THE DATA HANDLING SYSTEM FOR THE OMEGA AND THE SFM PROJECTS

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1. Introduction

The Omega and the Split Field Magnet (SFM) projects involve the construction and operation of two large magnets which will be used over a number of years for a series of experiments using different arrangements and types of electronic detector. The Omega project, which will be used for experiments at the CERN PS, is described in Reference (1) and a preliminary discussion of the data handling problems is given in (2). The Split Field Magnet project is described in (3); it will be used for experiments at the CERN Intersecting Storage Rings. Both projects will require on-line computers for data taking from experiments and during their lifetime will generate a large amount of data to be processed. Because the structure of this data and many of the problems related to its processing depend on the basic apparatus and are independent of the particular experiment being carried out, it has been decided to incorporate a data handling system as an integral part of each project. Because the data handling problems of the two projects are similar, they are being solved by a single group.

This paper describes the data handling problems of the two projects, the solutions being adopted and the proposed modes of operation to be implemented.

2. The Projects

The Omega magnet is shown in Figure 1. It will have superconducting coils and will be surrounded by a heavy iron shield, which has a number of removable blocks. The field will be 18 kGauss in the centre of a useful volume of $14m^3$, (2m high and 3m in diameter). It is expected to go into the West experimental area and to begin operation in 1972, and during the first 1 to 2 years optical spark chambers will be used as detectors, but later it is expected that filmless detectors will be used. The initial choice of optical chambers is based on the experience gained with the CERN-ETH Zürich-Imperial College London magnet spark chambers (Reference (4)) which has a layout similar to the one planned for Omega.

The Split Field Magnet is shown in Figure 2. It is a magnet system to be placed around intersection region I4 of the Intersecting Storage Rings (ISR). It is designed such that its net effect on the circulating proton beams is 0. The bottom part of the Figure shows the SFM seen from above. On one side of the intersection the field is +12 kGauss and on the other it is -12 kGauss thus deforming the primary beam paths into an S-shape and providing momentum analysis for the interaction products. On each side of the central magnet is placed a compensator magnet which brings the beams back to their correct orbits. Electronic detectors, most probably Charpak chambers which have a very high time resolution, will be placed inside and outside the magnets but they have to be outside the beam vacuum chamber. Each arm of the magnet has an aperture 5m long, 1m high and 2m growing to 3m wide at the centre giving a volume of $25m^3$. It will have conventional coils and is expected to be operational in 1972. Experiments without the magnet will, however, start in 1971 when the ISR will begin operation.

Estimates of the data rates and the structure of the data from the detectors are given in Table 1.

TABLE 1

Data Rate Estimates

1 coordinate = 16 bits	
Omega	
CPS cycle	~1.5 sec.
Burst duration	~0.3 sec.
Coordinates per burst	10000 - 45000
Coordinate rate during burst	33000 - 150000 coor/sec.
Average coordinate rate	6700 - 30000 coor/sec.
SFM	
No burst structure	
Continuous coordinate rate	4000 - 20000 coor/sec.

The values in Table 1 are estimates based on a particular model and serve as guidelines only, however, they do not depend too much on the model used. The fact that SFM data are continuously produced means that the data buffering problems for SFM are simpler than those for Omega.

The number of events per year from Omega depends very much on the type of experiments to be performed, but the amount of pictures per year which is technically possible is estimated to be about 12 million, while the number of triggers from a filmless detector may be about 5 times higher, i.e. 60 million per year, but this number may well be smaller because of physics limitations. Averaged over the different types of experiments, the number of good events is expected to be one quarter of the pictures and triggers thus giving estimates of 3 million good film events and about 15 million good triggers.

From SFM the number of triggers could be of the same order of magnitude as for Omega but reliable estimates are very difficult to obtain at this stage of development of the project.

3. Data Handling Requirements

The data handling requirements of the two projects cover a very wide range from checking the performance of the experimental equipment to full analysis of the data on a production scale. Omega experiments will be carried out by outside groups as well as by CERN groups and outside groups will be expected to process their data on their own computers. Although only a small proportion of the data will be analysed at CERN and so only the computing capacity necessary for the data acquisition phase and for the analysis of this fraction of the data is required there, an important fraction of the data processing facilities will have to be provided at CERN.

