OCTOBER/DECEMBER 1983
VOL. 6, NO. 4

JOURNAL

OF THE HP 3000 INTERNATIONAL USERS GROUP, INCORPORATED

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Editor's Note

This issue of the HP International Users Group Journal focuses on medical applications using HP 3000 equipment. The issue was coordinated by Dr. Ragnar Nordburg of the Department of Clinical Chemistry, University of Gothenburg, Gothenburg, Sweden. The Publications Committee is indebted to Dr. Nordburg for his assistance with this issue. We also appreciate the willingness of the authors to contribute information about their work.

The next issue of your Users Group Journal will be a general issue representing a wide range of HP International Users Group activities. Subsequent issues will have themes such as business applications and research applications involving the HP 3000.

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Publisher
William M. Crow

Associate Publisher:
Betty Martin

Typesetting
LARC Computing Inc.
Los Altos, California

HP 3000 International Users Group
2570 El Camino Real West, Suite 400
Mountain View, California 94040 USA
415/941-9960

JOURNAL
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A Complete Laboratory Computer System

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ORGANIZATION OF CLINICAL CHEMISTRY IN GOTHENBURG

Gothenburg is a city with a population of about 500,000 inhabitants, located on the west coast of Sweden.

The main hospital in Gothenburg is Sahlgren's Hospital. It has been at the present location since the turn of the century and some of the older buildings are still in use. The main block is 20 years old. At present there are about 1,900 beds. The hospital is owned and run by the city, as are all other hospitals in the city. Sahlgren's Hospital is also the main teaching and research hospital for the Medical Faculty of the University. The East Hospital has 906 beds and was built during the last 10 years. It is a city hospital with medicine, surgery and orthopedic surgery, and it has university departments in pediatrics and infectious disease. The Hogsbo Hospital and the Vasa Hospital are geriatric hospitals (about 2,300 beds together). The latter has a university department in geriatric medicine. The Renstromska Hospital (141 beds) is a hospital for pulmonary diseases. Furthermore, there are a few small hospitals with out-patient clinics and approximately 50 beds for surgery.

Clinical chemistry in Sweden includes also the haematology laboratories. Our organization provides service for the hospitals in the city, for general practitioners and for health care centers for industry employees. It also provides service for the western region of the country for more complicated analyses. At present there are about 1,200 "customers" ("customers" in this article is to mean requesting sources). Our laboratory analyzes 510 parameters. To accomplish this in different biological samples, 560 methods are in use. In 1982 about 4.2×10^6 analyses were performed.

Department of Clinical Chemistry

The main laboratory is that at the Sahlgren's Hospital. It has about 5,000 m^2 of floor space and is located in different, mainly quite old, parts of the hospital. A new section is being planned for 1985. The East Hospital has a new laboratory, opened in 1978. Some small laboratories are located in the other hospitals.

The professor of Clinical chemistry at the University is head of the clinical chemistry service in the city. At present one associated professor and five assistant professors act as section heads at the laboratory. The staff also includes nine MDs and about 15 persons with academic degrees as well as about 213 technicians at various levels. The organization also teaches medical students at various levels, medical technologists, and gives Ph.D. courses, etc.

COMPUTER DEVELOPMENT

In 1970 we realized the need for computer technology within the laboratory. Computer companies like IBM, DEC and HP were contacted. We decided to install an HP 2114 computer with 4K of core memory. During the period 1970-1975 we developed two systems at Sahlgren's Hospital, one for chemistry and one for haematology. They were based on two HP 2100 CPU's (32K and 16K) 24 and 5 Mbytes discs, tapes, printers and card readers. All development was done in the laboratory and a small group of programmers was established. About 1975 it had become obvious that further development required (a) a time-sharing system, and (b) an online data acquisition system. An HP 3000 CX was then bought and we entered a period of frustration. In 1976 this system was exchanged for an HP 3000 Series 2 and updated to Series 3 in 1980. The opening of the new laboratory at the East Hospital

