy, adapted to the SAE mannequin, advanced to the dominant template in the German and Austrian automotive industry, and was only replaced in the mid-nineties by virtual dummies. The German man-model also formed the basis for the 1988 to 2005 efforts that were made in the development and standardization of a two-dimensional “European Template.” It was in a number of characteristics similar to the American standard model, the male template of the 50th Percentile according to SAE J 826, for example, in the h(ip)-point location. Then again, there were also significant differences. The knees and ankles were corrected because of recent anthropometric studies and now had 15 mm greater leg length.[18]

3. “The misery with the Dummies.” Development and use of “Anthropomorphic Test Devices” (aspects of European-American competition in the field of crash test dummies) since the 1960s

While the two-dimensional templates were used especially in the product development (the driver’s seat and driver’s workplace) of the automotive industry, in the field of passive safety/accident research, other human models are used: first simple, then increasingly complex test mannequins or crash test dummies. There are, in the context of our specific interest, some interesting findings and noteworthy aspects.

First, in regard to the question of security research, very different philosophies existed between the German or European and American automobile industries. Unlike the European automotive companies, the U.S. automakers, until the mid 1960s, had worked only incidentally on Accident Safety Research. In 1964, GM spent just 1.25 million U.S. dollars for this purpose. Investigating the accident safety by systematic crash-test series were for years seen as pointless in the eyes of the leading managers of the development departments in Detroit, even though the casualty figures rose steadily.[19] Especially in the U.S., there was a clear emphasis on passive safety, and accident prevention was only second on the priority list, while in Europe it was the other way around. Nevertheless, America and the American auto industry and the influential SAE soon took the lead in dummy technology for many years to come. Again, this is an early example of Americanization and Europeanization in man-machine systems.

Secondly it is remarkable that, although in the 1970s the third generation dummy was developed (first “Sierra Sam,” then the VIP Series, “Sierra Stan” and “Sierra Susie,” main-

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[16] FNErg Tätigkeitsbericht über die internationale Normungsarbeit im Jahre 1980, p. 4.

[17] Tätigkeitsbericht 1982, p. 14.

[18] See FNErg Jahresbericht für 2005, p. 11, Anhang A.

[19] See SPIEGEL Nr. 37, 1973, p. 62sq.

ly developed by GM, soon followed worldwide by the Hybrid Model II), the German automobile industry, especially Daimler Benz, expressed considerable skepticism towards the use of crash test dummies ("The misery of the Dummies"). It favored, on the other hand, until well into the 1970s, to crash test with corpses (cadaver tests) – following the motto: Better a German / European cadaver than an American test dummy. Self-testing (*i.e.*, the engineers put themselves in the impact sled) at times even played a role, and it was not until 1967 when Daimler-Benz made an effort to acquire more test dummies. They maintained close contact at that time with the U.S. manufacturers, investigated intensively in the then-existing crash test dummies, and compared their possibilities of application. According to Gerhard Fuld, who was for many years the "dummy head" of Daimler-Benz, one worked with dummies of different suppliers because, up into the 1970s, no standards for design or properties of dummies existed and each dummy model showed a different behavior. Again and again, the question of the reproducibility of test results dominated the discussions. "The biggest gap," the then Daimler-development chief Hans Scherenberg complained in a SPIEGEL interview in mid-1973,

> *is the unknown relation between the human body and the test dummy. Furthermore, a single dummy's tests are the same but [with] different values, different dummies also give different values, [which] is also a degree of aging. We have variations of up to plus or minus 35 percent, and so of course what ultimately provides no reliable values.*[20]

How should the safety engineers recognize a difference in the risk of injury by 10 or 20 percent when the readings of the experimental puppet fluctuated by 35 percent? "It is therefore an extremely urgent task," wrote the Daimler engineer Karl Wilfert in a report in March 1972, "to standardize a test dummy to the best of current knowledge, to define the correlation for living people and ensure reproducibility."[21] The already mentioned problem of reproducibility of the measurement was related, in the early 1970s, to the dummies and not to the test cadavers. However, there were also (not only moral) problems in this field:

