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USE OF A DATABASE IN THE ON-LINE ENVIRONMENT OF A LARGE-SCALE HIGH-ENERGY PHYSICS EXPERIMENT

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ABSTRACT

Here we report our experience in building a database (DB) inserted in the on-line system of the UA1 experiment at the CERN $p\bar{p}$ Collider. The main requirements that such a DB must fulfil as well as its main possible uses are described, and we explain how this has been handled. The problems encountered, and which should be avoided, are discussed, and some solutions for the future experiments around the next-generation accelerators are proposed.

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INTRODUCTION

The aim of this paper is to show why and how a database (DB) is a major tool for the on-line system of a large high-energy physics experiment. For this purpose, the work that has been developed in the UA1 experiment at the CERN $p\bar{p}$ Collider will be quoted. In this respect also, UA1 has pioneering experience, since the experiments which are going to be set up in the next 10 years at the new accelerators (LEP, SLC, HERA, Tevatron, etc.) will have the general features of the UA1 experiment.

Section 1 of this talk will describe the main characteristics of the UA1 experiment and in particular those of its on-line environment. Section 2 covers the main properties and the main uses of such a database (DB). Section 3 defines the conditions which faced us when we started this work, our aims, and the facilities we developed to attain them. An explanation of how we developed the different uses of the DB is given in Section 4. Finally, Section 5 recounts the problems we faced, and makes some proposals for the future.

Before starting these lectures it is important to note that the point of view expressed here is not the one of a database management system (DBMS) specialist, but that of a physicist who wants to *use* a database. This means that the original characteristics of such a DB will be strongly emphasized.

1. CHARACTERISTICS OF A "LARGE" HIGH-ENERGY PHYSICS EXPERIMENT

The UA1 experiment at the CERN $p\bar{p}$ Collider is a general-purpose 4π detector (Fig. 1) characterized by

- its LARGE SIZE,
- its HYBRIDITY,
- the SEVERE REQUIREMENTS ON PRECISION AND LONG-TERM RELIABILITY.

The main consequence of these characteristics is the need for

A SOPHISTICATED, HIGH-PERFORMANCE, ON-LINE SYSTEM.

Let us first explain these different points in more details.

1.1 Large size

This has different aspects:

- i) *the large size of the apparatus itself*⁽¹⁾ (Fig. 1);
- ii) *the large amount of information* provided by the apparatus (a great number of electronics channels to be read, calibrated, and monitored);
- iii) *the large size of the collaboration* [the large number of physicists (135); and the many institutes participating in it (12), spread all over the world, thus requiring a corresponding diffusion of information) (Fig. 2)].

1.2 Hybridity

The size of the detector and also the various types of completely different devices and associated electronics (drift chambers, drift tubes, electromagnetic calorimeters, hadronic

calorimeters) create more complexity for the overall set-up and the special type of information originated by it.

1.3 High precision and reliability

Our physics aims require increasingly better performance of the apparatus in terms of precision and long-term stability and reliability. This implies a perfect knowledge of the apparatus itself (the good calibration of each piece of the detector determining the main parameters of each device) as well as of its performance versus the time (for which good monitoring is necessary). Any change in its behaviour must be recorded so as to be able to account for changes in the calibration constants and other characteristic parameters (thus it is necessary to have a short-term and a long-term history). This point as well as the two previous ones is illustrated in Appendix I of this talk.

So already a very important point arises at this level; namely, we have a great deal of information, but it is of many different kinds and needs to be accessed in many different ways.

Most of the requirements mentioned above are fulfilled, thanks to the sophisticated system which has been designed for this experiment.

1.4 UA1 on-line system²⁾

1.4.1 Data read-out

All the data to be read from the different detectors are essentially analog signals which are then digitized (ADCs for calorimeter signals, CTDs or MTDs for drift-chamber or drift-tube information). They are finally collected in five CAMAC branches, grouping a total of about 200 crates. The calorimeters and trigger information read-out uses standard CAMAC; the central detector crates (drift-chamber information) run the ESONE COMPLEX PROTOCOL.

The number of channels read from the different detectors is as follows:

drift-chamber:	6,000
calorimeter ($\times 2$):	2,140
position-detector:	3,600
drift-tube:	6,000
pretrigger:	200
trigger	288
	<hr/>
channels:	$\simeq 20,000$
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1.4.2 Main on-line tasks

The most important tasks of an on-line system are

- i) to perform the data acquisition and to record the data on tape;
- ii) to make a regular calibration on the different pieces of the apparatus;
- iii) to carry out regular monitoring of the different pieces of the apparatus;

- iv) to maintain a reliable bookkeeping system;
- v) to have a connection with the "outside world" for different purposes (e.g. to get the beam information from the SPS network, produce sophisticated display using a connection with the VAX and Megatek display, communicate file of information to the central computing system);
- vi) possibly to perform off-line tasks such as preprocessing of the raw data tapes in order to produce calibrated data tapes.

Let us now describe the on-line system which is able to handle such a list of tasks, and see how naturally we arrive at the need for a database as an essential element of that system.

1.4.3 On-line computer system

This is essentially composed of

- two main, large, on-line computers;
- a certain number of minicomputers or microcomputers and a microprocessed system having dedicated tasks and acting as the slaves of the main computers (Table 1).

Table 1
UA1 computing power

120	ROP dual processors (Signetics $8 \times 300 + M68B00$) Central detector readout
40	GPMC = general purpose microprocessor card (Motorola M68B00) Chamber controllers
18	CAVIAR microcomputers (M6800) Local test and development
6	HP21XX Detector development
8	Motorola 68000 Muon trigger and readout
5	168E processors On-line data filtering
2	NORD 100/500 Data acquisition & control/on-line monitoring
1	HP21MXE Histogramming machine

The main on-line tasks are carried out by two NORISK DATA ND 100/500 16-bit and 32-bit machines (2 Mbyte memory; STC 6250 bpi 125 ips magnetic tape units; and 75 Mbyte disks) (Fig. 3).

