COMPUTER FACILITIES FOR ISABELLE DATA HANDLING

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I. Conclusions

1. The analysis of data produced by Isabelle experiments will need a large system of computers. An official group of prospective users and operators of that system should begin planning now.

2. Included in the array will be a substantial computer system at each Isabelle intersection in use. These systems must include enough computer power to keep experimenters aware of the health of the experiment. This will require at least one very fast sophisticated processor in the system, the size depending on the experiment. Other features of the intersection systems must be a good, high speed graphic display, ability to record data on magnetic tape at 500 to 1000 KB, and a high speed link to a central computer. The operating system software must support multiple interactive users.

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3. A substantially larger capacity computer system, shared by the six intersection region experiments, must be available with good turnaround for experimenters while Isabelle is running.

4. The computer mainframes described in (2) and (3) should ideally be compatible members of the same family of computers.

5. A very large computation load will be generated by the post experiment data reduction. Much of this may have to be handled by the system described in item (3), presumably run at lower priority.

6. A computer support group will be required to maintain the computer system and to provide and maintain software common to all experiments. Such software support may include providing a compatible compiler if the commonality described in (4) is not achieved.

7. Special superfast computing hardware or special function processors constructed with microprocessor circuitry may be necessary both in the data gathering and data processing work. Thus both the local and central processors should be chosen with the possibility of interfacing such devices in mind.

II. Procedure

The Data Handling sub-group* of working group I, Detectors and Experiments, reached a few general conclusions at its first

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meeting. First, a luminosity of 2×10^{32} and a total pp cross section of $5 \times 10^{-26} \text{ cm}^2$ produces an interaction rate of $10^7/\text{sec}$. Conventional schemes for triggering on desired events can reject background to levels of 10^{-4} or possibly 10^{-5} in special circumstances. Thus, new techniques are clearly necessary to bring the data recording rate to a reasonable level of 10 to 100 events/sec. The events themselves will be generally of high multiplicity and will present new problems of particle identification and track finding. The recording apparatus will often be as large as the largest arrays in use today, involving perhaps 10^4 to 10^6 bits of data per event.

The subgroup then split into two sub-sub-groups - the "Upstairs" group to consider possible ways of bringing the net data rate below 100 events/second (corresponding to a cross section of $0.5 \text{ } \mu\text{b}$). Conversely, the study reported here took as input a selected (triggered and/or pre-processed) event rate of 100 events/second and tried to consider the computation facilities necessary to deal with this load. At various points discussions were held with the full subgroup. The diversity of opinions in both groups was so large that the first recommendation had to be the formation of the computer planning group for ISABELLE to resolve differences and plan acquisition of hardware and support in advance of the construction of actual experiments.

III. Local Intersection Computer Systems (LICS)

That computers would be needed at each intersection was not seriously contested. In fact, there was no dissent to the

contention that the computer devoted to one experiments at an intersection should be capable of performing pattern recognition on a reasonable fraction (say 10-20%) of the events in order to monitor device efficiency and performance.

The functions of the computer support facilities required for running physics experiments include data-collection and logging, testing and debugging of apparatus, and monitoring the performance of the experiment during running.

A. Data Collection and Logging

A typical experiment uses a large collection of different detectors. The first requirement for an experiment will be to select from the approximately 10^7 events/sec those events that are of interest by rapid logic on some or all of the data collected by the detectors, either in "hard-wired" electronics or microprocessors. Computer hardware will undoubtedly be involved in the task of gathering the data from the various detectors, perhaps doing some preprocessing and filtering of the data, and then storing the data on a permanent medium (e.g. magnetic tape) and simultaneously passing data samples along for further real-time analysis. This function could be served by a small job running in an on-line computer or by a dedicated minicomputer.

B. Testing and Debugging Apparatus

Most detectors to be used at Isabelle will consist of many elements and will use sophisticated readout techniques involving large arrays of electronics. The setting up and

debugging of such apparatus requires the ability to monitor and analyze the data in various modes, some of which could be the result of various levels of data simulation generated by the computer and injected at test points. We would anticipate substantial use of the on-line facilities at Isabelle for such uses during machine downtimes.

C. "Real-Time" Monitoring During Experimental Data-Taking

The purpose of the "real-time" monitoring is to enable the experimenters to make maximum use of running time and to produce data of the highest quality. The response time required for such monitoring will vary depending on the feasibility or necessity of the experimenters response. For example, variations in supply voltages or experimental magnet currents that can be corrected require fast responses, say on the order of minutes. Other examples in this category would be monitors of detector efficiencies which could indicate the necessity for adjustment of voltages or gas mixtures.

In general, a first, fast level of monitoring would consist of ensuring that the data from the various detectors is present and correctly formatted, and then, for example, checking ADC readouts of voltages and currents. This level basically determines that the experiment apparatus is turned on and responding.

