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ACCELERATOR DEPARTMENT
Informal Report

ICAM

THE ISABELLE CONTROL AND MONITORING SYSTEM

GLOBAL OVERVIEW

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ABSTRACT

A first draft on the definition of the ISABELLE Control and Monitoring System is presented. Emphasis is given on the design strategies and on the proposed architectural concepts. A triangular network has been selected and defined. Some structural consideration of processor and bus structure hardware are given.

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1. SCOPE

A minimum configuration of the ISABELLE Control And Monitoring (ICAM) System will interact with the data and control flow as well as maintain data bases and procedures necessary to provide at least the subsequently listed global functions:

a) OPERATION

The machine always operates within one of the following major phases:

SETUP of parameters, data and procedures;

FILL the two rings;

ACCELERATE beam;

MAINTAIN stored beam;

TERMINATE or ABORT (dump) beam.

b) MODIFICATION

Data, parameters and procedures may be modified at suitable operational phases within (independently set) limits.

c) MONITORING

The machine behavior will be selectively monitored.

d) MEASUREMENT

Physical parameters will be selectively measured within (independently set) limits.

e) MACHINE PROTECTION

The machine will be protected against damage caused by malfunctioning equipment.

f) ENVIRONMENTAL PROTECTION

Some functions concerning the protection of personnel against health hazards and protection of the environment will be provided.

g) OTHER FUNCTIONS

An array of support functions are expected from the system, such as:

1. bookkeeping of schedules, information, etc.;
2. small scale computation;
3. maintenance of history information;
4. program development.

2. SOME REQUIREMENTS

As justified subsequently, ICAM will be structured as a network of functional nodes, each containing at least one programmable processor and memory. Some of the key requirements to the network are:

- a) Operator interactions should always be straightforward;
- b) monitoring displays must be comprehensive;
- c) a complete record of the ISA status must be maintained in real-time within the network;
- d) one Main Machine Control room should be maintained, possible other control rooms will have a local scope, which is confined in the global scope of the Main Machine Control;
- e) the reliability of critical components should be very high by use of redundancy or other measures;
- f) flexibility must be provided in the sense that incremental expansions, improvements, and replacements can be made with prevailing technology, not the technology available at the time of system implementation.
- g) The most complex operational phase of the ISA Control will probably be the acceleration phase. Approximately 1500 correction coils will be stepped up synchronously with the main field. A minimum dwell time on a step is 15 msec. The steps are typically synchronized within 1% of the maximum dwell time. A high parallelism is necessary. The only conceivable resolution is to use a network of processors which are able to operate in parallel.

2. STRATEGY

The selection of the basic architecture of ICAM is of fundamental importance to the success of the later development, construction and operational phases. It is, therefore, justified at this early stage of ISA design to concentrate on a systematic study of the architecture of the system. Some reference to hardware and software selections are made in order to verify the suitability of the architecture.

The following sequence of steps have been taken in the system definition:

- a) A set of presently known global functional subsystems and their interconnections are defined. This process leads to an architecture called "Functional Distribution".¹
- b) The global functional subsystems are broken down into more elementary subsystems which are confined in the global subsystems. This process is pursued in a depth as is practical within the present early stage of ISA design.

1. D. Gerd Dimmler, "Functional Distribution-An Architecture for Real-Time Multi-User Computer Networks in Instrumentation. IEEE Trans. Nucl. Sci. NS-21, No. 1, 838 (1974).

- c) Some predictions are made as to the mapping of the functional architecture into a suitable set of hardware and software structures.

4. SYSTEM OVERVIEW

4.1 Flow of Data and Procedures

ICAM essentially manages numerous flows of data and procedures. It is, therefore, reasonable to consider the control of this traffic as the most basic function. As shown in Fig. 1, the originals of all data and procedures existing within the system are kept in a global data base (or a set of data bases). One or several working copies of the data and procedures are spread over various parts of the system. They may exist:

- a) in the data base itself;
- b) as working copies interfacing to the Manipulation Environment;^{*}
- c) as working copies interfacing to the Machine Environment;
- d) as working copies interfacing to the Automatic Output Environment.

If working copies are being modified, created, or released, then internal update cycles take care of the appropriate update of originals.

The time interval between the change of a parameter at the source and the updating of the original data base determines the time resolutions of the data base information and thus of the system. It is generally true for real time systems that there is a close relationship between cost on one hand and the required resolution as well as the required modification frequency on the other hand. Working copies appear on several levels of a hierarchy in different forms and different segmentations.

4.2 Global Architecture

The data and procedure flow suggests a globally triangular network as shown in Fig. 2.

The global functional subsystems are:

- a) a Common Node (or a set of nodes) containing the data base(s) of original data and procedures;

^{*} A Control System generally deals with three global environments.¹

AUTOMATIC OUTPUT ENVIRONMENT

Fig. 1

Global Data Flow

AUTOMATIC OUTPUT ENVIRONMENT

Fig. 2

- b) connected to the Common Node is a set of local Control Nodes, which are physically located around the ring as close as feasible to the appropriate machine electronics;
- c) on a second leg connected to the Common Node is a set of local Manipulation Nodes, which operate the various terminals, monitors, etc , in the Main Control rooms or local control rooms.

These three sets of nodes are interconnected via a long distance communication subsystem called a Transaction Communication subsystem.

The concept requires a minimum of three processors with associated memory. The actual number will probably be substantially higher in ICAM.