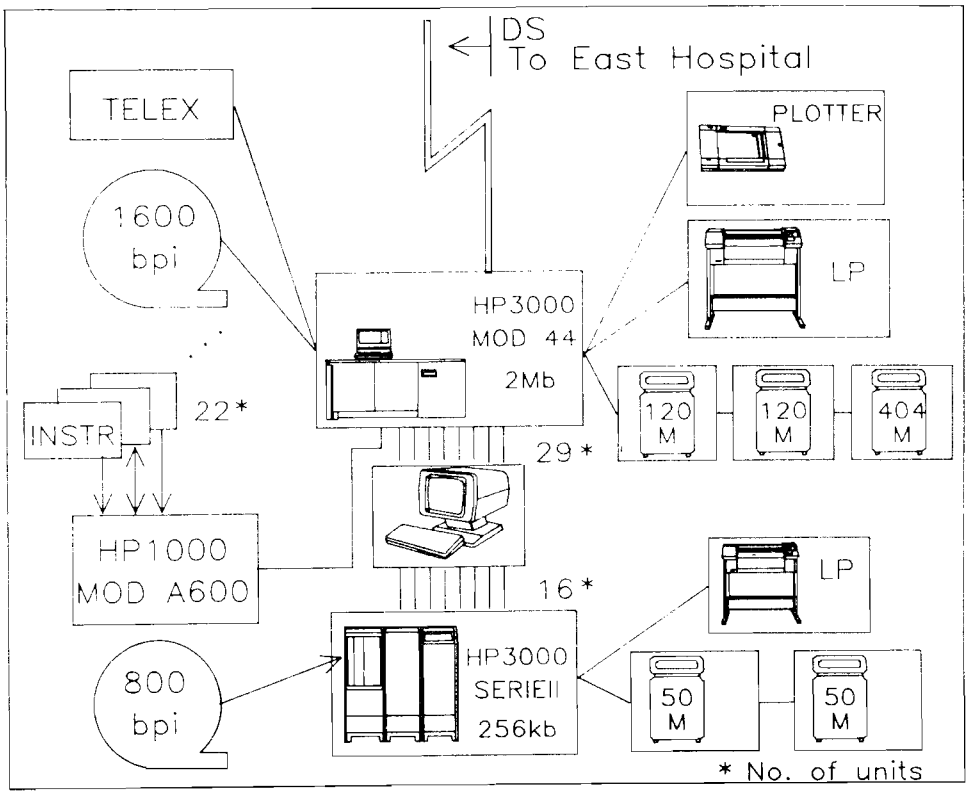

Figure 1

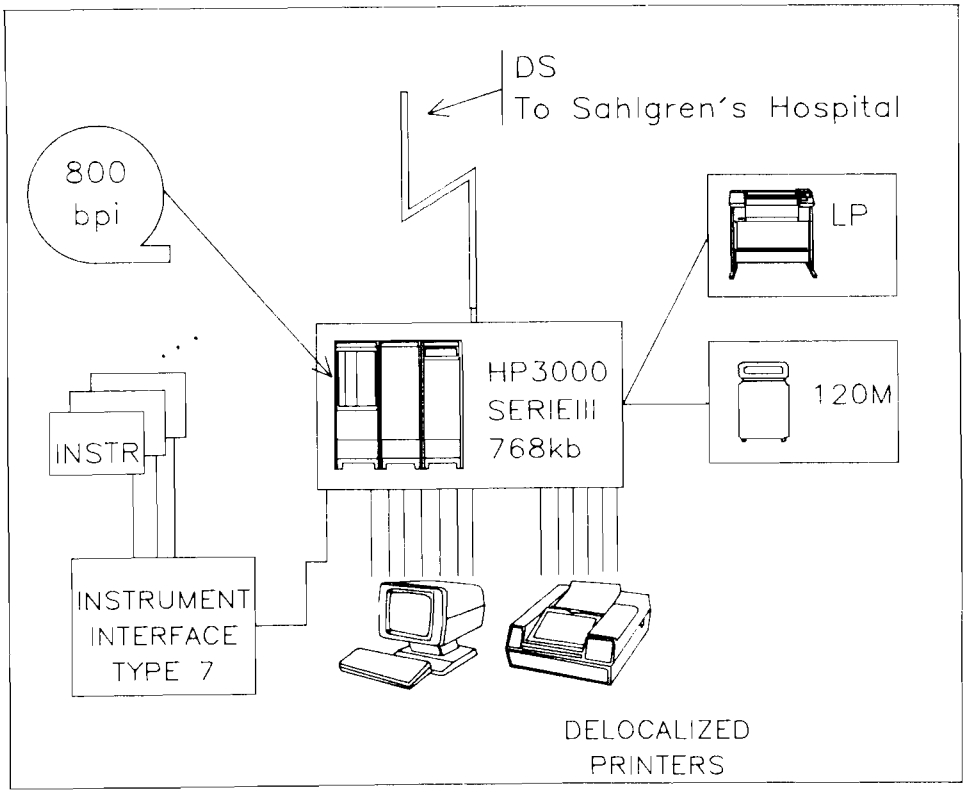

Figure 2

introduced a unique possibility to design a laboratory computer system, based on the experience from Sahlgren's Hospital. A new philosophy for data acquisition was introduced which will be described below. When the East Hospital was opened in 1978 we bought a second HP 3000 Series 2 for this laboratory. Both installations have been updated during 1983 as shown in Figures 1 and 2.

This computer system has been under continuous development since the start in 1970. It has led to a dialogue based system which, via the ATC, is connected with a data collection system. The data collection system consists of micro computer instrument interfaces and a front end computer. A data base constitutes the central part of the whole system. The system runs under a combined time sharing and real time operating system.

An analysis of the different tasks running on the laboratory computer shows that most of them are of administrative types. The idea that one needs a computer with a more technically oriented operative system for laboratory applications is nowadays recognized as a misjudgement. There are, after the data collection and evaluation which is of technical nature, numerous steps of administrative type in which the results are treated both before and after they are reported to the requesting wards. The existence of a computer in the laboratory does also open possibilities for the laboratory management to get support in plain administrative routines like inventory, supply, budget and personnel planning.

The application software is written (mostly in FORTRAN) in a modular structure making it possible to transfer the system without difficulties to other laboratories with different laboratory routines. Six laboratories, of various sizes, located in other parts of Sweden have installed the system, namely: Danderyd Hospital in Stockholm, South Hospital in Stockholm, the Regional Hospital in Orebro, East Hospital in Gothenburg, the Molndal Hospital in Molndal, the Hospital of Uddevalla in Uddevalla, and the Karolinska Hospital in Stockholm. The system has proved to be suitable for laboratories in hospitals with 300 beds to 2500 beds plus external service. The configuration at the Molndal Hospital consists of an HP 3000 Mod 39 (512 kb) and one 64 MB Winchester disc. The configurations at Sahlgren's and the East hospitals are shown in Figures 1 and 2. The intention with the application software system has been to make it easy for the users to maintain and modify. It is therefore based on standard HP 3000 system software. The software is also transferable between different types of HP 3000 models, making it possible to select a computer model that fits the size of the laboratory.

LABORATORY DATABASE

The database was built up by HP's IMAGE, which is a set of programs and procedures that you can use in order to define, create, access and maintain a database. IMAGE is a combined hierarchical network type of database with master datasets containing search items and corresponding pointers to detail datasets that contain information of similar type but from different events.

By this structure you can look at all the results of a specific patient or of a specific analysis. The advantage of using a database for these purposes is that no unnecessary reads are made, resulting in more effective systems. However, work is now going on to design the architecture of the third generation of laboratory database. The new design splits the original database into a number of subdatabases. The information in this new database system is simultaneously increased. The new database architecture will be described in a later publication after having been tested in routine operation.

For further details, see HP's reference manual *IMAGE Data Base Management System.*

The laboratory database contains the following main data sets:

- Analysis
- Mnemonic names
- Customers
- Patients
- Reference areas
- Working set
- Long-term storage set
- Preordered sampling
- Coded comments
- Free comments
- Results of control samples
- Rules for print out
- Number of analysis per customer

Besides these sets there exist further sets the function of which is to achieve a rapid retrieval of different kinds of stored information.

Analysis contains information such as the following:

- Numeric code
- Name
- Unit
- Reference values
- Report format (number of significant digits, truncations, etc.)
- Cost
- Identity of control samples
- Calculation algorithm
- Statistic information for quality control

Mnemonic names is a conversion table between alphanumerical codes and numerical codes for the analysis.

Reference values is a set for reference values related to sex, age, drugs, special status or different combinations of these parameters.

Customers contains the following information:

- Name of customer in an abbreviated form
- Name and address
- Customer account number
- Report distribution method

Patients contains the following information:

- Patient identification number
- Name
- Ward
- Patient category (diseases, drugs, etc.)

Working set is a set where all orders and results are stored and connected to each other. This set contains the following information:

- Patient identity
- Code of analysis
- Result, dilution factor, instrument code
- Type of sample (emergency, routine, etc.)
- Status information
- Address for reports

Long-term storage set is similar to the working set. This set contains laboratory records per patient that have been reported to the customer. The time that a specific record is stored in this set depends on type of patient and/or type of analysis. After this predefined period the record is transferred to magnetic tape.

Preordered sampling contains the following information:

- Patient identity
- Time and date of sampling
- Ordered analysis
- Status information

Coded comments contains predefined comments to be added to a test result.

Free comments contains comments that have been manually entered and stored. These comments are reported together with the analysis data.

Result of control samples contains the following information:

- Identity of control sample
- Code of analysis
- Date and time
- Result
- Status information

Long-term statistical reports for quality control are obtained from this set.

Rules for printout defines how to present different results. This data set provides a method for formatting according to result intervals.

Number of analysis per customer is used to produce production reports. This set contains the following information:

- Customer
- Analysis
- Cost from the beginning of a period
- Cost from the beginning of the year

Beside the laboratory database, the system has ordinary sequential files for storage of information from analysis instruments connected "on-line" to the computer.

