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PRELIMINARY STUDY ON THE OPERATIONAL ASPECTS AND HARDWARE STANDARDIZATION OF THE AGS CONTROLS

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June 1984

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U.S. Department of Energy

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AGS Division Technical Note
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June 21, 1984

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I. Introduction

At its very early stage, any project needs a requirement and constraint analysis, i.e., what is the project supposed to produce, how should it behave, etc. This is prime input for any design work. In the particular case of a process control system, the project has to satisfy operational requirements, i.e., how is the process (accelerator) going to be operated through the new control system. Operation is here understood in its largest sense encompassing all phases of machine operation; starting up, tuning, operation (surveillance), machine experiments, diagnostics, shutdown, by whoever is or may be involved. Though the major operators are the accelerator engineers and technicians, machine physicists and controls specialists may also be concerned, be it for experiments or commissioning purposes. A measure for the success of a control system is how efficiently it allows operation of the process. It is therefore of prime importance to involve Operations and to obtain their commitment throughout the life cycle of the controls project.

On the other hand, the control system has to cope with a variety of devices which drive the process through commands they receive from the operators. The cost of a control system over its life cycle is largely determined by the variety of these devices and the complexity of their controls. Standardization of these devices can yield significant savings on the control system cost while improving Operations efficiency.

The purpose of this note is twofold. First it summarizes the main issues which result from various discussions on OPERATIONAL ASPECTS and HARDWARE STANDARDIZATION. Secondly, it suggests how the various studies which were started could be pursued.

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The OPERATIONAL ASPECTS Working Group, whose participants are listed in Appendix I, focussed their attention mainly on:

- pulse to pulse modulation of the beam (its applicability to the AGS complex and a proposed implementation strategy)
- a shopping list of items concerning the operation of the accelerators through the new system (see Appendix II).

The HARDWARE STANDARDIZATION working group, whose participants are listed in Appendix III focussed their discussion on how to obtain a common standard for most families of devices (see Appendix IV) and on how these standards should be adapted as technology evolves.

The results of the discussions are summarized in chapter II of this note.

Chapter III suggests further investigations on various points which are still obscure. It is suggested to create small study teams, not exceeding say $\simeq$ 4 people involving various parties depending on the subject. The initiative and the coordination of the activity within these study teams should reside with the controls group, except for the operational aspects study team which should be chaired by a machine physicist (the ultimate client of the controls system!). As the activities of these study teams are not totally independent, overall coordination and inter-communication between teams should be handled by a "management board" including all study team chairmen and headed by a senior controls group member (Fig. 1). The study teams should produce written documents to be discussed in a broader circle of people concerned by the subject before they are being reviewed.

The collection of these documents, i.e., the OVERALL REQUIREMENTS AND CONSTRAINT ANALYSIS, is the input necessary to start the software and hardware design of the control system.

II. Summary of Issues

1. Operational Aspects

1.1 Introduction

The aim of the discussion was to learn how AGS-BNL people want to control their machine. To start the discussion, a brief description was given of what has been done at CERN-PS. The main topics reviewed are summarized below. They should be studied in further detail before any significant design work on the new AGS controls can be started.

Since the AGS complex will send beams to different users one should specify how these different modes of operation and the switch-over from one beam to another should be performed. A solution is being proposed which attempts to cover the medium and long term planning while considering the heavy ion beam line and the AGS-Booster as injectors for the AGS and the RHIC as user. Under these conditions we can sketch the possible different modes of operation within the AGS complex (Fig. 2).

a. Injectors:

Protons--The H^- and $H^-\uparrow$ preinjectors are used only through the 200 MeV Linac. Within the time frame of the controls upgrade, the Cockroft Walton preaccelerators may be replaced by an RFQ.

The output of the Linac can be used

- as input to the AGS
- as input to the Booster
- for its other experimental area.

In the last case the pulses not used by AGS or Booster can be sent to a standard default user (BLIP) for isotope production or on request to a Chemistry area, and a third default user has been proposed. Up to now the beam pulse-length is modulated at the 760 KeV input by a chopper. In principle fast switching between H^- and $H^-\uparrow$ should be possible.

Ions--The Tandem van de Graaf will be used as injector for heavy ions. In the first period (1986-1988), the ions will be sent directly to the AGS at 8 MeV/amu. Later on, after the initial running-in of the Booster with protons, commissioning will be done for ions also.

