ENABLING TECHNOLOGIES FOR LARGE MANIPULATORS
ESPRIT II PROJECT LAMA

Dr.-Ing. M.C. Wanner, Dipl. Ing. W. Engeln, Dipl. Ing. K.D. Rupp
Institut für Produktionstechnik und Automatisierung
Fraunhofer-Gesellschaft
Nobelstraße 12
7000 Stuttgart 80
Germany

SUMMARY

Programmable and mobile manipulators with very large reach are vital machines in the construction site of the future. This paper gives an overview of the developments in this subject which started in 1986. With the ESPRIT II project LAMA the enabling technologies for large manipulators will be provided in a joint European effort. The technical difficulties faced during the development process and the solutions found in the recent years will be described.

1. INTRODUCTION

The first developments in the area of large programmable manipulators started in 1986 in the German national project "Hochflexible Handhabungssysteme" within the consortium Putzmeister, AEG, Dornier and Fraunhofer-Gesellschaft. The result was the mobile, computer controlled manipulator FH26 /1/. With this development based on more or less already existing H/W components major progress was achieved in the following sense:

- o The laws of physics allow in general to operate such machines with a practical accuracy and speed.
- o The approach to use already existing components developed for industrial robots was sound in principle.
- o With the existing Mock-Up FH26 it could be demonstrated which applications are feasible for such machines.

In 1988 latest it became also clear, however, that this approach can not directly lead into a natural evolution. Still major components were not yet developed or integrated in a proper sense. With the ESPRIT II project LAMA /2/ a marvellous platform was found to overcome the existing deficits in a joint European effort which involved the following organizations:

- o AEG Aktiengesellschaft as prime contractor and responsible for the robot control
- o MOOG Controls Ltd. providing actuator control H/W and S/W.
- o Putzmeister as H/W manufacturer and responsible for the overall system.
- o The Danish Technological Institute in collaboration with H.F. Jensen is developing specific sensor systems for large manipulators.
- o BERTIN from France is contributing with experience in the area of active control.
- o CASA Space Division in Spain provides lightweight actuators.

- o And last but not least the Fraunhofer-Gesellschaft with project management, specific S/W for large manipulators, testing and commissioning.

An overview is given in the following chapter.

2. PROBLEMS AND SOLUTIONS

2.1 STRUCTURE OF THE CONTROL H/W

With the FH26 we had a conventional AEG robot control 500 linked with analog PID-cards from MOOG mounted in the drivers cabin. With this approach the following drawbacks became obvious:

- o More computing power was required in general. In addition the link to the CIM-level via RS 232 was not satisfactory considering also possible applications in this context for the construction site.
- o We required a huge amount of electric wires as the valves and a lot of sensors were mounted directly at the cylinders or at the arm structure.
- o With the mix of digital position and analog pressure control the gaines became very difficult to adjust. More demanding control laws could not be implemented with the existing lack of computing power.

- o Error flags and diagnostics from the MOOG H/W could not be computed with the AEG controller.

The new LAMA system is shown in Fig. 1. More detailled information is included in /3/, here only the integration aspects are covered.
With LAMA a more powerful H/W on the system level becomes available with improved links to the CIM-level. In addition far more computing power is provided with the AEG LAR 830 on the centralized servo level (e.g. gain adjustment, outrigger control or control of peripheral components). The most important item is the so called SERCOS ring which provides a powerful link to the decentralized MOOG controllers (PSC). The MOOG PSC have to provide for the local system position and pressure loops for the actuator system, signal conditioning of the attached sensors, peripheral arithmetic operations as well as error and health monitoring. The master (AEG) communicates with the slaves (MOOG) via SERCOS in both directions in the preset cycle time of the master. Within this framework different combinations are possible to adjust the control H/W properly onto the given application in terms of costs and performance.

2.2 SPECIFIC CONTROL S/W

With the FH26 approach the S/W design on the system level of the robot control nearly remained unchanged. Specific modules as coordinate transformation were included in such a sense that only minor modifications in the mechanical design created new S/W versions and the wrist axes were included in a very crude manner as the control H/W was designed for only six axes. The control on the servo level remained on the standards of industrial robots.

With the availability of new control H/W new ways in S/W design became feasible. First the AEG improved their standard S/W in terms of communication to the outside, flexibility of the S/W to cope with the progress of new processors (INTEL 8086 to 80386) as well as error and diagnostic features.

