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VOORSTEL TOT AANSCHAFFING VAN EEN
ELECTONISCHE REKENAUTOMAAT TEN BE-
HOEVE VAN HET FYSISCH WERK OP HET
INSTITUUT VOOR KERNFYSISCH
ONDERZOEK.

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Voorstel tot aanschaffing van electronische rekenmachine

Preambule.

Prof. Dr. A. H. Wapstra.

In dit rapport wordt voorgesteld ten behoeve van het Instituut voor Kernfysisch Onderzoek een electronische rekenmachine aan te schaffen voor een totaal bedrag van ten hoogste f. 2.000.000,-. In eerste instantie wordt overwogen een Electrologica X 8 aan te schaffen. Gezien de snelle ontwikkeling op het terrein van rekenmachines lijkt de kans niet gering dat ten tijde van de gehoopte principiële goedkeuring van deze plannen het voorstel zal dienen te worden gewijzigd, waarbij, gezien de dalende tendens van de prijzen voor dit soort apparatuur, niet gevreesd wordt dat het totale nodige budget dan hoger uit zal komen.

1. Inleiding.

De aan te schaffen rekenmachine zal als voornaamste taak krijgen het registreren en verwerken van de steeds grotere hoeveelheden gegevens, die de moderne kernfysische apparatuur in dit Instituut oplevert en die nodig zijn om op adequate wijze ons inzicht in de structuur van de atoomkern te verdiepen. Hij zal daartoe direct gekoppeld dienen te worden aan de experimentele opstellingen (gebruik "on line").

Voorgesteld wordt een rekenmachine aan te schaffen die bijna twee maal zo groot is als de meeste machines, die tot nu toe in andere laboratoria voor dit doel gebruikt worden. Dit zal de mogelijkheid scheppen óók het grootste deel van het gewone rekenwerk van het Instituut op deze machine te doen uitvoeren. Belangrijker is echter nog dat te verwachten valt dat in de toekomst ook elders grotere machines voor dit werk zullen worden gebruikt. Dit zal zeker het geval zijn wanneer de machine naast registratie óók de taak zal krijgen het experiment althans gedeeltelijk te sturen. Deze volgende stap van automatisatie wordt geacht voor de deur te staan en staat ons reeds in een vroeg stadium van het gebruik van de machine voor ogen.

In eerste instantie stellen wij voor een X8 aan te schaffen van de Nederlandse firma Electrologica. Naast deze machine hebben wij beschouwd de SDS 9300 van Scientific Data Systems, de PDP 6 van Digital Equipment Corporation en de CDC 3200 van Control Data Corporation. Hoewel deze machines in het algemeen vergelijkbaar moeten worden geacht met de X8, in sommige opzichten zelfs superieur, menen wij dat voor het door ons speciaal beoogde "on line" gebruik de X8 voordelen

biedt. De gevarieerde, zeer logische en omvangrijke collectie mogelijke machine-opdrachten en de zeer flexibele in- en uitvoerorganisatie, die volledig autonoom verloopt, maken het mogelijk door toepassing van verschillende trucs zoveel tijd te besparen dat deze intrinsiek iets tragere machine dan bovengenoemde, toch sneller met zijn opdrachten klaar komt. De firma Electrologica is bereid medewerking te verlenen aan de bouw van de voor het beoogde hoofddoel uiterst noodzakelijke koppeling (interface) tussen de meetapparatuur en de rekenmachine. Hoewel dat óók het geval is met enkele van de andere genoemde firma's, en hoewel deze gedeeltelijk meer ervaring hebben met "on line" gebruik, zij het met andere dan de genoemde machine's, achten wij de nabijheid van de Nederlandse firma in dit opzicht een aanzienlijk voordeel.

CHAPTER 1. LIST OF DEFINITIONS.

- BYTE : A number of bits, smaller than the standard wordlength of the computer.
- CHARACTER : A decimal digit zero to nine, or a letter A to Z, either capital or lower case, or a punctuation symbol, or a fixed sized group of bits, or any other symbol, which a machine may take in, store or put out.
- HARDWARE : The mechanical, magnetic, electrical and electronic devices from which a computer is constructed.
- INDEX : The means which indicate the position of the moving part of an instrument.
- INDEX REGISTER,
BASE REGISTER,
B-box, B-line,
B-register. : A machine register in which a variable, e.g. a number, is put in to change another variable, e.g. an address.
- ON-LINE : In direct electronic connection, via transmission lines and/or input/output channels with the central part of the machine.
- PRIORITY ROUTINE : A program which automatically gets priority over other programs.
- REAL TIME : Working mode of a computer in which the speed is sufficient to give an answer or to execute a task in the actual time and on the actual moment required by the experiment.
- SOFTWARE : All hand written machine programs consisting of sequences of instructions.
- WORD : An ordered set of characters (in most computers bits) which has at least one meaning, and is stored and transferred by the computer as a unit.

D.A. data acquisition, the collection and storage of data produced by the experiment. This job has to be done on a strict real time basis.

D.D. data display, a part of the total collected information has to be displayed for following and controlling the experiment by the experimentator. In many cases it will be necessary to apply numerical corrections and other data reduction actions on the data before display.