These files contain the following information:

- Laboratory identification number
- Sequence number
- Code of analysis
- Status information
- Result

When the results in these files have been verified they are automatically transferred to *Working set* or *Results of control samples.*

CRT ROUTINES

The interactive routines at the CRT terminals are reached through a menu with branched entries. The operator is guided in each entry by a display form. The forms in which the operator is supposed to key information are inversely displayed and the cursor is automatically located in the right position. The field between the registration fields is protected; any attempt to try to write anything outside these fields will fail.

The screen handler used up to now has been developed at the university, since no suitable commercial product was available in 1976, but the CRT routines are presently being rewritten for HP's screen handler, VPLUS/3000.

In order to avoid unnecessary registrations the computer itself adds as much information as possible. Thus, when the patient identification number has been registered by the operator, the computer checks if the patient was registered before; if this is the case, the computer adds the name of the patient, the ward where the patient was treated last time when the patient was active, and the name of the doctor that treated the patient. The computer then asks the operator if this information is still valid (which has been found to be the case in more than 90% of the cases). A secondary effect of this registration routine is that since the patient is only registered once with all parameters, it reduces the chances of finding the same patient registered with a variable set of identification parameters.

Retrospective searches for old results per patients, editing of patient information, verification of collected measurement data, etc., are examples of other interactive CRT routines.

REPORTING ROUTINES

The reports are obtained either via routines initiated by the software system or interactively via CRT or printing terminals.

Non-interactive Reporting

Daily Reports

When an analysis, consisting of one or several result parameters, is completed (including eventual transformation calculations), it is filed in sequential order in a report generating system. The file for results to be reported is subdivided depending on:

1. Type of analysis
2. Category of customer
3. Category of patient
4. Special information registered at the reception of the test specimen or any combination of the points above

Results pertaining to an emergency sample or other test results which may lead to immediate treatment of the patient are reported directly as they are ready.

If the customer has his own local printer connected to the laboratory computer, the result will immediately be printed on that printer. Otherwise, the emergency results are reported at a special printer beside one of the secretaries in our office who then calls the customer and reports the results. These results, marked as acute, will later on also be distributed among the rest of the results on the standard reports.

The result reports are sorted and printed on command or at certain fixed hours during the day. Most reports are printed on a lineprinter, while some are printed on printers located in different places within the laboratory or in the wards. The selection is governed by type of analysis/customer.

The reports are printed on forms with preprinted leading text or on labels, with or without preprinted headlines, which can be transferred to the patient record file in the ward. Results on forms with preprinted leading text are very easy to read. This, however, limits the flexibility of the system.

Cumulative Reports

When an analysis has been reported in one of the above mentioned ways its results are transferred to a cumulative register in the database. (The results are stored on discs during various time intervals depending on which analysis or patient category it belongs to.) A cumulative report consists of all results from all analyzed samples for one patient arranged in chronological order. The cumulative reports are then generated from this register.

The cumulative reports are normally generated only once or twice a day. A cumulative report for a patient is generated depending on (a) whether any new sample has been analyzed since the last cumulative report was generated, or (b) whether a cumulative report has been specially ordered for one patient.

A cumulative report is also formed when the results are reported on labels which are transferred to a patient file.

The result report must be easy to overview, and simultaneously be in the same size as one side in the patient file. One way to obtain this is to print the results on forms where the name of the analyzed parameter, the date, the unit of result, etc., are preprinted. A secondary effect of doing this is that one always finds the result for a certain analyzed parameter in the same predetermined area of the report, but at the same time large parts of the form are left without information. Contrarily, one obtains maximal information density if the reports are printed on plain white paper. A compromise between these two methods is a form where only the names of the most frequent analyzed parameters are preprinted and the rest of the form is left blank for printout of both parameter names and results. Reference values are mostly age and sex dependent; these values have to be printed on the report each time a report is generated in order to give maximum service to the customer.

In order to avoid the same results being filed several times, the cumulative lists are distributed in a way that makes it easy to exchange the former list for the new. The computer system keeps track of when one cumulative page is filled and shall therefore not be removed from the patient file.

Graphical Reports

Certain analyses, with time dependent reference values, are best reported in graphical form. This type of cumulative list in analog form gives the best overview of trends in the results but the relatively slow speed with which they can be produced limits the use of this type of report. The introduction of laser printers might be the future solution to this limitation of graphical reports.

One graph may also cover a combination of analyses.

Interactive Reporting

The software initiated result reporting complements the interactive result reporting routines at the CRT/printing terminals (sometimes supported by a

plotter). The purpose is that these routines should be used for data retrieval from the register of test under process as well as from the long-term register for any specified patient. When a search is initiated in the register of tests under process, information about status of the analysis is displayed. For especially detailed information, graphical CRT terminals are being used, allowing a flexible way to present different result comparisons.

All of the software initiated as well as the interactive report routines allow addition of the following:

1. Reference intervals (as a function of sex, age, drug intake, pregnancy stage, etc.)
2. Asterisk (or any other equivalent mark) for indication of pathological results
3. Comments in free text format
4. Exchange of results with text (for example, coagulated, <10, color: red)

PRODUCTION STATISTICS

This function covers accumulation of the number of analyses carried out per customer, updating of register of customers regarding their account, etc., and processing of quantitative production statistics from which the debiting is produced. Production statistics also include routines for report generation.

The quantitative production control accumulates the number and cost for produced analyses per customer, type of analysis and stores it in the "production register" of the database.

Updating of the production files is normally done during those hours when the computer is least busy. Different registers are simultaneously cleared of old information which is transferred to a magnetic tape. The register of customers is also updated at this moment. New customers are included and obsolete customers are deleted.

The different routines in this laboratory's administrative part of the computer system can be summarized in the following routines:

1. Addition of new customer account numbers, category of customer and distribution method of the result reports
2. Changes of account numbers, category of customer and/or distribution method of the reports
3. Changes of customer names
4. Deletion of customers in the register
5. Generation of lists of customers
6. Generation of production statistics

These routines are interactive routines which are initiated periodically. Generation of production statistics and invoicing is normally only done once a month. The output consists mainly of two parts. In the first part costs are arranged according to account numbers. It shows number of analyses delivered during the last month as well as accumulated for the year, and the cost for this.

The other part is arranged according to analyses and gives costs both for the last month and accumulated for the year.

Sampling (i.e., drawing of a blood sample) is treated in the same way as an ordered analysis in the administrative routines.

Routines for automatic invoicing have been made and are being used in one of the installations.

QUALITY CONTROL

Special routines for calculation, statistics and hypothesis tests of the results obtained from the analyses of quality control specimens are continuously running as background jobs. Special programs are coupled to these routines for display and printouts of the various quality control/samples per analysis.

The results obtained from the analysis of these quality control samples are stored in one of the registers of the database. From this register it is then possible to make special studies of certain parameters over longer time intervals in respect of quality control samples identification, analysis, index, date (-interval), time (-interval), and analysis result.

The identification of a quality control sample is built and treated like a patient identification number. The combination of the quality control identification number and an analysis code makes it possible to retrieve data from the quality control result register with a very short response time.

The index defines what is stored in the register for quality control results. The following gives some examples of indexes:

Index = 0; result from one determination of the quality control samples

Index = 1; a statistical summary of the results from a quality control sample during a specified time interval

Index = 2; truncated mean value for patients/analysis

The time interval for storage of a single result of a quality control measurement varies with respect to what is relevant for that specific analysis. For a low frequency analysis there is normally no summary. For more frequent analyses the single results are stored

for one week, then converted and stored as a statistical summary containing number of results, sum of results, square sum of results, etc.