The ND 500 is a 32-bit processor equivalent to a 0.3 IBM/370 168. It runs in multi-user mode and has the ND 100 as front end. One of the ND 100 computers (NORD-A) runs the data acquisition system (DAS) as master in real-time mode; it reads the CAMAC and writes data on tape. In addition, it handles tasks such as primary-level checks of the read-out system, and monitors the trigger and collider performances.

The other ND 100 computer (NORD-B) runs DAS in spy mode, servicing a variety of user-developed data-sampling programs for monitoring and calibration purposes.

In addition to these two main computers, a set of different minicomputers and microcomputers, having dedicated functions, act as the slaves of the ND computers. They are essentially the following:

- A HP computer acting as a histogramming machine is linked to the NORD-B computer. It provides an economical way of calculating means and averages of a large number of channels (~ 7500 channels of the calorimeter and trigger part of the apparatus) without overloading the main computer. This is a very important device in the monitoring and calibration of the electronics.
- A system of CAVIAR computers (Fig. 4) and of microprocessors having dedicated monitoring and control tasks; the system is seen by the main computer as a set of CAMAC modules. CAVIAR is an integrated microcomputer system, based on the 6800 microprocessor, with 256,000 RAM and up to 85,000 EPROM. The general-purpose microprocessor controller (GPMC) is based on the 6800 microprocessor with 2,000 RAM and 16,000 EPROM, and a 6800 bus extension to which is connected an interface module (IM) specific to the device to be controlled.

This system is also connected to the outside via two different paths: i) the CERN standard link (CERNET), providing the communication with the CERN central computer facilities; and ii) the remote Megatek interactive system driven by a VAX 11-780.

Let us show why it is necessary to have a DB in such an environment.

2. DEFINITION OF THE MAIN PROPERTIES AND MAIN PURPOSES OF AN ON-LINE DATABASE

Here we will answer the following questions:

- i) Why do we need a DB?
- ii) What was existing before?
- iii) What are the main purposes of a DB?
- iv) What are its main required characteristics?

2.1 Why do we need a DB?

In order to perform the different on-line tasks mentioned above (monitoring, calibration, bookkeeping, history keeping, etc.), there must exist a place where the information can be *stored*, *updated*, *kept*, and *accessed* from (or to) different users—and there must also be a place for dumping the general starting conditions of each piece of the apparatus at the beginning of a run period. This place is a DATABASE.

Let us first recall a little bit of “history” concerning the use of a DB in the on-line of a high-energy physics experiment.

2.2 What was existing before?

In the “old days” (i.e. up to UA1) there were not so many and different pieces of material and apparatus; neither were there so many people dealing with so many things in so many places. No such high precision was required for the measurement, and there was just a small-size on-line computer, dealing at the same time with the DAS, the monitoring, and the calibration tasks. There was just a disk file of a few thousand parameters, which was not normally called a DB. The values were initially entered by hand and then by dump tape. The database management system (DBMS) was restricted to Write or Read on (or from) disk. The back-up facility was a tape. The outputs of calibration and monitoring tasks during the running of the experiment were produced on raw data tape, on histograms produced as hard copies (reassembled in a handwritten logbook), or as messages written by the user program on the line printer. The history was kept by means of histograms copied on paper (typical histograms were regularly produced every few hours), or line-printer outputs (containing various messages, list of read-out problems, of dead channels, etc.), and in a handwritten logbook where various authors described the different problems that occurred with the hardware, the running status, the status of the beam, etc. All this was used afterwards by the off-line reconstruction program.

The “calibrated” data tapes were produced from preprocessing on the off-line side of the calibration constants previously written on raw data tapes.

So basically there was already an “embryo” DB, serving typically the same purposes as the one we are discussing now, but owing to the much more “reasonable” size of those experiments there was no need for a really sophisticated DB system.

2.3 What are the main purposes of an on-line DB?

An on-line DB in a sophisticated on-line system is associated with almost all the different tasks performed by this system (see Section 1).

As an example, we list below the tasks in which the UA1 on-line DB has been involved:

- Monitoring of the different parts of the experiment (electronics, DAS, trigger, pretrigger, read-out, beam).
- Calibration of the different parts of the apparatus (e.g. ^{60}Co calibration of the calorimeters).
- Keeping a general logbook system (trying to replace the usual handwritten logbook by an automated one).

- Bookkeeping for the experiment (e.g. listing the different pieces of material used in the experiment; taking into account, in particular, the possible changes or modifications; bookkeeping of tapes).
- Preprocessing of the data (using the calibration constants which are produced on-line to obtain the final data tape).
- Keeping the short-term history of the constants (for instance, the main parameters of the beam, and the data-taking during a shift period of about eight hours).

To perform these different tasks, the DB must have a certain number of characteristics which we will now describe.

2.4 The main characteristics of the DB developed in the UA1 experiment

The DB must be

ACCESSIBLE by any user program and by any external user.

INTERACTIVE, so that at any time one can access the DB by hand and scan it.

EVOLUTIVE in structure so as to be able to adapt itself to any change in the apparatus or in the monitoring or calibration system of the apparatus.

EASY TO IMPORT (EXPORT) DATA FROM (TO) THE OUTSIDE, because a good number of the data to be introduced into the DB are provided by external sources (for instance, the list of the values of the high voltages (HVs) to be set in each PM of the experiment).

EASY TO UPDATE OR MODIFY by any user program or by hand.

SAFE in having a **GOOD BACK-UP**, and also a safe way to modify it and restore it in case of crash.

OF REASONABLE SIZE, as it is an on-line object which is constrained to be restricted in size owing to the limited space available on the on-line disk.

ABLE TO KEEP SHORT-TERM HISTORY in order to get some idea of the evolution in time of some monitoring or calibration parameters.

Let us now elaborate on these features.

3. FACILITIES DEVELOPED IN THE UA1 EXPERIMENT TO ENSURE MOST OF THESE CHARACTERISTICS

Before describing these facilities, we must first mention the starting conditions of our work.

3.1 Main constraints

These can be summarized in the following way:

- There was an extremely short time in which to set up a working system.
- The on-line environment was totally **NORSK-DATA** oriented. This led to the fact that we had no time to develop our own DBMS, and that we bought **SIBAS I** while waiting for the **SIBAS II** ³⁾ version of the **NORSK DBMS**, which arrived three to four months later. This DBMS was still plagued by many remaining bugs and was not really adapted to our application (it was meant for much more restricted applications than those of a high-energy physics experiment).

