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STATUS AND FUTURE OF CAMAC IN NORTH AMERICA*

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Abstract

The progress of CAMAC in North America is traced from the time of the endorsement of CAMAC by the NIM Committee in 1970, to the present. Developments in laboratory data acquisition and control, medical applications, and industrial measurement and control are described. Possible directions of future development are discussed.

Historical Background

The first large-scale instrument standardization effort among U. S. nuclear laboratories was the well-known NIM (Nuclear Instrument Module) system,[1] begun in 1964 and reaching full fruition about 1966. The AEC NIM Committee, sponsored by the AEC National Laboratories and National Bureau of Standards, and including representation from university research laboratories, concentrated on developing a standard which would arrest the rampant proliferation of incompatible hardware and signal standards taking place at that time. The success of NIM is history and will not be belabored here, except to note that the NIM program subsequently provided a most favorable climate for the introduction of CAMAC.

During the time that NIM was being successfully introduced to the AEC Laboratories, a number of digital modules, such as analog-to-digital converters (ADC's), time digitizers (TDC's), high speed scalers, and multi-channel coincidence latches, began to appear in module format. These designs usually consisted of a low density of digital electronics per module; thus the digital data, either serial or parallel, was transmitted via low density front or rear panel connectors conforming to no particular standard. A number of laboratories developed discrete wire-harness dataway systems specially designed to suit their particular needs. However, it was generally felt that NIM would never see usage as a high density digital interface system; thus the matter of a standard data connector for NIM was much discussed but never resolved.

CAMAC arrived at an opportune time, since new high speed integrated circuits were having a major impact on nuclear physics instrumentation, and a standard dataway was becoming imperative. The NIM Committee, which endorsed CAMAC officially in May, 1970,[2] viewed CAMAC as a timely adjunct to NIM: it felt that NIM would continue in popularity for high-speed circuits having little or no slow-speed digital I/0 requirements, and that CAMAC would serve admirably for data-collection modules, such as ADC's or scalers, having many digital outputs. In the U. S. nuclear laboratories today, NIM and CAMAC systems are indeed usually integrated in a typical experiment, partly of course because of the presence of large stocks of NIM equipment which existed prior to the advent of CAMAC.

In the same way that the NIM system was introduced and promoted, CAMAC has been presented by the NIM Committee to both users and industry and actively promoted as a desirable standard. The NIM Committee formed several sub-committees, paralleling the ESONE organization, to help develop the standards further; these include an Executive group for CAMAC, and Dataway, Software, Mechanical and Analog working groups. The purpose of these groups is to work with, as well as in parallel with, the corresponding ESONE groups to develop further standards in areas presently undefined or unspecified; and especially to interpret and clarify specifications for users, as well as industry, including specification of preferred practices where options are possible.

Working Group Activities

The various working groups have maintained very close liason with ESONE in all of their efforts. The earliest activities of the working groups centered around participating in the revision of EUR-4100e, and producing National Bureau of Standards equivalents of the main CAMAC specifications.[3,4] The Dataway and Mechanical groups have also cooperated on a Supplement[5] which contains notes on preferred practices, and includes such items as dataway crosstalk measurements and a typical power supply specification. The most recent activity of the Dataway group revolves about specification of the Serial Crate Controller. The serial controller is an important question and it is hoped that a final specification acceptable to both NIM and ESONE is near at hand.

The Software group is considering the problems of CAMAC standardized software on a broad front.[6] Its major tangible product to date has been the endorsement of six recommended CAMAC subroutines[7] suitable for use with, but not restricted to, the FORTRAN programming language. These subroutines involve essentially the generation of CAMAC commands which reflect the complete generality of CAMAC hardware, and which hopefully can be used with a variety of procedural and assembly languages.

The Software group is also cooperating with the ESONE-initiated effort to specify a high-level language for the definition of CAMAC systems and procedures. Progress in this area is being coordinated and interpreted via meetings and reports such as (6, 7) previously cited.

The Analog group has collaborated in a series of meetings leading up to the currently proposed revision of EUR5100 (1972) "Specification of Amplitude Analogue Signals."[8] This specification covers primarily matched 50-ohm systems; additional specifications for standards appropriate to industrial control and measurement are under study.

Some promotional activities involving other organizations have taken place or have been scheduled. Committee or Working group members have exchanged meetings with the Purdue Workshop on Industrial Computer Systems, a group involved in instrumentation standards in the industrial control field. CAMAC equipment was recently demonstrated at Purdue and at the IEEE Industrial Applications Society meeting, October 8-11, 1973, in Milwaukee, Wisconsin. Also in October, the Dataway Group chairman participated in a panel called "Computer Industry Standardization Efforts—Their Impact on Process Control" at the Instrument Society of America (ISA) Conference, in Houston, Texas.

