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PROPOSAL FOR AN EJECTION MAINTENANCE ASSISTANT SYSTEM (E.M.A.S.)

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1. Introduction

During the last years the complexity of the ejection hardware which has to be maintained by the SR Ejection Section has steadily increased. This tendency will continue, e.g. SE 16, SE 62 with $Q_R = 6.33$, sharing SE 62 + SE 16, more fast ejection per cycle, shaving ejection, high intensity operation and ejection for the 300 GeV machine [1,2].

Already for the Straight Flush System an ejection diagnostic system was considered to be necessary. Today the operation assistance which has to be supplied by the SR Ejection Section has at least for fast ejection reached a level where the available maintenance effort gets seriously impaired. Only the subtle intuition and strong personal engagement of our specialists have up to now kept the down-time within acceptable limits (leaving ISR ejection out of considerations). The ejection efficiency and stability, partly our problem, gets nevertheless alarming because of the radiation damage caused on machine components. The extrapolation for the near future is simple: with the actual effort spent for ejection the situation will certainly not improve but most probably deteriorate.

To avoid this "automatic development" without simply increasing the number of maintenance staff approximately proportionally with the increase of ejection hardware, our attention has to concentrate on the following points:

a) continuation of the development of transparent controls for easy operation

b) continuation of the instruction of operators

c) electronic assistance for fault diagnosis and maintenance.

The following proposal deals with a) and c).

2. Review of septa and kickers in use

At the moment the SR Ejection Section maintains:

7 septum magnets: SD_f 16, SD_f 58, SD_g 62, SQ 63, SD_f 74,
SD_e 43, SD_e 45 partially

2 fast kicker magnets: FK 13, FK 97 3)

Furthermore, two septa are in construction: SD_e 83, SD_{th} 85.

Taking into account the modification of SE 62 (1 or 2 additional machine components) sharings and shaving 58 and FE to the 300 GeV machine, the number of components now in use will substantially increase.

3. Essential hardware parameters

The parameters referring to the present equipments can be classified into those

3.1 of septum magnets with their power supplies:

3.1.1 per unit: 3 current measurements
3 positions (e.g. radial, vertical, angular)
4 signals for timings
4 of the most significant interlock conditions

3.1.2 about 20 concerning the cooling systems like water pressures, temperatures and auxiliary supplies

3.2 of fast kicker magnets:

3.2.1 about 100 of pre- and post-pulse counter-modules (FE-timing)

3.2.2 32 of trigger-time and jitter measurements composed of (3+1) x (4 spark gaps plus

4 Marx triggers) corresponding to
3 ejections for FK 97 plus 1 ejection
from FK 13 within one PS cycle.
For each trigger measurement to be stored
100 channels must be available (multichannel mode).

3.2.3 per unit: 4 of hydraulics
3 of most important interlock conditions.

The addition of all parameters gives a number between 250 and 300.

4. Strategies to yield optimum maintenance and transparent controls of the operations of ejection hardware

Referring to 1c) this means for:

4.1 Optimum maintenance

4.1.1 a steady surveillance of all essential hardware parameters

4.1.1.1 check if they are in between defined limits

4.1.1.2 memorize longterm changes in time to get their time dependence (e.g. temperatures, pressures) to find out unwanted tendencies in parameter changes

4.1.1.3 memorize shortterm changes (within PS cycles; e.g. in electrostatic septa two kinds of sparks, one occurring randomly in time, the other at special time marks during the PS cycle, are known)

4.1.1.4 memorize (in dependence of time) interlock actions

4.1.2 automatisation of lengthy maintenance procedures

4.1.2.1 run-in of repaired components

4.1.2.2 check of optimal working points

4.1.2.3 check of proper operations under different working conditions (timings etc)

4.1.2.4 electrostatic septum formation

4.1.3 On-line treatments of timings and jitter information

4.1.3.1 memorize trigger times in FE kicker to find out jitter behaviour (ref. 3.2.2)

4.1.3.2 optimize high voltage pressure settings in spark gaps in a closed loop

4.1.3.3 driving of kicker hydraulics in a closed loop

Referring to 1a) this means for:

4.2 Transparent operations of hardware

4.2.1 sequencing of switching on and off of ejection hardware

4.2.2 status message generation for hardware in operation (e.g. giving on demand a survey of interlock strategy of a special unit)

4.2.3 generation of warnings in the case of malfunction of any unit

4.2.4 generation of fault messages classifying the kind of mistake (one word message to the IBM 1800 and translated and displayed on TV screen).