The next level is to evaluate the quality of the individual detectors. A major aid in this task is a good graphics display capability. Probably the most useful component

will be the ability to provide a visual presentation of the hits, pulse heights, etc. of each event, so the experiment can judge the quality of the data and investigate problems. In addition, to an individual event displays the computer can display accumulated wire maps, multiplicities, pulse height distributions, etc. The computer can also be accumulating data for setting thresholds, gains, etc. (perhaps from calibration events interspersed with the data).

Another vital monitoring function is checking the efficiencies of the individual detectors. Depending on the experiment this can be done at some level by simply monitoring detector hits, but the best information is usually obtained by performing some level of data analysis to ensure the quality of the event sample being used. (It is difficult to fault a device for not detecting junk.) For example, for drift chambers this could involve fitting tracks and then looking for missing chambers. At this stage, one would also monitor the quality of the Isabelle beams to determine when scraping is necessary.

The highest level is monitoring the physics quality of the data. Ideally, one would like to be able to check that analyzable events containing the intended physics are being recorded. Obtaining this complete sort of information may not be feasible for all experiments, especially those that will have small final data samples. However, the computer facility should be able to provide good statistics (approximately 3 events/sec average) on full track reconstruction, topological and kinematic fits,

trigger performance, calorimeter performance. This type of computer support will also be extremely important during the setup phases of the experiment as well as during data taking. Some of this support will probably have to be supplied via batch operation at a "remote" computer, but it is vital that it be responsive to the need of the Isabelle experiments to ensure the feedback that experimenters require to keep their apparatus working.

The exact division of this monitoring between intersection and remote computers will depend on the detailed nature of the apparatus and the local computer available at the intersection. However, we feel that the local on-line computer must be capable of providing the above functions up through at least crude pattern recognition and track-finding.

D. Minimum Configuration for LICS

In an attempt to be more specific about computing at the ISA than in the past, we have specified a computer configuration which would meet the requirements of most of the presently envisaged experiments. We realize that the rapidly changing state-of-the-art in computer hardware makes it almost futile to specify a system five years before it will be acquired, but we also appreciate the necessity of beginning our deliberations early enough to allow time to define the needs and goals of the system as well as to include a large part of the user community in its design. The system that we here specify is thus only intended to serve as a starting point for future discussions.

Fig. 1 shows a schematic drawing of the computer configuration. The dashed line designates that part of the system which will be located at the intersection region. It was decided at the outset that the housing for the computer system should have sufficient area and be of solid construction, i.e. not formed by a complex of trailers. This will be necessary to assure reliable operation and practical maintenance.

Since there will be large quantities of data coming from most of the experiments to their respective computers, it should be transmitted in parallel as much as possible. A special function processor, SFP, will receive this data, perform preliminary operations on it while it is still in its parallel form, e.g. apply gain corrections, suppress zeros, reformat, etc., and deposit it in a memory specified as "data box." This SFP may also begin the track recognition part of the analysis; again, since the data are still in parallel, certain manipulations might be performed more rapidly than would be possible later.

A data logging device, at present thought to be a 6250 BPI, 200 ips tape drive system, will be driven from the data box for recording of the raw data.

As discussed above, the local computer mainframe should have adequate power to determine independently that the experimental apparatus is functioning correctly and to give the experimenters sufficient information to make preliminary physics decisions. The configuration shown in Fig. 1 is essentially a minimum specification employing present technology. It should have a bus

structure which would permit attachment of SFP's to perform specific computations which are repetitive and amenable to hardware adaptation. This bus structure could also incorporate an interface device such as CAMAC which would allow pulses and controls to be sent to the detector for testing purposes. In fact, the bus may be the proper way to connect the "data box" to the CPU, so that the data box becomes an extension of the memory of the on-line computer.

A high speed data link should be connected between the local and remote computers. This link would couple to a fast access, responsive remote system that should be able to receive data and transmit fully reconstructed events at a rate of a few events per second. Which events are transmitted to the remote system would be determined by the local system.

Also located at each intersection region should be a remote batch station, RBS. This can employ a slower link than mentioned above but would allow communication between the intersection region and the remote computer for batch jobs and program modification.

An estimate of the cost of equipment at each intersection region is as follows:

high speed graphics	\$15K
data box and AFP	50K
on line computer mainframe	150K
keyboard terminals	15K
2 line printers	50K
3 6250 BPI tape drives/controller	<u>100K</u>
	\$380K

The cost of the RBS and data links would be included in the cost of the remote system. Some savings overall could be achieved if the remote batch could be handled as a background job by the main on-line computer.

IV. Major Isabelle Shared Computer (MISC)

Although some felt the need of a very large computer at some intersections, the major computer power for Isabelle experiments will clearly be a shared facility, centrally located. Some of the functions foreseen for this facility are listed here.

