# Design Work in Change: Social Conditions and Results of CAD Use in Mechanical Engineering

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***Abstract*—The findings presented on the employment of CAD in West Germany's mechanical engineering industry show that CAD is used in various ways by different firms and, thus, also has diverse results on working conditions. The various production structures used by the single-piece, half-standardized, and standardized series producers are considered to be the most important factors for explaining this circumstance. In addition, however, the influence of various interest groups in the firms concerning the introduction process also has to be stressed.**

**In view of their research findings, the authors argue against using the oversimplifications and rash generalizations regarding the reduction of personnel, Taylorism, and deskilling that dominated the discussion during the early days of CAD. They regard the changes taking place at the level of the "microstructures" of designing to be basically the general consequences of the employment of CAD. These changes have until the present had little influence on the division of labor and the development of skills.**

**The latter depend, according to the findings presented in this paper, on the various concepts of CAD utilization. Among other things, the following trends were discovered in this respect:**

- **within the field of design, skilled jobs retain their skill level;**
- **some already deskilled jobs disappear;**
- **the traditional three-way task split into design, detail design, and draftsmen is developing towards a two-way split into design and draftsmen;**
- **in addition, new jobs are being created for CAD experts in the fields of CAD development and support;**
- **stress is becoming a more important issue for the technicians;**
- **traditional, internal career ladders are losing ground;**
- **computerized monitoring and control threaten to introduce new ways of binding the design personnel into the design process.**

## I. Investigating CAD Implementation in West Germany's Mechanical Engineering Industry

MECHANICAL engineering is one of the most important branches of West German industry, with about one million employees and an export surplus of some DM 50 or 60 billion annually. It has been able to achieve its internationally recognized leading position above all because it does not manufacture standardized mass products but is rather concerned with the specific wishes of clients looking for tailor-made, problem-solving answers. As a consequence of this specialization, small and medium-size firms producing single products or small batches predominate in West Germany's mechanical engineering industry. As can been seen in Table I, the significance of small firms in West Germany's mechanical engineering industry has increased.

It is clear that design and planning activities are especially important in this form of production, which has to implement production innovations and variations at frequent intervals. This is demonstrated by the fact that some 10–30 percent of the employees work in the designing and operations planning departments in the mechanical engineering firms we have been investigating.

The findings of two representative surveys on employment structures in West Germany's mechanical engineering industry are presented in Table II (the findings from the most recent survey, made in 1988, are unfortunately not available yet).

The most significant finding is that the fields "product development and design" and "quotation processing and project planning" have also gained in importance quantitatively: in 1976, 10.5 percent of those employed in mechanical engineering worked in these areas (I.1 and I.2 in Table II), in 1984, the percentage increased to 12.3 percent.

The percentages given here are averages. In our investigation, the percentages referring to the employees in these job areas are spread out between 5 and 30 percent. In the case of the *series producers*, the percentage is lower (as low as 5 percent) and in the case of the single-piece producers, it is higher (as high as 30 percent). For more information on the types of producers, see Section II.

For several years now, a broad spectrum of techniques has been available in the shape of CAD, PPS, CAP, and NC programming systems that offer the mechanical engineering industry possibilities to rationalize design and planning activities. It even seems as if it would be possible to technically integrate the various task functions in the field of design and, even further, to fuse it with work planning and NC programming, a fusion that in the end would include CNC machines and from which significant effects for and on rationalization and flexibility can be expected.

However, it should be mentioned that the technical integration in the majority of the firms is not very advanced: heterogeneous computer and system landscapes still dominate the picture.

The employment of CAD itself in mechanical engineering is still not self-evident. This is in contrast to the case of the industries that can be considered advanced in this sense, such as automobile and airplane construction, where it has been, in the meantime, a proof of technical perfection if certain products are more or less completely developed using CAD (cf., e.g., [1]). According to a recent survey made in 1986 [2,

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TABLE I
FIRMS, EMPLOYEES, AND TURNOVER IN MECHANICAL ENGINEERING ACCORDING TO SIZE

| | 1972 | | | 1981 | | | 1986 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of Firms | Employees % | Turnover % | Number of Firms | Employees % | Turnover % | Number of Firms | Employees % | Turnover % |
| Small Firms (20 to 199 Employees) | 3603 | 22.2 | 19.6 | 4026 | 25.3 | 21.2 | 4114 | 26.4 | 23.5 |
| Medium-Sized Firms 200 to 499 Employees) | 738 | 20.1 | 20.0 | 719 | 20.2 | 19.2 | 713 | 20.1 | 18.0 |
| Large Firms (500 or More Employees) | 470 | 56.4 | 59.3 | 448 | 54.5 | 59.6 | 433 | 53.5 | 58.5 |
| Sum | 4811[1)] | 98.1[1)] | 98.9[1)] | 5193 | 100 | 100 | 5260 | 100 | 100 |

1) In 1972, firms with 1o to 19 employees were surveyed. They were not included in the figure in order to be able to compare the findings from 1972 with those of 1986.
2) The absolute number of employees was: 1972, 1,163 million; 1980, 1,099 million; 1986, 1,085 million.
3) The turnover percentages refer to the month of September of each year.

Source: VDMA, Statistisches Jahrbuch für den Maschinenbau: 1975, 1983 and 1988.