Switching between species is restricted by mechanical movements and manual settings. It should be of the order of 1 min when computer control is implemented.

b. Booster:

The following activities are anticipated:

- Initial running-in with 200 MeV H^-
- Improvement to its nominal performance
- Running-in of the Booster with heavy ions
- Use of the Booster ring as an intermediate storage ring for polarized protons
- Possible use of default booster cycles for 1 GeV physics test-beam.
- Last but not least, many machine experiments for studies and improvements.

c. AGS:

The following activities are foreseen:

- Running-in of AGS with 8 MeV/amu ions from Tandem
- Running-in of the 1 GeV injection from booster with protons and polarized protons
- Running-in of AGS with 400 MeV/amu ions from Booster -
- Improvements to get SEB and FEB working in parallel during SEB experiment tuning without disturbing FEB and giving good spill structure to SEB users
- Running-in as RHIC injector with 1 min switching time between species
- Routine studies and improvements

AGS Switching time planned (adapted from H. Foelsche's talk)

	Short Term	Medium Term	Long Term
SEB↔ FEB	1 hr	1 min	1 sec?
P↔P↑	1 hr	1 min	1 min
Heavy Ion↔ P (P↑)	1 hr	1 min	1 min
AGS ↔ RHIC			1 min
Magnetic cycle	1 min	1 sec	1 sec
Studies ↔ Physics	10 min	1 min	1 sec?

The subjects of discussion were pulse-to-pulse modulation (PPM) and the various items in the shopping list (see Appendix II).

1.2 Pulse to pulse modulation

Figure 3 shows a flowchart which should help in deciding whether the accelerators should operate in PPM mode, and if so, to what extent. As a result of the discussions of this flowchart, there seems to be a general agreement on the following points:

Concerning the AGS - if we take only the physics program into account some kind of fast switching can solve the problem. In particular, PPM would provide the most efficient and operationally reproducible way of accomplishing SEB experiment tune-up as a parastic activity with FEB.

As far as the improvement program is concerned--i.e., running-in of the 1 GeV injector with p and p↑, machine experiments to study the increase in intensity (in particular by dynamic stopband compensation) running-in as RHIC injector (with H.I. from booster) and routine machine studies--only the capability of working in a parasitic mode can provide the time required for these studies.

With regard to the AGS Booster - its initial running in could be done on default Linac pulses. Then when a decent beam has been obtained, it is sent to the AGS. Later PPM can relax the pressure on physics experiment time for studies on ions and polarized protons accumulator operation.

1.3 Centralized/local control, General purpose consoles

The situation is the following:

- The Linac is computer controlled, but through an ancient system. A lot of fine tuning is done locally mainly because of the vicinity of the Linac workshop. It can be controlled from MCR.
- The Siemens machine is manually controlled, but will soon be converted to computer control with a local dedicated access.

- The Tandem and ion source are manually controlled, however the good reproducibility of this set gives confidence in a conversion to computer control.
- The Heavy ion transfer line to AGS will be computer operated from the Tandem control room as a dedicated channel.
- The Booster will be computer controlled, but no decision has been made yet about console location.
- The AGS is controlled from semi-dedicated consoles in the MCR.

Several examples have been discussed including, among others, the CPS-Booster case which was run in from the main PS control room, without any local console. It is only 2 years ago that a standard console (except for its analog signal observation) has been implemented in the PSB radiofrequency area.

In the case of the AGS an agreement can be found:

- The RELWAY tranmission system allows consoles to be distributed in a very flexible way depending on project progress and program commitments.
- For an efficient use of the access points, a set of general purpose consoles, with their associated analog multiplexing system should be provided. This should reduce the number of consoles requested and lead to more flexibility in their physical location.
- In local areas, a subset of the general purpose console, without analog multiplexing facility might be provided mainly for early commissioning of machines and for later equipment fault diagnosis.

1.4 Division of machine operation into subprocesses

This implies structuring the access to the machines by grouping parameters and measuring devices in a machine physics-oriented manner. This is intended to:

- improve operators' skills by forcing or encouraging them to think in terms of machine processes instead of individual parameters (e.g., orbit correctors and orbit measurements; injection elements and measurements)

- define subprocesses which are as independent as possible with clearly defined quality criteria at input and output to reinforce a systematic approach to fault finding
- to provide them with significant global commands acting on the subprocess as a whole (e.g., storing or restoring all data belonging to the working line).

1.5 Access to programs, reservation of subprocesses

The tree structure is the natural consequence of the division of the machine operation into subprocesses. The group agreed that some kind of tree structure, which reflects the machine structure, would be needed (e.g. level 1-AGS, level 2-Low energy transverse correction, level 3-orbit corrections).

Reservation is a consequence of the general purpose console approach and PPM. As these consoles can be distributed around the AGS area, a reservation system has to be provided to avoid conflicts in controlling the parameters, while allowing reading access to all.

It should be pointed out that from the operation and machine experience point of view, the reservation must be done on the entire subprocess. If reservation of the subprocess is not achieved, global control cannot be permitted since coherence of the settings would not be preserved.

For local maintenance and test, reservation of individual devices should be sufficient.

The instrumentation should be treated in a slightly different way. Though not a real control device, it may need setting of control values and should be reserved only when the measurement is requested.