C.C. checking and control,

E.S. experimental steering ; the computer changes certain experimental parameters according to programme decisions.

S.C. sample computation ; computations that have to be applied on limited quanta of experimental data for the sake of compressing information before storage and for condensation of display information patterns.

CHAPTER 2. ARGUMENTS FOR ONE-LINE USE OF A GENERAL PURPOSE COMPUTER.

Up to 1962 almost only fixed wired analysers were used in low energy nuclear physics for data acquisitions and data display. An increasing complexity of the nuclear physical experiments causes increasing information flows, and thus there rose a demand for faster data acquisitions and data reduction systems. The prices of nowadays sophisticated fixed wired analysers and small computers are in the same order of magnitude.

There are two main arguments that can justify the use of a general purpose computer on-line with experimental set ups :

1. physical argument :

From a physical point of view it is justified to use a g.p.c. on-line in all those cases where in :

- a. for the sake of following the experiment, experimental control and steering, the immediate interpretation of intermediate experimental results requires complicated computations and data processing.
- b. large quantities of information have to be stored with a high speed and in such a manner that later economically off-line data reduction by a computer can be done.

2. financial argument :

If the amount of money that must be invested in traditional analysers required for a certain range of experiments rises to such an extent that it is comparable with the cost of a g.p.c., then it is justified to apply a computer because of the much greater flexibility.

For a greater flexibility means a more economical use of the invested capital : namely the more flexible the information processing system is, the greater the variety of experiments which can be done with it.

At the EANDC conference in Karlsruhe the advantages and disadvantages of fixed wired and programmable data reduction systems have been discussed. Below the results of these discussions are listed :

ADVANTAGES OF FIXED WIRED SYSTEMS.

1. fixed wired systems are cheaper.
2. faster for simple data acquisition on data display operations.

3. more reliable
4. requiring considerably less programming time.

ADVANTAGES OF COMPUTER SYSTEMS.

1. stored program systems are more flexible than fixed wired systems because of easy program changes.
2. the computer can be used to program itself and it can do calculation on real time, thus influencing the experimental proceeding.
3. for data reduction and sample computation stored program computers have great advantages.
4. Data can be handled faster because of the fact that a computer can perform several tasks simultaneously.
5. Systems with several parameters can be controlled and measured more easily ; this advantage is the greater the more parameters are involved.
6. A computer is better suited for checking and control.

When the computer is used on-line, the question rises whether comple DA, DD, DR, SC and CC functions have to be done by : fixed wired operations, programmable wired operations or by software. If a certain task has to be executed more frequently a tendency will grow towards faster fixed or programmable wired operations. However, in experimental work as it will be done in purely scientific physical laboratories, it is not very likely that the same data acquisitions and data reduction operations will be repeated many times without changes.

Therefore in this field more flexible programmable computer systems do have great advantages compared to fixed wired analyzing systems.

CHAPTER 3. A SHORT STUDY ABOUT THE ON-LINE USE OF A DIGITAL
COMPUTER FOR THE REDUCTION OF EXPERIMENTAL DATA.

INTRODUCTION.

In the following pages we shall try to study the use of a digital computer on-line with an experimental system. A trial will be made to find some basic principles to which the combined system will obey.

So far as these basic principles can be found and formulated, we will try to reach some conclusions, based on those formulations, concerning the desirable properties of computers and experimental apparatus.

When we use furtheron the term on-line, this means that the computer is directly, i.e. via an electronic way, coupled with the experimental apparatus, thus forming a real time system.

The computer at one hand and the experimental set up at the other can be considered as two separated information processing systems. The experimental system is a group of information sources. For every measuring apparatus, every detector etc. is producing continuously or discontinuously several quantities of information.

The computer can be described as an information accepting, processing and storing system, although the computer can also produce information, for instance in aid of some measuring and control devices.

Both of these information systems are characterized by their own variables and properties.

Studying the on-line problem means the study of the communication between the two systems. Investigating the communication means finding the principle relations between the mentioned variables.

A. VARIABLES OF THE EXPERIMENTAL SYSTEM CONSIDERED AS A GROUP OF INFORMATION SOURCES.

Considering the experimental set ups as a group of information sources we will now define all those variables which characterize the experimental system.

1. Suppose that the variables $A_1, A_2, A_3, \dots, A_n$ are to be measured.
2. These measurements are done discontinuously and give samples consisting of the values $\bar{A}_1, \bar{A}_2, \bar{A}_3, \dots, \bar{A}_n$.
3. Each variable value $= \bar{A}_i$ satisfies :

$$0 \leq \bar{A}_i \leq 2^{a_i} - 1 \quad (1)$$

4. Thus each variable A_i can be represented by : a_i bits.
5. Therefore each sample can be represented by :

$$c = \sum_{i=1}^n a_i \text{ bits} \quad (2)$$

6. Each information source produces samples random in time. (see chapter 5.1) Each source is supposed to transfer its samples through its own channel to the information accepting and processing system (the computer). (see chapter 4.2.2. and chapter 5.1).
7. The average number of samples produced per second by channel j is called v_j .
8. Let us suppose there are m information sources : $S_1, S_2, \dots, S_j, \dots, S_m$.
9. It is assumed that neither the average sampling speeds $v_1, v_2, v_j, \dots, v_m$ nor the sampling length in bits $c_1, c_2, \dots, c_j, \dots, c_m$ are equal to each other.
10. The measuring channels do not influence each other, that means : they can transfer information to the computer without hindering each other. (see chapter 4.2.2. and chapter 5.1).