TABLE II
DEVELOPMENT OF THE EMPLOYEES IN MECHANICAL ENGINEERING ACCORDING TO JOB ACTIVITY
(PERCENTAGE OF TOTAL EMPLOYEES)

| | 1976 | 1984 |
|---|---|---|
| I. Design and Planning Activities (1+2+3) | 14.2 | 16.0 |
| 1. Product Development and Design | 8.6 } 10.5 | 9.7 } 12.3 |
| 2. Quotation Processing, Project Planning | 1.9 | 2.6 |
| 3. Operations Planning | 3.7 | 3.7 |
| II. Other Activities (4+5+6+7) | 77.4 | 74.9 |
| 4. Material Control and Management | 4.7 | 4.8 |
| 5. Production and Assembly | 54.8 | 52.2 |
| 6. Administration | 9.3 | 8.6 |
| 7. Sales Department | 8.6 | 9.3 |
| I. + II. | 91.6 | 90.9 |
| III. Vocational Training | | |
| 8. Trainer | 0.5 | 0.5 |
| 9. Trainee | 7.9 | 8.6 |
| Total | 100.0 | 100.0 |

Source: VDMA, Abteilung Betriebswirtschaft und Informatik; Statistisches Handbuch für den Maschinenbau 1981 and BWZ 50, Sept. 1985.

p. 9], over 80 percent of the mechanical engineering firms still did not employ CAD. The minority, comprising about 18 percent, that utilized CAD at the time used it at a completely different level. Many are still involved in an introductory phase. In most of the mechanical engineering firms, the dominating situation is, in all probability, that one would find a few CAD workplaces confronted by many "conventional" workplaces.

Our research project has, in the face of this situation, to study, above all, the following questions:

- What are the task structures in the design and planning departments of West Germany's mechanical engineering industry?
- Which qualifications and skills are required of the employees as a result of the task functions and their organizational bundling so that they form jobs?
- Which forms of cooperation can be found in the technical offices? What chances and paths are there for advancement?

And naturally, it was necessary to study what changes take place in these structures as a result of the implementation of new techniques.

The introduction of these new techniques in mechanical engineering represents a *process* that generally takes several years. The character of the process corresponded to our research procedure: the surveys were conceptualized as *longitudinal studies.* The introductory processes were to be observed over a period of three to four years. The firms included in the survey were chosen on the basis of a preliminary test. The targets were on the one hand, to choose firms that produced different products; then again, they should be of different sizes (number of employees); finally, we also wanted to find firms that were a bit further advanced in the implementation process.

When choosing the firms, we were able to draw on two previous studies we had done on the employment of production planning and control systems (PPS) that were carried out from 1981 to 1985 [3], [4]. Our knowledge of West Germany's mechanical engineering industry was in other words, already quite comprehensive. In the end, we chose ten firms: three machine-tool builders, as well as one manufacturer each of printing machines, bookbinding machines, escalators, screen-printing machines, machines and systems for shaping steel, road construction machines, and supplies of the electrotechnical industry. The smallest firm included in the survey employed 60 people, the largest over 2000. Firms with more than 500 employees are clearly overrepresented. This is a result of the fact that the employment of the new technology is already more widely spread in these firms (cf. [2]).

The survey was carried out in the firms in three phases. The first phase involved preliminary investigations. This was followed, about four months later, by intensive surveys (approximately two weeks per firm). Finally, after approximately one more year, there were *intensive surveys* (approximately one week per firm). Expert talks were held with everyone from the heads of the firms to the heads of the departments (approximately two hours in length; a total of 129 talks) and intensive on-site job investigations that consisted of observations and talks (approximately four to eight hours in length; a total of 67 investigations). Included in the on-site job investigations were designers (36); technical draftmen, male and female (12); operation planners (7); and NC programmers (12).

All in all, it is a qualitative study. The findings, therefore, do not allow any generalized conclusions. On the basis of our comprehensive knowledge, however, it is possible to make qualitative statements on trends.

In this paper, we will concentrate on that part of the survey that dealt with CAD and design. This is possible from the viewpoint of the contents because, according to our investigations, even in the case of ties between CAD and NC programming systems the tasks in design and work planning remain clearly separated. On the other hand, it is impossible to present both subjects thoroughly as a paper is too short to be able to handle both properly – CAD and design, CAD + NC programming and work planning.

Furthermore, we abstract from the problems of *product complexity* to a large extent.

The presentation focuses on those factors that, from our point of view, most significantly determine the various areas and forms of employing CAD and the consequences of the CAD employment for designers, detail designers, and technical draftsmen.

## II. Traditional Forms of Design in Mechanical Engineering

### A. Types of Production and Design

The individual companies can deal with the situation within the branch as described above in various ways. This also has its effects on the importance and form for the design process. One can differentiate three types of production: a) single-piece production, b) half-standardized production with custom-made variations, and c) standardized production in fairly large series.

As a rule, firms belonging to category a) manufacture products tailored to the specific demands of the customer. Consequently, each special order requires a high expenditure of design work to be completed within the narrow time limits dictated by the delivery date. In contrast, the producer of series c) manufactures "ready-made" items and has a larger number of his standard products in stock. In this connection, product design does not depend on the individual client. Accordingly, it is detached from the actual production process as far as its time requirements are concerned. Firms belonging to category b) combine characteristics of both the single-piece producer and the series producer. The differences, which are only briefly mentioned here, in the design process in the firms have until now played an important role in the development of the different concepts of CAD employment which will have to be discussed further on in this paper.

Among the firms included in our study sample are series producers that manufacture between 1000 and 2000 machines per year. The total production covers various types of machines that are offered by the firms. One enterprise, for example, offers eight different types of machines:

- manual "universal" milling and drilling machines,
- small CNC milling and drilling machines,

- large CNC milling and drilling machines,
- machining centers,
- high-production machining centers,
- flexible manufacturing systems,
- engraving and duplicating milling machines,
- tool-grinding machines.

A series produced at any one time can amount to as many as approximately 100 machines. Usually, however, the total is lower. The single-piece a) and half-standardized b) producers manufacture a total of between 40 to 150 machines per year. The products are always single units.