5. Realization of an Ejection Maintenance Assistant System

The data transmission system (DTS) for data acquisition as well as control is partly in use since summer 1970 4). It is a parallel word transmission system, transmitting a 13 bit address in parallel with a 16 bit value. The time t to build up the information (e.g. by A/D conversion) is $(10 < t < 25)$ µs which allows a data flux of (0.4 ... 1.0) x 10^5 words/sec. The interface to STAR acquisition$^{5)}$ to make all data accessible for the IBM 1800 is in construction (MPS-CO, E. Asséo).

5.1 Realization by fixed wired hardware

The machine components differing in their tasks consequently require different surveillance and diagnostic gymnastics. This demands individual design and construction for each surveillance and diagnostic "slave" based on sequential logics. To satisfy the present ejection status about 10 slave units are necessary.

To enable timing and jitter measurements (see 3.21., 3.2.2) a multi-channel analyzer (4096 channels) is needed.

5.2 Realization by a mini-computer

All parameters can be transmitted to and stored in a computer. Choice and execution of individual surveillance and diagnostic gymnastics are treatable by computer software. By data processing e.g. on-line optimisation or automatisation of complex and lengthy maintenance procedures (see 4.2) become possible.

The implantation of a mini-computer can be arranged in a secondary loop of the DTS ensuring independence of computer and data system (see fig: structure of the system).

5.3 Remarks on the use of the IBM 1800

The steady surveillance during maintenance time as well as running of the PS demands data rolling-in every PS cycle several times at definite time marks.

The different data treatments between every PS cycle and during maintenance time periodically at definite times demand high memory capacity, time for execution and definite times for data rolling-out.

This will soon bring us in conflict with other IBM users (Linac, Booster and PS). The most important restriction for the use of the IBM 1800 as hardware maintenance assistant for ejection is the fact that proper maintenance is guaranteed only as long as the dependence of external conditions is not increased. At present we depend already on external conditions like water, power and vacuum, which are necessary but nevertheless very limiting factors of our maintenance work. Any additional and not absolutely necessary dependence is, even under optimistic assumptions, not justifiable.

6. Required performances of a mini-computer

6.1 Central processor unit (CPU)

6.1.1 to fit optimally the available DTS it must have at least 16 bits word size, parallel operation.

6.1.2 to facilitate data treatments and reduce processing time it must have more than 1 index- and 2 accumulator registers (general purpose registers are advantageous), a powerful set of instructions and addressing modes: direct, indirect, indexed, and relative.

6.1.3 for good real-time applications it must have a multi-level interrupt system with short response time (≤ 10 µs) of request.

6.2 Memory

The memory must have 8 k core store (RAM) with 16 bits word size, it must be expandable. Its cycle-time should be ≤ 1.5 µs.

6.3 Input/Output facilities.

The I/O bus must be 16 bits wide. Two modes must be foreseen.

6.3.1 program controlled transfer with data flux of 10^5 w/s (ref. DTS, see 5.).

6.3.2 direct memory access (DMA).

6.4 Peripherals: A teletype must be foreseen.

6.5 Protections: The system must be power fail-safe. Parity check and memory protection are desirable.

6.6 Software.

The basic software package must contain:
an assembler, symbolic paper tape editor, relocatable loader, utility programs (e.g. to drive I/O device routines), maintenance and diagnostic programs.