The average dead time of the ADC's is about 100 μs ec. After each sample the corresponding channel is therefore closed for this period

It will be clear that the total number of samples, V , per sec. produced by all sources together will equal :

$$V = \sum_{j=1}^m v_j \text{ samples per sec.} \quad (3)$$

The total of bits produced per sec. will be :

$$C = \sum_{j=1}^m v_j c_j \text{ bits per sec.} \quad (4)$$

Assuming that the information transfer channels do not hinder each other means that it is very desirable to use an interface, having between the group of information sources and the computer, as many information channels as there are information sources. (see chapter 4.2.2. and chapter 5.1).

Furthermore it is very desirable that each information channel can have simultaneous direct access to the computer memory, otherwise information transfer rates will be limited by queuing up and multiplexer delays. (see chapter 5.1).

Therefore the maximum number m of independent information channels between the two systems should be equal to or smaller than the number of free input channels of the computer.

B. VARIABLES OF THE INFORMATION PROCESSING SYSTEM.

Only very few of the many properties that characterize and qualify a computer system can be expressed quantitatively.

Thus all qualities, concerning the computer registers, register configurations, repertoire of instructions, properties of the ⁱ/o mechanism etc., will be symbolized by the quality factor K (see chapter 4.2.1.)

It should be remarked here that the value of K also depends on the size and type of a problem which has to be tackled by the computer.

It seems impossible to determine a value for K without detailed specifications of the computer system and the problem which has to be treated.

Variables that can be measured quantitatively are:

1. the wordlength in bits, w .
2. the total memory capacity, M .
3. the maximum memory access time, t_a .

C. SOME RELATION.

Let us assume that a sample arriving at the computer via channel number j , represented by c_j bits, will be handled by the computer as a group of W_j words.

$$W_j = 1 + \text{entier} \left(\frac{c_j}{w} - \frac{1}{100} \right) \quad (5)$$

It follows from the expression 3 and 5 that the total number of words arriving at the computer per sec. is:

$$N = \sum_{j=1}^m v_j W_j \text{ words per sec.} \quad (6)$$

Considering expression 5 and 6 one may conclude that the greater the wordlength w of the computer is, the smaller N will be, which means that less word transfers have to be performed by the input channels (see chapter 4.2.1.b).

The total number of bits to be transferred per sec. is:

$$\sum_{j=1}^m v_j W_j w = N w \text{ bits per sec.} \quad (7)$$

The optimum transfer rate can be obtained only when the total number of bits arriving at the computer per sec., C , is equal to the total numbers of bits $N \times w$ which have to be processed by the computer.

In the first place this means that the binary representation of a sample has to be chosen in such a way that c_j is equal to or a little bit smaller than $n \times w$ (where $n = 1, 2, 3, \dots$).

It will be clear that the number of spare bits of a group of W_j words has to be as small as possible.

Let us call the number of words produced during the entire experiment N_{exp} .

If $N_{\text{exp}} < M$, then the computer can simply store each incoming word.

The time required to store N words is:

$$T = \sum_{j=1}^m v_j W_j t_a \text{ } \mu\text{sec.} = N t_a \text{ } \mu\text{sec.} \quad (8)$$

If N_{exp} is only a little bit greater than M , then the total experimental information mass can be stored in the computer memory after some information reduction processing.

However if $N_{\text{exp}} \gg M$, then it is impossible to store each word and one

will have to process each sample in such a way that the total mass of information can be stored in the available memory without unacceptable information losses, or one will have to store reduced or raw experimental data on magnetic tapes or in other storage media. For almost all experiments that are planned now at I.K.O., N_{exp} will be about $10^3 - 10^4$ times greater than M . (see chapter 5.2.3.)

Let t_j the time which is needed to process a sample of source number j be t_j μ sec., then the total reduction time (acquisition time) for N samples (arriving in 1 sec.) will be:

$$T = \sum_{j=1}^m v_j W_j t_j \text{ } \mu\text{sec.} \tag{9}$$

Thus if for instance the computer has to process and store 50 000 samples per sec. ($N = 50\ 000$) then the expression 9 leads to the result that the average value of t_j equals:

$$t_j = \frac{1}{50\ 000} = 20 \text{ } \mu\text{sec. processing time per sample} \tag{10}$$

Assuming in this sample that we use a computer with a cycle time of 2.5 μ sec. and that per instruction an execution time is required of approx. 2 machine cycles, it can be concluded that in average only 4 instructions can be performed by the computer to process each sample.

It sounds reasonable that t_j is a function of t_a , M , w and the organisation of the whole computer system (quality factor K). See note 1.

Thus: $t_j = R_j (t_a, M, w, K, \dots)$ (11)

Note 1: Considering the organisation of a certain computer system, it can be stated for example that it is very useful and desirable to have character and byte handling instruction, especially in those cases where the applied computer has a rather long wordlength. In those cases many values A_i , each represented by a_i bits, may be packed in one word. During the information reduction process it will be necessary very often to separate these groups of a_i bits from each other. This can be done efficiently with byte and character handling instructions.