> *The majority of cadavers available were older European American adults who had died non-violent deaths; they did not represent a demographic cross-section of accident victims. Deceased accident victims could not be employed because any data that might be collected from such experimental subjects would be compromised by the cadaver's previous injuries. Since no two cadavers are the same, and since any specific part of a cadaver could only be used once, it was extremely difficult to achieve reliable comparison data.*[22]

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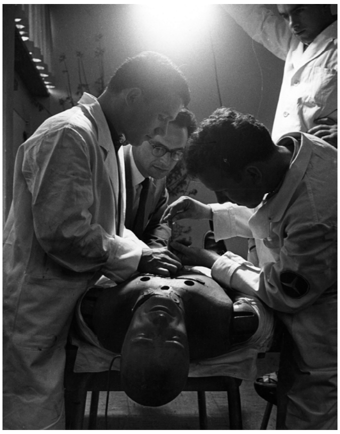
[20] See SPIEGEL Nr. 37, 1973, p. 82sq. See also H. Scherenberg, The Development of the ESV as seen by Daimler-Benz, in: Report on the Second International Technical Conference on Experimental Safety Vehicles, 26. bis 29. 10. 1971 (in Sindelfingen bei DB), p. 2/67-2/72, here Scherenberg critizised for the first time heavily the use of dummies.

[21] K. Wilfert, Kritische Auseinandersetzung mit dem Personen-Sicherheitswagen, Manuscript for a presentation on March, 17, 1972 at the VDO-conference, in: HIC Daimler, Bestand Wilfert, Vorträge 4, 1969-72. See also K. Wilfert, Sicherheitsfortschritte im Autobau, in: Automobil Revue 31 (1973), pp. 1-10.

[22] See http://en.wikipedia.org/wiki/Crash_test_dummy as well as M. Roach, Stiff. The Curious Lives of Human Cadavers, N.Y. 2003.

Third, since the mid/end of the 1970s, Crash Test Dummies prevailed, and until the mid-1980s automotive designers and engineers closely followed the American safety standard specifications in terms of the size, appearance, *etc*. of the dummies, while also evaluating the collected data of the crash test programs that were concerned. There were also European efforts on the part of the automotive companies as well as at the institutional level, but nothing happened at the legislative level.



Pictures from the Daimler Benz Archive Stuttgart, Bestand Barenyi 6.

The efforts to develop and deploy the dummies always became greater in each case, but they were unsuccessful in significantly narrowing the gap between crash tests and real accidents. The major unknown remained the relation between the human body and the test dummy. Here, simply basic biomechanical research was lacking. There were, though, quite a few activities at the European level. In October 1970, the European Experimental Vehicle Committee was established, not in the least as a response to the American initiative, with the aim "to co-ordinate the car safety technical activities of the European participants in international programs."[23] Member countries of the EEVC were France, Germany, Italy, England and Sweden. Since its foundation, the Committee had tried "to define on the basis of European experience a sufficiently common view of the future needs for car safety in Europe." This referred particularly to the test procedure)[24] Finally, a working group (WG3-Human Tolerance Levels and occupying protection evaluation techniques) was established which included, *inter alia*, representatives of the French automobile companies as well as representatives of Daimler Benz, Fiat and Vauxhall Motors UK Ltd. This working group dealt *inter alia*, with anthropomorphic dummies. "All dummies currently commercially available have limitations when assessed against the requirements for an ideal test dummy," according to a first interim report. Problems have arisen, for example, with the Hybrid II dummy, which was originally intended only

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[23] See the extensive discussion at the EEVC-workshop on „The future for car safety in Europe", June 1974 in London, in: HIC DB, Bestand Automobil und Sicherheit 1971-84.