### B. *"Product Experience" and Teamwork in Traditional Design Offices*

The typology of work in design offices is relatively diverse and is divided among development and calculation engineers, draft designers, detail designers, and draftsmen. Very few graduate engineers have until the present been employed in these jobs in West Germany. The typical trend has been, instead, to choose people – even for the most demanding positions within the job hierarchy – on the basis of long experience and skills gained on the job. These employees were often skilled workers who worked their way up. In most firms, the technician or draftsman is expected to gain higher qualifications during the course of his time spent on the job. It would, therefore, be inappropriate to conclude on the basis of a brief glance at the relatively refined task structures that there are very permanent and solid lines demarcating the division of labor in design departments. The transitions are, on the contrary, "soft" and flowing and promote the necessary flexibility. In addition to product and component specialization and subdivision within the departments, this flexibility is often characterized by a "task force" organization during which various specialists (designers, detail designers, draftsmen) cooperate for a fixed period of time on a particular task required by a specific order. Such varying forms of cooperation, which frequently change and offer diverse ways of approaching a problem, present an opportunity to work with sundry aspects of the object and, thereby, offer the chance to accumulate knowledge closely related to different products and tasks. The great significance of this "knowledge gained through experience" in the company is a result of the fact that the design process in principle normally uses, although it may take on a number of variations, familiar solutions specific to the particular firm and the particular product. So far this has hardly required any advanced theoretical or academic skills which could be acquired outside the process itself. This is also the reason for the "permeability" of the work structures which makes it easier to make "careers" on the basis of advancement within the firm.

Essentially there are two factors which, today, have made these working conditions (which had remained stable for a long time) an important, new area of rationalization in the engineering firms. One factor is connected with the necessity of adapting to the changed utilization conditions and of integrating new, in particular, microelectronic-based, technologies in the products and production processes. Now ever more complex machines must be more rapidly developed, designed, and produced. As a result, there was an increase in the old requirements, and in addition, new requirements were added, particularly in those departments that plan and prepare the production, such as the design department. At first, it seems, the firms were only able to meet these conditions by hiring additional staff and employing better qualified employees in these areas.

This constellation results in the firms needing a whole new package of rationalization measures. The classical goals of rationalization, such as reducing personnel costs and speeding up the work process, receive an importance hardly known before in the sectors employing technical personnel.

The second factor we spoke of relates to the means of rationalization themselves, which are available in improved and gradually adjusting quality and dropping in the price of hardware. They are, thus, more economically feasible.

Last but not least, it should be mentioned that the government of the Federal Republic of Germany has made large amounts of money available to mechanical engineering firms in recent years in order to speed up the diffusion of CAD technology, particularly in small and medium-sized firms. From 1984 to 1987, these firms received as subsidies up to 40 percent of the costs involved in the introduction of CAD.[1]

## III. Concepts on the Employment of CAD and Their "Logic" from the Perspective of the Firms

The first important result of the survey on the present types of employment of CAD that were discovered during the investigation is the fact that the firms develop and utilize various concepts of the usage and arrangements that have to be met respecting the organizational integration of CAD in existing structures. Three brief case descriptions should make this clear. We have not chosen the firms to be used as examples randomly, but rather have selected those that afford insight into typical introduction constellations and employment strategies.

Firm A is a firm which designs and manufactures machine systems for steel mills. It has 2000 employees and can, according to our experience, be considered a typical representative of the current mainstream found in the West German machine construction industry that can be used to illustrate the way CAD is introduced and used and the consequences for work arising from the new technologies. CAD was first introduced just four years ago, and the still relatively limited capacities are being only hesitatingly enlarged. CAD is mainly employed to make drawings for the workshop, and the majority of those working with CAD are draftsmen. The CAD workstations are used by several employees for whom the work with CAD makes up only part of their overall jobs, i.e., they continue to also carry out tasks "conventionally" on the drawing board. We will refer to this mixture of tasks and work from now on as hybrid work. The operating times are divided among the various users according to a schedule. The users utilize CAD to solve their "own" tasks, i.e., as a rule those

[1] Of the total DM 610 million granted by the Bundesminister für Forschung und Technologie's "Programm Fertigungstechnik" in the years 1984 to 1987, DM 369 million alone were granted for the "indirect, specific" support of the development and introduction of CAD/CAM systems in the firms. Subsidies were given to 1285 projects in this area [5].

tasks which have been assigned to them in the design team to which they continue to belong.

In Firm B, an affiliate of a general mechanical engineering enterprise with approximately 500 employees, the utilization of CAD is likewise not very developed. In this case, however, according to the management's plans, the goal from the very beginning was to integrate the computer into the total system of production and filling of orders. CAD is understood and conceived as a constituent of this system. The employment of CAD in this case does not begin in the area of routine technical drawing, but rather commences from "above" and is used to solve the more difficult problems of conception and design. Accordingly, the engineers are among the first users. In this case we also find a mixture of various tasks and types of work, and the few available workstations are used by different members of the staff.

Firm C manufactures machines used to process synthetic materials. It has approximately 800 employees and has in just a few years furnished its design sector extensively with computers. There are no more drawing boards in the design department. The CAD display screens constitute the central work element for all of the designers and technical draftsmen. Traditional forms of the division of labor and cooperation (teamwork) still exist, but they exist on the basis of the new technology.

The three case descriptions verify how different the strategies of use and the resulting forms of organization and work in engineering firms can be. Firm A represents, as stated above, the currently dominant constellation found in the firms we investigated. The essential characteristics of the way CAD is employed in this "mainstream" firm are that CAD is primarily employed as an aid in working out plans for production facilities; as a rule, draftsmen are engaged at the CAD workstations; there is a work schedule for the CAD workstations since these are to be used by several persons and should be used continually and for as long as possible. Thus the traditional organization structures in the design office are retained (first and foremost, teamwork). A variation of this concept that, admittedly, is only relatively seldom met with is the total organizational segregation of a group of CAD users who carry out tasks for other design sectors ("service team").