Date and time tells when a quality control result was obtained. When the index defines the record as a summary, date and time gives you the time interval for which the summary contains information. Result contains either the result from a single test or a statistical summary.

The register of quality controls is thus used for storage and for treatment of the results to obtain summaries of quality control results. Standardized statistical calculations, such as U-test, chi-test and t-test, are included in the program but the user may apply any statistical routine.

Time dependent trends can be presented graphically as, for example, in "cusum"-plots.

The patient results are stored in the same way as the control samples and are daily reduced to mean value for the group.

The results from the analyses of the two nearest quality control samples plus statistical parameters are always displayed together with the result obtained from a patient sample, enabling you to check the results before release. Work is in progress on an alarm generator which will check the trends of the results from the control samples. It will alarm the technicians if the analysis is out of control.

REGISTER SUPPORT

The database contains a number of registers which keep detailed information about, for instance, reference values, customers, etc.

In the register of analysis, for example, information is stored regarding cost of the analysis, format for printout, units and type of reference value, etc.

All these registers can be updated and changed via a user-computer dialog program called EDITREG. This program contains the following main branches:

- Addition or changes of analyses
- Changes of name, cost, format, etc.
- Addition of analysis combination
- Changes in the analysis combination
- Addition and changes of customer
- Changes of customer name, address, customer category, etc.
- Changes in the rules for the printout on different types of forms
- Alarm limits for the deviation from the expected quality control value
- Addition or changes of fix comments
- Deletion of fix comments
- Addition or changes of reference values
- Addition and changes of quality control samples and statistical parameters for the quality control samples, e.g., expected mean value and expected standard variations

Fix comments are short coded comments which may either replace the numerical information or may be printed as comments to the numerical results.

READ DATA

A special program has been developed to communicate with the front-end computer or with the microprocessors that are connected to the analytical instruments.

The purpose of this program is to control and distribute the results to the database or to special dedicated sequential files for later verification.

This program also distributes information about an ordered analysis to the front-end computer.

Plans exist, as mentioned above, to add procedures to this program for an automatic quality control.

OPERATING PROCEDURE

At Sahlgren's Hospital we are routinely receiving the samples at the laboratory by special pickup service from the wards and from external customers. We also do the sampling on request from the wards.

When sampling is required, the patient identification, ward and tests are registered in the computer when the request enters the laboratory. Personnel from the laboratory then go to the clinic in question and take the samples. The samples are brought back to the laboratory and merged with the samples that have been sent to the laboratory. All samples are sorted and given a laboratory identification number and distributed to the different analysis stations within the laboratory. The samples are simultaneously registered in the computer with laboratory identification number, patient identification and ward (if not registered earlier) as well as which tests are ordered for the specific samples.

The samples are analyzed and the results are collected by the computer system either through online acquisition or, for low frequent analyses, through manual registration. The computer recognizes the quality control samples and calculates the statistical parameters which are used for the judgement of the correctness of the results from the patient samples.

Two different criteria are used for the release of a result report. The first is that the obtained results are released and distributed to the wards automatically when the results from the controls fulfill predefined critera. The second is that a laboratory technician or a laboratory doctor, depending on the type of analysis, has to look at the result and the two nearest results from quality control samples. From this information they verify whether the result from the analysis shall be distributed to the ward or if a reanalysis is necessary before the result is reported.

INSTRUMENT INTERFACING

System Configuration

The data acquisition system consists of a front end computer HP 1000, mod. A 600 to which it is possible to connect different instrument interfaces (II). All interfaces are constructed, using a modular board system with a Zilog Z80 microprocessor.

The A 600 is connected to the ATC, ADCC or ATP of the main computer.

The connections between II's and the A 600 are all identical and the communication protocol is designed in such a way that the II's may also be connected directly to the ATC, ADCC or ATP without changes in configuration and software. This reduces the stop in data collection, in case of an A 600 failure, to the time it takes to switch the connectors from the A 600 to the main computer.

The protocol also takes care of communication in both directions, data check and continuous line check.

Interface signals according to RS232C.

Front End Computer A 600

The main task for the A 600 is to maintain communication with the II's and with HP 3000 and to buffer and switch data in both directions. The various tasks of the A 600 are described below.

Communication between II and A 600. A 600 maintains communication with the II's and stores analysis results and execute commands, such as retrieval of request information.

Buffering of data from II's. Incoming data from the II's are mainly analysis results. These are buffered in the A 600 to make it possible to transfer them to the HP 3000 via a low priority port. This means that these transfers do not disturb other HP 3000 activities. A consequence of this is that a very fast response time is obtained for the interactive routines at the CRT terminals.

A 600 is equipped with a mass storage device in order to maintain data acquisition even when the main computer is down.

Processing of data from the II's. A 600 software makes it possible to perform quality checks of the incoming analysis results continuously and immediately.

These calculations are performed immediately in the A 600 and the results are transferred to the appropriate working site.

Values to support the calculations are delivered from the main computer.

Printing of results. All incoming analysis results may be printed on the log printer. The purpose of this feature is mostly for system test and control but can also be used to print results from working sites without local printer facilities.

This is controlled either from the logprinter keyboard or the HP 3000.

Request handling. Request information is transmitted to A 600 from HP 3000 and enables, at demand, the A 600 to send this information to the specific instruments or work stations.

Communication between the A 600 and the main computer. Identical communication procedures as between the II and the A 600.

Information A 600 =>HP 3000

Results, status

Information HP 3000 =>A 600

Requests, commands, time calculation support.

II's

The instrument interfaces are constructed to achieve the best possible flexibility in order to adapt them to the various instruments and working sites. Thus, both software and hardware are constructed in a modular way to simplify the adaptation and future changes due to system developments.

The various tasks for the II's are described below.

Instrument communication. The instruments are interfaced using one hardware part (PCB and cable)

and one software module to be able to transmit information to and from the instrument.

Protocol conversion. Almost every different instrument has its own data protocol and format of the data string. The interface converts the significant data to a "standard" protocol and format.

Buffering of results. The analysis instruments cannot in general hold their data output. The II units contain buffer areas in their memory in order to buffer results until the A 600 (or HP 3000) is ready to receive them.

Operator communication. If the routines at a working site require some kind of operator communication, then it is possible to connect several peripherals such as videomonitor, printer and keyboard. The keyboard may also be equipped with either an OCR-reader or a barcode reader. Every peripheral is easily implemented using one interface card and a software module.

Communication II - A 600/HP 3000. As mentioned earlier it is possible to connect the II either via A 600 or directly to the HP 3000 due to the identical communication protocols.

WITHIN HOSPITAL MAINFRAME COMMUNICATION

The HP 3000 family has a number of facilities to communicate to other computers, for example:

DS a system for communication within the HP family

RJE allows an HP 3000 to emulate an IBM 2780 as IBM 3780 work station

IMF allows an HP 3000 to emulate BSC 3270 cluster control units and the 2271 SDCC control unit. It also allows the HP 3000 to be physical unit type one in an IBM SNA network.

