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SURVEY OF DATA-ACQUISITION SYSTEMS FOR TEST BEAMS AT CERN

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Abstract

This paper reports the results of a survey of data-acquisition systems used in test beams at CERN. Technical data on more than 100 projects was collected and some 200 people interviewed. The hardware and the software systems currently used are described.

1 INTRODUCTION

This note reports the results of a survey of data-acquisition systems used in test beams at CERN. Technical data on more than 100 projects was collected and some 200 people interviewed. Even if the coverage is not complete, we believe that we have managed to obtain useful information on all the major activities in this domain.

The overall structure of the report is divided into sections covering distinct areas of application of data-acquisition systems, namely: test beams of running experiments and current R&D projects, the ISOLDE experiments, the ECP electronics groups, the CN division and, finally, the test beams of future experiments.

1.1 The mandate

The inquiry was given the following terms of reference at the end of June 1994:

"To analyse the present situation of data-acquisition systems for test beams at CERN; the range of activities to be surveyed includes the test beams used for tests of detectors by presently running experiments, the test beams used in R&D projects and the test beams planned for the preparation of the future CERN physics programme.

"To collect information concerning the hardware used for data-acquisition, with particular attention to the read-out architecture and the type of electronic modules employed.

"To collect information concerning the software used for the data-acquisition; items of particular interest are the software architecture, the origin of the software and the software engineering tools used.

"To estimate the effort invested in each system for development, maintenance and operations.

"To make a summary of the various systems in use, in order to identify common aspects.

"To find out about future requirements and expectation of evolution.

"To report to the Research Director by the end of September 1994."

Making recommendations was neither part of the mandate nor is it the purpose of this report.

1.2 The inquiry method and subjects

The method adopted for the inquiry was the individual interview. About 200 people were interviewed (see list in the Acknowledgements), each interview took more than two hours on average, and more than 500 e-mails were exchanged in order to have the most appropriate person to talk to about each experiment.

Five distinct test environments were surveyed.

1.2.1 Test beams of running experiments and current R&D projects

One hundred and nine interviews were performed in this area. Since they constituted the main focus of interest in the survey, they have been handled in a special way. A questionnaire was prepared which included general questions on the approach adopted, more precise ones on the technical details of the hardware and software used, and some questions on the manpower invested. During each interview, the questionnaire was used as a guideline and completed. Notes were taken when further information was given outside the range of the questionnaire. The questionnaire information was subsequently entered in a database (Filemaker Pro on a Macintosh was used), in order to be able to extract a statistical summary.

1.2.2 ISOLDE experiments

The approximately 40 experiments were not individually covered. Since there is a large uniformity among them, as far as the data-acquisition system is concerned, only a few representative individuals were interviewed.

1.2.3 ECP electronics groups

The essential information was collected at the management level (group leaders). The emphasis was put on the present situation of the test set-ups for hardware modules and on future strategies.

1.2.4 CN division

The CN/CE group contributed to the survey as a provider of support services in the data-acquisition area.

1.2.5 Test beams of future experiments

Discussions were held with those responsible in ALICE, ATLAS, CMS and NA48 aimed at capturing the current thinking concerning the future test beams.

1.3 Some comments about the inquiry

The majority of the people contacted were very willing to collaborate. However, a small but significant number did not seem to appreciate the survey approach chosen by the CERN management and they considered it a waste of time to explain how their data-acquisition systems work. Quite surprisingly, one of the most difficult parts was to get people's answers concerning "future requirements and needs". It was as if they either had no time to think about these fundamental issues due to the normal day-to-day pressures, or did not want to commit themselves.

Technical descriptions of the systems used have almost always been provided. In 28% of the interviews information on the manpower (man-years to build the system) was not provided as requested. In some cases the software used is so old that nobody remembers who wrote it nor how long it took. In other cases, people were reluctant to provide this information.

2 CURRENT TEST BEAMS

Contributions have been received from the following collaborations:
ALEPH, ATLAS-H8, CMD-2, CMS-H2, CMS-H4, DELPHI, Energy Amplifier, GDD-PD, H1, HERA, Kloe, KTev, L3, ATLAS MSGC, ATLAS Muon tests, NA12, NA43, NA44, NA45, NA47, NA48, NA49, NA50, NA52, OPAL, PBscint, PbW04, PS185, PS194, PS195, PS196, PS197, PS200T, PS201, PS202, PS203, PS205, PS206, PS207, PS208, RD11, RD12, RD13, RD16, RD17, RD18, RD19, RD2, RD20, RD21, RD23, RD24, RD25, RD26, RD27, RD28, RD3, RD33, RD34, RD36, RD37, RD40, RD5, RD6, RD8, RDP48, RDP56, RDP57, SL tests, TIS tests, WA89, WA91, WA95, WA96, WA97, WA98, WA99.

It should be noted that the number of test beams is greater than the number of experiments. In fact, in almost all cases there is more than one test beam for a given experiment. We found only one experiment without a test-beam activity at CERN. This is an irradiation experiment that runs parasitically and all data collection is carried out in the United States.