A doubtless decisive and important argument, from a firm policy standpoint, for the legitimization of this concept of use is the assumption on the part of the management – and above all in the eyes of the superiors in the design department – that an employment of CAD which in the beginning is limited to working out preconceived solutions would lead most likely to rationalization effects and allow continual utilization of the expensive system. In addition, we have to consider the circumstance that firm A – which is also in this sense typical of large areas of the West German engineering sector – is a single-piece producer and, accordingly, the designing takes place essentially simultaneously with the process. As it is, thus, in any case functional element of the fabrication of each single product, the total lead time of the single products depends to a large extent on the time necessary for its designing. Shortening the lead time, which is an important rationalization target, in order to beat the competition on the relevant terrain of "readiness to deliver," seems likewise to be most easily attainable through a speeding up of the so-called routine functions.

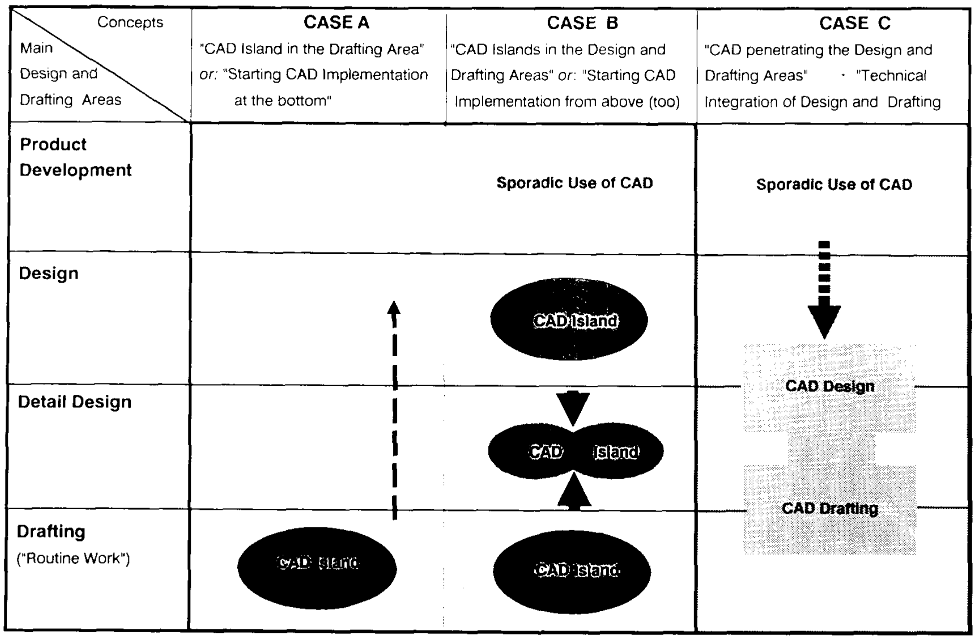
However, these varieties in concept do not coalesce into rigid forms of organization where future technological and organizational development must take place within set barriers. In fact, it is possible to observe "learning processes" in some of the firms. For example, the borderline marking a type of utilization of CAD is sometimes, so to speak, spontaneously crossed by some "courageous" users in everyday practices. This is, first and foremost, made possible by the relatively free access to the computers by various operators solving various problems from various fields, i.e., hybrid work forms. There are also examples of an organizational development of the concept variant "service team" to that of "hybrid work forms." The former (service team) is sometimes even used consciously as a transitional solution during the introductory phase of CAD.

In the case of B and C, which both produce series, other technological and economic frameworks are significant for the design work. This particular design work can sooner be characterized as development work which is done for a specific production program. This work normally takes place before the product is produced and is principally finished before the program is mature. In this case rationalization in design departments is, to a much smaller extent than in the case of single-piece production, a contribution to the reduction in lead times. It appears as though this leads to a greater "degree of freedom" during the establishment of fields of application and organizational forms of computer use in the preparation for production. This is expressed, above all, by the fact that the use of CAD, should it not have its starting point here, will be very quickly developed in the core areas of the "actual" design work – the design to scale of the product, even if this manner of proceeding at first seems to hold greater uncertainties than the pure "drawing solution." Even in product development functions – so to speak "above" the design to scale – there is sporadic use of CAD in the cases of B and C (see Fig. 1). The continual use of CAD systems to capacity is also not placed in the foreground as strongly by department heads and organizers as in the other firms. Such organizational leeway in the structuring naturally depends a great deal on the general economic situation and capacity of the firm.

Aside from the fact that such forms of CAD employment are usually found in series production, it is typical that in such firms the data-processing department has a strong position and decisively influences the introduction of CAD. The particular tenacity and dynamics of the introductory process are also partly explained by this. In addition, the plan from the very beginning to try to overlap and tie the departments together on the basis of data technology can ultimately be traced back to the powerful position of the data-processing departments within the firms.

In Fig. 1 the CAD implementation concepts are summarized.

Besides the areas in which CAD is directly employed in order to solve designing problems – the areas that the techno-




Explanation: Until now in Mechanical Engineering there has been little Use of CAD in the Process of Product Development.

Fig. 1. CAD implementation concepts in mechanical engineering.

logical and organizational structuring of the above-described usage concepts are based upon – additional, new tasks arise as a result of the introduction of CAD. CAD systems are, indeed, usually bought as standard systems, but getting them to "work" effectively is relatively complicated. It requires, first and foremost, the creation of data banks; an appropriate systematization of the design procedure; the choice, care, and constant adapting and updating of hardware and software for the firm specifically; and, last but not least, training employees to use the systems.

Some of the new functions that will have to be carried out for an "indefinite" period of time are delegated to people working in existing departments in the firm (above all, the data-processing department). However, there always remains a central core of tasks that demand new, specific knowledge, and the firms assign these tasks to a new group of employees who do not employ CAD themselves but rather must see to it that it is used efficiently: the *CAD experts*. These are mainly recruited from outside the firm and frequently as a direct consequence of the introduction of CAD. Usually they are young graduates from technical colleges and universities who have, as a rule, studied mechanical engineering. They also have additional qualifications in the area of computer science and knowledge of the CAD programs and other computer systems available on the market at the time. On the other hand, only rarely have they had any experience in designing departments.