The list of jobs which have to be done by the data handling system is as follows :

a) Film Measurement As mentioned above, about 3 million good events could be recorded during each year that optical spark chambers are used inside the Omega magnet, and FSD capacity for the CERN share of these pictures and control programs will be needed to measure them. The film format and the type of track patterns to be measured is expected to be similar to those of the current series of CERN-ETH Zürich-Imperial College experiments (Reference (5)).

b) Equipment Checking and Fault Finding for on-line experiments. Diagnostic programs and programs for the determination of experimental parameters are required. The diagnostic programs must include testing facilities for the principal electronic detectors and other input devices such as counters, pattern units* and digital voltmeters and must have error tracing capabilities. The most important experimental parameters to be measured are the efficiency and resolution of the detectors and alignment checking programs would be necessary during their installation.

c) Data Acquisition involves control operations, read-out of digital coordinates from the experimental equipment, buffering this data and storing it on magnetic tape for processing later. The system must be able to operate flexibly and reliably for long periods and must provide samples of data for checking as described below.

d) Sample Checking The data handling system must be capable of providing rapid feedback of information which can be used to tell if the experiment is proceeding as planned and if the equipment is working properly, and which also enables the physicists running the experiment to make adjustments of parameters or equipment settings in order to improve the quality of the data. The data handling system will do this by carrying out checks on samples of data at two levels. Firstly, routines similar to those used in the setting up phase of the experiment will be used to check the performance of the equipment. Secondly, complete processing of a sample of events through the stages of track and event recognition and geometric and kinematic reconstruction will give intermediate information showing the quality of the raw data and give an indication of the physics conclusions to be found when all the data is processed later. It is impractical to process even a very small sample of the data simultaneously with its acquisition because

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* Pattern units on registers containing information on the status of the equipment which can be interrogated by the computer.

the processing time per event on existing computers is much greater than the time between events, but the sample calculations provide a means of regularly showing how the experiment is progressing. Because the physicists will want to change their criteria of judging the experiment and to examine different parameters from time to time, the system should allow frequent changes of the sample analysis programs and distinguish clearly between these and the data acquisition programs so that the latter will continue to run and store all the available data even if an error in a sample analysis program causes it to fail.

e) Full processing of the CERN share of the data Programs have to be provided to carry out pattern recognition for both film and filmless events, geometrical and kinematic reconstruction and post kinematic analysis.

f) Display of results and events Graphic display facilities are required for showing the results of sampling calculations during data taking, for visualisation of filmless events, and for event recovery procedures in both film and filmless experiments.

Furthermore, the use of interactive graphic displays for the development, testing and assessment of new pattern recognition methods is considered indispensable for making this development sufficiently fast to cope with the requirements from different experiments.

g) Simulation of Experiments Programs are required for feasibility studies of possible arrangements of experimental equipment and ways of operating it. The output from these programs should have a form such that it may be used instead of the real data without requiring modifications to the processing chain for the real experiment, thus also allowing development and testing of the processing chain before real data is available.

All the requirements listed above will involve the development of a large amount of software, and this will in turn lead to demands for efficient program development facilities.

It is expected that when the projects are fully operational, data taking on a production basis will occupy about 25% of the time (taken over a period of several months). The rest of the time will be spent in equipment development and setting up new experiments.

4. Principles of Implementation

After the description of the data characteristics and the requirements of the data handling system in the previous sections, this section will describe how this information has determined the design of the system.

The fact that optical spark chambers will be used only during the first one to two years of Omega operation has lead to the abandoning of a first idea of constructing a special HPD for Omega. Instead, the more economic solution of modifying the CERN HPD 1 such that it can measure the pictures has been adopted, and the modified machine will remain connected to a CDC 6000 computer.

During experimental runs a powerful computer with a large memory must be available on-line to perform sampling calculations for up to two simultaneous experiments and to provide enough buffer space for storing the data for the entire burst from Omega at the highest data rates. However, because any experiment is expected to do production data taking during only 25% of the time and because the setting up and testing of new experiments or detectors are activities of a kind which will prevent the use of the on-line computer for other activities, it seems natural to attach a small computer to each of the Omega and SFM detectors and connect these via data links to the more powerful computer, thus freeing the latter from the interference from the setting up activities. This arrangement will lead to a more economical use of the total system. The actual locations of the two magnets, they will be about 0.5km away from each other, also supports the choice of attaching a small on-line computer to each of them.

For the more powerful computer there are essentially two possibilities, it could either be a fraction of a very large computer at the CERN central computer installation or it could be a dedicated medium-sized computer. If it is a fraction of the central installation it may either be connected to the FOCUS network (Reference (6)), or have a private data link to the central installation.

The FOCUS solution must, however, be discarded, because FOCUS is not designed for providing the buffer space necessary for the data acquisition at the higher rates from Omega, also the amount of sampling computations required by the projects is on the limit of the FOCUS design aims.

The private link possibility does not involve the limitations of FOCUS, but has a number of disadvantages both for the projects and for the central installation. For the projects, fundamental changes to the system may have to be made when major changes are made in the central computer installation, and this may occur several times during the lifetime of the projects. The disadvantages for the central installation are that the existence of such permanent links places heavy limitations on the possibilities for modifications and development of its system, and that a large fraction of memory must be permanently assigned to the Omega and SFM sampling programs.

A dedicated machine thus seems the best solution, especially if it can compete economically with the other possibility. For the tasks required by the projects, especially the running of the pattern recognition programs, which use mainly integer arithmetic, tests have shown that a medium-sized 32 bit machine is more economic per event than the general-purpose, long word length computers at the central installation, and remembering the number of events to process estimated in section 2, it is seen that there will be a sufficient load to keep it busy full time.