5. Transaction Communication Subsystem

5.1 Communication Lines

The local Control Nodes, as well as Manipulation Nodes, are connected to the Common Node by (logical) point-to-point long distance communication lines as shown in Fig. 3. The physical layout of this communication line has not been determined yet. In addition, the Control Nodes are connected to a set of conceptually significant multi-drop lines as shown in Fig. 4. They are:

The Absolute Synchronization Signal

A synchronization signal is broadcast around the ring giving every Control Node the opportunity to execute functions synchronously with other Control Nodes. The resolution time of the signal depends on the cable transfer time around the ring. It is assumed that $\sim 30 \mu\text{sec}$ can be achieved. The source of the signal is different at the various phases, i.e., at the acceleration phase the signal will be generated by digitized values of the main field.

Initialization and Abort Signals

It is a nontrivial consideration to identify within the global network an "idle" phase. The global network will be set to this state after:

- a) power turn-on (initialization);
- b) ISA is shutdown, either controlled or in an emergency action (abort). The emergency abort process is complex and presently not entirely understood.

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Fig. 3
Transaction Communication
Subsystem

Fig. 4
Local Control Node
Connection

Selective Attention

This signal will be explained in Section 5.2.

5.2 Transaction Protocol

A Control Node requiring a block of data or a procedure from the Common Node initiates a request/response cycle, here called a transaction. A transaction consists of 3 phases:

- the REQUEST phase;
- the ACKNOWLEDGE phase, and
- the TRANSFER data or procedure phase.

The Transaction Protocol, as shown in Fig. 5, is initiated by the Control Node.

It should be noted that the control node always functions as a requestor, or Master, and the Common Node always functions as a responder, or Slave. In the case where a Control Node is requested to execute a new procedure, an extended Transaction Protocol, as shown in Fig. 6, applies. An asynchronous Selective Attention Flag (Fig. 4) is raised which is interrogated voluntarily by the appropriate Control Node. The Control Node then initiates the above described request/response cycle.

In the REQUEST and ACKNOWLEDGE phases, blocks of control information with predetermined length and predetermined structures are transmitted. In the TRANSFER phase, data or procedures as described in the previous two phases are transmitted.

6. Control Nodes

A Control Node may be described as an "execution computer" in traditional terms. A maximum of two global procedures, as shown in Fig. 7, operate at any given time in one node. Figures 8 and 9 show some of many possible configurations at a Control Node. As far as feasible, digital control loops are used. The procedures, thus, control directly Digital-to-Analog converters and Analog-to-Digital converters. More elaborate configurations may include processors at lower levels. Figure 9 shows an example of such a configuration.

7. Manipulation Nodes

Figure 10 shows the Manipulation Nodes which are probably necessary. With the exception of the Manual Control Node, which is ISA specific, the Manipulation Nodes can be considered as general systems which are, hopefully, commercially available as "turn-key" systems.

Fig. 5
Basic Transaction
Protocol

Fig. 6
Extended Transaction
Protocol

Fig. 7

Control Node
Standard Configuration

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Fig. 8
Control Node
Example of Specific Configuration

Fig. 9
Local Control Node
Example of Local Data Reduction
(Generation of Spectrum)

8. Common Node

A processor, memory and disk system, with some necessary peripherals, will be dedicated to operate the Common Node. Transactions submitted to the Node will be processed here. A description of the architecture is given elsewhere.²

9. Reliability

A key requirement of the system is that the detection and the impact of malfunctions, may they originate from hardware or software, are confined to a small local area,³ i.e., if a Control Node component fails, the system should be able to proceed as long as no dynamic activity by the failing node is necessary. Also, repair of one node should be possible without impact of any kind to a neighboring node.

The data base node operating system will be structured in a way that the usual safeguards against loss of data are incorporated. They are:

- a) recording of every modified record on a magnetic tape associated with periodic selective dumps;
- b) keeping the data base node hardware in a closely environmentally and otherwise controlled room with no traffic;
- c) designing a very stable software within the data base node.

It is the present thinking that more expensive measures, such as redundant data base nodes, may not be necessary.

10. Hardware Structure Considerations

Although it is too early to make definite statements about hardware structures, a few points are clear enough now that they are worth being stated.

- . All processors should be, as far as feasible, instruction set compatible. More than two instruction sets should be avoided under any circumstances. This requirement may, under certain circumstances, not necessarily hold for nodes, which are acquired as selfcontained "turn-key" systems. The Monitoring Node may be such a candidate; one would, however, then give up the possibility of later economic expansion.
- . Preferably, all nodes should use the same bus structure.

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- 2. F.W. Stubblefield and D.G. Dimmler, "Transaction Processing in the Common Node of a Distributed Function Laboratory Computer System" IEEE Trans. Nucl. Sci. NS-22, No. 1, 473 (1975).
 - 3. D.G. Dimmler, "Architecture of a Maintenance Subsystem in a Multi-User Computer Installation. Proc. Workshop on Fault Detection and Diagnosis in Digital Circuits and Systems, Lehigh University, Allentown, 1970.

The bus structure must meet at least the following requirements:

- . minimum restriction on mechanical measurement of devices;
- . uncommitted data and control flow;
- . provisions for separation of data and control flow;
- . asynchronous request/response relationship between devices;
- . widespread acceptance in order to be able to purchase major portions of the necessary devices commercially.

11. Software Structure Considerations

It is probably too early to make definite statements about software structures.