Of the 109 interviews, 71 concerned test beams using SPS beam lines (33 in the West Area and 38 in the North Area), 29 PS beam lines (20 in the East Area and 9 at LEAR) and 9 carried on in laboratories (at CERN and outside).

2.1 Present status

In this section the data is presented in the form of a statistical summary.

For numbers given in the tables below:

1. All the percentages are calculated over the total population (109 test beams).
2. Often the categories presented are not mutually exclusive, therefore they do not add up to 100%.

2.1.1 Data-flow architectures

The architectures used in the data-acquisition systems are very similar. Usually there is some front-end (FE) electronics constituted by readout modules (e.g. ADCs, TDCs) connected to the detectors. The readout process is driven by processors residing in the local system crate (LSC). When multiple LSCs are present, an event builder processor (EVB) merges the data from the parallel LSC streams. The back end (BE) is made up of workstations, which are normally devoted to supporting basic tasks (such as run control and file base), and data analysis and visualization. The data recording may be performed by the LSC or the EVB or the BE. This architecture is used in 14% of the test beams (see Fig. 1).

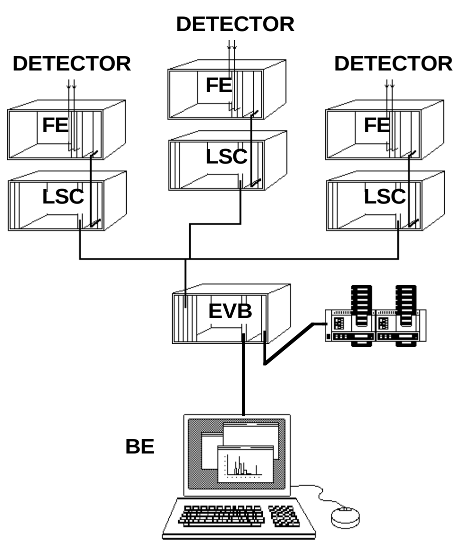

Fig. 1

Variations of this architecture may be possible; they usually result in the absence of some components. The EVB processor is missing in 86% of the cases, when there is one data stream only. In this case, the architectural variations observed are the following: 36% of the test beams present an LSC with a BE and the recording is performed at the LSC level (Fig. 2).

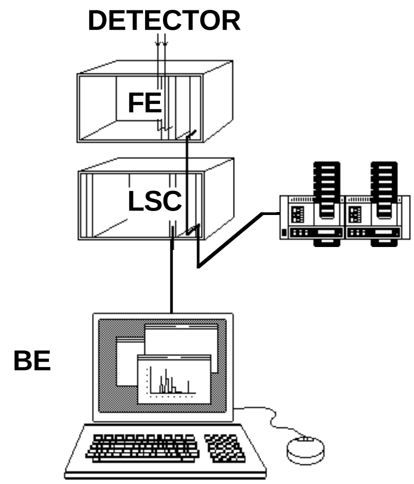

Fig. 2

If the LSC processor is missing, the readout of the FE electronics is performed by the BE (27% of the test beams) (Fig. 3).

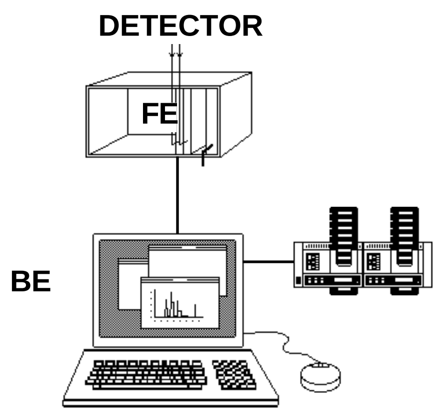

Fig. 3

If the BE is missing, a dumb terminal allows interaction with the LSC (23% of the test beams) (Fig. 4).

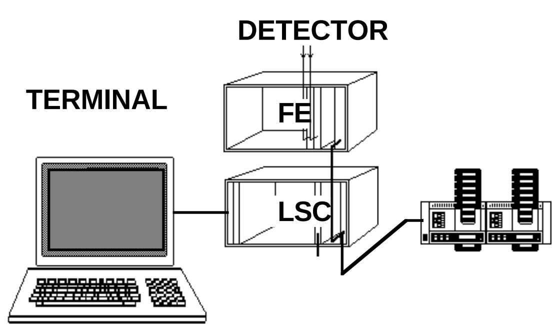

Fig. 4

Most of the test beams have a simple hardware configuration: they use one single LSC and therefore do not need an EVB.

2.1.2 Front-end electronics bus

In 90% of the cases the front-end electronics is not based on a single readout bus, but rather several types of busses are used (Table 1).

Table 1

CAMAC	Fastbus	VMEbus	Others
87%	18%	35%	20%

This distribution shows that CAMAC is nearly ubiquitous, while VMEbus and Fastbus are strongly present. Note that at least one of the major busses (VMEbus, CAMAC or Fastbus) is always present.

Other busses include RMH, REMUS, ECL, HiPPI, transputer links and some home-made solutions.

2.1.3 LSC crate

Since the LSC is supposed to host processors, there is clearly a predominance of VMEbus (Table 2).