Finally, the reservation has to be automatically released when the console leaves the subprocess control level.

1.6 Interactive tools

Based on AGS and CERN-PS experience, the consoles should provide the following activities in parallel, hence providing maximum flexibility and operational efficiency.

- Analog signal selection
- Control of a subprocess
- Video signal selection
- Alarm treatment

How interaction is performed depends strongly on the physical devices used. Further detailed study is needed on this subject.

1.7 Performance

If we take all requests in different contexts, the control system has to be fast, well synchronized, be able to display numerous graphics and numerical data, be reliable, and finally, cheap! More systematic and quantitative studies must be done on these matters to provide control people with the necessary specifications.

1.8 Alarms

The AGS control system services already a large number of alarms, resulting from the programs (software problems) or hardware. Up to now, however, except in the special case of the magnet string before the superconducting magnet in the FEB, little systematic scanning of hardware is done.

It is thought that a more systematic approach to these alarms, sorting them into different classes like efficiency warnings, radiation warnings, hardware fault, software fault, etc. with its dedicated output format should improve operation efficiency.

These matters are closely related to hardware and software standardization.

1.9 Analog and video signal multiplexing

The general availability of analog signals through a facility multiplexing system has been found most improtant at the CERN-PS. There was agreement on the high density of information contained in analog signals for diagnosis and status monitoring. The use of general purpose consoles carries implications for the universal availability of the interconnections and is closely related to equipment standardization. A globally acceptable bandwidth (probably larger than that of the present slow AGS CROSSBAR facility) must be specified for the common pathways of this system.

2. Hardware Standardization

2.1 Needs for standardization

In a Computer Control system, large amounts of data have to be transferred between the computer and the devices that are distributed around the machines. In particle accelerators devices may be far away from the computers. A data transmission system must be interfaced to both the computer and to the various devices that are required to operate a machine. The interface between the data transmission system and the devices must be designed to guarantee a minimum implementation cost, an efficient maintenance and an easy expansion. In the case of large quantities of similar devices a standardized interface will bring many advantages. Those advantages are:

a) A limited set of standard hardware modules will require a small number of corresponding software driver modules to be developed and maintained. High quantities of identical modules can be purchased at low cost from many vendors, even for home-designed modules. This will guarantee a better availability.

b) With a limited number of modules one can invest more on each module either for design or for selection from commercial sources. A better documentation can be provided.

c) It will be easier for users to learn how to use a limited number of modules.

d) The exploitation and the off-line repair will be more effective.

The set of standard modules must be built according to the specifications of the selected data transmission system.

2.2 Prerequisites for hardware standardization

Prior to making a selection of commercial modules or designing special purpose controllers, one must set up a method to control the devices. The method should define the meanings of the data flowing through the interface, and should lead to a controls protocol for large families of devices (e.g., power supplies, vacuum, etc.). The controls protocol will be built up from the hardware description and the functionality of the family of devices to control. It should be as general and as technology-independent as possible; however, it should be easy to use and the number of control parameters should be as low as possible. Provision will be made for future extension of the controls protocol; however the subsequent upgradings of the protocol should be significant and fully documented (not mere ad hoc additions).

The controls protocol must cover the requirements of

i) the operators or machine physicists,

ii) the device specialists who may incorporate extra features to ease hardware diagnostics from the control consoles or from some local control facility.

iii) the control specialists.

Hardware and software structures should be optimized through mutual understanding. Future maintenance aspects have to be considered (not in full details) at this stage. One should ensure the control protocol to be fully documented (avoiding ambiguities) and widely distributed so as to be agreed to and supported by everyone concerned. In addition, the various protocols should be consistent.

2.3 Detailed hardware standardization

Starting from the agreed protocol, standard-interface modules should be provided by the hardware specialists of the computer controls team while specific interfaces (fitting the standard interface as described in the control protocol) should be built by the device specialists. Both these activities should be continuously moinitored by the controls team, at least during the development phase. Prototypes should be fully tested together with their driving software before mass production is started.

The specific interface should as much as possible be built with standard modules provided by the computer controls team acting as a central service group.

If local intelligence is required in the specific interface to meet the control protocol requirements, the device specialists will get support from the microprocessor experts from the computer control team and should use the already prepared and documented software modules (e.g., conversion subroutines). On the other hand, the device specialists must provide a documentation abiding to the standards to ensure efficient exploitation of the local microprocessor's software.

2.4 Implementation

Long term planning must be envisaged to convert all existing and implement all future devices to the established standards. A unique document should be provided for each implementation step. This document should cover all aspects (device hardware, interface, application software, etc.) involved. It will be used for installation, exploitation, and maintenance and should be updated whenever necessary.

The standardization should be continuously monitored by the controls group and adapted to new technologies whenever necessary. This may imply an upgrading of the existing controls protocol (to be investigated case by case), which is to be preferred to special ad hoc solution which would put a heavy burden on the exploitation.