[24] Ibid., p. 5.

for evaluating airbags.[25] Since about October 1971, there was also a European working group of automobile companies on "biomechanics and accident research," with representatives from VW, Fiat, Daimler-Benz, Peugeot and Renault – at first remarkably without English experts, and even without any Swedes.[26] On the third meeting in April 1972, the British (British Leyland engineers) received access, and all participants praised the "valuable experience" and the "open and fair manner in which all parties discussed more or less common problems."[27] Indeed, the automobile companies exchanged details about the problems with reproducibility of the dummy data from seatbelt tests, airbag tests, head acceleration data and the problems arising from the different constructions of the dummy neck.[28] Since 1977, this working group has been supplemented by a European biomechanics research connection. Through this connection, the European automobile manufacturers cooperate with domestic and foreign research institutes. "The goal of this alliance is to determine the correlation of tolerance and protection criteria," according to a status report of the Federal Republic of Germany from the 7th ESV Conference in June, 1979, Paris. Selected crash tests and accidents are costly to reproduce and simulated in laboratory experiments both with cadavers and dummies.[29] The competition of real and artificial human models in the R & D in the automotive industry, thus, continued through the late 1970s.

Picture from VW Report 2: Sicherheit. Forschung und Entwicklung im Dienste des Autofahrers (1975), p. 14/15.

Fourth, since the early 1990s, independent European activities began, both in the dummy and dummy-technology development (*e.g.,* EuroSID; TNO TNO Q3 or-10) as well as in cross-enterprise exchange and publishing, *i.e.,* the harmonization and standardization

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[25] Ibid.

[26] An application for the membership of Volvo had been refused, arguing: "No-EEC country, little influence on government, prejudice for accession of other small companies such as Alfa Romeo, BMW, etc."

[27] See Aktennotiz vom 14.4.1972, in: DB-Archiv.

[28] See on that matter also Aktennotiz 1682 and 1759 as well as the Protokoll der 4. und 5. Sitzung der Biomechanik-Gruppe am 18./19. 7. 1972 und am 26./27. 10. 1972, in: DB Archiv, o. Sign.

[29] See Statusbericht in: DB-Archiv, o. Sign..

of crash-test data (PROMETHEUS; Partnership for Dummy Technology and Biomechanics-PDB). For the verification or development of occupant protection systems with MADYMO3D, for example, only three different dummy sizes existed at that time. The size classification of these dummies, however, did not reflect the real distribution of body size and mass of the European population. A closer look at the distribution of body mass and height of the northern European populations of both sexes clearly demonstrates that the three standard dummies did not cover the whole range of physiques. Furthermore, the populations in southern Europe and Asia, on average, are up to 8 cm smaller and lighter than the population of northern Europe, but the standard dummies are far from this type of anatomy. The present simulation dummies do not cover especially small and corpulent persons. They represent an extreme however, due to their short legs and arms, which shorten the distance between the driver's seat and the steering wheel. This case is similar with very slim and large people. The aim of the study was, therefore, to expand the range of the existing three MADYMO3D dummies by new-scaled anthropometric dummies.

Meanwhile, there is an almost overwhelming wealth of different dummy models, thus concluding: the *Homo Europaeus* as an anthropomorphic test model or crash test dummy became a reality.

4. From experimental improvisation to 3 D computer simulation. Digital human models (ANTHROPOS, RAMSIS; HUMOS)

Not only because of high costs, but also due to the ambiguity of existing data in the automotive industry, numerical crash simulations were performed in addition to real crash tests. In addition to hardware-dummies, numerical dummy models were also used. This practice began in the 1960s, in connection with the advent of modern CAD technologies in the U.S. In Germany, this happened somewhat later. Around the end of 1972 Daimler-Benz thought about creating an algorithm to describe the movement of a vehicle occupant.[30] There are several factors to consider.