It seems impossible to formulate a general quantitative expression of the function R_j .

However some quantitative estimates and tendencies can be formulated. Probably in many cases one will find:

1. that the larger M is, the smaller t_j can be because of the fact that less reduction operations have to be performed on each sample.
2. that the smaller t_a is, the smaller t_j will be.
3. that the greater the wordlength w is, the smaller t_j can be in most cases, because of the fact that the greater w is, the smaller W_j will be and thus less transfers have to be performed per sample.

This it may be correct to define $R_j(t_a, M, w, K, \dots)$ more precise by writing it as a quotient of the functions g_j and h_j :

$$R_j(t_a, M, w, K, \dots) = \frac{g_j(t_a, K_1, \dots)}{h_j(M, w, K_2, \dots)} = t_j \quad (12)$$

M and w will always be $\gg 0$

$0 < h_j < \infty$

g_j will always be > 0

because of the fact that the double inequality:

$0 < t_j < \infty$ must hold (12)

A quantitative estimation of the total through put or a quantitative formulation of the functions g_j and h_j can only be given if the following specifications for one experiment and its corresponding data acquisition and data reduction process are well defined:

all numerical values of the mentioned variables, the precise specification of the required data reduction operations and results, and the configuration of the communication- and information processing system.

CHAPTER 4. A SURVEY OF REQUIREMENTS

I. Requirements of the computer as a whole.

Minimum requirements have been specified in order to conclude which computer can meet I.K.O.'s needs for on-line information processing and on-line computations as satisfactory as possible. Below these requirements are listed while in some specifications and motivations are given. (in a later chapter).

- 1.1. The computer must be a stored program , general purpose, digital computer of modern design.
- 1.2. Its solid state components must be carefully packaged for resistance to electrical and magnetical disturbances.
- 1.3. It must be capable of operating 24 hours a day, 7 days a week, requiring only a minimum of maintenance. (required maintenance time should be less than 2 hours a day as an average).
- 1.4. The computer hardware and software should preferentially have special provisions for multiprogramming.
- 1.5. Furthermore the computer should be capable of :
 - performing real time operations ;
 - rapid program testing and diagnostics ;
 - machine failure diagnostics with extensive indication on the operator console.

2. Hardware requirements.

2.1. Central processor unit (c.p.u.)

- a. It must work binary.
- b. Single word instructions have to operate on words with a length of approximately 25 bits (the required accuracy for on-line correction computations is of the order of 10^{-7}), or more. (see chapter 3.C.)
- c. Fast hardware fixed point arithmetic must be available, fixed point multiplication time should be of the order of 30 microsec., or less.
- d. Hardware for double precision instructions is necessary.
- e. Floating point hardware is absolutely required.
- f. Furthermore the instruction repertoire should preferentially include left and right, open and round shifts, logical instructions, jump instructions including subroutine jumps, jumps

combined with automatic index register incrementation, condition setting and testing for all instructions, instructions for automatic array transfer in memory, from memory and to memory, address modification for all instructions, search instructions and character and byte handling instructions.

2.2. Input/output channels and control (for motivations see chapter 5.1).

- a. The i/o channels must have the possibility to be concerned with asynchronous laboratory equipment.
- b. Therefore the i/o channels have to be buffered.
- c. As many as possible i/o channels should be available, all having direct access to mainstore, bypassing as much as possibly the c.p.u., such because of the great need for many simultaneous information flows between the computer and the experimental set up.
- d. The i/o channels or the i/o control unit must be capable of sending an "end of record signal" to an external information source or to an external information acceptor.
- e. The i/o control unit must provide external interrupt setting : if external demands for interrupt of the c.p.u. arrive, if an end of record signal is produced.
- f. Internal interrupt setting has to be executed: if overflow is detected,
if case of different machine failures,
at the end of an array transfer.

2.3. Priority distribution by the c.p.u. (see report by v. Oers, Tjin A Djie and Jonkers).

It is extremely important that the computer can honor interrupts in a sequence according to a program dependent priority distribution. It should be stated clearly that a fixed priority sequence is not acceptable because of the on-line application of the computer.

2.4. Multiprogramming.

Hardware program relocation and multilevel indirect addressing have to be available.

Because of the need for time-sharing and flexible switching from one program to another, memory protection, input-output device protection and register saving provisions are required.

2.5. Memory capacity. (for motivation see chapter 5.2)

In order to be able to use the computer on-line with the experiments

planned in the I.K.O. laboratory a minimum memory capacity of 16000 words is required.

It should be stated clearly here that it is better to save money by cutting off peripheral equipment from a certain configuration than by using only a 8 k memory capacity.

2.6. Memory extensions (for motivation see chapter 5.3)

At least 3 magnetic tape units with a speed in the order of 90-120 kch/sec are required.

2.7. Slow input/output equipment.

- a. the console of the computer has to include one or two i/o typewriters.
- b. further the configuration has to include a paper tape reader for 5, 6 and 7 channels with a reading speed between 500-1000 ch/sec and a paper tape puncher (5, 6 and 7 holes) with a punch speed of approximately 150 ch/sec.
If enough money is available then a line printer would be an extra-ordinary important tool for the Institute.