The S/W of IPA on the servo level (Fig. 3) became modular. In addition new features in the area of online collision avoidance (more objects), position observer (compensation of the tracking error in a centralized approach), calculation of the deflection online with mathematical models or, more accurate, with the deflection measuring system from DTI as well as the load observer to cope with different load conditions at the TCP were introduced. The computation can be performed either in 2-D or 3-D. With macros from AEG the system can easily be calibrated.

On the servo level the far increased computing power allows to implement adaptive algorithms to control the axes with very different inertial parameters as function of the position. A possible, more simple scheme is shown in Fig. 4. With these more advanced algorithms it seems most likely that the performance (e.g. accuracy and speed) can be much improved.

Without a clear understanding of the physical behaviour each approach must fail on a long term. In order to deal with this problem the IPA developed a test system (Fig. 5) which is directly linked with the AEG controller via the DPM-VME interface. With such a system more than 50 physical parameters per axis can be heard online and the signals can be interpreted on a powerful computer H/W. Additional S/W from the IPK-Berlin allows the identification of important parameters like friction and moments of inertia. In addition the test system can be used to bypass the AEG controller in order to test algorithms prior to implementation on the industrial H/W.

2.3 SENSOR SYSTEMS

With the FH26 we felt the drawbacks of the lack of proper sensor systems to measure the significant deflection of the arm structure. In addition low cost anti-collision sensors were considered as most useful for the operator for such large manipulators. This drawback was leading to the work of the DTI and H.F. Jensen which is described in great detail in /4/.

2.4 MECHANICAL SYSTEM

With concrete booms a high standard in the mechanical design is already achieved although minor improvements in terms of increasing safety and even more weight reduction seems possible. For more general heavy duty applications however (workpiece or tool handling on the construction site) a huge variety of different applications exist. Here a modular system is developed in LAMA (see Fig. 6) by Putzmeister backed up by specific S/W tools to calculate not only the mechanical but also the hydraulic structure.

With the overall hydraulic layout safety requirements do not allow fundamental changes in the design, however also here a modular approach for translatory and rotatory axes was found in LAMA.

Some resources of LAMA were directed in an area to save weight for specific components. An aluminium and a Kevlar cylinder were developed and have to be tested if these components have a chance for these heavy duty applications.

3. CONCLUSIONS

The first industrial protoype coming from the described developments with much additional industrial R&D outside (in financial and technical terms) the described projects is the M24 /5/. With LAMA it can be expected that industrial evolution also with much more demanding applications is normal in some years.

REFERENCES

/1/ Wanner, M.C., Results of the development of a manipulator with very large reach, 5th International Symposium on Robotics in Construction, 1988, Vol. 2, page 653-660

/2/ Wanner, M.C., Large Manipulators for CIM, CIM-Europe SIG 7 workshop, 1990

/3/ Wunderlich, H., Flexible robot control for the building industry, 8th International Symposium on Automation and Robotics in Construction, 1991

/4/ Johannessen, F., Kristensen, F., Rasmussen, J., Position and anti-collision sensor systems for large manipulators, 8th International Symposium on Automation and Robotics in Construction, 1991

/5/ Benckert, H., Computer controlled concrete distribution, 8th International Symposium on Automation and Robotics in Construction, 1991