- There were other on-line tools being developed by us at that time, or tools we had bought especially and that were used together with the DB:
 - *A touch control panel (TCP) facility* on an MVIT or VT 100 screen; this is a package which, by pressing predefined locations on the screen, allows certain on-line tasks to be started (it is a very useful interactive facility).
 - *The CERNET link*, which connects the ND computer to the IBM computer in the main CERN computer centre; it allows transmission of files of any type of character and deals with the difference between the two systems.
 - *The NORD Screen Handling System (NSHS)⁴⁾*; this is a package which we bought from NORISK DATA and which offered the following properties: it is an interactive package that makes it possible, through a *table* format, to get from or store in the DB a set of data (integer, floating, or character type). The NSHS also has a lot of safety facilities for avoiding user errors (by ensuring that certain parameters must not exceed certain limits, that certain values cannot be attributed to certain parameters, that certain characters are not authorized, etc.). A table is predefined by means of this package and according to the use one wants to make of it; with a cursor facility it is also possible to just change the required parameters and leave the others unchanged.

Let us now describe what SIBAS II provides for us, and then what we have to develop in order to achieve our main aims.

3.2 What is provided by SIBAS II?

SIBAS is a DBMS originally designed by the Central Institute for Industrial Research in Oslo. It is currently implemented on IBM, UNIVAC, CDC, DEC10, SEL, and NORD computers. The main characteristic of SIBAS implementation on ND is that it is strictly oriented towards a multiprogrammed, terminal-oriented computing environment. Thus many users may access one DB simultaneously (but in fact only one call at a time is processed by a SIBAS program, and SINTRAN facilities are used to queue the different calls), and it is possible to have several DBs in a system at the same time.

The different modules provided by SIBAS II (Fig. 5) consist of:

- *A definition/redefinition language (DRL)* to define the database and redefine it when some changes have to be introduced. This DRL is working, but it is not really flexible in the sense that each time the DB is defined or redefined its content is reset to zero. So there is essentially no interactive way of carrying out such an action, and we had to build a modular structure and live with this situation. (See example in Appendix II.)
- *A data manipulation language (DML)* which, through simple FORTRAN calls, allows one to STORE, GET, FIND, or MODIFY information in different parts of the DB. It works well for a very restricted use, but for a much more general use, such as the one we need in our experiment, we had to develop a facility that would make it easily accessible to any user.
- *A DB exception condition (DBEC)*, allowing the detection of an error in any DML call.
- *A DB maintenance module (DBM)* to make some checks on the DB; it is a very imperfect package and is not really useful.

- *An interactive language (SIBINTER)* allowing DML calls to be performed in an interactive way. This is largely a pedagogic tool, but is not really useful since it is too slow, of very restricted use, very poorly documented, and by no means an “update” facility.

Taking all these starting points into account, we developed a set of “facilities” to ensure that our DB had essentially the main characteristics we mentioned previously. These are summarized in the following section.

3.3 Main facilities developed with the UA1 on-line database

i) Accessibility by any user program

We built a **GENERAL ROUTINE** which is started by a simple FORTRAN call and by specifying a few parameters. It provides the **POSSIBILITY** of performing any DML action (such as **STORE**, **GET**, **FIND**, **MODIFY**, **OPEN**, **CLOSE** the DB) in *any particular part of the DB*. This is to avoid the need for going through a heavy procedure to perform each DML action (as had to be done in SIBAS).

To this routine is attached a **DB LIBRARY** containing the full updated description of the DB. At the same time, this **DB LIBRARY** provides an additional and independent way of saving the last updated description and definition of the DB.

ii) Accessibility by the DAS

By means of an “**APPEND-BATCH**” procedure, the data-acquisition real-time program starts a background program which calls the wanted DML action in the DB.

iii) Interactivity or accessibility “by hand”

A facility using the NSHS, the touch-panel facility, and the general DML routine has been developed to provide a general tool for extracting or entering any information in any part of the DB, i.e.: to scan, at any time, the contents of any part of the DB; to enter a set of new parameters in any part of the DB; to modify by hand any part of the DB; and, more generally, to perform any DML action directly from the console.

iv) Evolutive capacity

Our ability to make the structure of the DB adaptable to any kind of possible change is very much constrained by the inflexibility of the DRL part of SIBAS.

Our main concern was to produce a *modular structure* that is essentially dependent on the different functions for which it is used; that is to say, each part of the DB is defined by independent cells (realms) containing the information corresponding to one special use of the DB (for instance, PM characteristics used for the monitoring of the PMs; see Section 4).

v) Ability to export (import) massive amounts of data

Using the **CERN LINK + IBM mass storage (or TAPES) + TCP + the general DML routine**, and acting directly from the ND console, we provide a general facility which allows a massive amount of data to be sent to or received from a particular part of the DB.

vi) Updating of the DB by a user program

Using the general DML routine with appropriate parameters, any user program can update the corresponding part of the DB with which it is concerned.

vii) Updating of the DB by hand

Using the TCP + NSHS + GENERAL DML routine, we provide an interactive and safe way (thanks to the safety facilities provided by the NSHS) of updating any particular part of the DB.

viii) Back-up

Here also, the NORISK DB system does not provide an appropriate safe back-up facility; so we have made a facility, using the TCP + NSHS and the general DML routine, which allows regular saving of the DB contents (or any part of the contents) either on tape or in the IBM mass storage (using the CERNET link).

ix) Keeping the information for a certain definite time

Long-term storage is obviously the affair of a very big mass storage system, such as the IBM, or of tapes.

For a few hours we record a small amount of information which is sent very frequently (such as the SPS beam information, the bookkeeping information, the general trigger status, and the run conditions).

This information is provided by the DAS. By means of an APPEND-BATCH procedure, a background program is triggered. This program then stores the required information, and can provide other facilities such as displays, histograms, etc.