2.8. The console.

The console has to provide display of all machine registers and failure testing results such as parity fault, overflow, etc.

2.9. Display.

- a. Furthermore the computer system must be capable of displaying data via oscilloscope screens.
- b. It must be easy to choose via switches or via keyboard control between display formats.
- c. If no memory scope systems are used then the display frequency should be approx. 16 pictures per sec.
- d. The display units must also provide means to select any arbitrary part of the total display for magnification and special treatments.
- e. It is highly desirable that the experimenter will have the possibility to communicate with the computer via light-pen-like systems.

3. Minimum software requirements.

3.1. Compiler.

An ALGOL 60 or a FORTRAN compiler, preferentially both ; be

delivered with a set of numerical subroutines, defined in machinecode as well as in ALGOL and FORTRAN.

3.2. Monitor.

The software system delivered must also include a monitor program which coordinates and supervises time sharing and memory sharing. The monitor must be capable of controlling many simultaneously operating programs which may be written in different languages. The monitor shall also include flexible input/output routines.

3.3. Documentation.

Extensive documentation of all delivered programs, compilers and subroutines should be provided by the manufacturer.

This requirement is very important.

4. Further requirements.

4.1. Because of the fact that for the on-line use of the computer new electronical interfaces have to be developed by the manufacturer or in our laboratory it is highly desirable that there will exist a close cooperation between the manufacturer and our laboratory. Therefore the manufacturer should at least have a settlement in Europe.

4.2. Service.

Service and maintenance should be done by a permanent, on site engineer of the manufacturing company.

4.3. Spare parts.

Spare parts should not have to come from stores situated far away.

4.4. Computer documentation.

A complete set of circuit schematics, logic diagrams and other engineering information for servicing and modifying the equipment must be delivered with the computer.

Chapter 5. SOME MOTIVATIONS.

1. Input/output channels (chapter 4, paraf. 2, 2.2.)

The i/o channels have to be buffered because asynchronous laboratory equipment has to be connected with these channels (see chapter 3. A.6). When the computer operates on-line with an experiment then, according to specifications formulated by MacLeod (CERN), several different types of work can be defined.

The computer has to perform the following jobs:

- data acquisition;
- data display;
- checking and control;
- experimental steering;

and sample computation.

All these jobs have to be done more or less simultaneously. That means that the corresponding programs have to be executed by the computer on a time sharing and memory sharing basis.

In order to obtain a maximum of efficiency the computer configuration should include as many independent information i/o channels as possible. For, the more channels there are (with direct memory access bypassing the c.p.u.), the more simultaneous automatic information transports can take place without disturbing the c.p.u. (see chapter 3. A).

For a detailed discussion about the advantages of programmable priority systems we refer to the report, written by W. v. Oers, H. Tjin A Die and H.L. Jonkers, entitled: Discussie rond huidige en toekomstige behoefte aan reken capaciteit van het I.K.O. (InterIKO 64/3).

2. Memory capacity (chapter 4, paraf. 2, 2.5)

The necessary size of the memory was estimated on the basis of a program of requirements, obtained in discussions of IKO physicists with Professor Dr. E.W. Dijkstra, that can be found back in the following report by the latter. Therein the minimum memory capacity requirements are given in case of the on-line use of the ELX8.

"In order to maintain a maximum data flow in a asynchronous application we consider the information flow in a period of 25 millisecc. In case of 5 information transports an interrupt will be set every 5 millisecc. Thus honoring one interrupt the computer needs approximately 0.5 millisecc. For switching over from one transport to another. This is a

implies a time consumption of 10 %.

In 25 millisecc. a cyclotron experiment can produce approximately 500 words corresponding to 500 samples or less.

For memory buffer areas we need:

- 1 k buffer area for the cyclotron experiment (2 x 0.5 k for 2 bufferareas used alternately).
- 1 k buffer area for information transfer to the magnetic tape units.
- 0.5 k for the prepared display pattern when a pattern is chosen of 64 x 64 points. For display of a pattern of 128 x 128 points a memory capacity of 2 k is needed.
- 0.25 k as bufferspace for the slow communication equipment as tapereader, tape puncher, typewriter.

2.75 k or 4.75 k in total if a 128 x 128 point display is used.

Program space:

- 0.5 k for tape handling program including actions like read-write instructions for the tape unit, control of return signals, detection of end of tape signals and the announcements of it to the operator, tests for exceeding the block boundaries and automatisisation of repair actions as rewrite-reread in case of failure detection.
- 0.5 k for the console communication program including translation and transfer of manually inserted information and analysis, and display of information given by the computer to the operator.
- 0.5 k for the coordinating program which has to perform time sharing and memory sharing control, the change of priority distribution as a function of internal and external criteria, and the honoring of signals produced by one or more real time clocks, etc.

This estimation is chosen very tight, especially when more is asked of the coordinator for instance in case of dynamical random supply and removal of programmes.

This is very likely with for example programmes as data display, calculation programmes, different experimental steering routines, etc.

0.5 k for checking and control. For this job a set of non-systematical actions and reactions have to be performed by the computer.