These various types of communication facilities give the laboratory system the opportunity to communicate with other systems, such as a patient administrative system and an economic system or other laboratory systems.

If you want some more information about HP 3000 communication facilities, see the HP documentation *Distributed Systems Network, HP 3000 Data Communication Products Specifications Guide.*

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A Clinical Academic Compatible Radiology Information System

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BACKGROUND

In 1979 the Department of Radiology received an excessive number of complaints from referring physicians with regard to late radiographic reports and inability to locate films. A systems analysis pointed out problems in all management areas under the then existing manual operations. From this analysis the manual system was streamlined, and it was decided to convert from manual operations to a department-wide computer assisted management system.

A three-stage departmental computerization plan was designed and has been implemented over the past eighteen months. The stages are:

1) Development of a stand alone system for transcription using computer terminals and slave printers which can be integrated into a fully computerized departmental system.

2) Introduction of basic radiology management modules that include registration, film library, reporting, on-line report signature, sorting and printing, management and billing reports.

3) Use of bar code readers to further automate Stage 2 and the addition of physician generated direct reporting.

Prior to Stage 2 implementation, with the assistance of the Bureau of Radiological Health, a baseline work flow analysis was conducted. The Department will be resurveyed in the near future to compare pre- and post-automation efficiency.

HOSPITAL AND MEDICAL PRACTICE

The Bowman Gray School of Medicine/North Carolina Baptist Hospital Medical Center is a teaching facility of approximately 700 beds with all specialties represented. The Medical Center has a central computer facility performing full Hospital and Medical School financial tasks and research capabilities but no automated patient information system. The Radiology System has been conservatively developed in terms of both cost and computer compatibility to ease interface with an eventual hospital-wide system.

The Radiology Department is staffed by 30 faculty members and 27 residents. All radiological subspecialties are represented. The Department performs approximately 200,000 diagnostic examinations per year. It bills separately from the hospital through an in-house service bureau, the Department of Clinics, which produces all professional billing for the institution.

SYSTEMS SOFTWARE

The Radiology Management System was developed by Smith, Dennis and Gaylord, of Santa Clara, California, for the Bowman Gray School of Medicine/North Carolina Baptist Hospital as a highly-flexible, on-line, interactive system. Their prior radiology experience and computer expertise was coupled with continuing involvement of the Radiology faculty and staff to develop a system which automates the functions of a large hospital radiology department while also provid-

ing the teaching and research tools desired by a medical school. The resulting system permits simultaneous access by many users in a multi-terminal/multi-printer environment. The Hewlett-Packard 3000 Series of computers drives the system. (For hardware listings see Table 1).

Smith, Dennis and Gaylord's Technical Resource Module (TRM/3000) was used in the development of the System. TRM/3000 is a standard methodology for structured software development. TRM's tools provide design, program, documentation, performance, support and use guidelines specifically tailored to the optimal use of HP 3000 computers. These protocols allow for much of the flexibility built into the System including the ability to easily make screen, sorting and other common revisions.

TRM/3000 also allows cost savings by supporting the terminals of four different manufacturers in any mix, permitting selection of equipment that fits both needs and budgets. Due to the standardized interfaces permitted by TRM, additional equipment may be added. The software is in compiled BASIC and is easily transferred to other medical environments.

DESCRIPTION OF SYSTEM

The application software is composed of four major modules each of which serves a different department function.

Admission/Registration Module

At six (6) entry points in the Department of Radiology the patient admission/registration module is utilized. The main features are:

1) Access of existing patient information by:
   a) Name or first four letters acronym
   b) Hospital unit number
   c) Requisition sequence number
2) Basic patient information acquired and kept on-line includes:
   a) Name and verifying demographics
   b) History of prior service including date, exam and referring staff are also listed

The completion of the registration process triggers printing of an adhesive bar code label (requisition sequence number) which is affixed to the requisition form. Simultaneously in the appropriate file room, a message alerts personnel that the patient is in the Department and then gives the location of the master folder. If the patient has not been previously radiographed, information is provided for a new file jacket. In addition, a bar code label is produced which represents the patient's hospital unit number and is affixed to the patient's permanent master film folder.

Patient Status Module

In this module, the System captures information detailing examinations done, film used, and time required for the procedures. In addition, a referring physician can query the System and determine the location of his patient's master folder, the exact location of the patient and whether an examination has begun or has been completed.

Bar code readers are located outside all examination rooms. Using the bar coded requisition, the technologist enters the bar codes representing the patient requisition number, examination room number and technologist number. At the completion of the examination and the patient exit, additional strokes record the examinations performed and film used. The bar code on the patient requisition is then stroked again, closing the file on that particular examination. Film utilization and examination bar codes are located in laminated folders adjacent to the examination rooms.

Film Library Module

After quality control, the new films are matched with the master folder in the file room. From the file room the folder is dispatched to the subspecialty interpretation area. As the films are loaded onto the alternator, a bar code on the viewer is stroked, and, the bar code affixed to the film jacket is then stroked, completing computerized film folder location update. Inquiry from any terminal in the System will then show the exact location of the patient's master folder.

Table 1

Original and Upgraded Hardware

HP 3000, Series 33 (768K memory)	$58,625
Upgraded to Series 44 (1.5 megabyte memory)	63,000
120 MegaByte Disc Storage	21,000
404 MegaByte Disc Storage (later addition)	23,000
1600 BPI Tape Drive	12,585
13 HP 2645 Terminals (alphanumeric keyboards)	45,500
12 Televideo Terminals (alphanumeric keyboards)	11,400
4 HP Printers	14,400
10 Anadex Printers	12,950
1 HP 2608A 400 LPM Printer	6,750
31 FCP 22 Computer Identics Bar Code Readers With Keyboard	24,520
12 FCP 12 Computer Identics Bar Code Readers	9,250
3 Multiplexors	10,750
Original Total	**$220,980**
Cost to Date	**$313,730**

Check-in and check-out of films for physicians is accomplished with a bar code unique to each physician which is laminated to a plastic card. During film check-out, the card and jacket are stroked to provide location and personal responsibility for the checked-out films. A stroke of the jacket upon return logs in the films. An exception report identifies film jacket delinquencies of over 24-hours.

Interpretation/Reporting Module

This module has six subsections: staff reporting/approval, resident approval, bar code generated reports, inquiry function, research case identification and printing/sorting.

With the requisition and film ready for interpretation, the radiologist selects one of two methods of reporting:

1) Bar code generated standard expressions
2) Conventional dictaphone dictation

With the *conventional dictation* method, the radiologist dictates to tape; the tape is transported to the transcription area and typed on-line. Once typed, the report is available on any terminal in the Department as a preliminary unsigned report.

Inquiry function. All preliminary reports are available on-line for review and approval. The radiologist, using a double security code, may access his reports singly or in sequential order, first in-first out basis. Then all patient information and the typed report are displayed. The radiologist types "Y" to indicate "Yes" if the report is correct. The report is then considered signed and becomes available in the System as a signed report and is ready for printing. When the report is printed it reads "Signed by Dr. XXXX".