## IV. Interests and Options of the Employees

We touched above briefly on another important determining factor that affects the technological and organizational structures: the interests and options of the employees in the firms. On the management side, the question as to the direction and dynamics of CAD utilization seems to be the most important in determining whether the sectorial middle management (heads of the designing departments) or the data-processing specialists get their own way or go together with the top management and are, thus, able to strongly influence the establishment of the utilization concepts.

For many chief designers – and it is they who play the decisive role in the introductory process – rationalization of the "routine jobs" and the creation of working drawings are clearly the first things that influence their motives when introducing CAD. They frequently consider drafting and planning to be the central, "creative" work process for which at first it does not seem to be possible to efficiently and directly employ technology. Their career backgrounds – usually they are engineers who in the past worked themselves in the design department – causes them to demonstrate solidarity with the more highly qualified employees who have similar opinions. The new technical possibilities should help make the drawing of the mechanical drawings more efficient and faster; at the same time, the "routine jobs" should be more clearly separated from the tasks carried out by the design engineers so that they can better develop their innovative potential.

Such behavior-determining viewpoints obviously support one or the other variations of the presented "mainstream" models when the organization is determined. This is at first hardly affected by the sometimes nearly contrary opinions of the CAD experts in the firms who gain their position during the introductory phase, as we have seen above. They do indeed often mention the opinion that the new technology is an exacting aid for the work of highly qualified users (designers/

engineers) that can only be used really efficiently by them, i.e., utilizing the full technical potential. But their precarious position in the firms as externally recruited experts, who are frequently recruited directly in connection with the introduction of CAD, means that they have no great influence on the firm's policy in the beginning unless they receive the necessary support. This forces them to take a pragmatic attitude and stick closely to the firm's instructions.

The situation is different, as already indicated, if one – as was indeed atypical in the case of the small and medium-sized mechanical engineering firms – meets with solidly established data-processing and organization departments that have a strong position in the firms. These departments, it is true, work together closely with the specific technical departments, but their work transcends the specific sectors; thus, they are in a position to plan the data-processing procedures themselves. The CAD expert teams in this case are employed in the data-processing departments; they are not, as in most cases, a small staff established within the production planning sectors. A constellation like this seems from the management standpoint to correlate, on the one hand, more with the early realization of network plans (e.g., CAD/NC integration) and, on the other, with a more determined utilization of leeway in structuring the organization.

How do the technicians and their representatives in the firm react to the rationalization process and the concepts of the management? Here we are confronted by an ambivalent situation. On the one hand, at least certain groups are by no means merely "concerned," but are rather motivating moments in the change themselves. Their help is an important prerequisite in reaching the rationalization goals because the lengthy implementation and development phases of CAD make their participation necessary. Within the framework of these requirements it is indeed possible to represent their own interests. On the other hand, such "uncontrolled codetermination" hardly touches the major lines of the management planning and remains restricted to a mere individual interest perspective. In addition, by no means do all groups in the technical offices have the same chances to participate.

The workers' councils, finally, do not seem at the moment to have established an adequate course for their policy when representing the problems of the technicians. Their activities are, with few exceptions, characterized by an uncertain and mainly wary attitude towards the introduction of CAD. The "participation" in the introduction process remains, as a rule, limited to a more or less passive acceptance of information given out by the management about the planned measures. The direct influence of the workers' councils on the realization of the employment concepts and the organization of the work thus remains very limited in the case of CAD – as in the occurrence of other forms of technology.

## V. Personnel Cuts and Deskilling? A Warning Against "Simple" Theories

The effect of the technological and organizational changes on the professional qualifications of the blue-collar and white-collar employees as well as the amount of endangerment for workplaces and the resulting "rate of dismissal" is traditionally the focal point of interest in the debates carried out by the public and industrial sociology. The loss of jobs through technology is now at least conceivable in the case of employees in the designing departments. This is certainly a new situation for technical employees. However, until now in the wake of the introduction of computers in the technical offices only those jobs that where occupied by "marginal" employees – usually women (typists, helpers) were done away with. The actual specialists have been spared until now; even more, the growth of this group has, in some cases, clearly overcompensated the loss of jobs in other sectors of production planning and preparation. In fact, the number of draftsmen – in other words, the professional group most affected by the employment of CAD at the moment – increased slightly once again in the 1980's.[2] It is also questionable whether – at least in the near future – jobs will be lost in development and design offices as a result of the employment of technology.

On the other hand, as far as the presumable direction the changes in the required qualifications will take in the sector employing technicians as a result of the increasing use of CAD is concerned, relatively clear and oversimplified assumptions were made at an early date. If one ignores the opinion of those engineers who are themselves involved and interested in the technical development in question and with hardly an exception have predicted that work in designing offices will become even "more creative" because of being freed of "routine jobs" and thus will result in generally higher qualifications thanks to CAD (cf., e.g., [7, p. 26 ff.]), the pessimistic prognoses have definitely outweighed the optimistic ones in the wake of the popularity of Bravermann's theory [8] on the "degradation of work."

It was in particular Cooley [9] who soon pointed out the dangers connected with CAD, saying that as a result the technical offices would also be afflicted by Taylorism, which would naturally lead to a drastic deskilling process in the offices. In this case, it was first and foremost the directly affected and politically motivated trade unionist who spoke up and wanted to awaken his audience through his message and move them to take action because of the negative brisance contained in that message.

Our discussion to this point should have made it clear enough that firms can employ CAD in very different ways. It is impossible to speak of a uniform development of skills for entire professional groups or even all employees working in design, something not a few observers seem to presume. Instead, the way in which the requirement structures for the individual types of task (designer, detail designer, draftsman) change depends decidedly on the above-described organization concepts existing in the firms and not primarily on the particular characteristics of the new technology.