The more refinement is asked from the computer, the larger the required program space will be.

1 k at least, for kicksorter program including storage according to the partition method and corrections.

0.5 k for servicing the beta spectrometer.

0.5 k for working space of the coordinator, including the memory locations primarily assigned to the communication equipment containing : information concerning the state of the equipment and start and stop instructions for transfer.

4 k

4 k for registering and kicksorting of coincidence spectra in a 64 x 64 points resolution.

10.75 k Total of buffer areas, program areas and coincidence spectra areas.

If two or more pictures have to be displayed each approximately having a point density of 64 x 64, or if one such 64 x 64 raster has to be displayed combined with several single spectra, then the required memory capacity rises up to 12 - 14 k.

In these estimates no memory space was reserved for numerical data reduction programs such as defined in l. e S.C.

All these considerations show clearly that a memory capacity of 8 k will never satisfy the needs which will rise when the computer will be applied on-line with the experiments planned in I.K.O.

3. Memory extension. (chapter 4, part. 2, 2.6.)

In order to be able to store large quanta of experimental information, the memory capacity of the computer configuration has to be extended with at least 3 magnetic tape units.

It must be possible to operate 2 units simultaneously. Especially for searching and sorting purposes it is very important to be able to write information on one unit while simultaneously new information can be transported from the other unit to the computer memory and vice versa. Also for D.A. it is very important to use two units in simultaneous operation for the sake of time saving.

Because of the fact that in general it is experienced that magnetic tape units are rather unreliable, a third unit is very desirable to be available in case of repair of the others.

The reading and writing speed should be approximately 90-120 kch/sec. because of the data flows expected by the experimentalists.

CHAPTER 6. COMPARING TABLE of EL X 8 , SDS 9300, PDP-6 and CDC 3200

DESCRIPTION	EL X 8	SDS 9300	PDP-6	CDC 3200	180	RE 211
<u>DATA STRUCTURE</u>						
Word length in bits	27	24	36	24	16	24 + P
Floating point radix	binary	binary	binary	binary	2	2
Floating point exponent size	sign+11	9	8	11	1 60	8 + S
Floating point mantissa size	2 sign+40	39	27	sign+36	60	38 + S
<u>CENTRAL PROCESSOR UNIT</u>						
Arithmetic radix	binary	binary	binary	binary	2	2
Operand length in words per instruction	1 or 2	2, 1, n x 1/8	2, 1, byte	2, 1, 1/2, 1/4	1, 2	1, 2
Instruction length in words	1	1	1	1		
Addresses per instruction	1	1	1	1		
Bits per address	15	15	18	15		
Bits per function	12	9	18	9		
Execution times in usec. of						32 (5)
basic fixed add	2.5	1.75	2.7-4.3	2.5-2.9		
basic multiply	30	7	14.5-16.1	8.75-12.6		
basic divide	40	?	23.4-25	12		
floating add	7.5-11.5	14	5.8-8	12		17.4
floating multiply	27 - 54	12.25	12.4-14.5	29		21.8
floating divide	67	?	18.4-20.5	29		31.7
Provisions for extended precision	yes	yes	no	yes		no
Number of fully independent accumulators	3	ex - 1 + tensin	16	2	gercheiden	4, 3 / sec
Number of index registers	3 + 65 63?	3	15	3, not equally usable		3, 6H
Multiple level indirect addressing	yes	yes	yes	yes, but not for all instructions		char. -
Separate floating point register	yes	yes, optional	no	yes, optional		no yes
Condition register	yes	in reduced form as flag reg.	in reduced form as flag reg.	no		no
Overflow register	yes	yes	yes	yes, not independent		no
Interrupt system with programmable priority distrib.	yes	no	no	no (?)		no (34) (16, 12)
Direct input access to index registers	yes	no	yes	no		yes?



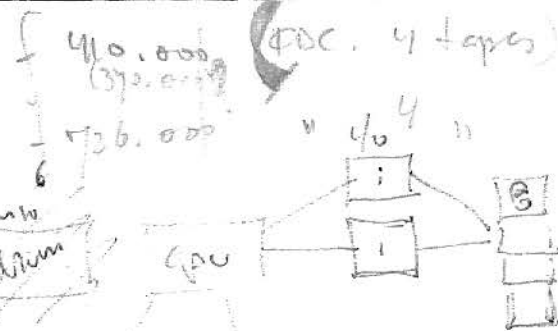
Interrupt -
Break program able priority
break?

safe fall.