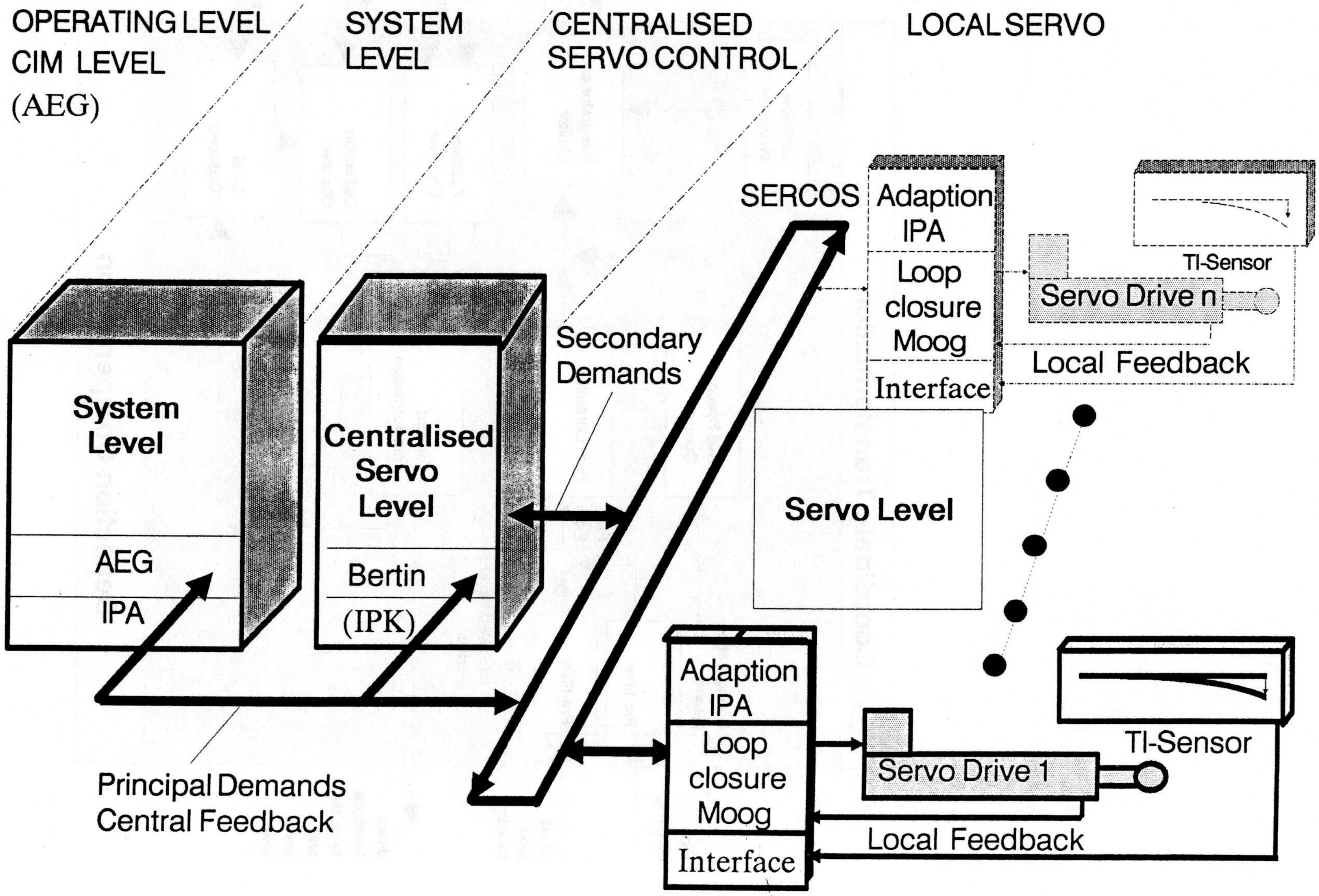


Fig. 1: Overall layout of the LAMA control scheme

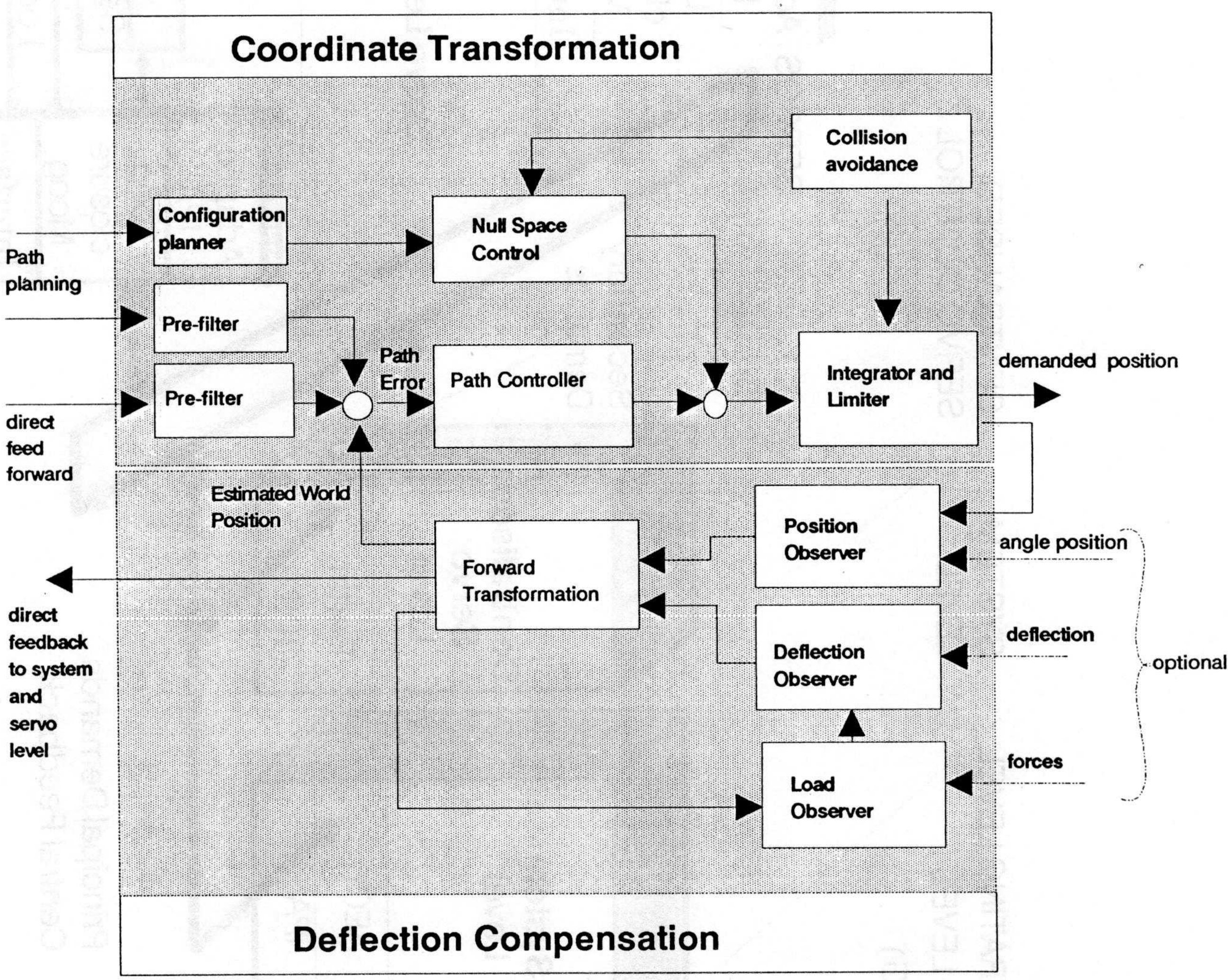


Fig. 2: S/W for large manipulators on the system level

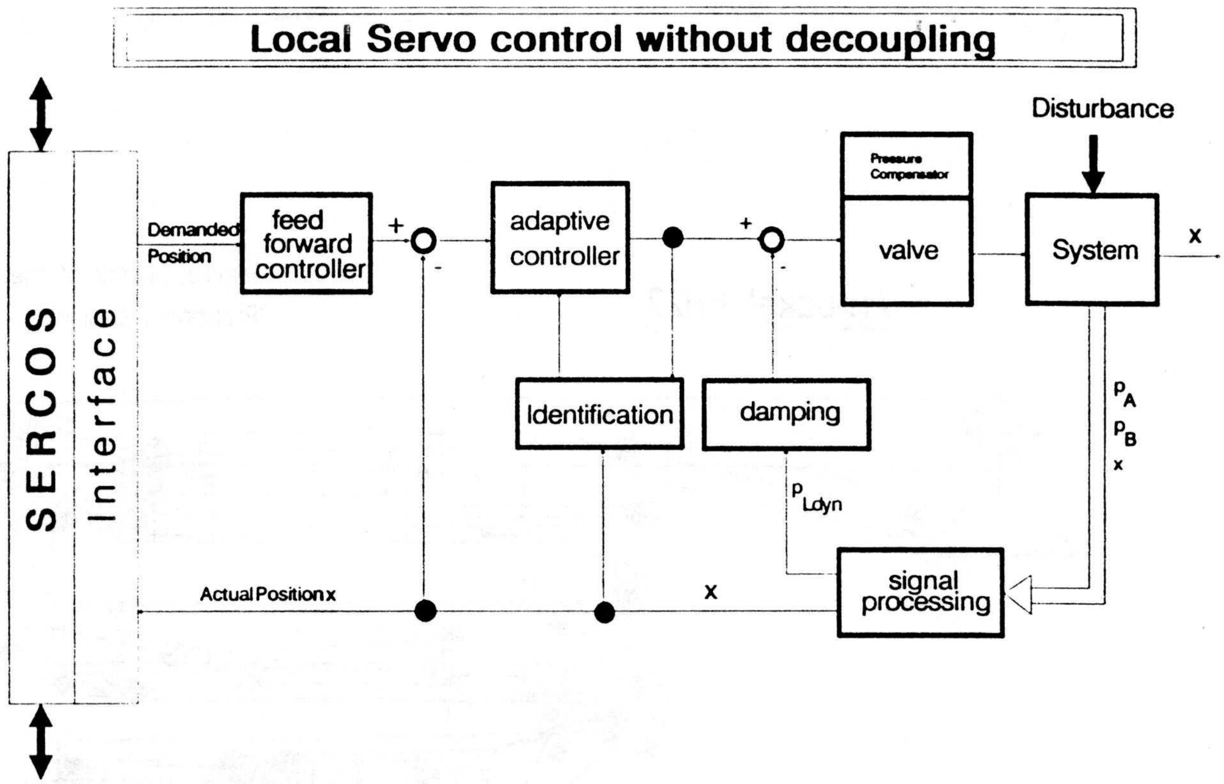


Fig. 3: Possible servo control scheme for LAMA

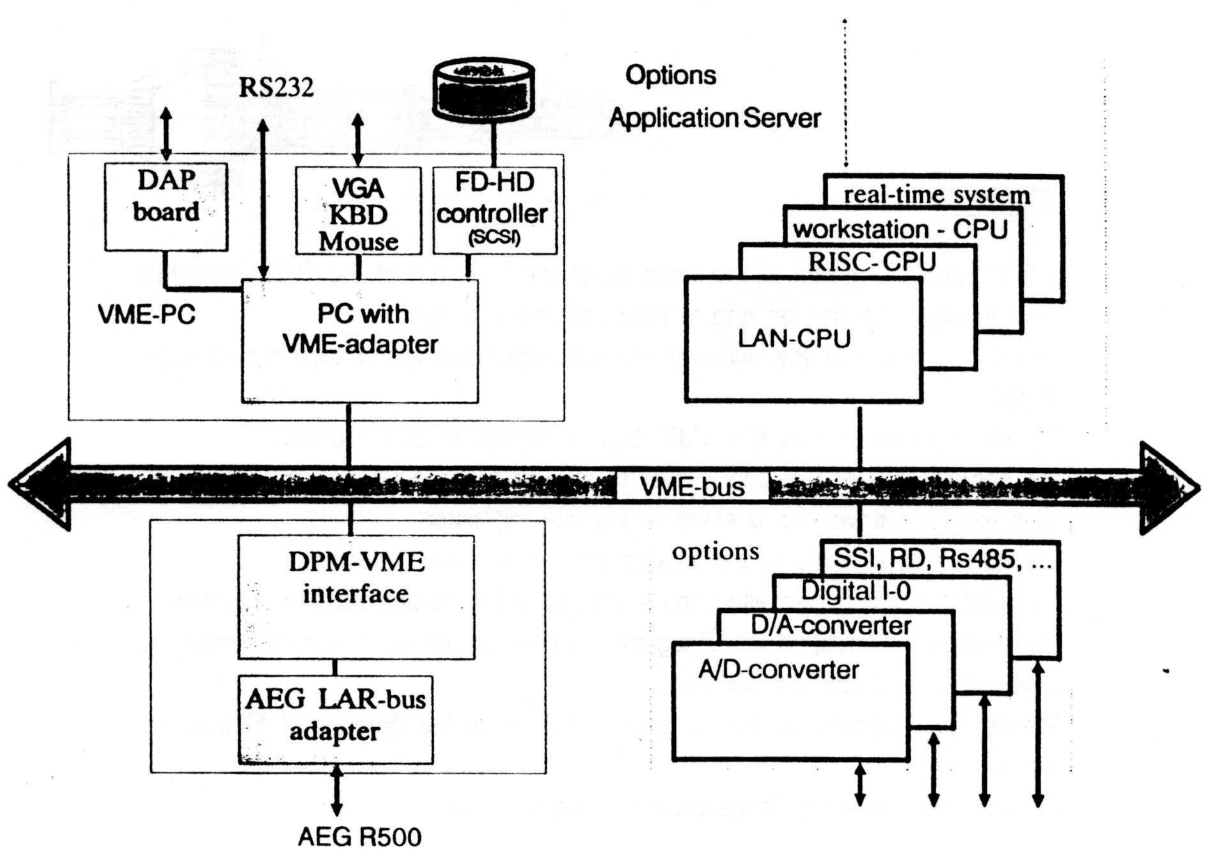