Without a doubt, however, a few general characteristics of CAD technology do exist that directly affect the required skills and give them, at least, new contours. Thus, before we turn to the specific changes in the working conditions of the various occupational groups concerned, we would like to make a few

[2] The number of draftsmen in the whole West German metal industry, which along with mechanical engineering includes the automobile and electronic industries, has increased by 2400 from 1980 to 1986. The total number then was 57 800 (of which 27 000 were women) [6, p. 27].

remarks on the "organizationally neutral" effects of CAD with a view to the skills that are demanded.

A number of elementary prerequisites respecting the work behavior of the entire design staff grow out of the fact that the design work is basically "abstract work." The processing of real objects is not the focal point of the work, but rather the creation and presentation of new products that do not exist materially as of yet, will be produced later, and in the production of which the designers and male and female draftsmen are not directly involved. Nonetheless, however, these products are the dominant subject of their work. Thus, the existing temporal, spatial, and material "gap" between the worker and the object of his work must be "bridged" or reconciled: reconciled in such a way that the worker can cope cognitively with the "gap." In order to do this, as is well known, special forms have been developed to reconcile this gap; the mental production process in (mechanical) design takes place in the abstract world of engineering draftsmanship with the help of an extensive, analog geometrical presentation of the product.[3]

It is these specific forms of "reconciliation" between the worker and the object he is working on that are directly affected by the employment of CAD. To put it briefly, the relationship of the (altered) abstract presentation to the subject of the work (work object) changes when working with CAD, as well as the instrumental execution of this presentation. This has consequences regarding the cognitive demands on the staff. The studies made by Wingert *et al.* [10] and Muggli and Zinkl [11] did supply primary findings and incentives on which further analysis can be based. They "translate" the above outlined subject essentially into two concrete ways of posing the problem; the demands on the spatial powers of the imagination and the entire complex of "dealing with the new technology" and the qualifications necessary to do this.

Accordingly, there is a great demand on the spatial powers of the CAD user's imagination: in the first place because of the smaller picture on the screen in comparison with the much larger drawing on the drawing board and the resulting limited possibilities of grasping the total picture at any given time of the object being designed and, thereby, a precise idea of the proportions.[4] This is true in the case of the currently common two-dimensional CAD systems. Three-dimensional systems, which today still hardly find any productive use in mechanical engineering, will indeed – as Muggli and Zinkl suspect – make the presentation of the product "more graphic"; however, the process of "working on" the product model by means of the computer leads to a drastic change in the conventional methods of working, which likewise implies an increase in the necessary spatial powers of the imagination. Regarding the second problem, the studies to hand have observed a shift from such "manual" skills as are necessary in order to produce a clean, exact technical drawing to the "technical know-how" that is required to operate the system [11, p. 107]. Such a paraphrase remains, however, much too superficial and unclear. With interactive graphic CAD programs, the microstructure of the design activities changes as Wingert *et al.* have worked out. Their use means a switch from the relatively unmediated activities at the drawing board and on paper that are directly perceived by and connected with the senses to a state of being "confined" within the command structures of the program system. These "commands" must be "employed" consciously and deliberately; they intervene, as it were, between the intention and result of the activity. The system allows, at the same time, design steps very similar to those carried out before, but now they have to be done differently: by "applying" given commands. Wingert *et al.* have called this the mediatization of the design work. It is this point that CAD experts, as well as CAD users, refer to when they say that design work has become "more abstract."

## VI. Changes in the Division of Labor and New Forms of Stress

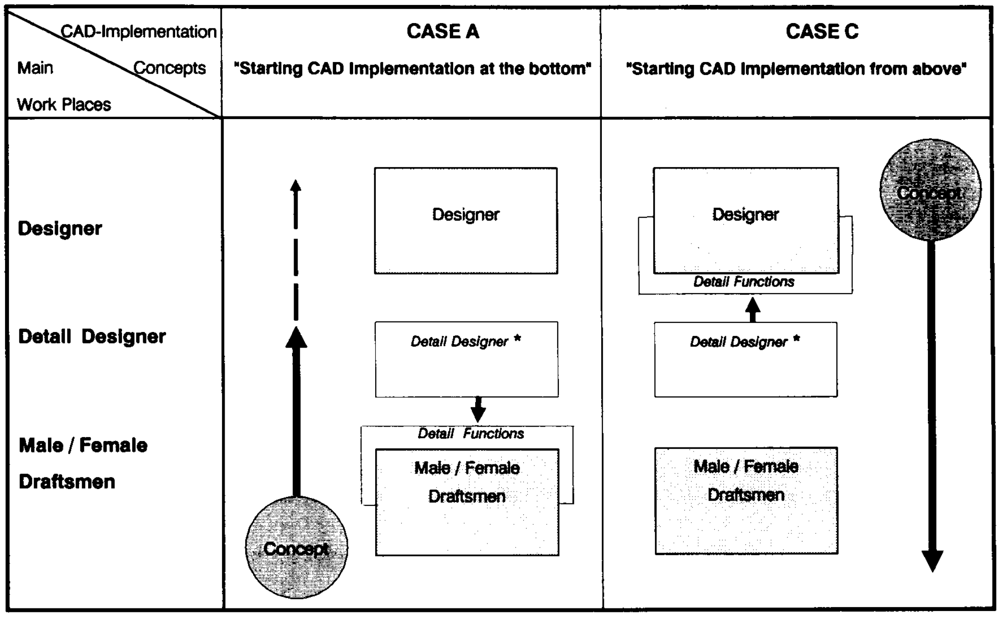
The dynamics in the areas of work, qualification, and stress structures has, in addition to the new technology, other, even more important sources: the sales and product strategies, as well as the connected variations of different concepts of the use of technology and organization found in the firms. The latter tie the ensuing work functions to particular jobs or types of activities with corresponding skill and load profiles. The general development of the working conditions for the technicians is thus in the end greatly dependent on the firm's concepts of use and the resulting specific use of the technical possibilities.