2.5 Fields of application

So far, the following fields of application were discussed with the specialists.

a) Power supplies

This is by far the most important field to be taken into account. DC, pulsed power supplies and kickers are single set-point devices, alternately programmed power supplies will require a function generator.

The starting points of a study team have been agreed upon (see Appendix V). It is suggested that the study team also deals with RF system, however, one should not make too large a study team. This team should define the control protocol.

b) Vacuum

There exists already a good control expertise for vacuum at BNL. The study team should be able to up-date its previous work so as to define rapidly the control protocol. It is suggested that mechanical movement be also treated by this team. It is hoped that, in doing so, the study team does not get too large.

c) Timing

Two Relway-compatible timing modules are already in use at BNL but they are not able to cope with the high frequency clock (20 MHz). Before redesigning a new hardware it is felt that an engineering approach has to be carried out. The operational aspects must be fully investigated in order to create a control method of the timing. The subsequent hardware and software developments will be the responsibility of the computer controls team.

d) Instrumentation

Not treated (lack of time)

e) Function generators

There is a definite need for function generators. Some generators are already in use at BNL. A general purpose function generator should be mostly based on the requirements of the power supply study team, however, other fields such as instrumentation must also be considered. The method used to generate the functions from the consoles has to be set up in collaboration with Operations.

f) Analog signal observation

Though not explicitly discussed, it is felt that the analog signals carry a lot of information useful for operators and machine physicists. The computer control team already has experience with its multiplex system.

III. Proposal

1. Operational Aspects

The following recommendations are made with respect to fast switching and pulse-to-pulse modulation:

- Linac: a kind of mini-PPM is presently done and must be kept and upgraded.
- Tandem: no computer control now exists. Control must be implemented for service as Booster injector with full fast switching capability for RHIC service.
- Booster: full PPM must be planned for efficient implementation of:
  - a. Improvements beyond initial operational performance once physics program uses Booster.
  - b. Running-in with ions
  - c. Running-in as a polarized proton accumulator
  - d. 1 GeV test beam or other area
  - e. Routine developments.
- AGS: Early implementation can be with a switching mode but provision should be made for PPM capability to ease the process of Booster injection commissioning, heavy ion injection and acceleration, SEB tune-up, and eventually the running-in of RHIC injection.

With the switching time specified above, the flow chart in Appendix V indicates that we must choose "host switching" or a "local switching" solution. The utilization of significant local microprocessor power in either case leads to no significant difference between solutions from the cost point of view. "Local switching", however, allows full PPM extension without changing existing software and hardware.

Our proposal is to implement "Local switching" on the AGS and start to gain experience with it. Then it can be upgraded to a full PPM during Booster running-in. This should avoid a prohibitive initial investment and will give time to hardware and software people to solve their specific problems. At the microprocessor software level full PPM capability would be implemented but with "static" program lines which can be changed from MCR for switching texts or operator switching. During the conversion period both systems could coexist.

There was a general agreement on a number of other points; but, in addition to PPM, further discussions are needed on:

- Division of machine operation into subprocesses
- Consoles tools, mainly selecting a standard work-station for MCR and local access when needed
- Access structure to programs (tree or other)
- Alarm definition and handling
- Analog and video multiplexer specification; mainly how many signals at the same time from one area used in MCR
- Expected performances

How these studies can be handled:

Who - It can be done with a study team consisting of

4 to 5 people

1 machine physicist

1-2 operation engineers

2 control people (1 for software, 1 for hardware)

The chairman of this operational aspect study team should preferably be a machine physicist with experience in operation. It would be helpful if he also had some practical knowledge of control systems. He should coordinate the activities of his team and be willing to accept anyone else who might be interested in a particular meeting.

How - Starting from the above list, they should make a new shopping list.

Expected output -

- Definition of the first subprocess on which fast switching will be tried with a possible test case
- First definition of the subprocesses
- Layout of consoles
- Specific requirements on performances, alarm, video and analog multiplexing.

2. Hardware

For the hardware standardization we propose the following study teams:

a) one power supply study team which may possibly also deal with RF.

This team will have people from the power supply division (1 or 2), from the computer controls team (1 or 2), and from Operations (1 or 2) and possibly one person from the RF group. The possibility of incorporating more than one power supply per control channel should be carefully investigated. Taken into account: operational requirements (division of process into subprocess, effect on beam in case of channel breakdown, etc.), software and hardware structures. The chairman of this study team should have practical knowledge on power devices, computer hardware, software, and operation. He will have to conduct frequent meetings, write minutes, obtain agreements, and produce a final comprehensive report. He should ensure coordination with other study teams. The chairman should be open to accept anyone else interested in a specific meeting.

b) one vacuum study team which may also include all mechanical devices.