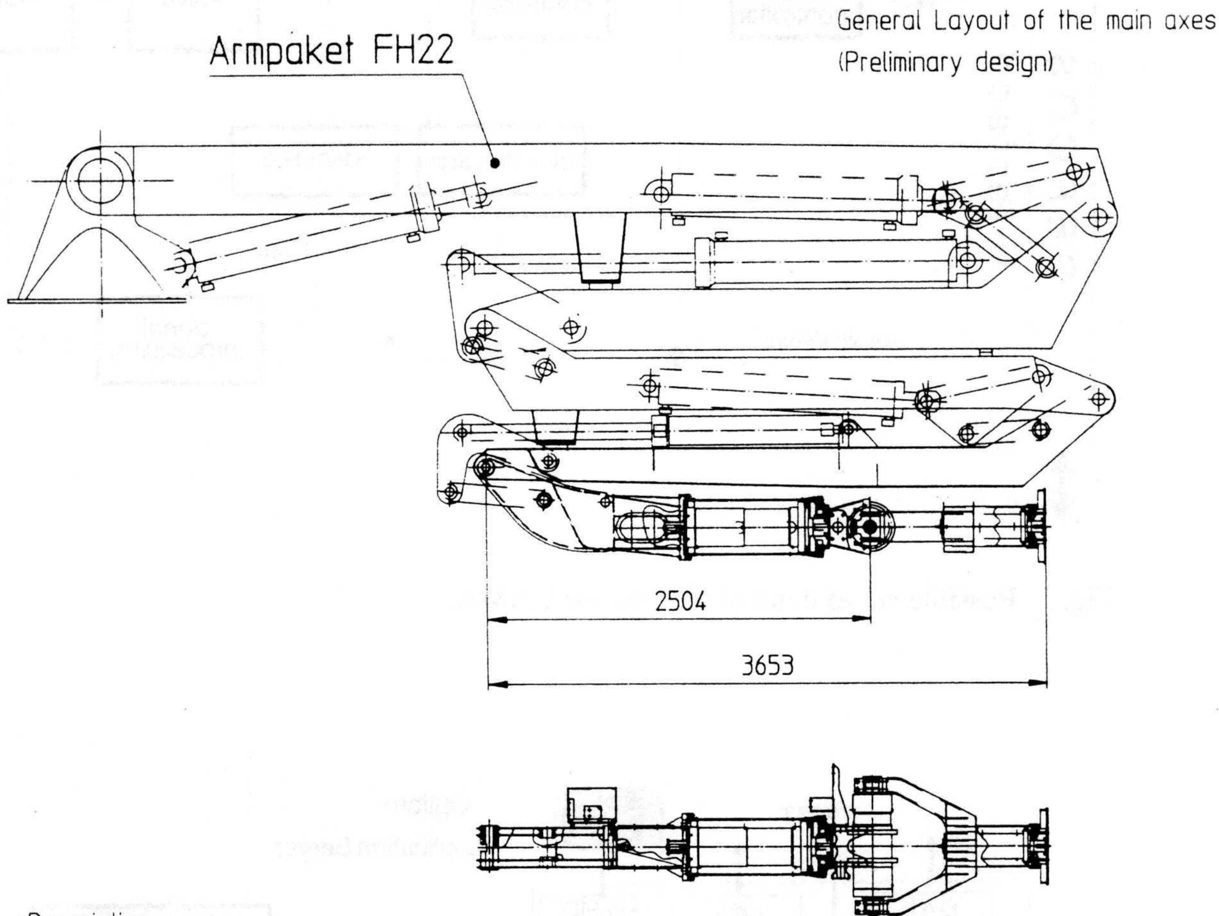


Fig. 4: IPA test and development system for LAMA



Description:

A 3 coordinate multijoint will be mounted at the 5 th. arm of the FH22. Therefore it is nesessary to shorten and to reinforce the 5 th. arm.
Axis C and axis A of the multijoint are the same level with a slewing clearance of 360°.
The slewing area of axis B is ±135° and is vertical to axis A and C.
The coordinate axes A,B and C meet at one intersection point.
All 3 axes are driven via a steeb thread slewing motor.
The clearance of angle at the slewing pin is max. 30 angleminutes.
The motors are equipped with control pins to drive the pathmeasuring system.
The multijoint is equipped with Moog proportional valves which are controlled via a manual control box with joisticks.
The net load capacity of the multijoint is 700 kg at the distance of 1000 mm to axis C.
At axis C is mounted a flange plate to take the tools.

Fig. 5: Heavy duty manipulator LAMA (Source: Putzmeister Werk, Aichtal, Germany)