The lack of these support facilities can extend commissioning and fault-finding times very significantly.

As a direct consequence of employing commercially available products, the documentation on the individual units is usually to a high standard. The system designer is left with the relatively straightforward task of describing the interaction between these items, and the overall system functions. Good documentation, however, is essential if a system is to remain serviceable in the medium term. It is not uncommon to find equipment that has had to be scrapped once the originator was no longer available to maintain it, because the documentation was never produced. Of course, problems in system design do not end with the commissioning of the system, even assuming that it does fully meet the user's requirements. The system has to be kept in service, and so ease of maintenance can be an important system design consideration. Certainly this was true of the camera system, and the CAMAC approach addresses this problem in several ways. For example, the structure is modular along functional lines. This simplifies the isolation of a fault to a particular unit, and allows first-line maintenance by unit replacement. The system-test software and hardware mentioned above also simplify this process. Faulty units can usually be returned to the supplier for rectification, thus taking advantage of their sophisticated automatic test equipment. As CAMAC equipment is often sold as individual products to system builders, items are often available either 'off the shelf' or on short delivery, and this can act as a valuable back-up to the normal system spares.

Initial system design often makes little or no allowance for the further development of the system. With the CAMAC approach the flexibility to cope with the needs for expansion and up-grading is built into the system structure. Since the initial camera system was commissioned, several additional requirements have been considered, that illustrate this point. The first is to connect the system to three other cameras over the next year or so. As the computer interface will support up to 49 CAMAC chassis, there is in practical terms no physical limit to the number of cameras that could be connected. The second is possibly more interesting, in that it demonstrates how the CAMAC standards have managed to evolve and anticipate new system requirements. As more cameras are added, the host processor will not be able to cope with the instantaneous data rates being generated, and the intention is to add local processing to each camera interface to preprocess the data. The most recent CAMAC standard covers exactly this requirement, and microcomputers are already available that will go into the camera interface assembly and provide the required function.

One final benefit that came from the use of CAMAC in this system was the genuine assistance the hospital staff were able to get from the CAMAC user community in Belgium, in terms of providing basic training and familiarity with CAMAC.

I thank Professor C. Beckers and M. Steels of the Department of Nuclear Medicine, of the Hospital UCL-St Luc, for presenting this interesting problem for us to solve and the directors of GEC–Elliott Process Automation Limited for permission to publish this article.

D. M. DRURY

GEC–Elliott Process Automation Ltd, Leicester, UK

CAMAC applications in biological systems

The application of CAMAC to biology has been given an impetus in recent years by the increasing use of large scale experimental facilities producing neutron or photon probes. Data rates may be high and to make the best use of these facilities it becomes of paramount importance that experiments should be highly automated.

From the point of view of such laboratories CAMAC provides a very good solution to several requirements. The systems must be flexible as they may be required to adjust to new experiments every few days so that the hardware must clearly be modular. It must also be largely available commercially because, though there will always be special units that must be designed 'in-house', the total quantity of units required will usually exceed the local design and production capacity of the laboratory. Maintenance problems are simplified as is software implementation as the use of a standard forms a well understood bridge between the programmer or maintenance engineer and the application.

These are general points that apply to systems outside biology as well as within it. Furthermore, though they may seem to be less pressing, these considerations arise also for the individual experimenter implementing a system at his home laboratory.

Several laboratories are using CAMAC to support experiments in biology. At the high flux neutron reactor of the Institut Laue Langevin (ILL) at Grenoble CAMAC output registers are in use for positioning stepper and servo motors on diffractometers and monochromators. Small Angle Scattering (SAS) cameras at ILL use incrementing CAMAC memories to interface 2-D detectors with up to 128×128 cells.

The European Molecular Biology Laboratory (EMBL) is standardising the use of CAMAC and it is in use at the main centre at Heidelberg and their outstations at the electron synchrotron DESY at Hamburg and the ILL. Among its present and planned uses are for experiments on fly flight dynamics, EXAFS (extended X-ray absorption fine structure) experiments, centrifuges, stepper motors and polar coordinate X-ray detectors. Three film scanners are interfaced by CAMAC to two Nord-10 computers and a PDP-11/45 and two film writers to Nord-10s. At the DESY outstation the CAMAC serial highway is used to connect two experimental areas separated by some 300 m.

On the electron synchrotron NINA (now closed) at Daresbury, monochromators were also positioned by CAMAC stepper motor drivers and monitored by shaft encoders. Incremental encoders were interfaced by CAMAC up–down binary counters and absolute encoders by input registers. CAMAC 24-bit pre-set scalars were used to record data from ion chambers on EXAFS experiments. An electron storage ring, known as the SRS, is being constructed at Daresbury as a dedicated source of synchrotron radiation, and it is due to become operational in Spring 1980. The data acquisition system will use CAMAC (as does the control system). Among the instruments planned for the SRS are multiple solid-state detectors. They are being made for energy-dispersive SAS experiments and high rates (100K counts s^{-1}) are desired from each detector. It is intended that incrementing CAMAC memory be used for the data accumulation.

The MRC (Medical Research Council) at Cambridge is developing an experiment using CAMAC to study the dynamic response of muscle to a stimulus. The magnitude of intensity peaks on a linear position sensitive detector will be studied over the 200 ms or so duration of a twitch with the aid of 100 buffered scalers. The scaler buffer registers will be read out every millisecond into a 32K word CAMAC memory while counting proceeds. To achieve the required high rate of transfers on the CAMAC dataway a simple auxiliary crate controller will be used to transfer data from the scalers to the memory.

We hope that these few examples have shown that the same units, stepper motor drivers, memories and scalers, for instance, are relevant to several different experiments. Note too that in CAMAC these units are computer independent it is apparent that an experimenter wishing to set up a new instrument or experiment will find that most if not all of the interfacing problems are already solved. As more systems are implemented in CAMAC the number of shareable and transportable solutions to problems in experimental biology will continue to grow. Daresbury intends to encourage this by loaning CAMAC systems to prospective users of the SRS. They may then develop instruments and experiments in advance of bringing them to the SRS and establish systems at their home laboratories which are compatible with those at the SRS.

To complement the ease with which CAMAC systems may be configured it is highly desirable to provide software that may be as easily written. CAMAC assists here too as the use of standard hardware promotes standard hardware-handling facilities the in software. Several different approaches to this have been adopted. At Daresbury a version of BASIC has been developed with extensions to drive CAMAC efficiently. This will make it possible for the biologist himself to write the programs to control his experiment. The extended BASIC compiler, called CATY, is also in use at EMBL, DESY enabling the two laboratories to share programs. This has happened in the case of EXAFS experiments even though different computers are in use.

As CAMAC finds application in the major facilities, techniques and equipment will evolve that match the many new applications in the area of biological science. This will lead to the availability of equipment that will be relevant also to the small biology laboratory and the scientist will be able to take advantage of the application of computing and modular electronics. This should enable scientists to use data acquisition and experiment control systems employing mini and micro computers in the study of biology without having to devote a significant proportion of their time to problems of electronics.

We thank Drs P. N. Clout of EMBL, R. Ghosh of ILL and A. R. Faruqi of the MRC, Cambridge for providing information used here.

A. C. PEATFIELD

P. A. RIDLEY

Daresbury Laboratory, Warrington, Cheshire, UK