If there is an error in the report the radiologist strikes "N" for "No", or disapproval. The report is printed for modification and returned directly to the reporting radiologist. After modification, a transcriptionist calls up the report and corrects the error. The report is again presented to the radiologist for on-line approval.

A third option is available to accommodate times when a faculty member is unavailable to sign his/her reports. An authorized faculty member may call up, review and approve these reports by striking "X" on the terminal. The computer is thus directed to approve the report and prints "Report Reviewed and Approved by an Appropriate Faculty Member." The name of the dictating physician is retained in the header information. The Part "B" Medicare intermediary for North Carolina has accepted the above signature methods as documentation of services rendered.

Resident approval module. To accommodate the teaching aspects of the Department a resident approval module is included. After entering a double security code the resident, in like manner, may call up one or all cases. He/She may approve or disapprove, but these decisions *do not* trigger a final report. If the resident approves, an asterisk ("*") on the report communicates to the faculty member that the report has been reviewed and approved by the resident. When the resident disapproves, an "E", for error, is generated on the report screen. In all cases the faculty member makes the decision for final approval or disapproval as described above.

Bar code generated reports. At interpretation stations there are bar code readers attached to each terminal. Each faculty member or group may have their personal or group standard expressions in the System. If the radiologist determines that his/her standard expressions can be used in a case, he/she strokes the bar code on the patient requisition and the patient information is displayed on the terminal. He/She may then generate personally or sectionally defined standard reports by stroking the standard report bar codes. There is also an option for entry of free text through the keyboard. The report is then displayed on the terminal and can be reviewed and approved. This process generates a signed report while bypassing manual transcription. It is immediately queued for printing and is accessible at any terminal in the System as a final report.

Research case identification. The System allows several methods for the identification of research or teaching cases. ACR codes or individual identifiers may be:

1) Dictated using the conventional transcription method
2) Entered through terminal keyboard during bar code generated reporting

Any number of codes may be used on a case and coding may be easily changed or updated by the faculty member.

Printing/Sorting. Twice daily the approved reports are queued for printing. The System includes a flexible sorting program which allows reports to be sorted by the following:

1) Referring M.D.
2) Floor/Ward
3) Patient unit number
4) Transcriptionist's code

The user can instruct the System to perform the sort routine desired, and thus have the sorted copies printed, and ready for distribution. This function reduces the clerical time required for collation and has proven to be a cost-saving process.

MANAGEMENT CONTROL

By-products from the modules of patient registration, patient tracking and report transcription can be captured and summarized on a timely basis to better manage and control our department. The framework for our management reporting can be summarized in three categories:

1) Daily management
   a) Exception reporting (incomplete work-in-progress)
   b) Billing
   c) Daily activity
   d) Overdue film reject report
2) Operation management
   a) Room/machine utilization
   b) Workload/revenue analysis
   c) Exam turnaround
   d) Film reject/film utilization analysis
   e) Shift analysis
3) Personnel management
   a) Technologist productivity
   b) Physician productivity

SUMMARY

We have designed and implemented a computer-assisted management system for radiology departments. We believe that it has the flexibility to be useful to departments of varying sizes. It may be used in toto or separated into component parts to meet the needs of various users. It is relatively small and inexpensive but is specifically designed to be able to interface with larger systems when desired.

JOURNAL
OF THE HP 3000 INTERNATIONAL USERS GROUP, INCORPORATED

A Total Solution for Healthcare Productivity

Don Barth
Martha Dwyer

Hewlett-Packard
Waltham, MA

HISTORY

Until recently, it was sufficient for a hospital to concentrate on patient care and to provide top-notch diagnostic capabilities, leaving the information management needs to the hospital data processing area. Those needs were almost exclusively identified with the financial aspects of the hospital, such as payroll, billing, financial planning and reporting.

Many computer systems in this environment tended to be time-shared systems, and the protocols for dealing with the financial aspects within the hospital were fairly uniform throughout the industry. These systems, whether shared or in-house, were characterized by large computers with single data bases, providing little access to information by those outside the computer department.

This style of healthcare information management would have continued unabated except for one single, disturbing trend: costs of providing services, facilities, and patient care were increasing three times faster than the rate of inflation (19 percent per year for Medicare alone for the period 1980-1982).

When the United States Congress passed TEFRA, the Tax Equity and Fiscal Responsibility Act of 1982, it brought a sudden and dramatic end to this situation. With this Act, Congress ended the unlimited reimbursement of expenses to U.S. hospitals with little accounting for their yearly growth. Instead, the former retrospective scheme of reimbursement (paying all claims expenses based on the hospital's cost of providing services) is being replaced with a prospective reimbursement approach. The new prospective reimbursement system will pay a predetermined rate for each particular service or treatment. These rates are based on diagnosis related groups, DRG's, which characterize the form of treatment received by the patient.

In the United States, approximately 7000 hospitals will be forced to address productivity and cost containment issues in all of the services they provid The most recent data placed labor as the large element of a hospital's total expense, representing 56% of all expenditures. According to some industry studies, as much as 40% of this hospital labor component is spent performing clerical tasks. In order to control growing hospital costs, hospitals will be required to operate more efficiently, requiring increased automation to provide management with the information necessary to monitor the true cost of services provided, and to identify areas of inefficiency.

IMPACT

The impact of all this on the healthcare community is nothing less than a complete re-examination of priorities within the hospital data processing environment. Improving communication between all departments provides the initial step toward increasing productivity and utilizing hospital resources more effectively.

A hospital's communication and information processing needs can be divided into five categories, each characterized by unique requirements and service features. These are: financial information, patient information, departmental information, medical information, and remote communications. A consistent and integrated approach to implementing these systems in hospitals plays a critical role in the day-to-day ta of running a hospital.

What roles would such a system play in this new environment? They would range among the following:

- create an information system to measure resource consumption, enabling management to effectively monitor and utilize key resources, while identifying inefficient use of resources
- schedule ancillary services and report results to minimize the patient's length of stay
- schedule ancillary services to maximize efficient use of hospital resources
- use key training and educational packages to alter the staff "modus operandi"
- tie together diverse functional solutions through networking, shared resources, and the integration of personal computers and office automation throughout hospital departments

Networking might be most important, since users in the hospital would not want to deal with different vendors nor to perceive disjointed solutions. Hewlett-Packard, leveraging both its computer experience with more then 12,500 HP 3000 installations and its many years developing medical products and instrumentation, is uniquely positioned to address these problems.

HEWLETT-PACKARD'S APPROACH

Hewlett-Packard has a major commitment to both the computer business and the medical business in the healthcare industry. In 1983, more than 2 billion of computer sales brought the total number of HP 3000 systems to over 12,000 installations, contributing to increasing profits in businesses around the world. During the same period, HP's Medical Products Group supplied close to 400 million in complex systems to hospitals. With its solid reputation as a leader in computer networking, interactive software, product reliability, support services and customer satisfaction, Hewlett-Packard is uniquely qualified to offer a total solution to hospital productivity.