7. Comparison of a mini-computer and fixed wired hardware assembly

7.1 Level of assistance

A fixed wired hardware can survey parameters, memorize faults and generate warnings. By the use of a computer a complete diagnosis becomes possible and by data treatment optimisation (closed loop system) can be achieved.

It is evident that a computer enables a higher level of assistance than fixed wired hardware does. Furthermore, it will facilitate the proposed data acquisition to STAR by the used DTS. Some surveillance and maintenance procedures (see e.g. 4.1.1.2 and 4.1.3.2) which are very important now, might later become much less important. Thus a software program would be the most economic way to handle those problems.

7.2 Flexibility of an E.M.A.S.

Corresponding to the rising flexibility of the ejection equipment there will be unforeseeable changes in maintenance and surveillance procedures. Hardware modifications demand more expenditure than software does. Test and re-modifications in the case of malfunction reduce the efficient maintenance drastically. During the modification in a special hardware unit it is out of use. Software modifications are computer independent, can be checked on one of the other CERN computers without any reduction of the performance of the system; a re-load of the unmodified software version does not take more than a few minutes.

7.3 Maintenance

From this point of view, especially considering down-time, the use of hardware slaves is a real advantage. Malfunction of one of them does not breakdown the complete system as it can happen when using a computer.

Two facts, however, will overcome this computer disadvantage. The meantime between failures (MTBF) for 24 hours a day and 7 days week operation for mini-computers of the 3rd generation (MSI) is > 10000 hours.

The computer can be implanted in a secondary loop (ref. 5.2) so ensuring (in the case of breakdown) manual maintenance and surveillance.

7.4 Costs

The price p_c of a computer with the stated performances including a CERN-built interface is

$$50\ \mathrm{k} \leqslant p_c \leqslant 100\ \mathrm{k\ frs.}$$

The price p_s per "slave unit" in a hardware system ($\sim$ 10 needed) is

$$15\ \mathrm{k} < p_s \leqslant 20\ \mathrm{k\ frs.}$$

The price p_A of a multichannel analyzer without ADC (the information to be stored is derived from a TDC) is

$$p_A \geqslant 40\ \mathrm{k\ frs.}$$

Even taking into account a price decay of IC components a hardware E.M.A.S. will cost twice as much as a computer.

7.5 Time to make an E.M.A.S. profitable

The design, construction and tests of about 10 individual hardware slaves will take nearly as much time as becoming familiar with a computer, design and construction of a data interface and setting-up of software. The time will be about 2 years from the delivery of the computer.

8. Conclusion

To avoid the "automatic development" of deterioration of ejection efficiency and stability due to maintenance and surveillance and to keep it on a level where improvements can be expected, it must be decided, as early as possible, which type of maintenance assistance should come into use. We think that we have reached the ultimate date to start the construction of an E.M.A.S. with our present staff. From our consideration we propose an Ejection Maintenance Assistant System by the use of a mini-computer.

We did not discuss the implications of a mini-computer on a future automatic control of the ejection hardware via the IBM 1800. But evidently it would drastically reduce the design effort for all control interfaces (see 5.1).

9. References

1) G. Plass: A survey of PS utilisation in the forthcoming years
MPS/SR/Note 70-21

2) 300 GeV Machine Committee: A design of the European 300 GeV research facilities
MC 60- 2 Dec. 70

3) U. Jacob: Occupation of straight sections
MPS/SR/Memo 71-12

4) D. Bloess: Data transmission, Conférence du Groupe SR
Jan. 1971

5) E. Asséo: Contrôle de processus via le STAR
MPS/CO Note 68-11

10. Appendix: rough preselection of small computers

Company	Name of machine
Compagnie Internationale pour l'Informatique CII	MITRA 15/20
Computer Technology Limited	MODULAR 1
Data General	SUPER NOVA
Digital Equipment Corporation	PDP 11/20
General Automation	SPC 16
Honeywell	H 316
Synelec France	SYN 909
System Engineering Lab.	SEL 72
Varian Data Machines	620/F

The computer HP 2116 B is very slow (1.6 µs core cycle), has poor addressing capabilities, reports from people programming this machine in CERN are not very favourable.

