It seems that the subject of "Labour-intensive Assembly Operations" as a contribution to the "Factory of the Future" includes some contradictions - at least, however, it gives the impression as if this subject is not quite opportune at this conference. Such catchwords as the "factory of 1990, 2000 or 2001", or how they may be called, are all too readily considered to be identical with the whole spectrum of automated production equipment ranging from the industrial robot via carriers to the flexible production centres, or in the indirect field, to all these C's such as CAD/CAM CAP, CIM a.s.o.. So all too often the impression goes the round, as if each enterprise could find its future only in the total automation.

In this connection, however, it must first be contemplated how today's reality looks like in the majority of all production plants. Only then will it be possible to make any cautious prognoses as to what the situation in the "Factory of the Future" might be. On behalf of the Federal Ministry of Research and Technology, several institutes tried to find this out by commonly conducting an "assembly study" in 1983, in which they probed the possibilities and limitations resulting from the automation of different assembly operations /1/. In this study, they came to the conclusion that it would be possible until 1992 to replace about 170 000 to 250 000 assembly workplaces in industry due to technological changes or automate assembly machines of different kinds. They found in this connection that of the 655 00 assembly workplaces estimated now-a-days in industrial series production, a maximum of 250 000 workplaces were "capable of automation". But at the same time they also found that in this "potential" even more than 400 000 assembly places will be retained, at which men and, increasingly more women, will do the most varied manual assembly jobs.

If according to the far more realistic extrapolation, however, the maximum of this "potential of redundancy" was to be reached only in the year 2000, about half a million men and women will still assemble. They will still assemble even in fifteen years all the products whose requirements either are too complicated to the ever so intelligent automatic machines or simply of no interest due to the production quantity. Thus, also in the year 2000, there will still be so-called "labour-intensive assembly systems", by which, according to /2/, such fields of assembly are understood in which mainly the personnel has the main work to perform, and this has its good reason. The assembly operations of the majority of the consumer and durable goods still calls for physical and mental agility, which is generally also called flexibility. And flexibility is an essential property of a human being who is ready to fully purpose use his five senses. So, it is certainly undisputed that man still is the most flexible of all the "production factors", if he is ready to make use of his strength, and if he is allowed to do so. Today, it seems that nothing is so much required in industrial production as flexibility. Flexibility is the precondition of the production of the enormous variety of product types and variants and of the quickly changing models - features characteristic of our affluent market of today. If there are no revolutionary changes in this variety of products and their designs, then, it can be assumed that, at least in the final assembly, the working man will remain superior to machines also in the decades to come.

This understanding given, it would however have to be a matter-of-course that even today and just for these some half a million assembly workplaces, something ought to be done both with regard to investments to be made and also regarding the further-reaching promotional measures. For re-
Regardless of all sociological and economic considerations, it is also in the very interest of many enterprises, if labour-intensive production systems are not only regarded as necessity, but if a virtue is made of the "human resources". Hence, the necessity to invest also in labour-intensive assembly operations get increasingly been recognized by many future-oriented enterprises.

For us at the "Institut für Arbeitswirtschaft und Organisation (IAO)", these findings have also been a major impulse to think about "modular assembly systems", especially for such labour-intensive assembly operations. In many preceding projects dealing with the structuring of assembly plans, we had to find out that better technical tools were desirable for the implementation - the last stage in the manufacturing planning process. The putting together of approaches from production equipment catalogues often proved to be just as unsatisfactory as the procurement of special production equipment to be made for a specific purpose. So we found that a new modular system ought to be developed which in its possible implementation was as good as our conceptual planning results. Since at that time the market only offered a modular system /3/ especially designed for assembly operations oriented in and aimed at increasing automation. This was found at least not suitable for the customers attended by us. Fortunately we could win the Baden-Württemberg Ministry of Economic Affairs and a few small and medium-sized firms to speed up a proper development together with us.

All participants had different motivations. The fact that they were aiming at "more flexible assembly systems", whatever they understood by it, was common to all. With regard to their products, the structure, the quantities, and the variety of types and variants, there was one thing in common - the fact that automation or an appreciable higher mechanization of the final assembly could not be thought of within the near future and with the foreseeable technological development. Making assembly "flexible" could thus only be expected from the design of the interface between man and production equipment.

Conditioned by the selection of the participating firms, the scope of this project had to be reduced and limited confined ourselves to assembly systems for small-volume, bench-top-bound manufacturing of products under labour-intensive conditions, with the emphasis oriented at the special requirements of the precision-engineering and electronics industry.

In the course of a requirements analysis, a specification of the requirements was first prepared for each of the firms; these specifications were then compared and balanced in common sessions. Apart from specific detailed requests for the technical design of the benchtop workplaces and many other useful assembly system elements, it was above all found out that the modular assembly systems should feature the highest flexibility or variability on account of the difficult-to-forecast developments. Such things as variable division of labour, flexible interlinking, different and maybe changing forms of material supply, simple shifting of tools and fixtures, and the greatest possible reusability of all modules and structural elements were significant variables of the pattern of requirements.

These options had to be transformed into technical elements and optimum designs had to be searched or developed. Initially, functional modules, followed by prototypes, were developed for each element, and these were then discussed by the partners participating in the project. The process of refinement passing through several stages of criticism in all detailed designs resulted in a round, but open modular assembly system, which we called "Modulares Montagesystem (MMS)".

Now, what are the modules or system elements? Here, a distinction has been made between main groups such as workbenches, transport vehicles, roller conveyors, belt conveyors or other equipment. Figure 1 shows such a main group with a series of additional elements for workplace design. Further, sub-groups have been developed such as design and form elements, with an aluminium profil in the centre (Figure 2).

Profil or aluminium sections and sectional connectors constitute the "supporting structure" for a wide variety of conceivable system components developed under this project and used as useful examples by the