Table 2

Fastbus	VMEbus	No LSC
6%	67%	27%

Fastbus's apparently small but significant percentage comes in reality from several test beams related to only three experiments.

In the cases where no LSC is present, its function is performed by the BE, usually a Macintosh or a PC (a VAXstation in one case).

2.1.4 LSC processors

The following table shows the well known predominance of CES (the CES processors included are the FIC 8230, 8232 and 8234) in the 73% of the cases where LSC processors are used (Table 3).

Table 3

CES FIC	Motorola MVME	Others
35%	19%	19%

The Motorola processors used are MVME 147, 167 and 337.

Other processors used include the CES RAID 8235, Force, Eltec, Saclay FIP, ALEPH Event Builder, Cetia, CHI and GPM. However, their presence is restricted to a few units.

2.1.5 LSC operating system

Table 4 shows the overwhelming predominance of OS-9. Note that EP/LX is used by the test beams supported by RD13. Other operating systems include VxWorks, UNIX on Cetia processors and the monitor MoniCa.

Table 4

EP/LX	LynxOS	OS-9	Others
4%	5%	52%	12%

2.1.6 Back-end stations

The hardware used is shown in Table 5.

Table 5

DEC Alpha	DEC Mips	DEC VAX	HP
4%	4%	28%	5%

IBM PC	Macintosh	SUN	X terminals
14%	21%	19%	14%

This table shows an even distribution among the various brands of stations. DEC workstations are mainly VAX-VMS (see below). X terminals are connected to a variety of UNIX hosts. Only one test beam is currently using OSF and only one other is planning to.

Not shown in the table are one IBM RS6000 and one Cetia.

The operating systems used are shown in Table 6.

Table 6

Macintosh	MS-DOS	UNIX	VMS	Windows
21%	10%	33%	30%	4%

2.1.7 Networking

Except in a few cases, the majority of test beams use Ethernet to link processors and workstations and to access the outside world. The TCP/IP socket library is used as network protocol in 95% of the cases (the remaining use DECnet and CERN RPC).

Many of the test beams have chosen VMEbus as their data-acquisition system integration bus and the VICbus is present in all the LSCs with FICs.

High-speed links are not used, with the exception of one HiPPI link.

2.1.8 Data-acquisition software

We have grouped the data-acquisition systems in the following categories:

- LEP experiments: the current test beams have often started after the installation of the final data-acquisition in the experiment, therefore the systems are a replica of the one used at LEP. With one exception, these systems use the same software running in the corresponding LEP experiment.

- Macintosh-based: this category includes systems that are mainly constituted by the MacUA1 library and specific FORTRAN code as well as systems using LabView. LabView is an icon-based programming system for building software modules called virtual instruments (VIs). A set of libraries, developed in the RD12 context in collaboration with National Instruments, is freely available at CERN.
- SPIDER: this category includes system running the SPIDER software modules provided by the ECP-DS group.
- General CERN: new systems currently developed at CERN (CASCADE and RD13).
- Specific CERN: systems developed at CERN which are not for general use; they are self-supported by the test beam users.
- Specific non-CERN: the same as above, but taken from an external institution or developed by external collaborators.

Table 7 shows that there are a large number of systems used at CERN and that more than half of the test beams use private systems, which are self-supported. In most cases, these private systems have not been developed for the test beam but were picked up from previous experiments (many coming from other institutes) and adapted to the specific needs. A person involved in more than one test usually brings along the system, therefore not all private systems are unique (for example, a total of 24 test beams use 8 private systems).

Table 7

LEP exp.	Mac-based	SPIDER	General CERN	Specific CERN	Specific non-CERN
6%	18%	25%	9%	9%	33%

The success of systems such as SPIDER and the set of virtual instruments available as LabView libraries is due to the fact that physicists appreciate the chance to get something working quickly in an early phase of the experiment. They can immediately use these systems to test part of the equipment, whilst working on a more elaborate system for the final running conditions.

2.1.9 Data recording

In Table 8 ‘Others’ includes Floptical, DLT and ST IBM 4280. Disk recording is also heavily used in addition to tape recording on 21% of the test beams, while it is possible (but not often used) in 15% of the cases. The SCSI intelligent mass storage bus is the de facto standard connection medium. When present, data recording on tape is performed at different levels of the architecture: the recording units are directly connected to the LSC in 60% of the cases, to the EVB (9%) or to the BE (31%).

Table 8

Disk only	Exabyte	3480 cartridge	Others
23%	51%	14%	12%

2.1.10 Manpower

We have collected information on the manpower required for the development and implementation of the data-acquisition software when it is not an off-the-shelf system. Therefore we do not include systems such as SPIDER, MacUA1, the LabView set of libraries. The more recently developed software products, such as CASCADE and RD13, have also not been included.

Values in the Table 9 are expressed in man-years. They refer to 79 test beams, since 30 out of 109 were unable to provide an estimate.

The sources indicated are: ‘CERN’ for people paid by CERN and ‘External’ for people not paid by CERN, whether belonging to other institutes or CERN associates.

We have grouped under the heading ‘TB+EXP’ those systems that are also used in the related experiment; on the other hand, the ‘TB only’ heading includes systems that are used exclusively in the test beam.