There are several further advantages to be gained by using a dedicated computer, the most important of these is related to the use of displays. The envisaged use of interactive graphic displays for rescuing of failed events and for development of pattern recognition methods will represent an extensive use of the display equipment, so it is most practical to have it attached to a computer which will have a stable configuration during the lifetime of the projects, especially when the pattern recognition programs will be run on the same computer.

We have thus arrived at a system layout as shown in Figure 3 with a small computer attached directly to the experiments and connected to a medium-sized main computer via data links.

5. Modes of Operation

In the system of Figure 3 three distinct modes of operation can be separated out. Which mode is chosen at any particular time depends on whether experiments are running or not, and on their data rates. The three modes also correspond with three phases of implementation.

Mode 1 No experiment is in progress. The on-line computers are used for setting up and check-out of new experiments, the main computer is used for processing of events written on to tape during earlier experiments, general program development, and for display activities. The off-line event processing will mostly consist of the pattern recognition stages of the processing chain for which the computer is best suited, while it is not yet clear how much of the geometric and kinematic reconstruction which contain many more floating point computations, will be shared between the main computer and those of the central installation. The programs will however be able to run on both.

Mode 2 An experiment is in progress at one or both of the magnets, and the data will be collected and stored on magnetic tape by the on-line computers. Samples of data will be stored on the disk of the on-line computers from time to time and used by the basic equipment checking programs. Other samples of data will be sent to the main computer via the data link for more complete processing; the results of these calculations will be either displayed at the main computer or sent back via the data link to be displayed in the experimental area.

Mode 3 The data rate from Omega is too high for the on-line computer to buffer the data so it will be sent from the Omega on-line computer to the main computer via the data link. The memory of the main computer provides the buffering capacity required and the main computer writes the raw data on to magnetic tape. Equipment checking can still be done by the on-line computer and sampling calculations will also continue in the main computer, though necessarily at a lower rate than in mode 2.

6. The Hardware Elements

After the general description of the system given above, we shall describe in this section the individual hardware elements in the system and give their actual status.

The expected characteristics of the modified HPD 1, renamed the HPD Omega, are given in Table 2. The main modifications are the

TABLE 2

Expected Characteristics of HPD Omega

Length of scan line		66 mm.
Spot size		12-15 μm.
Spot least count		~2 μm.
Stage least count		2.54 μm.
Stage speed		5-50 mm/sec.
Stage retrace speed		100 mm/sec.
Film transport :	Min. time to advance small numbers of pictures	1.5 sec.
	Film speed for large numbers of pictures	2 m/sec.
Disk speed		1500 - 2200 r.p.m.
Number of fibres		8
Length of film scanned in a single scan		170 mm.
Resolution		~35 μm.

scan line length of 66 mm (which makes it possible to cover the two stereo views placed side by side on the film in one sweep), the smaller spot size, and the improved resolution required to match the Omega demagnification ratio of about 50. For a scan line separation of 50μ the maximum measuring speed becomes 450 2-view pictures per hour. The HPD Omega will be ready to start operation during the summer of 1970.

The configuration of the on-line computers is shown in Figure 4. They are both EMR 6130's from Electro Mechanical Research in Minneapolis, U.S.A., and will have identical configurations except that only one will have a card punch. There is 24K of 16 bit 0.775μsec. memory, two 60kb/sec. tape units, a backing disk store and a full complement of standard peripherals, such that it is a stand-alone configuration which makes development work on it independent of support from the main computer via the data link. The first computer will arrive in summer 1970 and the second about a year later.

The main computer is shown in Figure 5. It is an CII 10070 from Compagnie Internationale pour l'Informatique, France and is a French-built version of the XDS Sigma 7. It will have 64K of 32 bit words, 5 tape units of which two have a 120kb/sec. recording speed, such that it can cope with the highest data rates from Omega. Besides the standard set of peripherals, there will be 18M bytes of fixed head disk space for use by the system, for sampling data, and for permanent files. It will have a multiprogramming system developed by CII, France and it will be delivered end-1970.

The data links will be designed and produced by CERN, they will have a transfer rate of 400,000 bytes per second over a distance of 500m. They are expected to be ready during 1971.

7. Development of Programs

The program development for the data handling system is still at the design stage so this section will essentially describe the basic principles which have been adopted.

It is clear that a large number of programs will have to be provided both at the basic system level and for the applications. Some of them, particularly the applications programs, will be developed from existing routines which already work on the CERN central computers, but the major part will have to be written from scratch.

Experience from the analysis of data from both film and film-less experiments has taught us that a system of program modules, which can be assembled into entire programs, is very important for the fast production of working programs. Also flexibility of operation is a primary design goal, so that frequent ad hoc modifications can be avoided.

As much as possible of the operating systems delivered with the computers will be used, but because they will be used for a particular application and do not have to process a completely general work-load, it is reasonable to remould part of the manufacturer's software to optimise it for this particular application.