A. Real-Time Operations

Experiments at the ISA will require a responsive off-line computer to serve at least two real-time functions. The first of these functions will be associated with program development which will continue through all stages of an ISA experiment. In order for this work to be accomplished as efficiently as possible, the off-line computer should be useable from interactive terminals with a time sharing system for editing and compiling source programs. This will require adequate disk storage for permanent source program and data files and a software system for the editing, filing and bookkeeping operations and submission of jobs to the batch stream. At least three terminals will be required at each intersection station.

The second real-time function of the off-line computer will be to perform a complete analysis of events sampled during the data taking runs of ISA experiments. Such analysis will involve

pattern recognition and track formation from as many as 10^4 words of information per event, construction of the momentum vectors for these tracks, and the calculation of physically interesting quantities such as invariant masses, transverse momenta, etc. These results should then be available for immediate display at the intersection station. The off-line computer should be capable of analyzing several events per second for each experiment, a rate which will, in general, be beyond the capacity of the on-line computer. This operation implies that the remote computer should be a fast machine with at least some of its capacity dedicated in a priority way to the ISA while experiments are running. There must also be fast two-way data transfer links to each of the on-line computers. In addition, we believe that the off-line computer should be capable of utilizing special function processors to perform some of the redundant operations in this analysis such as coordinate sorting, least squares track fitting, vertex reconstruction, etc.

There were different opinions in the study group as to how much "on-line" sampling use of this facility will be feasible. Leith's group at SLAC, for example, uses the central SLAC IBM 370/168 system for their data logging. Others see the central computer as reliable enough only for the remote batch use. A high speed data link should certainly be one of the design features of the intersection computers and the central system, in order to allow experimenters to make as much use of the shared facility as they find practical.

B. Batch Operations

Program testing, final data processing, preparation of data summary files and physics analysis will be done on the off-line computer using the usual batch processing operation. A remote batch station will be required at each intersection region including a line printer, card reader, and typewriter-video terminals. Links should also be established to remote batch stations located at the home universities of the ISA experimenters. Special requirements of this operation will include a mass data storage capacity and graphical display equipment and software capable of producing publishable quality figures.

It appears that experiments are done more and more by large teams of physicists for whom computation at diverse local university computer centers becomes less and less practical. The planning group should verify that this is so and plan accordingly for a large part of the final data analysis for Isabelle experiments to be done by the MISC.

C. Administration and Siting

There was considerable concern over whether the central computer was an adjunct of the lab-wide computer facility or a system dedicated to Isabelle users. Many felt that flexibility, quick response, adequate attention to Isabelle operating schedules, etc. required a dedicated facility. This is clearly a serious matter for resolution by the appropriate authorities. The planning group called for in recommendation #1 should make the resolution of this problem one of their first concerns.

D. Scale of the MISC

With Isabelle in full operation (perhaps four or five of the six intersections taking data) at rates up to 100 events/second for each experiment the total computing capacity needed for full data reduction can be projected to be several times the capacity of the present BNL CDC 7600. Clearly, the practicality of dealing with the data must be a serious concern in the design and approval of Isabelle experiments.

V. The Ubiquitous SFP

Many see an important role for microprocessor circuitry in future high energy physics data handling. They offer the possibility of duplicating a substantial part of the functions of a large computer processor in an inexpensive way. Thus, if many similar circuits can be fed data in parallel a large increase in processor capacity is possible at modest cost. Since the individual μ -processors are comparable in speed to the normal computer circuits this parallelism is essential to effective use. The nature of detector data and physics events suggests that such a system should be developed. Leith's group at SLAC is connecting a large number of μ -processor emulators of the IBM 370/168 to the SLAC central computer. Further developments in this direction are to be expected. The architecture of the computers selected for Isabelle should not preclude this development.

VI. Hardware and Software Support

The overlap of the problems dealt with at the local intersection computers and the central computer leads to the recommendation that they be different sized but compatible members of a family of computers. Maintenance will be cheaper and more effective if all intersection computers can be serviced from a common pool. Similar savings in software support will be realized with a common library and at least a totally compatible FORTRAN compiler language. The maintenance of separate versions of routines for performing the same tasks on different computers, given the constant upgrading of experimental hardware and goals is a very time consuming chore.

The software support should also include those programs necessary to interface the computers to the hardware, e.g. data transmission along the data links, tape writing, data transmission from the data box to the local computer, etc. There should also be "canned" programs for graphics systems and a library service to make available to the community those programs written by other experimenters which might be useful. Another area of software support would be in the programming of micro-processors. It will be most helpful to have methods of programming these devices, the heart of the above mentioned special function processors, available in high level programming languages.

FIGURE CAPTION

Fig. 1 Schematic drawing of the computer configuration proposed for ISABELLE. The configuration inside the dotted line forms the Local Intersection Computer System (LICS) and will be located at each active intersection. The "Remote Computer" represents a Major Isabelle Shared Computer (MISC). SFP indicates possible application of Special Function Processors constructed from micro-computer circuitry.