The employment of CAD affects the functions of design and drafting. What is meant here is the determination of the dominating characteristics of the object that is to be constructed; its presentation in the form of a design to scale; and, based on this, the establishment of the details of these elementary characteristics (using, if necessary, once again a detail design to make it more graphic); and, finally, putting together "readable" documents suitable for the needs of the production process (drawings, lists of items) that can serve as information for the final production of the products. The "middle" function of determining the details of the already existing design, in other words the precise and final establishment of diverse parameters at a level in which the product is broken down into its various components, will now – according to our empirical findings – fall largely in the realm of CAD. Tasks that would traditionally take place prior to or following this "middle function" are so restructured that it is hardly possible to build up an independent area of work on the basis of the remaining "rest in-between" these task – that of the detail designer. The widespread three-tiered division of the design staff into designers, detail designers, and draftsmen is thus questioned. The possibilities arising from the employment of CAD indicate that the "middle" function, which has been carried out by the detail designer until now, could be passed on to the designer or draftsman, making the detail designer dispensable.

Diverging trends become apparent depending on which of the concepts of use described above are found in the surveyed

[3] The development in electrodesign was quite different. In this case, the subject of the work has always been to show how abstract functions are tied together. This is demonstrated by means of symbols (e.g., circuit plans). As a result, the switch to CAD should be "easier" to manage in some respects in this field of design (and should be easier for the employees as well).

[4] It is symptomatic that the usual practice found among CAD users is to have the interim results of their work printed out as large-scale drawings and to use these drawings to support their powers of imagination.




* Detail designing no longer constitutes an independent job.

Fig. 2. CAD implementation and its effects on the structure of jobs in the field of design.

firm. This can once again be demonstrated on the basis of the chosen examples from among the firms. In firm C, in which the designers already develop their plans and designs directly on the CAD screen, they also in the meantime carry out many of the earlier "detailing functions." As the new medium has, as it is, on the basis of its more or less standardized geometric elements, a high degree of exactness and precision in its presentation, only a small amount of additional effort on the part of the designer is needed in order to establish the design parameters well enough and exactly enough so that additional detail work in the old sense is hardly necessary anymore. The draftsman is left with the task of "extracting" details for the detail drawings from the draft and supplying them with the information necessary for production. Their new task at the CAD workstation remains, thus, regarded from the viewpoint of extent and type of job that is to be done, quite similar to the earlier "conventional" task.

Another development seems to be unfolding in firm A, where CAD was first used, in contrast, to develop production drawings, and this will remain the main focal point for the time being. In this case, therefore, the detailing function is part of the task of developing production drawings. Otherwise it could result in considerable "double work" for the detail designer and CAD draftsman because the latter has in any case to convert the instructions for the detail and compilation drawings into CAD geometry, regardless of how precise his instructions already are. In contrast to firm C, the final draft and detail work are growing together, above all because the development and design stages are still largely ignored when CAD is used. In such a constellation it is still possible, on the one hand, for the draftsmen working with CAD to enlarge the spectrum of their activities and raise them in quality and, on the other hand, for this work to be taken over by the former detail designer, for whom this would signify a kind of demotion. Accordingly, it is possible to formulate the following hypothesis on the correlations between concepts of CAD use and the resulting task structures: the intermediate design function of detailing is subject to a kind of "magnetic force" when CAD is introduced that can take several directions according to the firm's particular concept of use. If CAD is introduced "from above" (design), then the force also works upward and ensures that there will be a relative preservation of the area of work carried out by the draftsman. If, on the other hand, the starting point begins "from below," which was the case in the majority of the firms we investigated, then the force works in the other direction – in other words, downward towards the development of the drawing and possibly, as a result, the draftmen may have the chance to take over more demanding elements of the work. This discussion is summarized in Fig. 2.

We have consciously spoken of the emerging trends. At the level in which CAD is generally employed at the moment it is possible to find them; however, they do not cause any drastic and radical changes in the work situation. The individual tasks still have to, in any case, be characterized as forms of skilled work. For this reason, the aspect of qualifications does not dominate in the concerned technicians' perception of the changes. For them, rather, the dimension of stress is clearly in the foreground, and that indeed is seen as a clearly negative sign.

The dominating way CAD is employed – represented by firm A – is marked by two characteristics: 1) "hybrid work," i.e., the CAD users continue to also carry out design tasks "conventionally" on the drawing board; and 2) personnel scheduling, i.e., "timetables" for the CAD workstations in order to guarantee their uninterrupted use. This has two important consequences for the users' stress burden. On the one hand, it results in frequent situations that require adjustment and getting used to the new work situation in which a high degree of concentration is necessary. On the other hand, the rigid limitation of the time available for use makes relatively precise planning a must and forces the users to carry out the work as fast as possible at the terminal, an aspect that can lead to a general psychological and cognitive overtaxation.

In firm C, on the other hand, such moments of stress, induced by the organization of the work, are done away with to a large extent. There is no longer any "hybrid" work and each worker has his "own" screen. Instead, in the foreground we find forms of stress that can be traced back directly to the "medium" employed in the work, CAD itself. CAD seems to have a kind of "magnetic effect" that, irrespective of the explicit or implicit demands made by the firm on the individual workers regarding their work at the terminal, results just the same in a spontaneous intensification of the work (cf., e.g., [12]). The more the work at the CAD workstation takes on the shape of more or less routine work, the more this form of stress becomes oppressive. It is obvious that the circumstance of having one's "own" screen at one's own disposal, if there is no strict control of the rate of utilization, can lead to the employees at least being able to individually regulate and temporarily alleviate to some extent the stress effects resulting from working with CAD. The CAD users working in the firms classified here as including the organizational type "service team" are, in contrast, continually and directly exposed to this type of stress.