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CAMAC In Laboratory Data Acquisition, Measurement and Control

The greatest impact of CAMAC to date of course has been in the nuclear laboratories. In the established laboratories, where data acquisition systems and interfaces already existed, the main impact has been at the module and crate, rather than the branch, level; that is, CAMAC equipment has been interfaced to existing systems via simplified branch drivers and sometimes simplified crate controllers in systems requiring usually a read-only operation. In these laboratories, implementation of full CAMAC data acquisition and control systems has been slow, mainly because of this common requirement to interface with older non-CAMAC equipment.

In the newer laboratories such as the National Accelerator Laboratory (NAL), Los Alamos Meson Physics Facility (LAMPF), and Tri-University Meson Facility (TRIUMF), where clear choices could be more readily made, CAMAC has enjoyed wide application and a growing popularity in both data acquisition and control. At NAL, for example, CAMAC is used for complete experimental data acquisition systems, as well as monitoring and control of the extracted proton primary beam and meson and neutrino secondary beams.[9,10,11,12] Additionally, the Synchrotron Booster control system uses CAMAC for control and monitoring of magnet power supplies, etc.[13] Because of the extremely long distances involved at NAL (3-mile circumference of the 400 GeV main ring), it has been necessary to develop serial crate controllers[14,15] which are now in wide use. A recent order has been placed by NAL for fifty serial controllers based on the existing NIM-ESONE draft specification for a CAMAC standard serial crate controller. Approximately 250 CAMAC crates are presently in use at NAL.

At LAMPF,[16] similarly, CAMAC systems are used in conjunction with minicomputers for data acquisition and control in each secondary beamline; for some special primary beamline diagnostics systems; and for data links between satellite computers and a main control computer. Most of the present systems utilize a Microprogrammed Branch Driver[17] (MBD) interface to provide a very powerful and versatile system, while some of the simpler systems use single crate (Type U) interface controllers.

At the TRIUMF laboratory, CAMAC is used to interface a central control console to a SuperNova computer; this computer is in turn linked to a second SuperNova having six CAMAC branches to separate remote control console areas. These consoles control such systems as the ion source, injection, ring magnets, etc. Ultimately the entire machine control system will be operated from the central console. A special optically-coupled serial system[18] has been developed for control of the ion source, which operates at a potential of 300 KV. About 30 CAMAC crates are involved in this system.

These and other laboratory activities have stimulated the development of new CAMAC hardware among manufacturers in North America. Essentially all the important module and controller functions, as well as crates and power supplies, can be purchased from domestic sources. This includes a variety of branch drivers, Type A and Type U controllers, multi-channel ADC, TDC, and register modules, relay control and multiplexer modules, etc. Further details of specific components can be found in the various CAMAC products guides such as the periodic listings in the CAMAC Bulletin.

The laboratories themselves have developed special modules and readout schemes for such devices as proportional and magnetostrictive wire chambers,[19,20] scalers and scaler displays,[21,22] magnetic tape interfacing,[23] etc., to name but a few examples.

In addition to the National Laboratories, CAMAC has been introduced into many user groups at major universities throughout the United States and Canada.

One non-nuclear laboratory where CAMAC is being broadly implemented is at Kitt Peak National Observatory (KPNO) in Tucson, Arizona. Here, CAMAC is being used in a new installation to interface a total of eleven telescopes to individual control and data acquisition minicomputers.[24] A special branch driver has been designed for this system.[25] To date, six of the eleven telescopes are fully operational.

Another observatory using a small CAMAC installation is the Lick Observatory, operated by the University of California at Santa Cruz, California.

CAMAC In Medical Applications

CAMAC has had some significant beginnings in the field of medical computing. At Vanderbilt University, CAMAC has been used to implement a nuclear detector scanning system using a small computer.[26,27] The computer both programs and controls the scanning table, as well as processes the data and generates visual displays. A variety of different detectors can be accommodated; in addition an Anger type camera is being implemented. In future, this group is also proposing to utilize CAMAC in developing a computer controlled radiological therapeutic facility.

At the Los Alamos Meson Physics Facility (LAMPF), a biomedical group is in the process of implementing a system for pion radiotherapy.[28] This system, consisting of a Microprogrammed Branch Driver (MBD) connecting three CAMAC crates to a minicomputer, will use the computer real-time operating system for control of treatment and planning as well as for beamline diagnostics.

At the University of Toronto Department of Medicine, CAMAC has been used to implement a large data acquisition system involving a 128 K core time-shared central computer serving a total of five individual medical research laboratories over a standard CAMAC branch.[29] The remote crates in turn are used to interface to local minicomputers through autonomous controllers for real-time high speed data acquisition. The central and local computers communicate through a special Link Module. A local CRT display is also interfaced via CAMAC. The system also provides background batch processing in the central computer. A balanced long-distance branch, as well as a serial crate controller, have also been implemented. The system is used to support various experiments in neurophysiology, pharmacology, otolaryngology, and biochemistry.

More recently, two independent CAMAC systems are being installed in the laboratories of the Zoology Department, for behavioral experiments and neurophysiological monitoring, and in the Addiction Research Center, similarly for neurophysiological studies.[30] The former system involves three minicomputers sharing a CAMAC branch, while the latter involves a single minicomputer.