Using these different facilities, we then built up the possibility to carry out a certain number of tasks involving the DB.

x) Database dictionary

A DB dictionary has been made available on the IBM side; it contains a complete description of the contents of the on-line database, updated each time the DB is redefined. It is a passive dictionary in the sense that, owing to the very restricted DRL of SIBAS, it cannot be used to automatically produce a redefinition of the DB. Its use is mainly to provide an updated compilation of the different types of information contained in the DB, as well as a description of the DB structure. It can be consulted, thanks to the Wylbur interactive facility, on the IBM. (Table 2 is an example of the output provided through this interactive facility.)

4. EXAMPLES OF TASKS INVOLVING THE ON-LINE DB

We give here some examples of applications of the on-line DB which has been developed in the UA1 experiment.

4.1 On-line monitoring of the high voltages of the PMs

This is an example of an on-line task performed by a microcomputer (a SUPERCARIAR) which controls the high voltages of all the 2400 PMs of the experiment. The incorporation of a

Table 2
List of REALMS and ITEMS

REALM	ITEM	comments ...
COBRCOND	COBRUNNB	contains the condition of each cobalt run (as an header)
	COBRDEF	cobalt run number
	COBRDEF	cobalt run definition (type of scan and what element is scanned)
	COBMAGTP	magnetic tape unit used to register cobalt data
	COBRDT	date at which the cobalt run is performed
	COBRHR	hour at which the cobalt run is performed
	COBPMS	PM's used in the cobalt run
	HVPM1	HV value of PM 1 in volts
	HVPM2	HV value of PM 2 in volts
	HVPM3	HV value of PM 3 in volts
	HVPM4	HV value of PM 4 in volts
	HVPM5	HV value of PM 5 in volts
	HVPM6	HV value of PM 6 in volts
	HVPM7	HV value of PM 7 in volts
	HVPM8	HV value of PM 8 in volts
	HVPM9	HV value of PM 9 in volts
	HVPM10	HV value of PM 10 in volts
	HVPM11	HV value of PM 11 in volts
	HVPM12	HV value of PM 12 in volts
	HVPM13	HV value of PM 13 in volts
	HVPM14	HV value of PM 14 in volts
	HVPM15	HV value of PM 15 in volts
	HVPM16	HV value of PM 16 in volts
	GAIN1A8	gain set on ADC MOTOROLA for channel 1 to 8
	GAIN9A16	gain set on ADC MOTOROLA for channel 9 to 16
	COBSTAT	status of the cobalt run
COBGDMAP	MESURENB	contains the map corresponding to each cobalt run
	COBRDEF	measure number
	COBRDEF	cobalt run definition
	SOURCEFL	source flag (0 if source off, 1 if source on)
	COORD1	coordinate 1 value (depends on scan definition)
	COORD2	coordinate 2 value (depends on scan definition)
	ADC1	measured value on ADC 1
	ADC2	measured value on ADC 2
	ADC3	measured value on ADC 3
	ADC4	measured value on ADC 4
	ADC5	measured value on ADC 5
	ADC6	measured value on ADC 6
	ADC7	measured value on ADC 7
	ADC8	measured value on ADC 8
	ADC9	measured value on ADC 9
	ADC10	measured value on ADC 10
	ADC11	measured value on ADC 11
	ADC12	measured value on ADC 12
	ADC13	measured value on ADC 13
	ADC14	measured value on ADC 14
	ADC15	measured value on ADC 15
	ADC16	measured value on ADC 16

BORER 1635/16 RAM permits the storage of the contents of all updated sets, and of measured and original voltages. The RAM is capable of storing 16,000 16-bit words. It plays the role of an interface between the ND master computer and the CAVIAR (Fig. 6). This system provides a continuous monitoring of the HVs of all the PMs with display of the current situation and alarms, and includes an associated DB ⁵⁾. This part of the DB performs the following tasks using the touch panel interactive facility (Fig. 7).

- *Automatic setting-up from the DB* of all or part (to be specified) of the PMs.
- *Comparison between the value stored in the DB and the value really set on the HV power supplies*: a message on the screen shows which channels have discrepancies between the two series of values.
- *Updating of the DB*: this allows a continuous updating of the DB to be performed by the monitoring program. This can be interrupted only from the terminal (by hitting any key twice).

The record corresponding to each PM in the DB is given in Table 3.

Table 3
Contents of the real used for PM monitoring

Object definition	Type
PM number	Integer
Date of entry into DB	Integer
Hour of entry into DB	Integer
Status flag	Integer
Original HV value	Integer
Measured HV value	Integer
Set HV value	Integer
Slope (= exponent of dependence of gain on high voltage)	Real

In addition, three interactive facilities are provided:

- i) *to extract* the data for a contiguous set of PMs from the DB and to write them into a file in the user's area, or to the screen, or to the line printer;
- ii) *to load* the data for a contiguous set of PMs from a file into the DB;
- iii) *to modify* a contiguous set of records in the DB. The data for the records to be modified are read from a file.

4.2 ⁶⁰Co calibration of all electromagnetic calorimeters

This calibration is a good example of a completely independent microprocessed system. It delivers the data to the main ND computer, which is just acting as a supervisor.

The purpose of this calibration is to produce an attenuation map of the scintillators of the electromagnetic calorimeters by scanning them with an intense ⁶⁰Co source. The response of each

PM is an analog signal, which is first multiplexed to access an analog-to-digital converter (ADC) microprocessed card (MC 15A/15A1). The addressing of the corresponding channels that are looked at, the source movement, the ADC read-out, the displays (a display of the run evolution and the source movement is continuously provided), the filling of the buffer with data (which is then read by the ND computer) — these are all done by this microprocessed system. This system, through a CAMAC interface (CCI), is then just like a CAMAC module for the ND computer.

The ND 100 computer starts the run (Fig. 8) by sending to the microprocessed system, through the CCI interface, the parameters defining the run conditions. These parameters are also stored in the DB. The data, as transmitted back by the microprocessed system, are then stored in the DB and transmitted as a file from the ND 100 to the ND 500 to compute the attenuation length (fitting the data). These results are then transmitted back through a file to the ND 100 and stored in the DB. An analysis of the data is performed on-line, delivering the results almost immediately (Fig. 9).