This study team will have people from the Mechanics Division (2 or 3) and from the computer control team (1 or 2) and one from Operations.

The chairman must have practical knowledge on vacuum and mechanics, computer hardware and software. He should coordinate his team's activity with that of the other teams.

If local intelligence is required for the optimization of the motor drives, the microprocessors embedded in the specific interface should be treated as the power supply ones.

c) Timing

A study team having people from Operations (1 or 2) and from the Computer Controls Team (1 or 2) should work in collaboration with device specialists in order to produce a fundamental controls philosophy for the timing system. The chairman should have good knowledge of operation and software and hardware. He should be able to understand the problems of the hardware specialists (power supply, RF, instrumentation).

The design, implementation, and exploitation of hardware and software modules will be the responsibility of the computer controls team.

d) Function generators, analog signal observation

Contrary to previous families of devices, general purpose equipment such as function generators and analog signal observation, and video signal selection may not require a specific study team for definition.

It is felt that they could be dealt with by engineers (one per item) of the controls team who would work together with Operations, getting information from the appropriate study teams.

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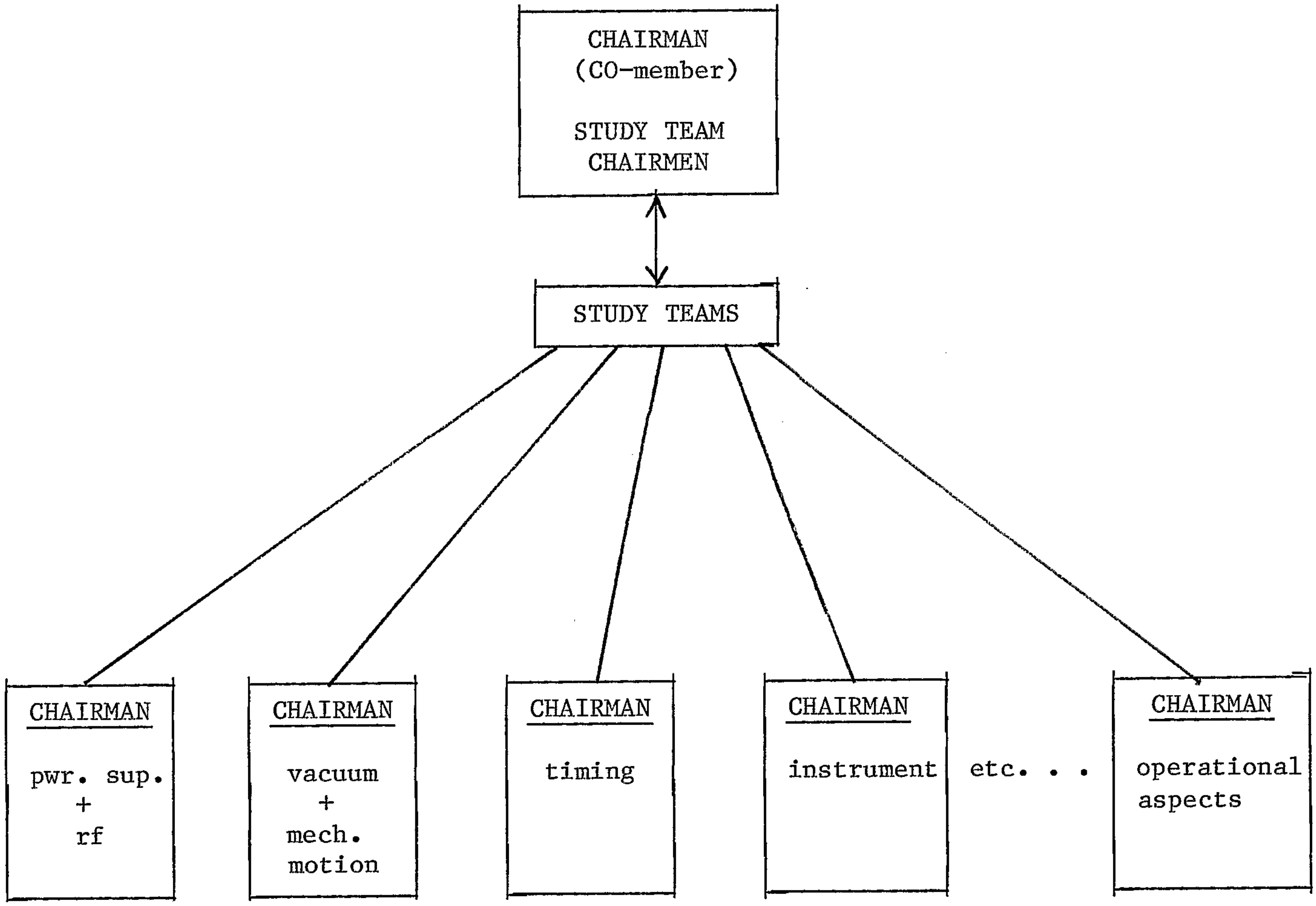
STUDY TEAM COORDINATION