CAMAC In Industrial Applications

CAMAC has made some modest beginnings in the field of industrial control and measurement. A prototype system being implemented to control and monitor natural gas demands for an aluminum plant is to be described later in this conference.[31] As has already been mentioned, CAMAC is being studied by the Purdue Workshop on Industrial Computer Systems, and some significant demonstrations of CAMAC equipment have taken place.

The application of CAMAC to industrial environments introduces new problems of electrical noise, isolation of high voltages and currents, suitability of current software developments to industrial applications, and overall system reliability. It is clear that although a few of these industrial environmental problems have received attention in the National Laboratories in applications such as the control and monitoring of very high current power supplies or high voltage ion sources, the operational requirements for CAMAC in a non-laboratory environment are in general much more stringent, and some important questions remain to be resolved.

It should be noted that in an electrically harsh environment, certain problems of machine control interfacing may be more readily solved using a NIM module; thus the potentiality for combined NIM-CAMAC systems should be considered for such applications.

Future of CAMAC

The immediate future of CAMAC in nuclear as well as other laboratories seems assured. CAMAC, because it has been a well-engineered system from its inception, has indeed become the desired standard for future data acquisition and control systems. The development of commercial controllers and branch drivers for a wide selection of computers, and at reasonable prices, has been instrumental in promoting this trend. As more practical operating systems are demonstrated, the advantages of CAMAC become ever more obvious. The major point in favor of CAMAC is that in many cases it offers an off-the-shelf hardware solution to complete data acquisition or control system problems, thus relieving the experimental user of much repetitive and costly design effort. This feature is of particular value to small and medium sized user groups who usually have minimum engineering resources at their disposal, and also in large laboratories where many similar but flexible systems must be implemented. In future, the generation of standard software will make CAMAC even more simple to implement and to re-configure.

In medical applications of CAMAC, the situation seems to encompass features of both laboratory and industrial environments. In general, it appears that CAMAC is capable of solving a host of problems in medical system monitoring and control; however from a user standpoint the need for reliability and availability of outside maintenance and engineering services would appear even more important than in many industrial applications, both because of the possible interruption of a vital medical service, as well as because of a possible complete lack of in-house technical service or engineering personnel. Hospital personnel are not electronics specialists; hence the practical problems of operating and supporting sophisticated electronics equipment in such an environment must be met as a prerequisite to widespread acceptance of CAMAC as an instrumentation system.

Similarly, certain environmental problems must be solved if CAMAC is to receive widespread popularity in the industrial control field. The situation here is somewhat better in that the tasks of automatic control and measurement are relatively straightforward from the computer standpoint, and a minimum interaction with technically unskilled personnel is necessary in many applications. CAMAC appears capable of meeting the environmental requirements, possibly needing some expansion of existing hardware options to do so; however its success will depend strongly upon the development efforts of independent industrial users themselves. Again, such efforts require teams of engineering personnel, and many industries will not use CAMAC widely until complete systems engineering and servicing are available commercially because of an in-house lack of such personnel.

It should be noted in all of the foregoing that there are no indications that CAMAC is incapable of meeting the technical requirements in all of the fields mentioned, only that certain practical conditions need to be met for CAMAC to continue to expand into these and other areas of application. Thus the problems mentioned apply equally well to any competitive system or systems which would hope to operate in these areas, and CAMAC may well have a significant advantage because of its current widespread acceptance in the nuclear field.

In considering the long-range future of CAMAC, the question of its suitability as a packaging standard for future integrated circuits inevitably is raised. Even in the very beginnings of CAMAC it was argued by some that the CAMAC packaging concept was too restrictive for large-scale integrated circuits (LSI) and hence would quickly become obsolete. That CAMAC has in fact become a practical, cost-effective system in many areas, with much promise of further success, simply demonstrates that standards such as CAMAC do serve a useful purpose even in the face of change, due to the finite time lag between initial development and widespread availability and utilization of new, more complex families of integrated circuits. Furthermore, the advent of higher density, more complex integrated circuits does not automatically outmode a given packaging scheme, since real systems are more often influenced by other constraints such as the available connector, cable or mechanical hardware, than by the introduction of a new configuration of integrated circuit into the system.

Still, it must be recognized that just as CAMAC initially received impetus from new developments in integrated circuits, so also CAMAC may eventually become obsolete because of the advent of totally new logic packaging or organizational concepts at the device level. If and when this happens will be dictated by compelling technical and economic factors. Whatever the outcome, however, the lessons of NIM and CAMAC will surely serve as an invaluable model for future standardization efforts in the field of instrumentation.

Acknowledgment

This brief status report could not possibly convey the extent of the effort required by the NIM-CAMAC groups to bring CAMAC to its present status in North America; nor could it properly convey the extent of the mutual benefits derived from the NIM-ESONE collaboration. We on the NIM Committee are grateful for past associations with our ESONE colleagues and pleased to share in the continuing successful development of CAMAC.

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