4.3 Automated logbook

In a large group where people come from many different institutes spread all over the world, it becomes really necessary to have a way of producing an automated logbook, for two main reasons:

- i) to standardize and centralize the general information to be included in the logbook;
- ii) to have a means of spreading the corresponding information easily.

This does not at all impede the use of dedicated handwritten logbooks for more specialized and restricted purposes.

We built such a facility, using the TCP + the NSHS + the DB + the CERNET link with the IBM, to be used for the following purposes:

- the TCP is used to interact directly with the action to be taken;
- the NSHS produces the required page of the logbook that has to be completed;
- the DB is used to get or store the corresponding information (the short-term history is kept for a period of about 24 hours);
- the CERNET link is then used to transfer the contents of the logbook to the IBM for long-term history purposes.

The automated logbook is built up of three different types of pages; each type corresponds, in fact, to each of the three different situations that have to be faced during a shift (see Table 4).

The page called LOGSTART (Fig. 10) has to be completed at the beginning of a shift. It automatically gets information from the DAS and the SPS beam; the user has to complete the corresponding remaining information by hand, using the NSHS facilities.

The page called LOGFLASH (Fig. 11) has to be completed each time something happens during the run. It consists essentially of a message informing the user of the main facts that occurred during the shift. Together with this option, the user can also initiate the display of a running message during the time he wants — for instance, in order to transform the information into a public message.

Table 4
List of REALMS and ITEMS

REALM	ITEM	Comments
LOGSTART		start run page of the logbook (to define the starting SPS run conditions)
	SPSRUNNB	SPS run number
	DAYSPTS	date
	HOURSPTS	hour
	TRIGCOND	trigger condition
	PEOPLE1	name of people on shift
	PEOPLE2	name of people on shift
	PEOPLE3	name of people on shift
	PEOPLE4	name of people on shift
	PEOPLE5	name of people on shift
	PEOPLE6	name of people on shift
	BEACOND1	beam condition
	BEACOND2	beam condition
	BEACOND3	beam condition
	BEACOND4	beam condition
	GCDCDF	general condition flag of central detector (ok or not ok)
	GCDCDC	general condition on central detector: comment
	GCDHADCF	general condition flag of hadronic calorimeter
	GCDHADCC	general condition on hadronic calorimeter: comment
	GCDEMF	general condition flag of e.m. calorimeter
	GCDEMC	general condition on e.m. calorimeter: comment
	GCDMCF	general condition flag of muon chamber
	GCDMCC	general condition on muon chamber: comment
	GCDFWF	general condition flag of forward detector
	GCDFWC	general condition on forward detector: comment
	GCDVFF	general condition flag of very forward detector
	GCDVFC	general condition on very forward detector: comment
	GCDLUF	general condition flag of luminosity chamber
	GCDLUC	general condition on luminosity chamber: comment
	FDATAPNB	first data tape number
	FEVNUMB	first event number
	CDCALF	central detector calibration flag (means calibration has been done or not)
	HADCALF	hadronic calorimeter calibration flag
	EMCALF	e.m. calorimeter calibration flag
	FCALF	forward detector calibration flag
	VFCALF	very forward detector calibration flag
	COMMENT	comment

LOGFLASH	“FLASH” page of the logbook (allowing to write any important message during the SPS run)
FLASHNB	FLASH number
NAMFLASH	name of the author of the flash
SPSRUNNB	SPS run number
DAYFLASH	day
TIMFLASH	time
FLASH	flash comment
ACTION	action taken

LOGSUMRY	summary page of logbook (summarizing information of an SPS run)
SPSRUNNB	SPS run number
SUMDATE	date of the run summary
SUMHOUR	hour of the run summary
SUMSTART	hour at which starts the run
SUMSTOP	hour at which ends the run
TOTEVENT	total number of events
TOTSPEVT	total number of special triggers
TOTWTAPE	total number of tapes written
TOTSPETP	total number of special tapes written
AVELUMIN	average luminosity
ENERGY	energy in $\text{GeV}/c \cdot 10$
TOTPBUNC	total number of proton bunches
TOTANTIB	total number of antiproton bunches
TOTPCURR	total proton current
TOTANTIC	total antiproton current
CDPERF	central detector performance
HADCALPF	hadronic calorimeter performance
EMCALPF	electromagnetic calorimeter performance
MUONCHPF	muon chamber performance
LUMCHPF	luminosity chamber performance
SUMNAME	name of the author of the summary
SUMMARY	summary comment

The page called LOGEND (Fig. 12) has to be completed at the end of the shift; it gets some automatic information from the DAS and the beam, summarizing the status of the whole experiment during the shift; users have also to add some information by hand through the NSHS.

At the end of the shift, the user must press the corresponding location on the touch panel; this starts a program to transfer the information of the logbook to the IBM, and prints on paper the contents of the logbook for this shift, so that a copy also remains in the control room.

4.4 Example of bookkeeping tasks

4.4.1 Bookkeeping of raw data tapes

For each raw data tape taken during the run of the experiment, we record in the DB the main characteristics that are provided by the data-acquisition program, stored during a few hours, and then transmitted through the CERNET link to a bookkeeping system sitting off-line in the IBM computer. This information is described in Table 5.

Table 5
Contents of the realm used for the bookkeeping task

Definition of information	Type
UA1 run number	Integer
SPS run number	Integer
Day of start of the run	Integer
Hour of start of the run	Integer
Hour of end of the run	Integer
Trigger words (5 words defining the trigger conditions)	Integers
Tape label	Integer
Number of files in this tape	Integer
Total number of written words on this tape	Integer
Total number of calibration records	Integer
Total number of real events	Integer
First event number	Integer
Last event number	Integer

4.4.2 Bookkeeping of material

For instance, we store in the DB a list of CTD cards and ROPs (part of the read-out electronics) and their characteristics; so in this way we build up a catalogue which contains all the different problems, different changes, and present status of these devices.

4.5 Short-term history

The DB has been used to store over a restricted period of time (24 h) the information provided by

- the SPS computer network: 256 words each 5 min;
- the DAS bookkeeping: a few dozen words recorded at each end of tape (which occurs every 20 min);
- the general trigger information: about 10 words;
- the run conditions: about 10 words;
- the automatized logbook contents.