First, there are methodological issues. The main problem was to derive from the static, collected, often for other purposes, metrics of the human body and form a dynamically consistent human model. The requirement to collect dynamic body measurements and to show and reproduce them in the form of movement spaces implied numerous methodological problems.[31] For a long time, anthropologists shied away from the claim to deliver and create anthropometric data for computer-aided human modeling. Yet, real dummies, like their numerical representatives, formed the human body inadequately. Thus, the various human tissues such as bones, muscles, ligaments or skin had been reconstructed by using industrial materials like metals and plastics. The degree of biofidel-

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[30] See Aktennotiz Nr. 1818 vom 13.12.1972, in: DB-Archiv.

[31] See K. Erichsen and H.W. Jürgens, Human Body Measures – Dynamic Body Measures, Bremerhaven 1993.

ity, *i.e.,* the figure of the human body by the hardware or software dummies was lacking from the perspective of the engineers and medical experts, despite the elaborate evaluation efforts in several comparison tests with living volunteers and cadavers.[32]

Second, at least since 1985, the call for three-dimensional mathematical models (3D-doll) with anthropometrically correct representation of the shape and of the joints was getting louder in German automotive companies. The tools that were used at that time were anthropometric templates SAE (SAE J 826), SAE-measuring machines, mannequins and templates according to DIN 33408 (Kiel puppet), as well as U.S. crash dummies part 572nd. Therefore, the industry worked almost exclusively with non-European data. For example, the SAE-template and measuring machine was based on completely outdated U.S. body mass data prior to 1962, and the anthropometric reproduction was poor due to the use of simplified swivels instead of joint paths (*Gelenkbahnen*). Moreover, the torso portion of the stencil of a 50% of man-size, head and arms were not available. The outer areas of the basin and back shell of the measuring machine were not derived anthropometrically but defined arbitrarily. The "Kiel" puppet still represented the state of the art, though it also worked with earlier data from 1975 (the acceleration per decade was at least 23 mm). Also, the crash dummies had simplified joints, based on outdated body measurements, and above all, they were not compatible with the SAE template and SAE measuring machine! Thus, the anthropometric equipment of the automobile companies in the mid-80s pretty was desolate. Therefore, the demand for new mathematical and computer simulated human models was understandable. However, it was surprising that for Daimler Benz, as a basis for the urgent need to redefine 3D mannequins, German or European body data should not be applied, but "taking into account the acceleration, the development time of new development and the lifetime of the vehicle two 3D puppets to the year 2005 'grossed-up' were to define, that is for the 5% Japanese and the 95% U.S. men."[33]

Since the early 1980s, more and more European computer-human models also appeared on the market, such as the human model Ergoman, developed in 1984 at the University of Paris in the Laboratoire d'Anthropologie et d'Ecole Humaine. It was based on a vast international database of anthropometric measurements (40,000 people) and was even used in the automotive industry. In Germany, also in the mid-1980s, computer-based human models were developed, especially within the framework of a BMBF-funded research program conducted by the TH Darmstadt. These included the models "Franky," "Heiner" and "Anybody." By the late 1980s, the number of the developed and used computer models of man worldwide was already so great that the Kiel Anthopometrie-Pope Jürgens, on behalf of the Federal Office for Defense Technology and Procurement,

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[32] See K. v. Merten et al., Computergestützte Analyse von Verletzungsmechanismen. Numerische Menschmodelle zur Untersuchung von Verletzungsmechanismen bei stumpfer Gewalt, in: Rechtsmedizin 6 (2008), pp. 431-436.

[33] Forschungsantrag DB an den FAT-Forschungsbeirat vom 6.8.1985, in: DB-Archiv.

prepared an overview study. There are now real genealogies of generations of human models since the 1960s.[34]

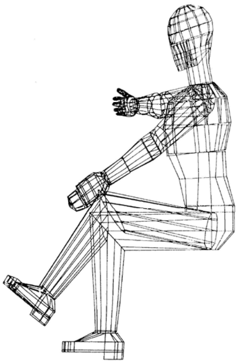

Abb. 33

HEINER ist ein modular aufgebautes Menschenmodell, das an der TH Darmstadt entwickelt wurde (nach Schaub & Rohmert, 1988).