Table 9

Source	TB+EXP	TB only	Total
CERN	54	5	59
External	70	31	101
Total	124	36	160

The table shows (quite predictably) that systems specially developed for test beams tend to be developed outside CERN; however, CERN invested 59 man-years in the private systems. The total amount invested in private systems is quite substantial (160 man-years) over the last 10 years.

2.1.11 Electronics pool items

Some 48% of the test beams make use of equipment rented from the electronics pool, mainly NIM equipment (such as crates and power supplies, coincidence units, dual timers, scalers), CAMAC, Fastbus and VME crates, CAMAC modules (such as crate controllers and branch drivers, ADCs and TDCs), VME modules (such as CORBOs and VCCs), Fastbus modules (such as SI, CI, fan units and power supplies), and all kinds of specific connectors. The regular support of the ECP pool is considered crucial for the maintenance of the data-acquisition electronics.

2.1.12 Languages

The software has been written in a mixture of languages. Nevertheless there has been a strong trend to use C in the LSC processors. Only 14% of the test beams have used some assembler (together with C) for the time-critical parts and Real Time FORTRAN has been used by 10% of them. PILS has been used in only 2% of the test beams.

The situation is slightly different in the BE, where there is a clear predominance of application programs developed in FORTRAN (43%), followed by C (37%). Object-oriented languages (such as C++) have been used in only 2% of the cases. LabView has been used in about 10% of the test beams.

2.1.13 Data visualization

More than half of the test beams use the Physics Analysis Workstation (PAW) as the standard interactive data analysis across a wide range of mainframe computers, terminals and workstations. PAW is not often used during data-taking, but usually in a ‘quasi-online’ mode: data is transferred somewhere at the end of the run and immediately analysed in the hour following recording.

Twenty per cent of the test beam users considered PAW too heavy and difficult for online purposes, and wrote their own home-made presenter.

LabView is used in 7% of the test beams. The remaining test beams do not use a uniform way of presenting histograms; the application software calls the appropriate presentation routines directly.

2.1.14 Databases

It is difficult to find today a unique way to cover the whole range of online applications, such as the hardware configuration description, the run parameters and the calibration constants. This has led to a large variety of individual solutions: hard-coded descriptions, home-made databases, and ASCII file based descriptions. The latter is the most frequently used, together with the associated parsing code. With one exception, commercial databases have not been used in the test beams.

2.1.15 Software engineering methods

None of the software used in private data-acquisition systems for test beams has been developed using software engineering methods. With one exception, modelling tools have never been used and no simulation of the system has been done. In particular, the data-acquisition software for test beams has been considered as a second-class activity compared to the testing of the detectors and not deserving of much attention and investment in terms of manpower and money.

2.1.16 Documentation

Except for where the data-acquisition system is a package provided by CERN and where the same software is used in the test beam as well as in the real experiment, almost all the private systems have no documentation and the reading of the code itself constitutes the only way to know more about them.

2.2 Observations and comments

The first observation that springs to mind is the impressively high number of different systems in use. This may be explained by taking into consideration the factors that determine the choice of a data-acquisition system.

Most of the people responsible for the experiments do not consider the data-acquisition system for test beams as worth the bother. Therefore, they tend to minimize both the time and the effort needed to be spent in learning and setting up the system.

They will look for an existing system, since its availability and a quick start are considered an advantage. On the other hand, they systematically underestimate problems of system evolution and maintenance.

They often take a system because they have already used it on another occasion or because someone else in their entourage is acquainted with it. They do not favour using new (and therefore unknown) systems, even if 'standard' and supported, unless the system is extremely easy and quick to learn.

Finally, they want to keep control of the software production and evolution. They are reluctant to choose a general common data-acquisition system, as they have the impression that in this case they don't have control of it, and so will not be able to get the needed modifications quickly, if these are not shared by a certain number of other experiments or are not general enough to fit common development. It is similar to the reluctance they feel about relying on commercial tools requiring licences not directly maintainable by CERN.

Whatever system is adopted, it evolves and more and more experiment-specific software is added to it. This new software is highly dependent on the basic system tied to the experiment owing to the large non-portable investment made. This explains why most of the people interviewed would not like to change their present system, even if a new system had the most wonderful features.

Only when the point of no return is passed does the amount of effort necessary to maintain the system become apparent. Indeed, scarcity of human resources was the leitmotif of a large number of the interviews. A cause of this shortage is the fact that most of the developers are temporary labour, visitors who return to their institutes, or non-established staff (fellows etc.)

We have seen that, with few exceptions—about 10% of those interviewed—the idea of having a common approach does not appeal to people, but it can be acceptable for 'turn-key' systems, because they are self-contained and can be set up very quickly by the users. Virtually no programming is needed, at least for the more straightforward usage. This approach is still attractive for small experiments, as the amount of work to be done before being able to run is very small. On the other hand, such systems are criticized because of their rigidity. Customization is almost impossible and quite soon such systems show an intrinsic inadequacy to keep up with technological evolution.