The Health Care Productivity Operation, part of the Medical Products Group, is oriented toward providing total solutions to the healthcare delivery industry. As part of that charter, it has made productivity in the hospital environment one of its highest priorities.

HP Hospital Accounting is a hospital financial system, operating on the HP 3000, utilizing the latest development tools available in the information processing industry. It is geared to the specific needs of the hospital and includes:

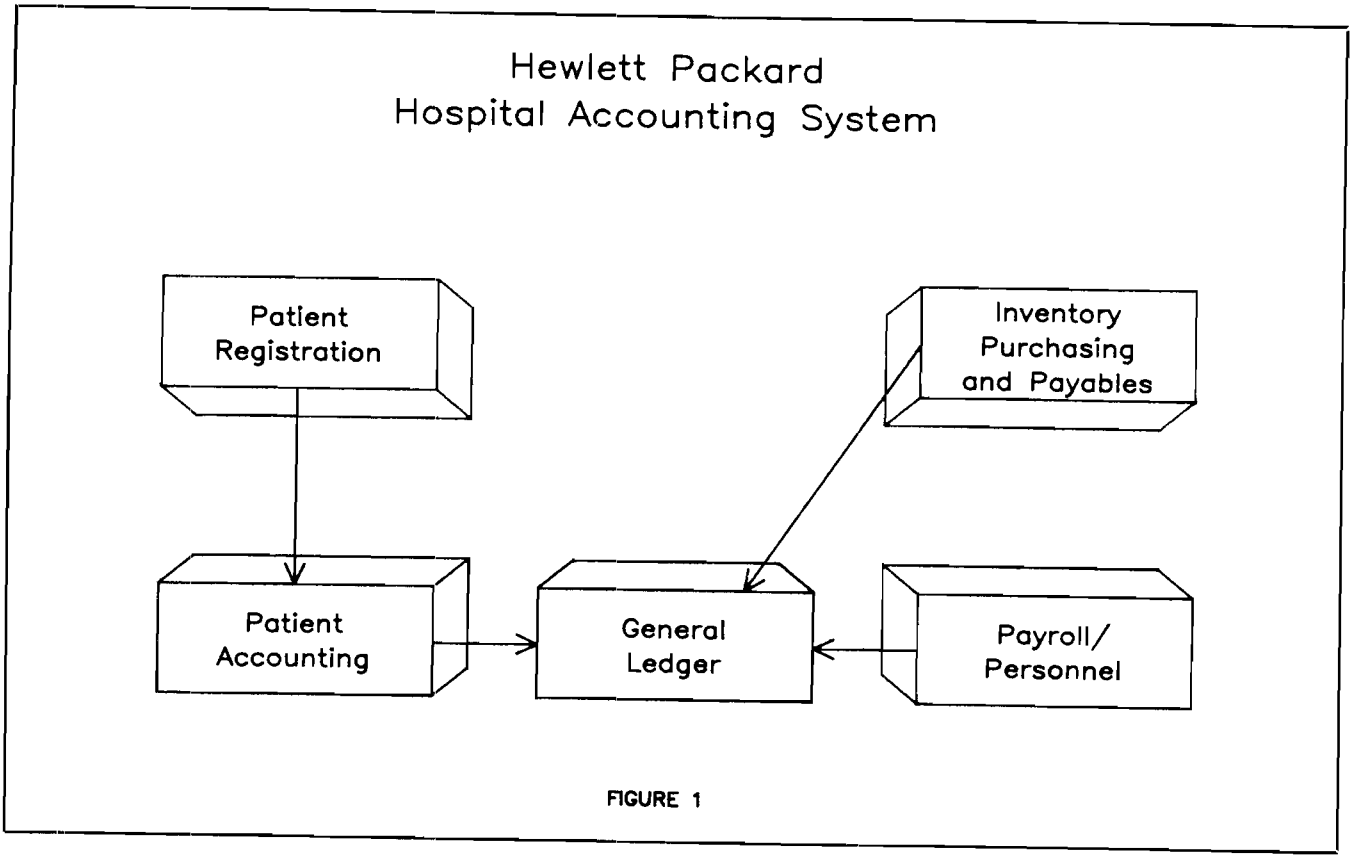

FIGURE 1

General Ledger: the heart of hospital accounting, it records, classifies and summarizes information from all other applications and consolidates it into meaningful reports.

Patient Financial Management: from the time that a patient is registered in the admission or outpatient area, through billing and collection cycles, PFM keeps track of a patient's account. On-line credit information and flexible third party billing can all improve cash flow management.

Payroll/Personnel Management: a complete labor management and control system, it can track detailed data, has flexible coding system and can produce a full complement of labor management reports.

Hospital Materials Management: a powerful management tool for the hospital's purchasing, receiving, inventory and accounts payable areas.

These packages represent an integrated accounting solution that gives the user detailed information to effectively manage the hospital — to make long range plans, or to take immediate action! The next critical step in providing integrated communication and information processing solutions to hospitals is to capture patient demographic and clinical order/charge data and to communicate this information to the concerned departments in a timely fashion. HP's Patient Administration and Communications System is designed in a modular fashion and provides the framework for a total hospital information and interdepartmental communication system.

This communication begins during the registration process when patient demographic, medical, credit and guarantor information are collected and ancillary deparments are notified of the admission. During the patient's visit, their orders are entered into the system from the nursing stations and requisitions are immediately printed in the ancillary departments, reducing the paperwork, lost charges, and telephone calls needed to track the services. Figure 3 shows that orders can be entered from the nursing stations, requisitions are printed in the ancillary, and the ancillary can then update charges, if necessary, to reflect the actual services performed. Notifications of patient movement due to patient transfers and discharg-