A number of special problems arise from the inter-connection of the computers and the attachment of non-standard peripherals. Each of the on-line computers will have to communicate with the main computer via the data links, and the main computer, besides operating the data links simultaneously, must at the same time be able to handle a display system, which may itself contain a small computer. A multiprogramming system provides a good basis for doing all this, as it contains most of the facilities which are needed for managing the simultaneous operations.

In order to have a protected data acquisition program and a flexible means of changing between operational modes in the main computer, the data acquisition and sampling programs will operate as normal independent jobs in the multiprogramming system, transmitting data between each other by means of shared files on disk. Changes in the sampling programs may then be made without stopping the data acquisition and possible errors in the changes cannot affect the data acquisition.

8. Conclusion

This paper has described the principles which have been adopted in the provision of a data handling system for two large experimental projects. We realise that it contains mainly plans and intentions but we believe that the information is of value at this stage because our plans may affect those who want to make use of the facilities we shall provide.

As both the projects are long term ones there are many problems which cannot be attacked yet, because not enough is known about them. For example, some of the biggest uncertainties are related to the performance of the filmless detectors, which are still at the development stage.

A set of general problems arise from the changing nature of the experiments and the data to be analysed, in particular from the increasing amount of data produced by a single experiment. Solutions to the problems of changing from partially guided measurement to completely automatic measurement of pictures on the HPD and of speeding up the analysis programs to cope more efficiently with larger quantities of data are already being studied. A description of the activities in these applications-oriented areas is given in Reference (7).

References

(1) "The Omega Project", CERN internal report NP-68-11 (1968).

(2) J-C. Lassalle, P. Zanella, "Developments in the evaluation of magnetic field spark chamber pictures". Proceedings of the Int. Conf. on Advanced Data Processing for Bubble and Spark Chambers, Argonne National Laboratory, October 1968.

(3) L. Resegotti, Progress report on the Split Field Magnet for the ISR, CERN internal report ISR-MAG/69-58 (1969).

(4) P. Astbury et al. "Performance of a large magnet spark chamber", Nuclear Instrum. Methods 46, 61 (1967).

(5) R.A. Bowen et al., "The measurement of spark chamber film at CERN using HPD I", Proceedings of a 1967 Int. Conf. on Programming for Flying Spot Devices, Munich, January 1967.

(6) M. Palandri, "The FOCUS remote access system", paper submitted to the Tenth Int. Conf. on Data Handling Systems in High Energy Physics, Cavendish Laboratory, Cambridge, March 1970.

(7) F. Bourgeois, H. Grote, J-C. Lassalle, "Pattern recognition methods for Omega and SFM spark chamber experiments. "Paper submitted to the Tenth Int. Conf. on Data Handling Systems in High Energy Physics, Cavendish Laboratory, Cambridge, March 1970.

Figure Captions

Figure 1	The Omega Magnet.
Figure 2	The Split Field Magnet seen in two views. The central magnet and the two compensator magnets are shown in a side view in the upper part and in a top view below. The deformation of the primary beam paths is indicated in the top view.
Figure 3	Principal layout of the data handling system with an on-line computer attached to each experiment and connected to a main computer via data links.
Figure 4	Configuration of an on-line computer, the EMR 6130.
Figure 5	Configuration of the main computer, the CII 10070. The MIOP is a multiplexed input/output channel with an individual and total transfer rate of 400,000 bytes/sec.