The new IBM-MSP/7 system has monolithic memory only; it costs >120 k fr.

Those machines were excluded immediately.

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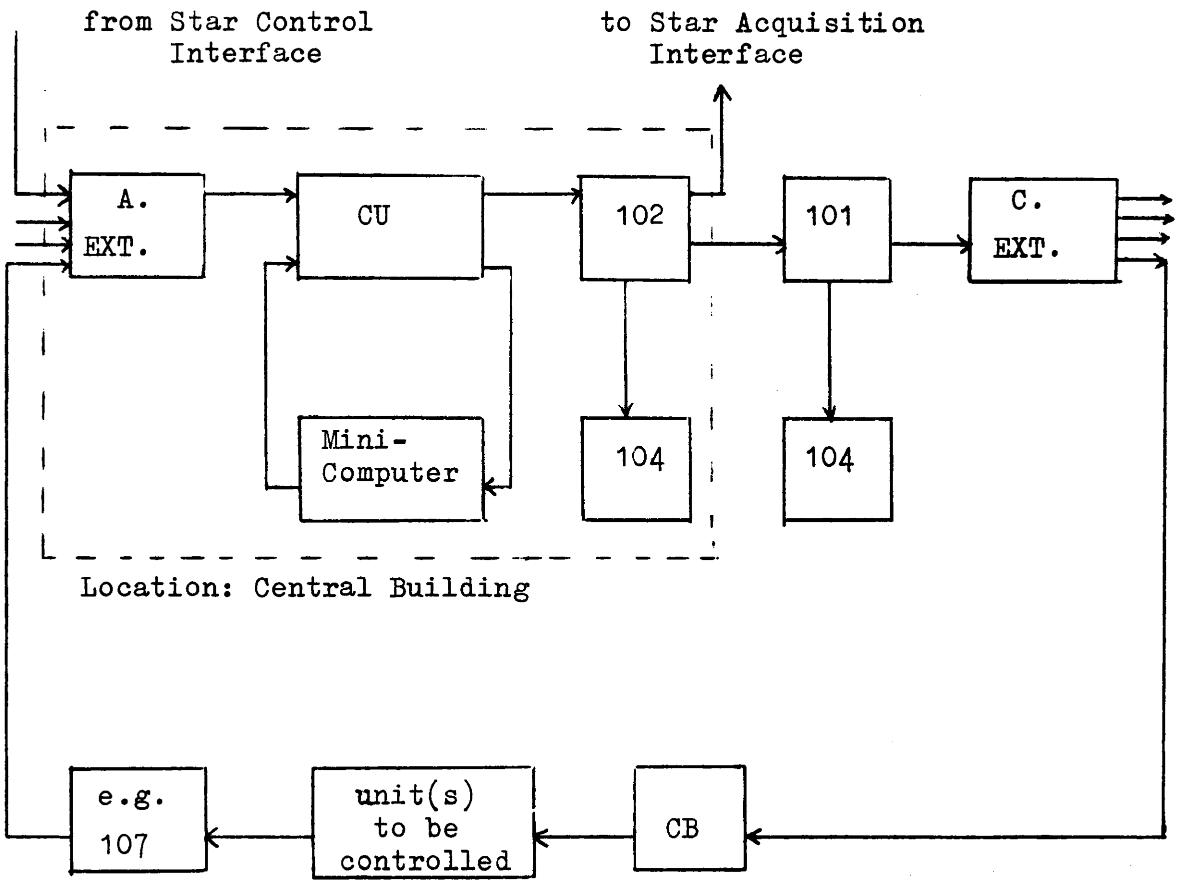
11. Structure of the system



CU : Central Unit of the existing data transfer system

A. EXT : Extension for data acquisitions

C. EXT : Extension for data controls

CB : Command box

101 : Receiver

102 : Transmitter

104 : Display unit

107 : Septum position unit