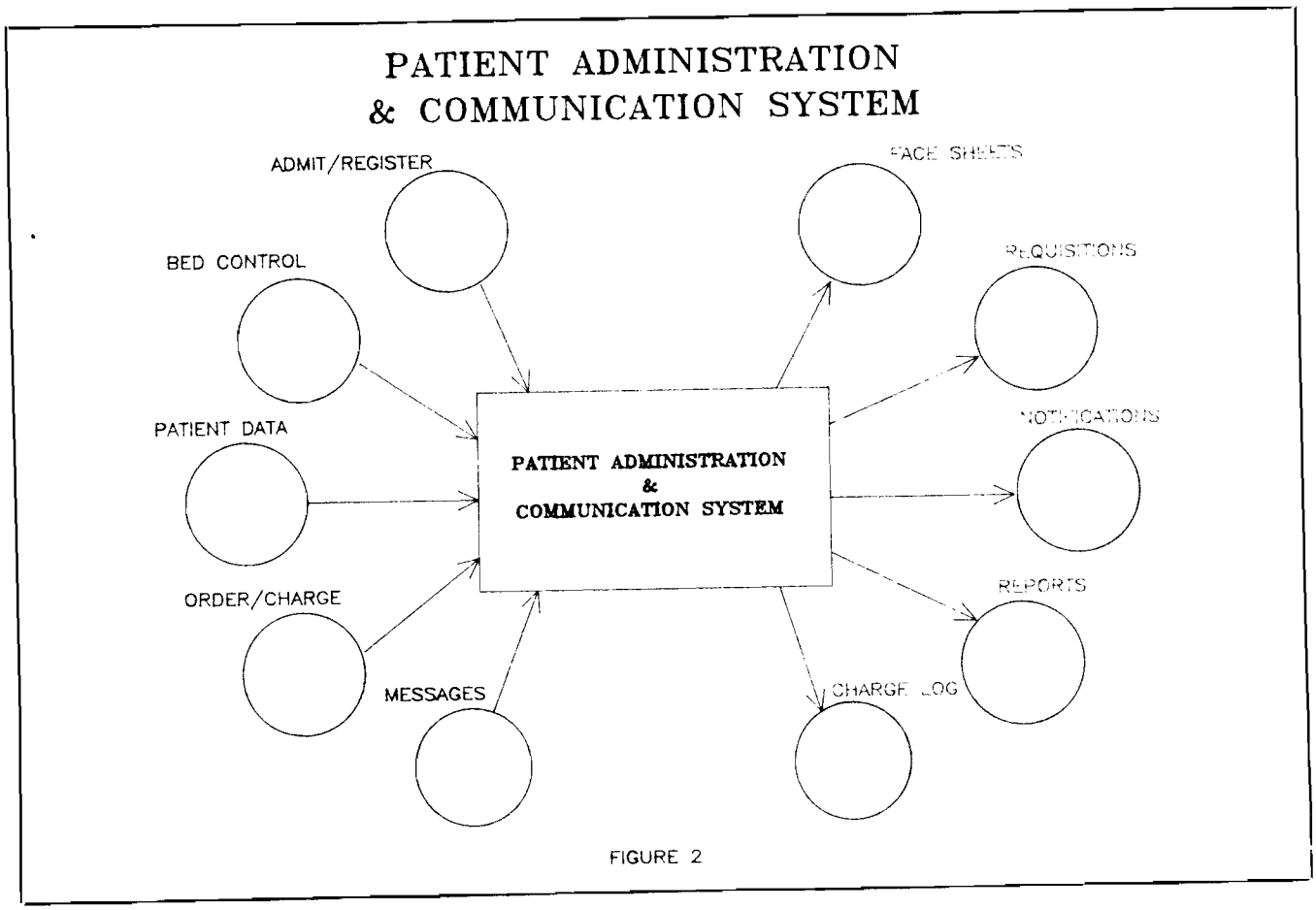

FIGURE 2

es are also sent to interested departments, providing an accurate and timely census throughout the hospital.

The functionality of HP's system is greatly enhanced by a wide set of powerful configuration tools to customize the system for each customer. The base capabilities include:

- a wide set of functionality which can be individually configured
- the ability to integrate this system to the financial system, ancillary systems, and future systems as a coordinated whole
- a powerful modular architecture that provides a maximum growth path for future functional enhancements

Hewlett-Packard's solution to a total hospital management system has only been briefly touched upon here. Training, implementation, and support present another whole array of considerations. Multi-hospital communication and information systems add yet another dimension to the picture. Additional considerations are the impact on and integration with physician offices, group practices, HMO's, satellite clinics and emergency treatment centers.

The challenge to automate the hospital has been made. Individual user needs must be addressed while, at the same time, the overall hospital objectives must be met. HP plans to play a key role in creating the right environment for hospitals and in providing integrated solutions for their needs ... today and tomorrow.

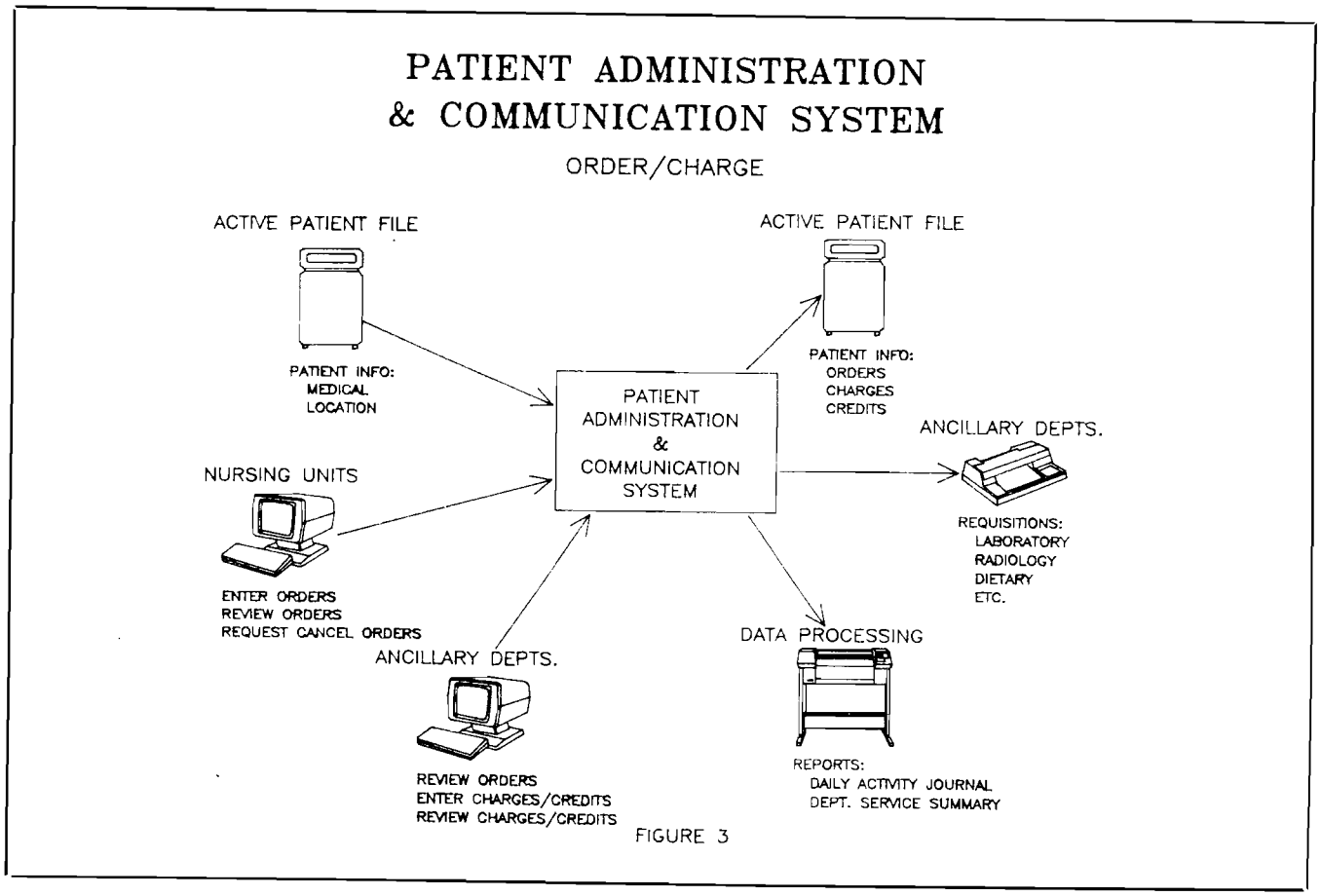

FIGURE 3

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