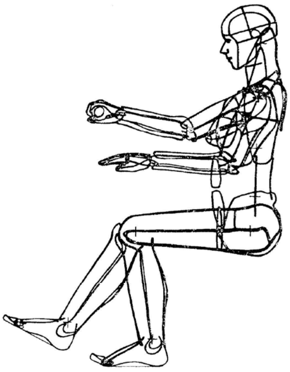

Abb. 32

Die Körpermaße des OSCAR-Nachfolgers ANYBODY sind DIN 33 402 entnommen (nach Lippmann, 1988).

The result of this study was twofold. First, beyond the traditional focus of development work in the U.S., a surprisingly great diversity and great number of computer-based models of man could be concluded in Europe. There were not only the German and French models, but also developments in Finland, Hungary, Romania, England and the Netherlands. Secondly, the problem was that it was far from any uniform standards. Island solutions prevailed, "which is desirable neither from the point of computerized technical perspective (compatibility) nor in anthropometric view (comparability and reliability of data bases)."[35]

Third, since about the beginning of the 1990s, a fundamental shift took place: from dummy models to realistic human body models, *i.e.,* direct numerical representations of the human body. The statements about the probability of occurrence of injuries in traffic accidents with crash test dummies could be made only indirectly by statistical evaluations of individual technical measurements related to specific body parts. Hardly any relevant statements could be made regarding the injury of broken bones and internal organs. With the help of two newly developed numerical modeling methods, most of these problems could be overcome. When using multi-body system models (MBS), the kinematics and the joints in the various acting forces can be calculated. When using numerical human models on the basis of the other method, the finite element method (FEM) also imposed burdens on all organ systems, for example, individual bones. It

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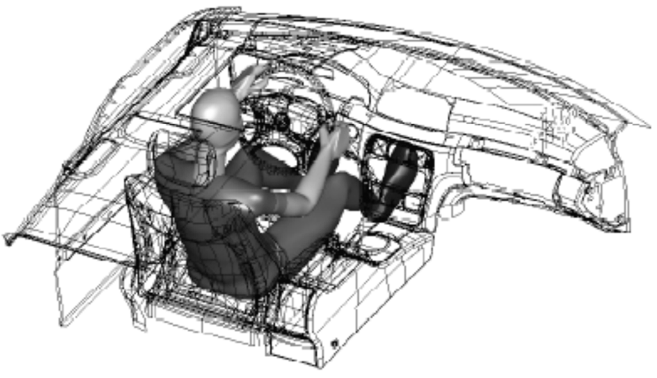
[34] H. W. Jürgens, Computermodelle des menschlichen Körpers, Kiel 1989.

[35] Ibid., p. 1.

could even calculate the effects on the aorta. Thus, it is possible to significantly increase the knowledge of injuries that occur during an accident.[36]

Fourth, The Germans (automotive engineers, such as university researchers) played an important and crucial role in the research and development of digital human models at the European level, accompanied by the French. In close cooperation with the German car companies and the Technical University of Munich, the digital human model RAMSIS was developed between 1987 and 1994, which, in a way, set a world standard. It was built on an extensive database of newly collected (approximately 7000 persons were measured using a novel method of body mass scaling) data, supplemented by other large, international anthropometric databases at the University of Potsdam with statistical data on populations from Europe, North and South America, China, Japan, Korea and India and realized by innovative statistical procedures, a typology of anthropometry, posture and comfort.[37]

The close anthropometric measurement and innovative measurement techniques, without any interface combination of 3D modeling (outer skin and inner skeleton model), and the newly developed software gave RAMSIS a competitive edge over other relevant systems. The system thus contains a typology of persons, which is much more realistic concerning the population than a percentage of several parts of the human body.[38]



Fifthly, although there was and is perfect trans-national/international cooperation, ultimately the R & D activities for Dummy Technology and industrially usable digital human models can be broken down into triadic projects: The European Humos 2 Project,

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[36] See also H. Mutschler, Menschmodelle bei niedrigen Beschleunigungen, Diss. Universität Tübingen 2007.