Experiments composed of a number of different detectors have an additional requirement. Each detector demands a substantial effort in itself: they are developed by teams of specialists, often in different institutes, using their own hardware and software tools. Even when they are incorporated into the final experiment set-up in the host laboratory, the specialists must still be able to use their own tools. It is considered very important that the data-acquisition system used for the detector tests be the same as the one used in the experiment. Even then, this goal has not always been reached in the current test beams. There is a conflict between the discipline needed to achieve a coherent production environment and the flexibility and freedom needed by the detector experts. As a consequence, some running experiments make use of completely different systems in each test beam.

The availability of general OS-9 libraries was highly appreciated. These libraries are distributed independently of any data-acquisition system, and include the CAMAC ESONE library, the library and driver for the STK4280(SUMMIT) and for Exabyte, a general-purpose interrupt driver, the HMINI histogramming library, the HBOOK histogramming library and related PAW server, and the CORBO library.

None of the people interviewed expressed concern about the foreseen closing down of the West Area at the end of 1996 or the intention to continue the test-beam activity elsewhere. This has always been mentioned as the expected shutdown date.

3 ISOLDE EXPERIMENTS

3.1 Present status

The ISOLDE experiments (around 40 in number) are generally small and only about half of them need a complete data-acquisition system. Of this half, 70% use GOOSY (see below) and the remaining 30% use private systems, which are often chosen on the basis of availability in the home laboratory and for cheapness.

GOOSY is a PL/1 based data-acquisition and analysis system implemented on VAX/VMS computers. It has been designed and developed at GSI Darmstadt and has been used since 1986. For small experiments with low data rates GOOSY supports a CAMAC single crate system. A J11 running RSX-11S reads out the CAMAC modules and sends events via DECnet to a transport manager on the VAX. The CAMAC set-up is described by a text file provided by the user. No programming work is required. Data are always recorded on Exabyte drives connected to the VAX through SCSI.

A new version of GOOSY has recently been developed at GSI. The J11 processor has been replaced by an MC68030-based STR612/CVC processor from STRUCK (running LynxOS).

Data recording is performed on Exabyte drives connected to the STR612/CVC and transferred to the VAX via TCP/IP for online monitoring, performed with GOOSY or PAW. This new version is being validated at GSI and has been now introduced at ISOLDE.

The manpower invested in the hardware and software at GSI has been estimated as 10 man-years. Help and support for new experiments running GOOSY is provided by two people (one staff member plus one fellow working at 10%), who also make the link with the GSI developers. On average, a new experiment needs one day of configuration effort for setting up its GOOSY-based system.

The experiments with private systems are completely self-sufficient, since they are not using any service provided by CERN (except the public Ethernet network to control ISOLDE and to exchange data between the different set-ups). At least five of them make use of NIM crates and MCA (Multi Channel Analyser from ORTEC) and MP (Multiparameter cards, 3-dimensional Multi Channel from FAST) in PCs running self-made software. Data recording is performed on the local disks of the PC. Other experiments use completely home-made hardware (mainly CAMAC modules, microprocessors and HPC interfaces for the PC) and software.

The control system of ISOLDE itself has been in continuous operation since April 1992. The hardware is made of industry-standard PCs (there are roughly 15 computer units), and low-cost control/acquisition cards (ADC, DAC, I/O register, GPIB interfaces and CAMAC).

There are roughly 350 devices and 1700 control channels in the system. The computers and the majority of the control/acquisition cards are made in European Member States (Italy, United Kingdom).

The development of this system took 17 months from December 1990 to April 1992 and involved three part-time staff members. Two of them monitored the running-in of the system between May 1992 and December 1992. Since January 1993, all development on ISOLDE has been completely frozen, with the exception of one week of small improvements during March 1994.

3.2 Observations and comments

The environment under consideration has specific requirements, distinct from the majority of test beams at CERN. Most of the physicists come to CERN for the short period of test beam immediately followed by another period of data-taking (one or two weeks), bringing with them the equipment needed for the data-acquisition system, then return to their home institutes. In general, the experiments are not very demanding in terms of data-acquisition system needs. In the light of this, the present environment is well organized and self-sufficient. It can easily accommodate private data-acquisition systems or offer a common one to those experiments without a system. The introduction of the new GOOSY system will give the possibility to offer mixed solutions with various peripheral busses accessible through a uniform interface (CAMAC, Fastbus and VME), removing one of the main drawbacks of the present system.

The future plans for ISOLDE are that it will go on as long as the scientific programme justifies its continuation, and at least into the next century.

The people interviewed did not express any particular new requirement for data acquisition related to future ISOLDE experiments nor the wish to change the present situation.

4 ECP ELECTRONICS GROUPS

Contributions have been collected from all the electronics groups in ECP, namely EDA, EDE, EDI, EDU, ESS, MIC and PES.

The software systems they use are in most cases tools for testing hardware modules, which can only marginally be considered as data-acquisition systems, since their requirements are radically different.

One exception comes from a section which hires out to users complete data-acquisition systems for small tests and provides support for system installation and testing. This section provides and uses application-level test software.

There are three distinct phases when functionally testing hardware modules. The first is prototype debugging or in-depth evaluation of new boards, the second is production verification of the type ‘pass-nopass’, all these phases and the third is diagnosis and repair.