COORDINATION OF ACTIVITIES OF VARIOUS STUDY TEAMS

Figure 1

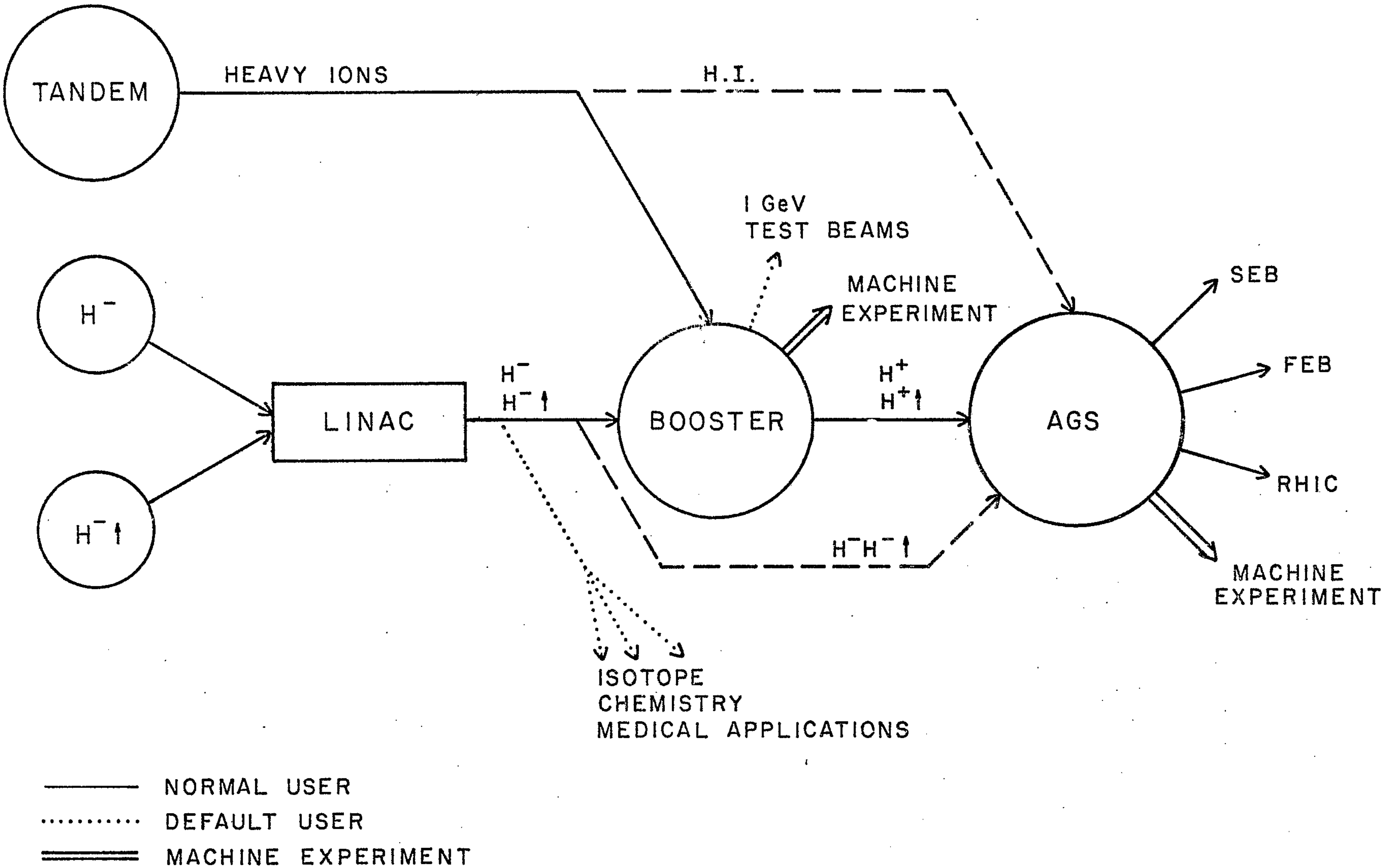


Figure 2 - BEAM UTILIZATION AT THE AGS COMPLEX

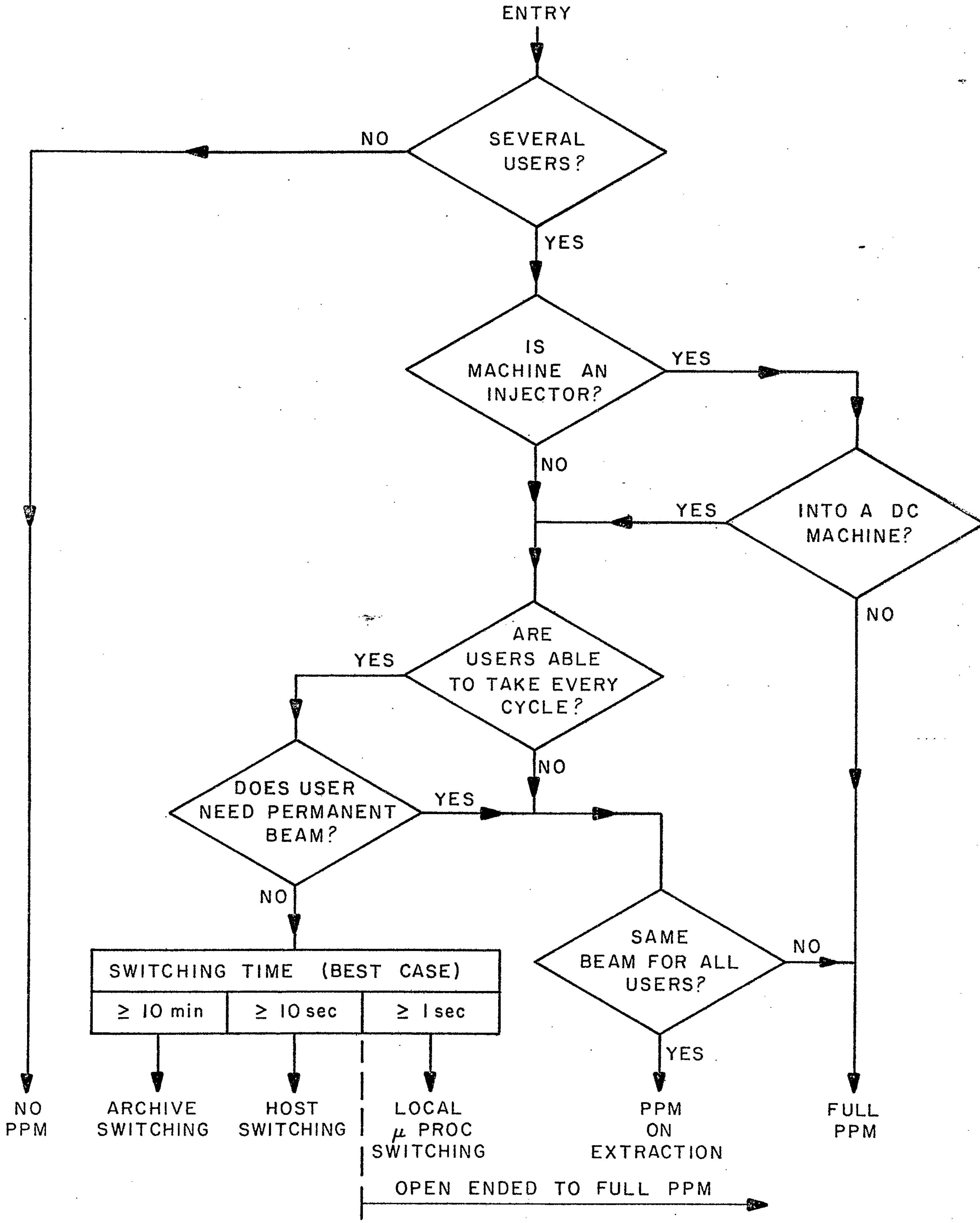


Figure 3 - PPM DECISION MAKING FLOWCHART

APPENDIX I

DISCUSSION GROUP II

OPERATIONAL ASPECTS - BEAM MODULATION

CHAIRMAN: JEAN POTIER (D. BARTON)

RAPPORTEURS: L. AHRENS/J. ALESSI

MEMBERS: J. ALESSI
J.W. GLENN
J. SKELLY
A. STEVENS
T. CLIFFORD
K. REECE
P. INGRASSIA
R. WARKENTIEN
A. DANEELS

APPENDIX II

OPERATIONAL REQUIREMENTS

1. CENTRALIZED OPERATION
   LOCAL OPERATION
2. DEDICATED/GENERAL PURPOSE CONSOLE
   SUBDIVISION OF PROCESSES
   CONFLICT PREVENTION WHEN ACCESSING PROCESSES
3. GRACEFUL DEGRADATION
4. TYPE OF INFORMATION NEEDED AT THE CONSOLE
   - DISPLAY PROGRAM
   - CONTROL FACILITIES/INPUT DEVICES (T.B. . .)
   - ALARM MESSAGES
   - ANALOG SIGNAL/VIDEO
   - HOW TO CALL PROGRAMS (TREE STRUCTURE . . .?)
5. HOW MANY DATA TO BE DISPLAYED SIMULTANEOUSLY? REPETITION RATES/SYNCHRONIZATION
6. WHAT TYPE OF ALARM NEED TO BE REPORTED AT THE CONTROLS. WHAT IS AN ALARM-WARNING. HOW ARE ALARMS BEING HANDLED--AUTOMATIC SENT!