So, typically a relatively small amount of data is stored but it is frequently updated.

This information was first centralized by the DAS in the ND 100-A computer, which then transmitted it to a background program (started by DAS with an append-batch procedure) which stores the information in the DB (using the general DML routine facility) and also produces displays and outputs of this information for bookkeeping purposes.

This information is transmitted regularly, once per day, to the IBM mass storage, using the CERNET link and starting the program by pushing the corresponding location of the TCP. If the CERNET link is not available, this part of the DB is saved on tape.

5. CONCLUDING REMARKS

We have built and developed a lot of tools and facilities in order to adapt SIBAS to a DB system compatible with the UA1 on-line environment. All the DB facilities we described before were working for the first run-period of 1981; the DB was used for the automated logbook, the bookkeeping, the beam monitoring, the survey of the run conditions, the HV monitoring of the PMs, and the ^{60}Co calibration. However, owing to lack of disk-space and manpower, for the 1982 run, only a fraction of data have been handled by this DB system.

So we are now going to discuss the main problems we had to face, and at the time try to propose some solutions.

Database also means CONCENTRATION OF THE BASIC INFORMATION which concerns the *running* of the apparatus during the data-taking period and then the exploitation of this information for the *analysis of the data*.

This implies

- i) a WELL-CENTRALIZED ON-LINE SYSTEM;
- ii) a WELL-EQUILIBRATED AND CO-ORDINATED ON-LINE VERSUS OFF-LINE;
- iii) ENOUGH SPACE FOR and AUTONOMY and PRIORITY OF THE DB IN THE ON-LINE SYSTEM;
- iv) NEED FOR GOOD TECHNICAL SUPPORT.

Let us now describe the problems that may be encountered when facing these four points. Some are peculiar to UA1, but most of them are of general interest.

5.1 Need for a centralized on-line system

This is implied by the definition of a DB, and it is inevitably correlated with the need for a well-coordinated on-line system — which is not always easy to achieve in practice. The general framework of a large high-energy physics experiment is an assembly of many different institutes, each providing its own piece of apparatus and working very often in an almost INDIVIDUAL way (this is a psychological but strong enough fact, remaining from the “old days” when people used to work in small groups). The use of a DB in such a big on-line system can also pose the same problems of management as those encountered in a modern factory; physicists must get accustomed to working in the new industrial atmosphere that now surrounds most high-energy physics experiments.

5.2 Need for a good equilibrium and co-ordination between the on-line side and the off-line side

The on-line side is essentially composed of people working “on the floor”, i.e. in the experimental area or very nearby, whereas the off-line side is usually composed of people who work relatively far away from the experiment. So, once again, taking into account the framework of the new big experiments, where many people cannot remain near the apparatus for any length of time, there is usually (it is also the case in UA1) a disequilibrium in number between the two sides. In addition, owing to the geographical distances, there can be bad or difficult communication. Also, because of this last point, the people on the off-line side do not like to have the concentration of the main information about the experiment (which also means a concentration of power) too far away from them, located in a place which is not their “familiar” place (once again an important psychological point!).

To tackle this problem, one must ensure the existence of a very good system, one which allows the transmission of the information to the outside from the on-line DB. In our case we have tried using the CERNET link from the ND on-line computer to the IBM off-line computer; but this transmission system is not always available. In addition, one must also provide a good “maintenance” system which takes care of the regular transmission of this information, deals with it on the IBM side, and in particular distributes it to all the interested off-line users.

5.3 Need for enough space, and for autonomy and priority of the DB in the on-line system

As we have seen in the previous sections, the use of the DB implies the need for enough disk space. In addition, most of the on-line tasks which use the DB are background programs. One must again take into account also the fact that many different people performing many different tasks at the same time on an on-line computer, *slow down* greatly all the background tasks. So an overloaded on-line can make the use of a DB inefficient.

The solution to this is not only a good co-ordination of the different on-line tasks and a good handling of the different priorities but also the use of slave minicomputers or microcomputers and microprocessed systems that are able to handle dedicated on-line tasks and to predigest a lot of information for the DB. This saves a lot of space and time for direct manipulation of the DB. This is more essential and would result in a more important factor of efficiency than making the DB itself work in real time.

In fact a good way of solving most of the problems mentioned above, is to handle the DB in a much more autonomous way (see subsection 5.5).

5.4 Need for good technical support

The point to be emphasized here is that the DB, like many other tools used in high-energy physics, remains a common problem for both the physicist and the technical expert—even though more and more expertise is employed. In our case we suffered from a lack of technical support from the ND specialists, so we ourselves had to develop a lot of such facilities. In other cases I feel that people are orienting themselves too much on the “specialist” side. It is clear that the choice of DB

required for the high-energy physics experiments is largely determined by the use to which it will be put. In particular, this work requires a very good knowledge of the different calibration and monitoring tasks being carried out on the different parts of the apparatus.

So such a DB must be built both by the physicist and the DB expert.

5.5 Some possible solutions for the future

In connection with the different points we have discussed in this section and taking into account the new developments on the DB techniques side, there are essentially two possible solutions.

One way is to keep a *centralized DB system* but to have it autonomous from the master on-line computer. This means that there has to be a DB dedicated minicomputer, with its own disk and peripherals (display facility, teletype, etc.). It can be linked to the on-line system by means of the main on-line computer, and through it can receive or send the information from or to the different slave parts (Fig. 13). Another way is to link the minicomputer directly to the different parts which provide it with information, using the "ETHERNET" link facility⁶⁾. This in fact means that there could be the possibility to share the information directly in the memory of the different slave parts producing it.

Another way is to have a *distributed DB system*—in other words, a set of locally distributed DBs, each one attracted to a specific task or a set of specific tasks handled by a local system. These DBs are working with the same DBMS. This DB structure is more adapted to the case where the on-line system is built up from a set of diverse and autonomous (thus responsible) small on-line centres, each one having a dedicated task, and each managing its own part of the DB or mini-DB. These would then be connected through a purely software protocol in order to solve the concurrency problem⁷⁾ or, preferably, even using a more hardware-oriented protocol through, for instance, a FASTBUS system. Several microprocessor-based DB processor cards [e.g. the INTEL iDBP(432)] are already commercially available and could be evaluated for this purpose.