[37] See J. Hudelmaier, „Das Menschmodell RAMSIS", in: http://www.lfe.mw. tum.de/forschung/humanmodeling/Ramsis_Flyer.pdf ; FAT-Bericht 123: "RAMSIS- ein System zur Erhebung und Vermessung dreidimensionaler Körperhaltungen von Menschen zur ergonomischen Auslegung von Bedien- und Sitzplätzen im Auto" Frankfurt a. M. 1995; FAT-Bericht 135: „Mathematische Nachbildung des Menschen – RAMSIS 3D-Softdummy", Frankfurt a. M.1997.

[38] More in detail A.. Seidl, H. Bubb et al., RAMSIS: 3D-Menschmodell und integriertes Konzept zur Erhebung und konstruktiven Nutzung von Ergonomie-Daten, in: VDI-Kongress, Mensch-Maschine, Frankfurt a. M. 1992, pp. 297-309.

the American Global Human Body Model Consortium, and the Japanese Human Body Model Project (JAMA). The development of digital human model Humos (Human Model for Safety) was truly a European project. In 1998, the European vehicle passive safety network (EVPSN) was established; working with EU funds from 2002 to 2006, they collected biomechanical data and launched the mathematical modeling of the complex geometries of the human body. The automobile companies and several universities partnered with the project: the Eindhoven Technical University, the University of Heidelberg, a number of French universities and from industry, Renault, Volvo, VW and Peugeot/Citroën. "The objective of the project is," according to a paper on this partnership, "to develop human body numerical models representing a large range of the European population and allowing an accurate injury risk prediction." In practice, the Humos project means that a corpse has been frozen and then cut piece by piece into thin slices, scanning each in detail and then digitizing. Again, it is therefore the case that research is done with real (dead) people, however, not directly but indirectly as the aim is to continuously improve and validate the computer models.

5. Conclusion and outlook

First, the computer simulation of the human body made it possible for the database to no longer represent a kind of *Homo Europaeus*. Now, depending on the application-specific database, individually shaped people can be "created," for example, German men, French women, or Italian children.

Secondly, the development and marketing of digital human models is now a global business. Innovative engineering and software companies, such as the German Human Solutions GmbH, Carhs GmbH and the First American Technology, now offer a wide range of products and services (see, for example, the annual RAMSIS user conferences). Carhs, under the label eDummy, according to its own statements, offers "the first dummy for numerical simulation in Vehicle Security." There is another European project, DHErgo, which focuses especially on the simulation of human musculature and the skeleton. The objective is not only to simulate complex movements and the changes of movements with increasing age, but also the interaction of man with his environment. Since 2002, there is also a Partnership for Dummy Technology and Biomechanics (PDB) in which the five genuine German automobile companies (excluding Opel and Ford) and the First American Technology Group work together to improve the crash test dummy technology. The R & D laboratories deal with issues such as the validation of a MADYMO occupant-simulation model to real crash tests using stochastic optimization processes.[39] Even after more than fifty years of crash-test dummy supported research, the experts

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[39] Overview in E. Haug et al., Human Models for Crash and Impact Simulation, in: N. Ayache (ed.), Handbook of Numerical Analysis, Vol. XII: Special Volume: Computational Models for the Human Body, Amsterdam 2004, pp. 231-450.