DESCRIPTION	EL X 8	SDS 9300	PDP-6	CDC 3200	
MEMORY					
Type of memory	core	core	core	core	
access time	2.5 μ sec	0.7 μ sec	0.8 μ sec	1.25 μ sec.	
Parity check	1 parity bit	?	?	4 parity bits	
Minimum capacity, directly addressable	16 k	4 k	8 k	8 k	
Maximum capacity, directly addressable	262 k	32 k	262 k	32 k	
Automatic array transport from and to memory, bypassing the Central Processor Unit	yes	yes	yes	yes	
MAGNETIC TAPE UNITS					
Information density in symbol per inch.	220,556,800	200,556,800	200,556,800	220,556,800	200,556,800
Tape speed	112 $\frac{1}{2}$ - 150 inch/sec	75 - 112 $\frac{1}{2}$ inch/sec	75 - 112 $\frac{1}{2}$ inch/sec	75 inch/sec	150 inch/sec
Tape length	2400 feet	2400 feet	2400 feet	2400 feet	2400 feet
Tape width	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch	$\frac{1}{2}$ inch
Gap length	3/4 inch	3/4 inch	3/4 inch	?	?
Maximal block length	4 K words	?	?	?	?
Number of record tracks	6 inform + 1 parity	6 inform + 1 parity	6 inform + 1 parity	6 inform + 1 parity	6 inf. + 1 parity
Longitudinal parity check after parts of blocks	yes	?	?	?	?

\$64,000
\$40

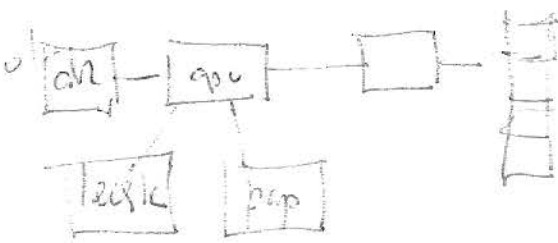
240,000



- 1) automatics.
- 2) min. time per/w

drum

- no. of tracks
- no. words/track
- no. of heads
- min. time of succ. words.
- buffered?
- steering?



DESCRIPTION	EL X 8	SDS 9300	PDP -6	CDC 3200
<u>PUNCHED PAPER</u>				
<u>TAPE READER</u>				
Reading speed	1000 ch/sec	300 ch/sec	400 ch/sec	350 ch/sec.
Type of reader	photoelectric	photoelectric	photoelectric	?
<u>PAPER TAPE PUNCHER</u>				
Punching speed	150 ch/sec	60 ch/sec	63.3 ch/sec	110 ch/sec

7.1. Machine speed.

It can be stated that it is not justified to base a machine speed comparison on a consideration of the execution times of a few instructions or on cycle times. Even the scientific mix indices do not give reliable speed ratio figures.

As a matter of fact a speed comparison can only be based on a comparison of the execution times which are required to execute a similar task with the computers under consideration.

In order to obtain a reliable general impression about the speed ratio between several computers, the above mentioned procedure should be repeated for many different tasks.

Not only the instruction execution times, but also the quality of the instruction repertoire influences the machine speed to a great extent.

The less powerful each instruction is and the less instructions are known to the computer, the more instructions one will need to perform the same set of actions.

This general statement is underlined again when one compares the EL X8, the SDS 9300, the PDP 6 and the CDC 3200.

As shown in chapter 6 the average instruction times of SDS 9300 and PDP 6 and even of CDC 3200 are shorter than the instruction times of the EL X8.

However a more detailed study of the instruction repertoires of the four considered machines has shown that in general e.g. The CDC 3200 needs 3-6 x as many instructions as the EL X8 to perform the same task. Thus, although the single CDC 3200 instructions are in the average 2-3 x as fast as the EL X8 instructions, the CDC 3200 is in fact about $1\frac{1}{2}$ - 3 x slower than the EL X8 in executing the same task.

Moreover an other important shortcoming of the CDC 3200, SDS 9300 and PDP 6 in this respect concerns the memory capacity. When this capacity is limited it is a severe disadvantage that these computers need approx. 3 - 6 x more program space in memory. The memory capacity required for on-line operations with the CDC 3200, the SDS 9300 and the PDP 6 can therefore be derived from chapter 5.2 and turns out to be, at a conservative estimate, approx. 16.25 k.

This conclusion is not only based upon the comparison of the programming abilities and instruction execution times of the four considered computers in connection with the execution of one similar task.

The fact that nor CDC 3200, nor SDS 9300, nor PDP 6 have a condition register which can be set and sensed by each instruction causes considerable programming complications in all those programs where conditional decisions and program switches have to be made. In the three computers CDC 3200, SDS 9300 and PDP 6 there are test, jump and skip instructions.

The disadvantage of this type of instructions is that condition sensing and testing and switching have to be executed at the same moment.

Because of the fact that there is no condition register to store the condition setting, only the actual values of the arithmetical and index registers and the memory locations can contain condition setting information.

Thus, if the contents of a certain location includes switch or choice information, the program should provide protection of that location until a test and branch instruction has sensed its contents. Furthermore it is not possible then to use the condition sensing result at different places in the program because of the fact that the sensing has to be combined with the branching instruction. It is a well known fact that in many programs different branches start with groups of identical instructions. Thus, if the program chooses one branch the identical instructions of other branches occupy memory space without any necessity.

The flexibility of an instruction repertoire and thus of a computer can be increased highly by the use of a condition register in the way as it is done by the EL X8 designers. More efficient programming will not only provide more efficient use of the available memory capacity but also faster execution of each program.

Further arguments leading to the above mentioned result are discussed in 7.2.

7.2. Instruction repertoires.

The fact that the EL X8 has 12 function bits and the CDC 3200 only 9 and SDS 9300 only 9, indicates already that the instruction repertoire of the CDC 3200 and the SDS 9300 must suffer from more

restrictions. In the first place this leads to the above mentioned very unpleasant effects.