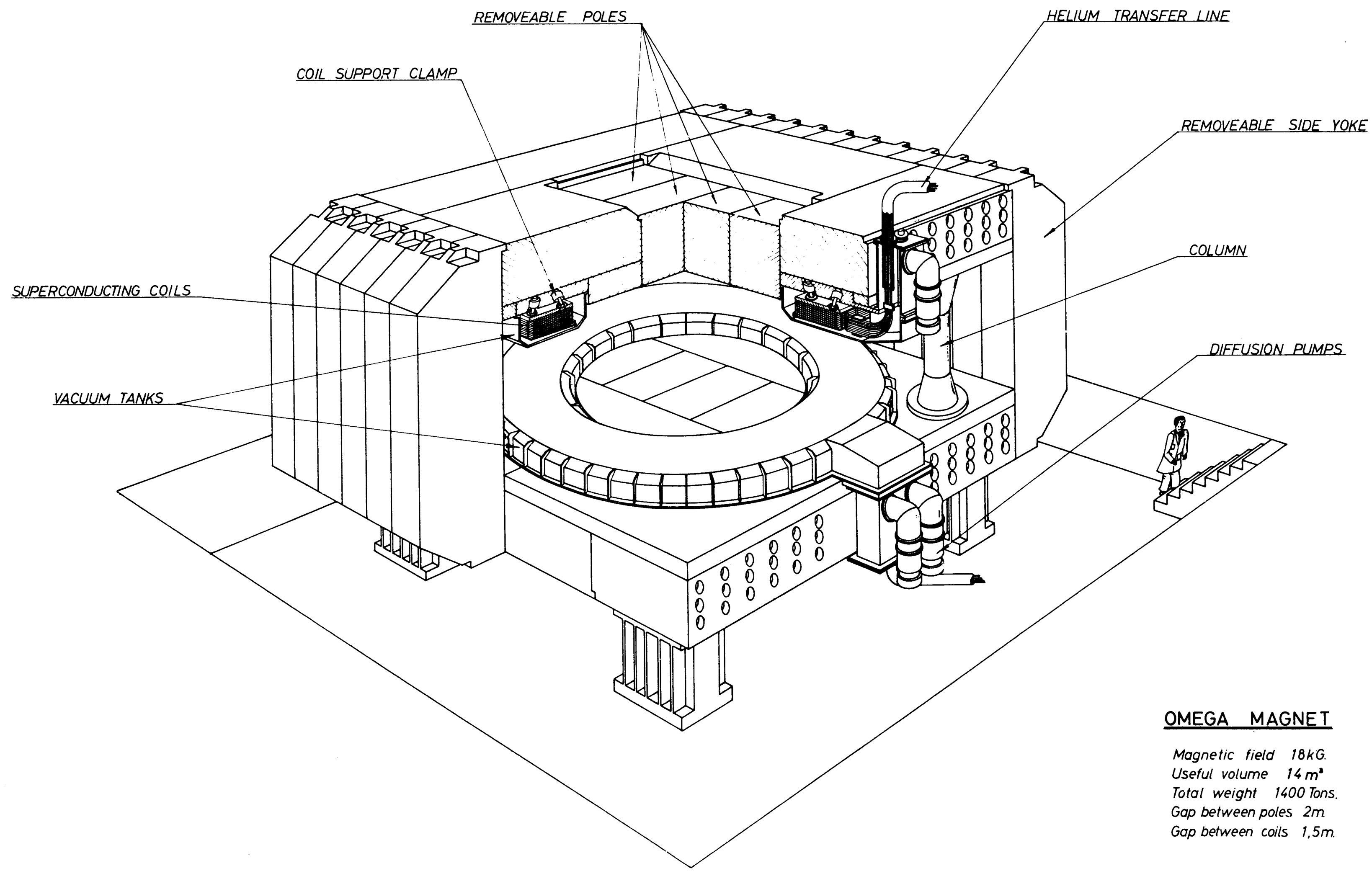
REMOVEABLE POLES
HELIUM TRANSFER LINE
COIL SUPPORT CLAMP
REMOVEABLE SIDE YOKE
COLUMN
SUPERCONDUCTING COILS
DIFFUSION PUMPS
VACUUM TANKS
OMEGA MAGNET
Magnetic field 18kG.
Useful volume 14 m³
Total weight 1400 Tons.
Gap between poles 2m.
Gap between coils 1,5m.