These two types of solution are much more adapted to the general diversity and tendency to sophistication of the present-day on-line systems. The next-generation experiments will become more and more the "distributed responsibility" type. We foresee an assembly of relatively small and independent systems for performing dedicated tasks, and these will be linked together through a new type of network. Note that this will replace the classical CAMAC architecture currently in use and which is more centralized.

CONCLUSION

The work we have developed in the UA1 group at CERN, building an on-line DB for our experiment (which is the first high-energy physics experiment of such a size) is *pioneer* work; it shows what can be done, how it can be done, and also what are the problems one has to avoid.

It is quite evident that for the next generation of experiments which are going to be built around the new accelerators (LEP, HERA, SLC, Tevatron, CBA, ...) a DB is a very essential and necessary part of the on-line system.

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APPENDIX I

THE STORY OF A PULSE DELIVERED BY A PIECE OF EQUIPMENT BELONGING TO A LARGE-SCALE ENERGY PHYSICS EXPERIMENT

We would like to mention the complexity involved in handling information delivered by a detector—for example, when we want to extract the physical measured quantity from the information originally delivered by the detector. To illustrate this, we take the case of a piece of the UA1 central e.m. calorimeter. We follow the original signal it delivers when a particle goes through it until we get the information finally produced by the DAS.

When a particle hits such a scintillator, at a certain impact angle ϕ , the information delivered by the detector is read through the two photomultipliers, PM1 and PM2, located at each extremity. Each of these PMs gives a pulse height: $PM = PM_0 A(\phi)$, where A is an attenuation factor, which is a function of the impact ϕ -coordinate; we roughly have: $A(\phi) \simeq e^{-\lambda\phi}$ (where λ is the attenuation length). The amplitude PM_0 is given by the gain of the PM. The PM is HV power supplied. Its gain value depends on the value of the HV applied, and the stability versus the time of the gain depends on the stability of the PM, and also on the variation versus the time of the HV. In order to record any deviation up to 1% level, the PM gain is regularly monitored (once per day), during the running of the experiment, by means of a sophisticated laser calibration system. As a result of this calibration, the average PM gain value as well as the corresponding r.m.s. must be recorded for each PM channel, so we have a total of about 3000 words.

The pulse is then amplified by a linear amplifier; the amplification factor of such a device must be kept constant also up to the 1% level; again, this is monitored daily by a test pulse system (a microprocessed one) which monitors about 2000 channels. An average gain value and a corresponding r.m.s. are evaluated for each channel, so that we have a few thousand words per day. The pulse is shaped by a receiver, which introduces a third level of amplification. Finally, the pulse is digitized by 2282A LeCroy ADC channels which deliver charge information related to the digitized time t by: $Q \text{ (pC)} = At + B$, where B is an offset which also has to be regularly monitored, once per day. The average offset value as well as its corresponding r.m.s. must be recorded at each monitoring for each ADC channel (7600 channels in total).

Now the charge (in picocoulombs) provided by the ADC (and corresponding to a certain pulse height already corrected for the different effects mentioned above) has to be related to the energy in GeV really deposited by the particle in the detector. For this, two other steps are still needed. The first step is to get the attenuation map from which the coefficient $A(\phi)$ is derived. This is done by means of the ^{60}Co calibration. This calibration (as we have seen in subsection 4.2) is done three to four times per year, and involves the manipulation of a certain amount of data which have also to be included in the final estimate of the real information delivered by the scintillator. Once this last correction is applied, there only remains a final step; one has to measure the response of the detector to an electron beam of known energy hitting the detector at a known position. The device is then submitted to the radiations of the ^{60}Co source, in the same place; so that this source also ensures the transport of the absolute calibration. The resulting correspondence factor C which relates the energy deposited in this scintillator by the incident e^- to the pulse height measured by the ADC is then finally determined.

EXAMPLE OF DEFINITION AND REDEFINITION LANGUAGE IN SIBAS

We give here, as example, the definition of the realm LOGFLASH used for automatized LOGBOOK purposes (Table A.II.1). It consists of items such as FLASHNB or SHIFTNB which

Table A.II.1
Example of DRL in SIBAS

NEW SERIAL-REALM	LOGFLASH OS-FILE REALM SIZE 200 RECORD LENGTH 185 MAIN SYSFILE	DBFILE
NEW ITEM	LOGFLASH	FLASHNB TYPE INTEGER START 0 LENGTH 1 WORD
NEW ITEM	LOGFLASH	SHIFTNB TYPE INTEGER START 1 LENGTH 1 WORD
NEW ITEM	LOGFLASH	UA1RCNB TYPE INTEGER START 2 LENGTH 1 WORD
NEW ITEM	LOGFLASH	NAMFLASH TYPE CHARACTER START 3 LENGTH 4 WORDS
NEW ITEM	LOGFLASH	SPSRUNNB TYPE INTEGER START 7 LENGTH 1 WORD
NEW ITEM	LOGFLASH	DAYFLASH TYPE CHARACTER START 8 LENGTH 4 WORDS
NEW ITEM	LOGFLASH	TIMFLASH TYPE CHARACTER START 12 LENGTH 4 WORDS
NEW ITEM	LOGFLASH	FLASH TYPE INTEGER START 16 LENGTH 80 WORDS
NEW ITEM	LOGFLASH	ACTION TYPE INTEGER START 96 LENGTH 80 WORDS

DEFINITION OF THE KEY OF THE RECORD IN THE REALM

NEW INDEX	LOGFLASH	FLASHNB UPDATE IS AUTOMATIC DUPLICATES ARE NOT ALLOWED SYSTEM-REALM SYSFILE
NEW INDEX	LOGFLASH	UA1RCNB UPDATE IS AUTOMATIC DUPLICATES ARE NOT ALLOWED SYSTEM-REALM SYSFILE
NEW INDEX	LOGFLASH	SHIFTNUM UPDATE IS AUTOMATIC DUPLICATES ARE NOT ALLOWED SYSTEM-REALM SYSFILE

refer to the numbering of the flashes or to the numbering of the shifts, and which are of the integer type (1 word); or of items used to insert comments in the DB. For instance, the flash itself, which is called FLASH, can contain, according to our definition, up to 80 words as well as the description of the action taken, which is called ACTION. Different keys have been defined such that this realm can be accessed in different ways. None of these keys can have a duplicate value and they are automatically updated.