in the automotive companies do not really know much about what happens inside a human body if, for example, a car with a speed of 50 km/h hits a tree frontally. Crash test dummies still differ significantly from real human bodies.[40] More and more, experts criticize the increasing efforts to perform crash test simulation techniques, the exploration of the stochastic nature of the crash phenomenon and the logic behind it: "that the crashworthiness optimization of vehicle is possible."[41] Despite this, another powerful consortium of science and industry was erected in 2006, the U.S. Global Human Body Models Consortium (GHBMC). The members were the former American automobile companies GM, Ford, Daimler-Chrysler and the Japanese car companies Toyota, Honda and Nissan (and the Korean Hyundai Group). European members include the French manufacturers Renault and PSA Peugeot Citroën, and also two suppliers, TRW and Takata. The representatives of science are the Wake Forest University NC (Center for Injury Biomechanics), the Wayne State University, Michigan, the University of Waterloo, Canada and the Virginia Tech University, supported by the European Center for Safety Studies and Risk Analysis (CEESAR) and the French National Institute for Transportation and Safety Research (INRETS). The goal of this project is described as follows: "We are changing our philosophy of designing cars for crash test dummies to designing for humans…"

The cases of the SAE-template, the "Kiel puppet," Euro-SID dummy and RAMSIS illustrate very clearly the professionalization of the user design within the automotive industry. To that end, particularly the transfer of anthropological standards into the production sphere contributed substantially. They also show, however, the differences between science and practice. Digital human models cannot only be implemented earlier in the development process, but allow for greater individualization and the consideration of biomechanical properties such as weight and body part areas. This can be done through the involvement of medical knowledge such as crash tests, or for the necessary homologation test scenarios, thus significantly reducing costs. However, real crash tests and dummies still cannot be renounced, so that the latter, as well as virtual human models need to be implemented in an analysis of the construction of scientific users in the automotive industry. In other words:

> *Auto-safety experts use a mix of tools today to measure and improve crashworthiness, including dummies, computer models and even human cadavers. Automakers routinely use exact computer models of their vehicles and parts to run hundreds of virtual crash tests, making small changes later verified with actual crash tests.*

Without taking into account operational factors, the interest of the company to design a scientific user remains frightening and ambiguous. It is not about the control of the user

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[40] J. Wismanns et al., Computational Human Body Models, in: M. D. Gilchrist (ed.), IUTAM Proceeedings on Impact Biomechnics: From Fundamental Insights to Applications, Amsterdam 2005, pp. 417-429.

[41] J. Marczyk for example critizised under the headline "Automotive Crash: From Bifurcations to Chaos" that the „phenomena that may be catalogued as chaotic and/or random in nature, are inherently deprived of any form of predictability." J. Marczyk, Automotive Crash Simulation: A Personal Perspective, sl. 2001, pp. 1-12.

but to control the costs. Without taking into account technical factors in the historical interpretation of the human models and the products, the potential of user designs remains in the dark. All human models are fed from data, which can be generated in the human sciences such as anthropology, medicine, and ergonomics. Last but not least, the actors of the specific networks in which the scientific design of user images takes place must be identified and the negotiation processes should be analyzed.

A Europeanization of knowledge of the (West) European automotive industry on the anthropology of its users, for a long time, appeared only as an implicit goal. Europeanization is a contingent outcome of the tense interplay between national and global factors. In the experiment they increasingly felt that the overall liability of the U.S. automobile industry, their standards, and the scientific basis of their approach were lacking. The auto companies in Western Europe began, only by the late twentieth century, to come to an understanding of common technical standards on the basis of an integration of their knowledge about the *Homo Europaeus* as an automobile user. However, this understanding of technology is actually already becoming obsolete. Additionally, the automobile industry develops, ultimately, more and more cars for specific user groups (Smarts, SUVs, vans, electric car, cars for older drivers, cars for heavy and tall people, *etc.*). There is a potential departure occurring from the *Homo Europaeus* to a *Homo Mobilis*: people driving cars, which are designed to their specific and individual (not only in color) needs and constitutions. They are tailor-made cars that are developed by first collecting the individual body measurements and then by taking acceleration into account.