Fig. 1

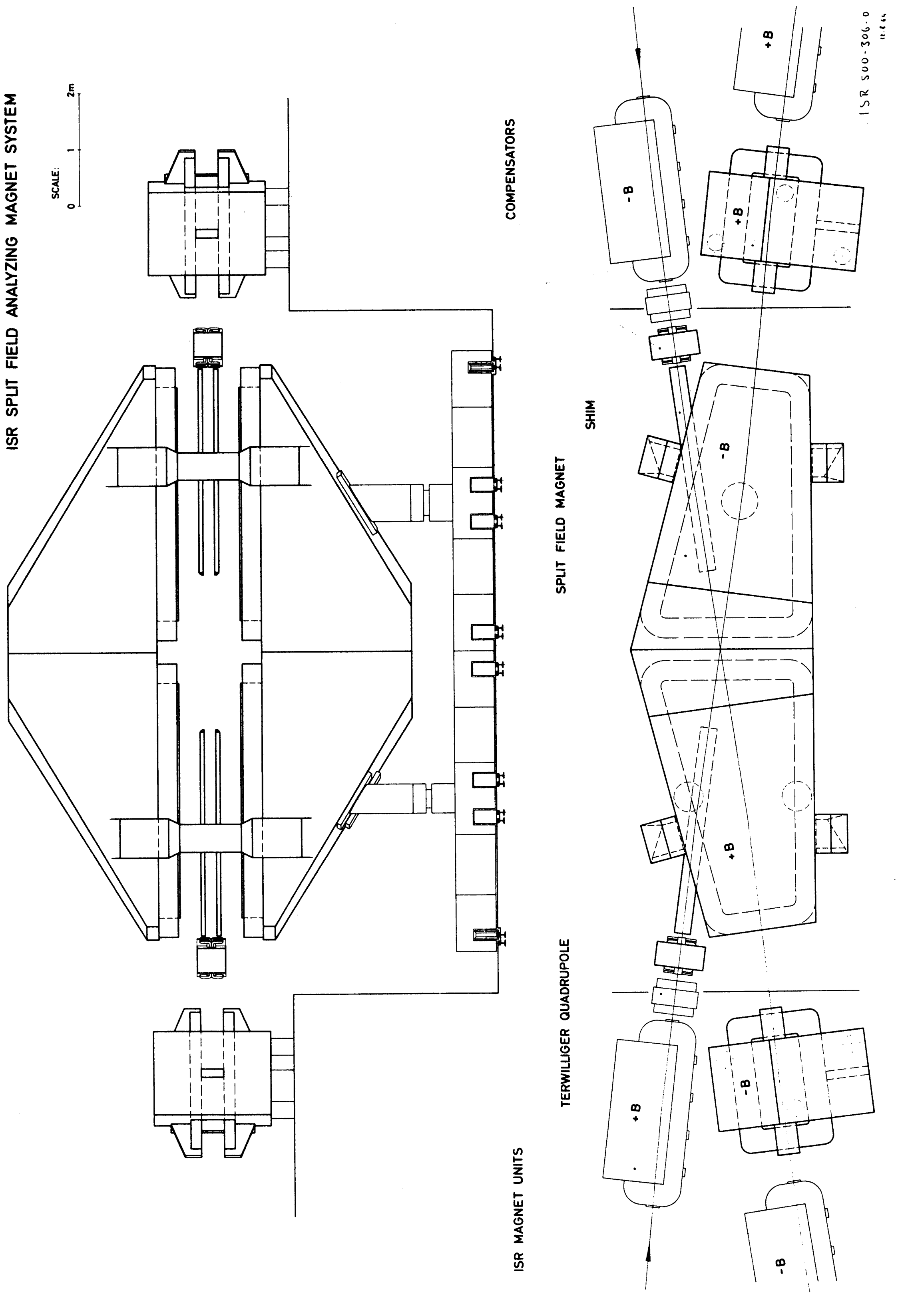
ISR SPLIT FIELD ANALYZING MAGNET SYSTEM
SCALE:
0
1
2m
COMPENSATORS
SHIM
SPLIT FIELD MAGNET
TERWILLIGER QUADRUPOLE
ISR MAGNET UNITS
+B
-B
ISR 500-306.0

Fig. 2

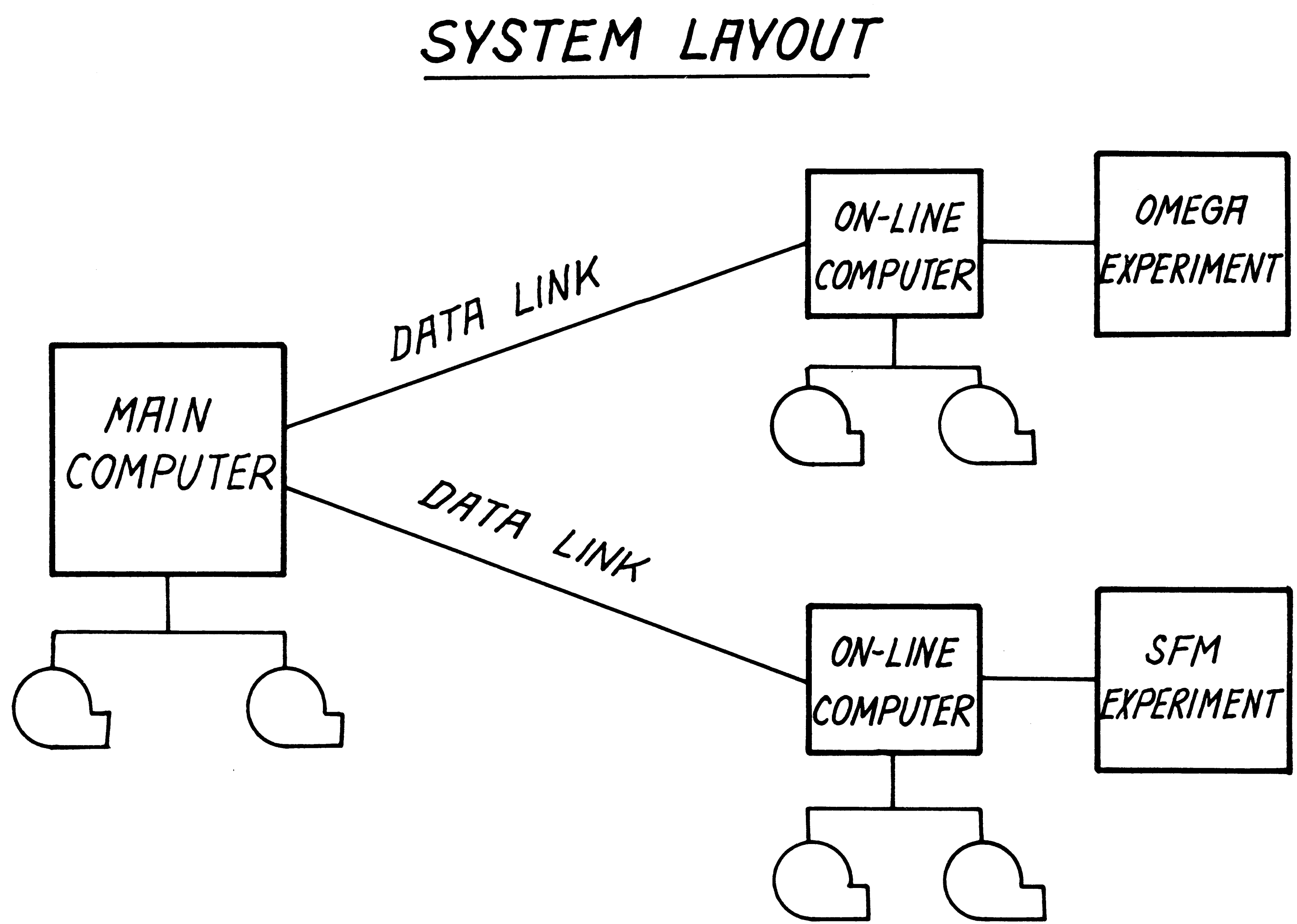
SYSTEM LAYOUT
MAIN COMPUTER
DATA LINK
DATA LINK
ON-LINE COMPUTER
OMEGA EXPERIMENT
ON-LINE COMPUTER
SFM EXPERIMENT