The PDP 6 could have with its 18 bits function part an instruction repertoire considerably better than the EL X8. Moreover, although it is a larger and more elegant computer than the SDS 9300 and the CDC 3200, also because of its 16 accumulators and index registers, the instruction repertoire and the computer set-up is still less efficient than the EL X8.

A disadvantage of the CDC 3200 is that a number of programming methods can not be used. For example : indirect addressing and address modification are not applicable in case of the following instructions : halt, selective jump, return jump, index jump incremental and decremental, load A character, load Q character, load index, store A character, store Q character, etc.

Therefore indirect addressing is impossible in programs for data reduction and information transfer (in our case 70% of all programs). Thus multiprogramming on a memory- and time-sharing basis is almost impossible, especially if program locations have to be changed dynamically.

All instructions of the SDS 9300 and the PDP 6 and the EL X8 can be used with indirect addressing.

In contrast with the EL X8 the 3 B-registers of the CDC 3200 can not be used all equally. There are several instructions that can only co-operate with one fixed B-register. This is a great disadvantage in formulating general saving rules for program to program switching and subroutine jumps.

The SDS 9300 has 3 B-registers. All index register instructions for loading and storing index register contents can be used with indirect addressing, but in contrast with the EL X8 they can not be modified by the B-register contents at each indirect addressing level.

In the PDP 6 all instructions can be used with indirect addresses and the address of each instruction (without any exception) can be modified with index register contents.

In this respect EL X8 and the PDP 6 are equally elegant. However, the EL X8 is better suitable for multiprogramming on a memory- and time-sharing basis than the other computers, because of the fact that it has 63 extra index-registers.

With respect to the memory-register communication the floating point register $E_u - E_1$ of the CDC 3200 can not be handled in the same way as its accumulators, the EL X8 floating point register can be used in the same way as the other accumulators.

The SDS 9300 can be provided with optional floating point hardware. The SDS 9300 has only one arithmetic register, while the second arithmetic register can only be considered as an extension register. Therefore the SDS 9300 does not perform arithmetic operations on operands stored in the second register.

The PDP 6 has 16 arithmetic registers. All of these can be used equally. Interregister transfers and transfers between memory locations and registers are provided without special exceptions.

7.3. Input/output channels.

An advantage of the SDS 9300, the PDP 6 and the CDC 3200 is that there are more i/o channels available which have direct access to memory modules (bypassing the central processor unit).

The CDC 3200 has one channel per 8 k memory capacity, while the EL X8 has one per 16 k. The SDS 9300 can have one channel per 4 k, 8 k and per 16 k. Thus, in this respect the SDS 9300 is the most favourable computer for on-line application.

7.4. Software.

Considering compilers it should be remarked that Electrologica has more experience in constructing ALGOL compilers than CDC has. The quality of the ALGOL compiler that will be delivered by CDC in about one year is not yet known. The quality of the FORTRAN compiler for the CDC 3200 could not yet be determined because not enough information was available. The same holds for the monitor programs.

For the PDP 6 only a FORTRAN IV compiler can be delivered and for the SDS 9300 a FORTRAN II compiler. ALGOL is not available for these computers.

The names and experience of the team leaders of the software development groups who work for Electrologica do justify good expectations for this field.

7.5. Manufacturer settlement, co-operation with I.K.O.

Because of the fact that the Electrologica factories and laboratories are situated in Rijswijk and Amsterdam, and the CDC, SDS and PDP laboratories in America, it will be much more easy and cheaper to co-operate with Electrologica for the development of interface hardware. Also for the development of new software there are three groups in the Netherlands, situated in Amsterdam, Eindhoven and Utrecht, which can co-operate closely with I.K.O.

From the point of view of servicing and supply of spare parts the situation of Electrologica is advantageous compared with that of CDC, SDS and PDP.

CECIS which manufactures the SDS 9300 in Europe and which laboratories are in Paris, is willing to help I.K.O. with the interface development.

7.8. Prices, a warning.

CDC, Electrologica, SDS and PDP have formulated and made some proposals. When the prices of these proposals have to be compared one should never forget that transport, insurance costs nor import duties and installation costs are mentioned by the American manufacturers.

These costs may rise to approx. 15% of the total purchase price. Furthermore when one signs a contract with a computer manufacturer, the contracts should include statements about the way in which price reductions that occur after the contracts signing date will be incorporated into the final price calculations which determine IKO's effective expansions.

CONCLUSION

Based on the arguments described above and on a number of other arguments which lay beyond the scope of this report, I came to the conclusion that the EL X8 computer meets I.K.O.'s needs and satisfies the described requirements the best of all four considered computers.

I advise the laboratory to apply the following computer configuration :

1 EL X8 central computer with :

32 i/o channels

16 k memory capacity

a punched tape reader type EL 1000 (1000 ch/sec.)

a console i/o typewriter

3 or preferably ~~4~~ magnetic tape units with 1 double channel magnetic tape control

and a special EL stabilized power supply.

The set up of the interface should be discussed in further detail with the engineers or with other firms which may be interested.

~~XXXXXXXXXX~~

prijs 2 x 3 00.000.
1.5 ton.



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