The maximum number of pages (each page in SIBAS corresponds to a half SINTRAN page) that this realm is allowed to have according to the definition is 200 pages; this is its realm size. Each record in this realm may have up to 185 words (which is the record length).

Fig. 1 UA1 detector

Fig. 2 Demographic evolution of experiments

Fig. 3 UA1 data acquisition computer system

Fig. 4 Linking of CAVIARS to the main computer

SIBAS II MODULES

Fig. 5

Detailed view of the crate 1

Fig. 6 Monitoring system of the HVs of the PMs

PAGE 1 :

HELP	SWITCH ON	SET	READ
AUTOMATIC SETTING-UP FROM D-B	SWITCH	ZERO	PRINT
COMPARE DATA-BASE WITH SET		RESTORE	DISPLAY
UPDATE DATA-BASE		BACK	RESET

PAGE 2 :

HELP	ALL	ALL C's	ALL I's
ALL GONDOLAS	ALL BOUCHONS	ALL FORWARD	ALL V-FORWARD
C's	I's	GONDOLAS	BOUCHONS
FORWARD	V-FORWARD	BACK	RESET

Fig. 7 Touch panel for the control of the HVs of the PMs

**HIGH-VOLTAGE
MONITORING SYSTEM
(LINKED TO ND 100
THROUGH A 16k BUFFER)**

CAMAC CRATE

CAVIAR

CAMAC CRATE

**DISK
OF THE ND**

THE DATABASE gets from the ND:

- the run conditions
- the file of data
- the results of the fit

TERMINAL

CONTROL ROOM

UNDERGROUND

CAMAC CRATE containing the CAMAC interface which links the Exorciser to the ND computer

3. Data and all information about the run are sent from the Exorciser to the ND

UAI DETECTOR

EXORCISER

It contains different microprocessed cards (A/D, display matrix card, etc.) and so:

It initiates the run

It performs the addressing
the source movement
the ADC read-out
the displays
the filling of the buffer with data

EXORCISER

MULTIPLEXING BOXES

Fig. 8 Schema of the ^{60}Co calibration system

Fig. 9 Schema of the ^{60}Co on-line analysis system

UA1 FIRST RUN NUMBER : 1267		SPS RUN NUMBER : 38		DAY : 11/12/81 ; HOUR : 23/46/11	
TRIGGER CONDITIONS : ET GT 30 GEV					
PEOPLE ON SHIFT : ALAN PIPK T. WILSON A. HONMA G. GRAYER					
<u>BEAM CONDITIONS :</u>					
LUMINOSITY		NO. OF P BUNCHES		NO. OF ANTIP. BUNCHES	
1.7 E27		1		1	
<u>GENERAL STATUS OF THE APPARATUS</u>				<u>COMMENT</u>	
CENTRAL DETECTOR : OK				BS NOW ON	
HAD CALORIMETER : OK					
EM CALORIMETER : OK				GOND 33 1 PM DOWN	
FORWARD : OK				CHAMBERS OFF	
VERY FORWARD : OK					
MUON CHAMBERS : OK				BOTTOM TOO NOISY	
<u>CALIBRATION STATUS</u>					
CD CALIBRATION : DONE		FORWARD CALIBRATION : DONE			
HAD CALIBRATION : DONE		VERY FORWARD CALIBRATION : DONE			
EM CALIBRATION : DONE					
<u>DAS STATUS :</u>					
		FIRST DATA TAPE NUMBER : ZA 0 232			
		FIRST EVENT NUMBER : 1			
<u>COMMENT</u>					
LUMINOSITY IS 1.7 E27					

Fig. 10 LOGSTART page of the automated logbook

<p style="text-align: center;">NO BEAM UNTIL TODAY 4 P.M.</p>	<p>FLASH NUMBER : 132 SPS RUN NUMBER : 146</p> <p>AUTHOR OF THE FLASH : ANATOLE DAY: 13/12/81</p> <p style="text-align: right;">HOUR: 1/13/50</p> <p><u>COMMENT :</u></p> <p style="text-align: center;">LASER RUN</p> <p><u>ACTION TAKEN :</u></p> <p style="text-align: center;">WRITE ON TAPE ZC0103</p>
---	---

↑

screen for the running message

↑

screen for the flash

Fig. 11 LOGFLASH page of the automated logbook

UAT LAST RUN NUMBER : 1403		SPS RUN NUMBER : 192		DAY : 8/12/81 ; HOUR : 13/08/23	
AUTHOR OF THE SUMMARY : CLINE					
RUN START AT : 8/00/00 ; RUN STOP AT : 13/00/00					

DAS PERFORMANCES

TOTAL NUMBER OF EVENTS :

TOTAL NUMBER OF SPECIAL TRIGGERS :

TOTAL NUMBER OF TAPES WRITTEN :

TOTAL NUMBER OF SPECIAL TAPES WRITTEN :

* * * *

BEAM PERFORMANCES

AVERAGE LUMINOSITY	ENERGY IN GEV/C * 10
TOTAL NUMBER OF ANTIPROTON BUNCHES	TOTAL NUMBER OF P BUNCHES
TOTAL ANTIPROTON CURRENT	TOTAL PROTON CURRENT

* * * *

APPARTUS PERFORMANCES

CD	HAD CALO	EM CALO	MU-CHAMBERS	LUM. CHAMBERS
----	----------	---------	-------------	---------------

COMMENT :

SHIFT .OK, BEAM LOST AT 12^h15'

Fig. 12 LOGEND page of the automated logbook

Fig. 13 Schema of an autonomous DB system

Fig. AI.1 Chain followed by the information provided by a scintillator