Fig. 3

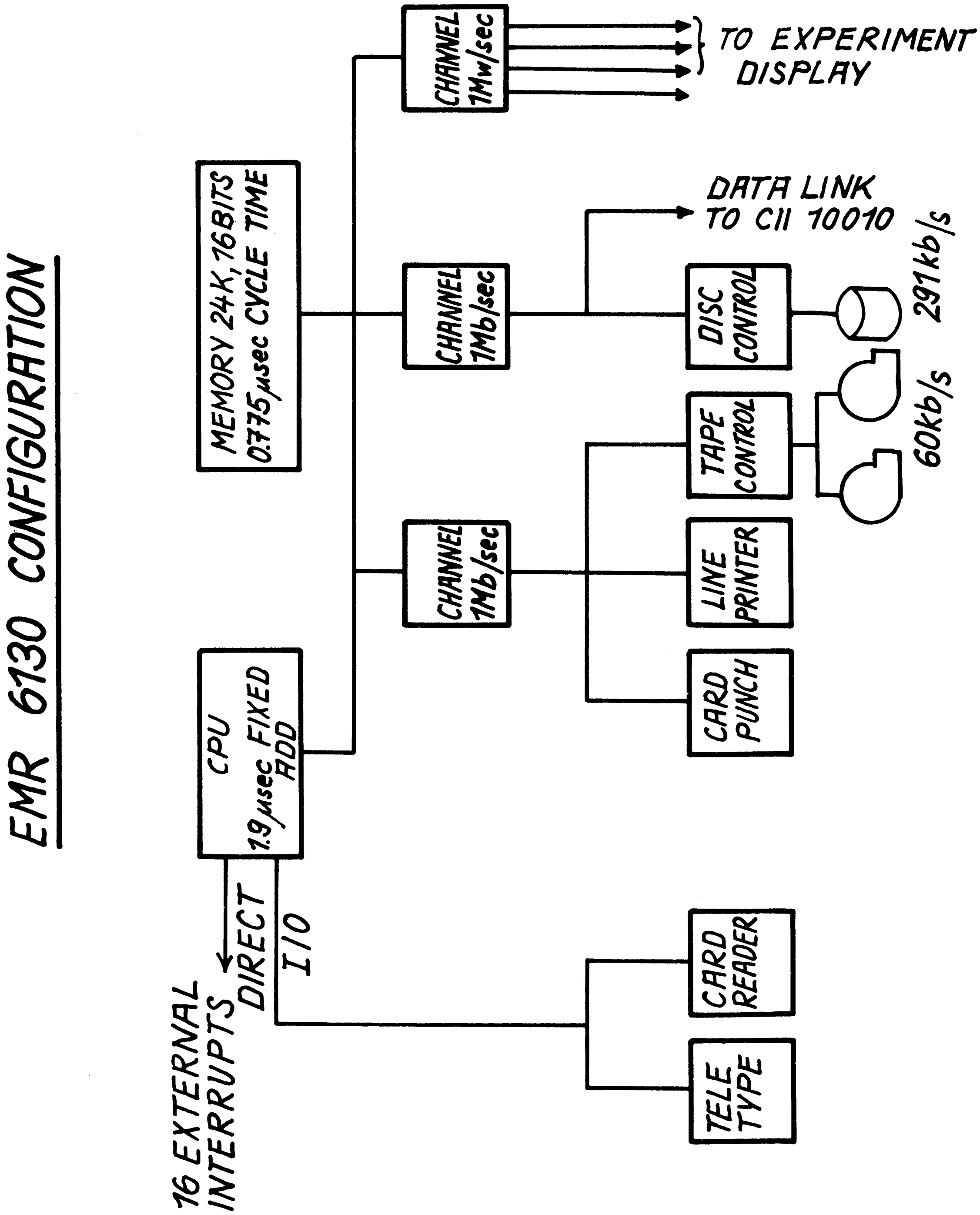
EMR 6130 CONFIGURATION
CPU
1.9 μsec FIXED ADD
MEMORY 24K, 16 BITS
0.775 μsec CYCLE TIME
CHANNEL 1Mw/sec
TO EXPERIMENT DISPLAY
CHANNEL 1Mb/sec
DATA LINK TO CII 10010
DISC CONTROL
291 kb/s
CHANNEL 1Mb/sec
TAPE CONTROL
60 kb/s
LINE PRINTER
CARD PUNCH
16 EXTERNAL INTERRUPTS
DIRECT I/O
CARD READER
TELE TYPE