The ability of a test system to cover is essential. A unique approach for all the phases avoids the need for the expertise (and the maintenance charge) for a wide spectrum of software and hardware tools and set-ups, reduces considerably the development efforts in each phase, and allows technicians to be involved in all these activities. The software written in the evaluation or prototype debugging phase should also be reusable for the production verification and for diagnosis and repair purposes.

Nevertheless, each phase presents different requirements. Prototype debugging or in-depth evaluation requires high flexibility, rapid changes, good graphics display and good interaction with the test program. Production verification needs less flexibility, minor changes, almost no display capability, little interaction, but sufficiently high execution speed, since extensive tests can take hours. Diagnosis and repair are add-ons to the verification programs (different 'mode' of running the test programs) and again need high flexibility and rapid changes.

4.1 Present status

There are about ten test benches using stand-alone programs written in C, running on FICs over OS-9. The programs are organized as a fast loop of some functions performed on the hardware modules sitting on either CAMAC, Fastbus or VME. The corresponding standard library for bus access is used.

There are seven installations based on VALET-Plus and running the interpreter PILS with the related libraries.

There are still five CAVIARs programmed in Basic.

There are several PCs running Windows where the test programs have been written in C or Visual Basic.

Several groups are beginning to use LabView on either Mac, SUN or PC.

Various groups involved in mass production for experiments adopt a strategy where the final testing of modules is made in the same environment as the experiment, in order to detect eventual timing problems that may have escaped the test bench. This integration phase is considered necessary in any case and the groups rely on the end-user experiment to provide the needed software. The experiments also provide a person to collaborate closely with the people involved in the hardware development. A scale replica of the experiment's data-acquisition system (hardware and software) is set up in these cases, and examples of this practice are the tests of the Sirocco modules for DELPHI (EDE), of the CCD cameras for CHORUS (EDI) and of the ALEPH Trigger Supervisor Readout (EDU).

4.2 Observations and comments

The requirements and the wishes expressed by people dealing with hardware test set-ups are quite different from those expressed by people running experiments. This is not surprising since, as we have already seen, their needs are very different. In the hardware test set-up, it is important to let the user have an as-direct-as-possible interaction with the hardware in the most user-friendly way. The most important requirements are ease of use and flexibility of programming; efficiency is considered to be less important.

Very old systems are still in use in the electronics groups. VALET-Plus and CAVIAR are appreciated because they are both easy to learn and simple to use. However, since these systems are frozen and unsupported, there is a distinct trend to move away from them. More than the support, what is badly missing is the possibility of building graphical user interfaces to present the test results in a nice way—important when the end-user is supposed to use the program to test production quantities of the chips.

The only available option to fulfil the requirements described above is LabView, and several groups are seriously investing in it. Some people have expressed concern over

LabView's timing performance. One possibility is being discussed which would involve using LabView for friendly interaction with the system and to visualize the test results, while the real hardware tests would be performed by the standard C routines running in a VME CPU. The two systems could communicate through RPC. This solution of a 'mixed' system looks attractive to many groups, but there is the need to benchmark it further, before a definitive commitment.

If this happens, a coordinated approach across ECP electronics groups would evidently benefit everyone. The ESS group is even prepared to take a central role in this effort. In addition, the electronics pool might provide VIs for common modules and could rent out the test software together with the hardware. Obviously this could only be done for new modules, since the overall investment on the software test programs written in C and making use of the standard libraries for the existing 300 items provided by the pool has been estimated at 18 man-years.

The major problem is that no-one has enough experience in the use of LabView—naturally since everyone is just starting—and people have not enough time to learn it or to develop test programs, due to other commitments. In addition, the level of programming required by LabView is beyond the capability of the average electronics engineer. In several cases, collaborators from the end-user groups develop and install the test software, but this it is not always possible.

Therefore, a common service providing technical support for LabView would be very much appreciated. Another possibility would be to have somebody in a software support group work closely for a short time with the people developing the hardware and provide test programs, rather than having to rely on a common service. The software for the R&D programme in which the groups are today heavily involved often relies on non-established persons.

5 CN DIVISION

CN division does not use data-acquisition systems, but provides support in several areas directly linked to this domain.

The PRIAM activities are to provide support for the real-time operating systems LynxOS (one staff member) and OS-9 (one staff member plus one fellow).

Some 1000 OS-9 systems (3000 licences) and about 300 LynxOS systems are currently in use at CERN. The difference between the number of OS-9 systems and the number of licences comes from the fact that a typical system requires the runtime licence plus add-on licences, such as NFS.

OS-9 is the main real-time operating system used in experiments at CERN, while only some 300–400 licences are used in the accelerator sector. On the other hand, LynxOS is used in the research sector almost uniquely at an experimental level: around 10 LynxOS licences are in the research sector. However, one could expect the use of LynxOS in experiments to increase, particularly with the arrival of Power PC-based VMEbus single-board computers.

The support is both commercial and technical. The general work consists of testing new versions, troubleshooting and bug reporting, organizing technical meetings, and handling administrative tasks (e.g. price negotiations and licence distribution). Additional tasks are the support of cross-software tools or other relevant development tools (e.g. GNU tools, FasTrak, an X-based user-friendly development environment for OS-9).