APPENDIX III

DISCUSSION GROUP I

STANDARDIZATION OF CONTROL DEVICES

CHAIRMAN: GUY BARIBAUD (A. SOUKAS)

RAPPORTEURS: R. WITKOVER/I.H. CHIANG

MEMBERS:

R. FRANKEL	L. BURGAR
J. SKELLY	B. OERTER
P. ZUHOSKI	R. LAMBIASE
R. LEE	P. STATTEL
D. HSEUH	A. McNERNEY
J. GABUSI	A. STEVENS
A. DANEELS	

APPENDIX IV

HARDWARE STANDARDIZATION DISCUSSION GROUP

1) POWER SUPPLIES

2) TIMING

3) VACUUM

4) INSTRUMENTATION (*)

5) RF

6) FUNCTION GENERATORS

7) MOTOR DRIVES

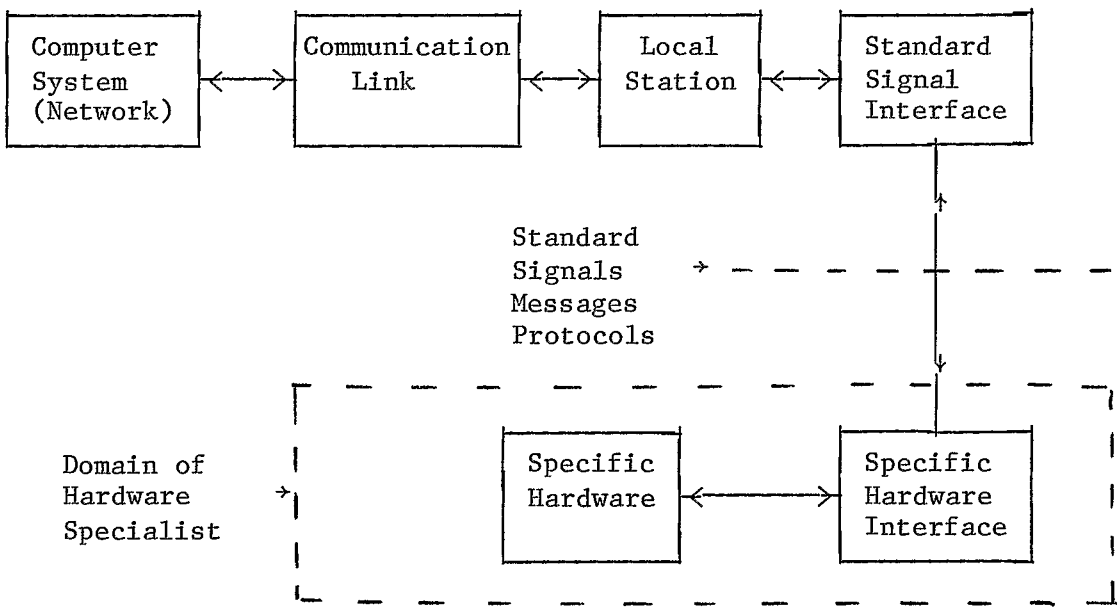
8) MULTIPLEXING (*)

(*) COULD NOT BE DISCUSSED DUE TO LACK OF TIME.

APPENDIX V

Summary of Standards Discussion

1. A control system may be characterized as below:



2. To keep the control system standard and avoid continual change of the system software, the control system must have an output of standard signals, messages, and protocols.

3. The task of taking these standard messages and protocols and making them control devices of complex behavior belongs to the hardware specialist (device designer). He shall accomplish this by using standard hardware and software modules which have been designed (or purchased) and made available by the controls group. This will prevent the growth of "one-of-a-kind" devices in the control system.

4. A committee shall be set up for each device type, which will review the implementation of the controls in the specific hardware. The

committee shall consist of permanent members from the operations/ physics group and controls group, and shall draw upon the hardware specialists as required for each implementation. This committee shall provide the means of incorporating non-standard hardware into the system.

5. Conversion of the standard signals to analog reference and read-back, and digial I/O could be accomplished in either of two ways:
   a. In the case of single parameter installation it would be most effective to install a module which performs A/D, D/A as well as bit I/O. This module would have only digital I/O connecting it to the communications link and could be easily isolated electrically. The disadvantage is that it does not exist at BNL and would have to be developed. It also is inefficient when used in an application where many channels are required.
   b. If multi-channel specific function cards are used for D/A and for A/D and for digital I/O, then larger groupings of devices can be serviced at much lower cost using commercially developed and available cards. The disadvantages are: large number of unused channels result when only one parameter is required at an installation, and, problems with isolation can occur if the output signals are between racks.

6. Possibly both approaches can exist together but the single channel/ module approach is likely to require longer development time.