Fig. 4

CII 10070 CONFIGURATION

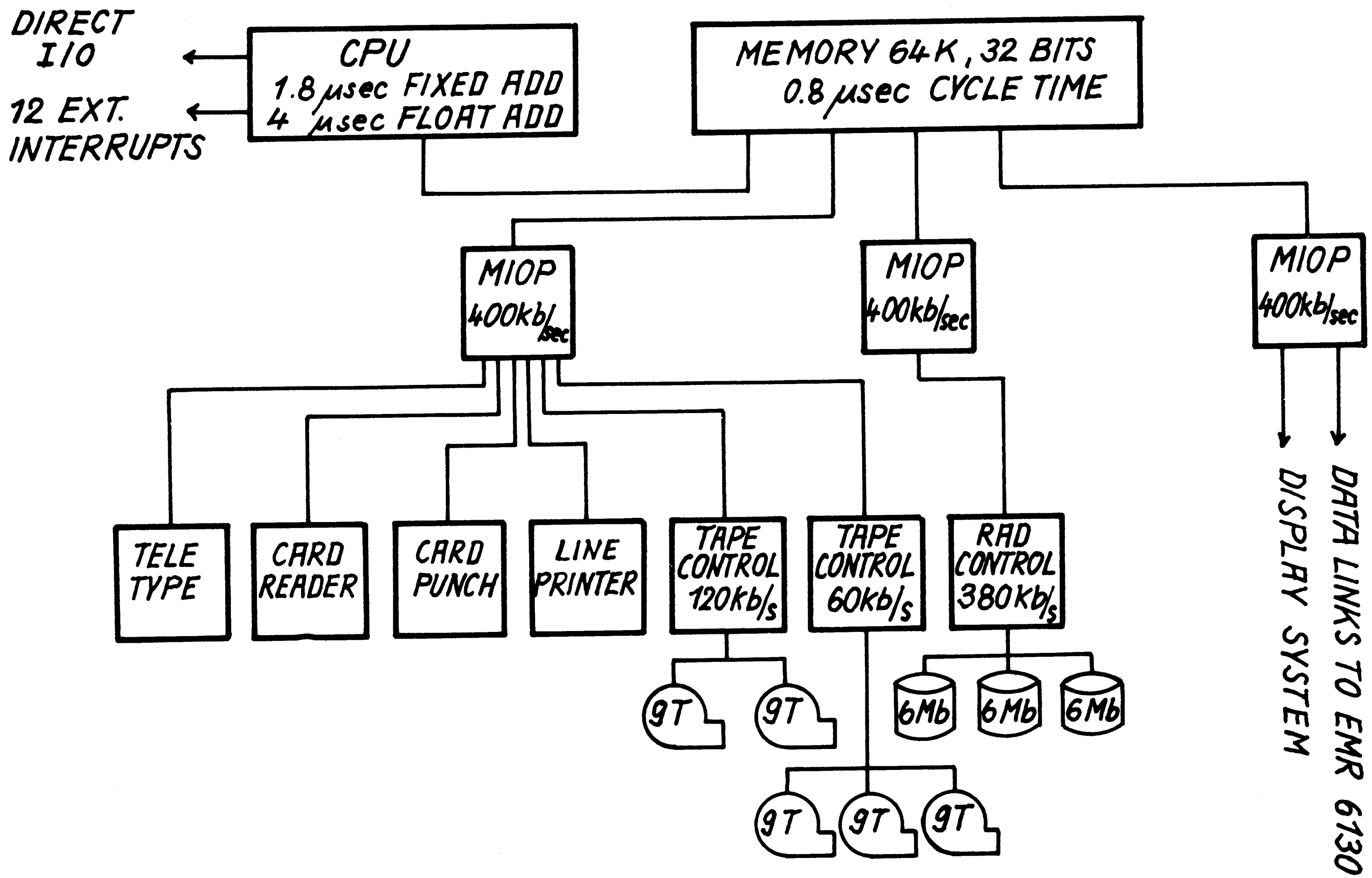

Fig. 5