Testing activities in direct collaboration with the operating-system vendors are an excellent means of detecting problems early and reducing the lead time for bug fixes. Furthermore, they are an important factor in preventing the proliferation of different, or differently flavoured, real-time operating systems at CERN.

CERN-wide administrative support for LabView started a year ago. This service is handled by one staff member and includes licence distribution, maintenance contract handling, purchasing of manuals and centralization of requests for technical support to National Instruments. When the requests for technical support concern CERN-developed libraries, they are passed on to the authors of the libraries who offer their help on a good-will basis. As part of the service, a filtered news group for LabView users at CERN has also been set up. The number of licences has grown from an initial 20 (18 on Macintosh, one on PC and one floating licence on SUN) to the present 100 (60 on Macintosh, 30 on PC and 10 on SUN). They are almost equally distributed inside AT, ECP, PS and SL divisions.

From now on, new versions of LabView for PC and Macintosh will be available on public servers at CERN, while the licence distribution will continue to be handled by the CN service.

6 FUTURE EXPERIMENTS

6.1 ALICE

ALICE has not yet set up a test-beam facility. Different private data-acquisition systems are at present being used by different R&D projects working on specific single detectors. The current systems will remain adequate for the next two years. Because the ALICE schedule is postponed with respect to ATLAS and CMS, a new system able to handle new readout and to cope with a higher data volume will not be needed before the end of 1996.

The ALICE group is proposing to use the ESA PSS-05 methodology for writing formal specifications of the data-acquisition system required for the future test beams. They have under discussion the setting up of a large test-beam facility for testing the different detector components. The current idea is that the data-acquisition system used for this should correspond as much as possible to the one adopted for the experiment.

6.2 ATLAS

ATLAS has several small-scale tests for prototypes of single detector elements under way in several beam lines. For these, the small stand-alone data-acquisition systems currently used (SPIDER, LabView-based, private data-acquisition software) are appropriate.

The main multi-detector ATLAS test beam is concentrated in the H8 beam line. An interim solution has been adopted to integrate the different detectors (each with its own data-acquisition system) into a joint test. While the front-end readout remains the one previously used in the stand-alone tests, the integration has been performed at the event-building level using the data-acquisition system developed by RD13.

The main requirement from ATLAS for test beam in 1995 and the following years concerns the gradual integration of the other sub-detector prototypes with the system currently being set up on the H8 beam line.

On data acquisition for test beams there is agreement inside the collaboration on the use of the RD13 system, which is technically adequate for the present and near future into 1996. The RD13 software is also expandable to meet the more demanding data-taking requirements of the future ATLAS test beam, planned for 1996 and 1997, when new, fast front-end electronics and the Barrel Sector Prototype will be installed.

There is a fundamental problem concerning the human resources available in RD13, which are estimated to be largely insufficient to support the immediate ATLAS test-beam requirements. In addition, there is the work needed to meet the project milestones specified by the DRDC and to guarantee the implementation of the data-acquisition system for the future ATLAS test beams. The ATLAS group estimates that the problem of manpower in relation to their data-acquisition system for test beams must be seriously addressed to avoid major problems.

The idea of a common approach with the other future LHC experiments does not appeal to ATLAS, if this means starting a new system from scratch, since they have already started test-beam activities where many sub-detectors have been integrated in a common data-acquisition system. On the other hand, in order to optimize resources, the ATLAS group are interested in a common approach which takes into account their present environment. The system they are setting up for the next runs will already be so widely spread amongst the many sub-detectors that it would be extremely difficult to proceed in any other way than that of its evolution.

More advanced versions of the system are already in operation in the laboratory (DBMS, multi-processor, etc.), but for the time being the collaboration's first priority is to consolidate the integration of the different detectors in the present system. New requirements, such as an event builder with a larger bandwidth, will become more urgent in the second half of 1995 and they foresee a change from the present system to the next version for 1996.

6.3 CMS

The present CMS test beams are concentrated in two main areas: the H2 beam—for tracking, muons, Hadron Calorimeter, Very Forward Calorimeter and all the tests in magnetic fields—and the H4 beam, which is mainly for tests with electron beam, shashlik calorimeter and crystals.

In the H2 beam line, CMS uses the RD5 data-acquisition system which has been continuously developed since the start of RD5 in 1991, while in the H4 beam line, a different system is used, based on one VME crate with a CES 8235 VME (RAID) module running LynxOS and recording data on Summit.

All the present test beams use old-fashioned, standard, front-end electronics (CAMAC, Fastbus and VME) and quite old data-acquisition packages have been adapted to fit the basic readout requirements.

At the end of 1995, new readout prototypes and larger detector set-ups will have to be evaluated. For that purpose a system which performs better is needed. This should be open to integrating the novel readout modules and the features specific to an LHC experiment (large data rates and data volumes).

The data-acquisition system needed should be based on VME and desktop computers such as UNIX workstations and high-end PCs, as far as possible hardware-driven (e.g. CES

Fast Link) and be able to handle peak rates of up to 50 MB/s (front-end to memory) and multi-megabyte events.