In addition to the above-mentioned aspects of the working conditions, which differ in their characteristics according to the type of utilization exercised, there are also general aspects in the development of the way the work is organized that are likewise not determined by technology. Thus, there is a tendency in almost all of the firms to take advantage of existing flextime regulations so that they can stealthily introduce shift work at the CAD workstations where it did not exist before. Since, as a rule, there is a consensus among management, workers' councils, and CAD users that this capital-intensive equipment should be used as extensively as possible, the firms can usually employ this tactic under the premise of allowing the user to regulate the working hours at his own discretion. This procedure furthers the acceptance of the new regulations governing the working hours and can eventually even be expanded by the firm until an efficient double-shift utilization has been established. Thus, without the firms having to pay the usual bonus for shift work common in the production sector, design work can become shift work – with all the well-known negative health and social effects.

Another common characteristic of the variation in the structuring of the organization is, as has already been pointed out, the widely found gap between CAD utilization and CAD development. One has to ask what this type of separation will mean for the work of skilled designers in the long run, especially as the programming is becoming continually more intensive. It could result in the work of the designers also becoming more drastically schematized, and the leeway they have for solving the design problems could be restricted by the CAD programs themselves. In connection with another rationalization strategy that can be observed in the case of single-piece work and customizing this could lead in a further development to a certain narrowing of the contents of the designers' work. In some of these firms, they are thinking of improving initial designs, which are used by the single-piece and custom manufacturers to define the product as precisely as possible together with the customer (and his own design), by means of a qualitative strengthening of the employment and integration of CAD so that they would be in a position to really carry out this task properly.[5] The "actual" designing of the product could then, under certain circumstances, be cut back to the level of specifying the already more or less defined order, defined on the basis of CAD data banks. Although the designers would retain their technical skills, their work will be confined to a segment of those job functions that had until now been characteristic of their broad range of skills.

## VII. Summary

1) The crucial areas in which qualified patterns of work are found in design are also found to a large extent when CAD is used, at least according to a first, superficial glance. The new tasks that result from the visible changes in the product – independent of whether CAD is employed or not – are combined to form new jobs with relatively high qualification requirements and added to the already existing jobs in the field of design (e.g., "software designer"). Less frequently found types of jobs such as that of the mere drawer and data typist disappear, or clearly lose their quantitative weight.

2) If one looks more closely, there are important shifts in the seemingly preserved crucial area of the qualified jobs. The work of the detail designer loses, as a result of the above-mentioned precision of the design drawings made with the help of CAD, the capability of constituting its own work sector. It is true that the job does not disappear entirely, but it is likely that the remaining functions will be passed on to designers or draftsmen.

3) In addition to the modified, reproduced crucial areas of work in design that are concerned with the product as their subject, there are also additional technical experts whose central task lies in the implementation and continual modification and further development of the CAD systems. By means of application programs, they could in the future have an indirect influence on the way the designers and draftsmen do their work. Furthermore, there is a tendency to assign standardizing and systematizing tasks to these experts.

4) Recruiting patterns and personnel structures are gradually changing. University graduates (mechanical and electrical engineers) coming from outside the firms, i.e., "intruders," are given good positions and are gaining importance both in new areas in design and among the staff of CAD experts. On the other hand, it would appear as if the traditional design career ladders are losing their significance. There is an increasing development of new fields of work which the "empiricists" in the firms cannot simply grow into because

[5] Here, too, it is clear how important it is to differentiate according to the type of firm or production. In the case of the series producers, the problem hardly plays any role that forces the single-piece producers and those producing custom work to produce a design that they present when they are making an offer; as a result, the same applies to the briefly sketched lines of rationalization.

they demand higher or theoretical, academic qualifications that were not demanded by the traditional design jobs. The result of the general increase in "scientific methods" in the entire production process is noticeable here. In all probability, the traditional promotional ladder for the engineering draftsman, which gave him a chance to work his way up to the position of a designer, will be blocked as a result of the tendency to do away with detail designing. The borders between "detail work" on the "end products" of design and the "actual" design threaten to become less transparent.[6] Counteracting this tendency could indeed by the continuation of the dominant forms of teamwork in which there are more or less inherent possibilities of gaining an increase in knowledge through comprehensive tasks and, thus, higher qualifications.

5) Until now there has been no mention of a further line of rationalization that can hardly by underestimated and is beginning to develop parallel to the use of CAD. It is now possible in connection with an already familiar form of "self-checking" (noting down the amount of time spent on certain design tasks) to increase the control over the work of the technical staff with the help of computer-supported organizational techniques such as PPS and production data capturing [14]. Transparency and the possibilities of planning work procedures no longer require detailed research and constituting each individual work step, something that would be much too time consuming and costly in the complex work areas considered here. The new organizational techniques lead to the same goal in a clever, more or less indirect way: the essence of the contents of the individual task no longer have to be exposed in order to be able to plan and control their temporal sequence by means of setting up time limits on the work. The high qualifications which are required and the relatively exacting control over the tasks evidently do not have to be a contradiction, as would seem to be the case according to the expectations in the Tayloristic hypotheses [15].

These summarized findings make it clear once again that the introduction of computer technology in technical offices is by no means followed by a one-dimensional Taylorization and deskilling logic. The complexity of the task function in modern design offices and the way in which they are clustered to make up certain types of jobs prohibit speaking of an "expropriation" of the technical and organizational knowledge of the people working in the offices that would affect them in their substance. It would be equally wrong to see the creation of new task functions solely as the result of the separation of conception from execution. It results, instead, in a variation of the old types of tasks and differentiation regarding the "collective laborer" in technical offices through the development of new types of tasks, and finally in stricter controls.

[6] This result seems to be true of the entire production planning area. The existing strategies of setting up computer nets, e.g., for CAD and NC programming systems, try to ensure that the tasks will *simultaneously* run smoothly *and* that the specific complexes of tasks are kept separated. In a consciously overstated, exaggerated position in opposition to the common ideas on the *technical* integration of computer systems (which equate this with the integration of tasks and the intensification of cooperation between the system users), we have in another instance spoken of "integrated specialization" and segregation of the areas of tasks concerned [13].

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