Some basic components have been highlighted where long-term support from the ECP division is required:

- real-time operating system for embedded processors (e.g. LynxOS) in a more general way than the present support, i.e. customizing it for different applications;
- general-purpose libraries for back-end data transport, such as data logging to permanent storage or data transport over the network;
- descriptor-oriented facilities for front-end readout, such as the future Dual Port Memory sequencer;
- graphical configuration editor and readout code generator;
- user interface and data presentation tools (LabView);
- integration of the run control system with the slow control system;
- on-line databases with highly interactive capability for small volumes of data—such as configuration and bookkeeping information—and low interactive capability and the capacity to handle large volumes of data (such as calibration constants).

Since most of the final data-acquisition functions will be implemented in hardware in a very specialized way, there is some scepticism about the possibility of reaching common general solutions in the online area for the final data-acquisition system. On the other hand, there is a consensus to reach a common solution with ALICE for the future test beams data-acquisition system.

6.4 NA48

The present NA48 test beams are concentrated in two main areas: the H4 beam for the Liquid Krypton (LKr) calorimeter and electronics tests, and the K12 beam for the integration of different sub-detectors and the final experiment tests.

In the H4 beam a data-acquisition system has been adopted, developed using SPIDER, which will last for the lifetime of the tests (until the end of 1995).

In the K12 beam, they will have real runs with the complete detector being set up in two phases: in 1995 all the sub-detectors will be present except the LKr calorimeter, and in 1996 the final detector will be installed. Data-taking is foreseen for the end of 1996.

Starting from 1995, the data-acquisition system used in the K12 beam line will be the final one: the data flow will be hardware-driven and they are now developing the software for the overall system control. The ECP/DS group will provide the software for the distribution of data from the Data Merger (DM) to the level-3 workstations (FEWS) over HiPPI link, the Data Merger Controller software to supervise the DM, the communication package used between the DM and the FEWS to ensure balanced and timely distribution of data to the FEWSs. Hardware-related monitoring of the various sub-detectors will be performed using either a Macintosh-based software developed at Mainz or with sub-detector-specific software running on a FIC8234. Global event monitoring will be performed on the downstream workstations using software developed at Mainz and at Orsay. Most of this software has already been tested in the K12 set-up.

6.5 Observations and comments

The whole domain of data-acquisition systems for test beams for LHC experiments is rapidly evolving, therefore any summary conclusions drawn today risk being obsolete tomorrow. This warning notwithstanding, a few general statements *can* be made.

ALICE is still in the process of defining its requirements. Even at this early stage, there is already strong evidence that ALICE and CMS intend to adopt common solutions and proceed to common developments.

ATLAS has a clear view on how to proceed and a well-defined development plan. The system architecture and the system components are objects of a research programme whose outcome will progressively be put into operation in the test beams.

CMS's plans are also precisely defined. The broad lines of the architecture are already decided, including the major components (sub-systems). They see their task as the development and building of the sub-systems and the final integration of all parts. The group is in favour of having some of the sub-systems—the ones of general interest, which may be shared by other experiments—made by external teams, in close collaboration with CMS.

The NA48 requirements seem to be well understood and the necessary developments properly planned.

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APPENDIX

UNATTRIBUTED QUOTATIONS

About manpower:

"We don't have enough manpower." The most common quote.

"CERN should provide us with people."

"The person who has done the work retired. The person who took over does not know the system yet."

About a common approach:

"We don't want a common approach, we want people."

"Three months to understand a data-acquisition system for one week of tests are too much."

"A common approach between experiments is interesting only if my experiment can gain from it."

"It is better to have our own data-acquisition system. The effort to interface to a common system would be equivalent to the effort to write our own."

"We have already got a common system: our system is really a straightforward yet versatile portable system as a modern test beam set-up ought to be and is reproduced and running in six universities outside CERN."

"A common approach would probably not fit in our analysis environment. The data-acquisition system used in test beams as well as the one used in the experiment should be the same and well integrated in the analysis environment. Online and offline monitoring should share the same library of routines."

"A CERN-made data-acquisition system does not support automatically very specialized readout, which could only be done by the experiment."

"Our test beam is an example of what should not be done: it does not use the same software as the real experiment."

"It is not a good idea since we are trying to avoid operating systems and use as much as possible existing hardware."

"It is not a good idea because what CERN offers is based on OS-9, which costs a lot and slows down everything."

"It is a good idea if it suits the hardware we have got." (Where hardware varies from CAMAC, Fastbus, VME, CPU processor type, etc.)

"It would be a good idea, but it is not applicable to this experiment for time scale reasons." Said by almost all the people that were in favour of a common approach in principle but are using private systems.

"It is a good idea if it suits the software we have got."

"It is a good idea if it is the solution to our high-speed data-recording needs."

"It is a good idea if it reads CAMAC through RPC and communicates with CERN mainframe."

"In favour in principle but we could not find anything suitable." (SPIDER not running on UNIX workstations, MODEL not running on UNIX, CASCADE not fitting in our time scale).

"In favour: local expertise would save time and manpower for physicists who prefer to concentrate on the detector building than on writing a data-acquisition system for a test beam."