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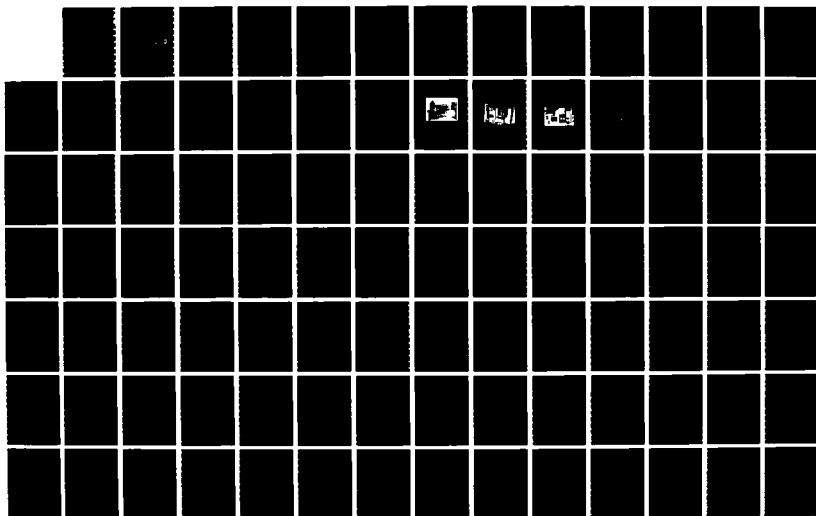
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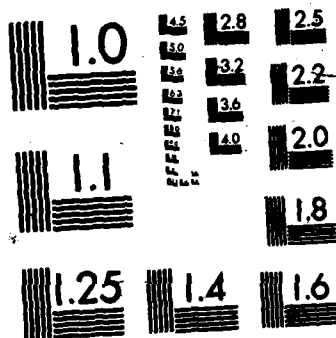
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A STAND-ALONE INFORMATION SYSTEM FOR SMALL
AIR FORCE HOSPITAL LABORATORIES

ABSTRACT OF THESIS

Presented to the Faculty of Trinity University
in Partial Fulfillment of the Requirements

For the Degree of
Master of Science
Computing and Information Sciences

By

Michael P. Fitch, B.S., M.T.(A.S.C.P.), C.L.S.

→ For almost two decades, there has been great interest expressed by the U.S. Air Force and the Department of Defense in using computing systems to automate the operations of their hospital laboratories. To this end, several projects have been initiated. The results have produced extremely large, complex systems as attempts were made to develop highly integrated methodologies for general use throughout the entire military hospital community. Consequently, the systems are still not fully operational or are unavailable to many sites. Even if these systems were currently in general use, their utility in small laboratories is limited due to the lack of

accessibility and flexibility these large systems can offer. In a given small laboratory, many of the features may never be used, but useful functions unique to the laboratory remain unsupported.

f. p. 1

→ This paper discusses the use of microcomputers running with the Microsoft Disk Operating System (MS-DOS) as part of an effective solution to this problem. Proper analysis, with particular attention being paid to the unique requirements of each user, can help design systems which can be made more efficient and effective for the various laboratories. The hardware and software required to fill the needs of the small laboratory are currently available at relatively reasonable cost. ← These "off-the-shelf" systems are already tested and supported by their developers. Since these stand-alone systems are intended to be augmentations rather than replacements, the integration achieved with the large, general-purpose systems will not be minimized. Even for microcomputers, communication and transfer protocols can easily be established and implemented. Above all, a large measure of flexibility will be introduced into the total computing capabilities of the laboratory.

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A STAND-ALONE INFORMATION SYSTEM FOR SMALL
AIR FORCE HOSPITAL LABORATORIES

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The views expressed herein are those of the author and do not necessarily reflect those of the United States Air Force or of the Department of Defense.

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CHAPTER I

INTRODUCTION

Scope and Objectives

One of the most difficult undertakings for a manager of a modern clinical laboratory in an Air Force hospital is to justify and ultimately to procure up-to-date equipment. He is all too aware of its availability and what it can do to help him streamline the operations of his laboratory, but obtaining the ideal instrument seems always to be beyond his reach. Part of the reason for this lies in the multitude of laws whose purpose it is to protect the government while at the same time satisfying other laws designed to assure equal opportunity for competing civilian businesses [8, pp. 9-12]. This typically creates delays which eliminate the possibility of having state-of-the-art equipment when it is most needed. The bulk of the remainder of the reason is based on cost in any of several ways. The public's demand for control over military medicine has resulted in strategies to track and document

its quality. Much time and money has been spent developing computing systems to aid this effort.

Hospital quality assurance systems are not new, nor are they unique to the military [7, p. 48]. Quality control is a full-time effort for any hospital, both to monitor and improve patient care and for defensive medicine¹. The military medical community, however, is subject to particular scrutiny by Congress and by the public in general. Much of the justification for development of the large hospital computing systems has been political. The systems have been intended to provide evidence that the quality of military medicine is equivalent or superior to civilian medicine, despite highly publicized public opinions to the contrary. The success of the system is measured by the familiar civilian criteria:

- (1) Has the quality of care improved? (Or at least, have the reports of deficient care been reduced?)
- (2) Has the cost of the operation been reduced?

The requirement for military hospitals to provide ever-improving care at lower cost is not unlike the goals of

¹The term "defensive medicine" is commonly used to describe as a group the routine procedures and practices intended to provide a medical entity and/or its staff with proper and sufficient documentation of, and justification for, the treatment given. These practices are designed to reduce the likelihood of lawsuits against the medical community and also serve as court evidence in its behalf.

civilian institutions. But do the systems also enhance the working environment of the grassroots users, here meaning the laboratory staff? At least one system, the Uniform Charting of Accounts (UCA), has even been detrimental.

It is not the purpose of this paper to address whether these systems succeed in their primary goal, i.e., to act as monitors of the medical community. Rather, the emphasis will be on augmenting the systems to help the local laboratory chief, technologist, or technician manage daily work. Although the software systems run on powerful computers, they do essentially only the function(s) for which they were designed. Since the hardware and software are necessarily protected and quite inaccessible, reprogramming or reconfiguring the system to meet a unique or temporary need is very difficult, if not impossible, even for those individuals who are capable of such an endeavor [16, p. 3-13]. Much of the capability of the hardware is lost by limiting the flexibility of the system to only the installed software.

The objective of this paper is to show that the real needs of the local laboratory manager can be much better served by augmenting the large laboratory computers with small, independent hardware/software systems where the

manager has complete control of both computer and software. The paper will outline the ways a computer can assist the manager in everyday duties rather than mandate what should be done and how to do it. This thesis will also illustrate how this approach can be cost effective when compared to using the large systems only, and in terms of taking advantage of the expertise which typically exists within the technical setting of the clinical laboratory.

What the Laboratory Manager Needs

The head of a military clinical laboratory is seldom able to interrupt his administrative or consultative duties to work side-by-side with the technicians. Nevertheless, the manager is ultimately responsible for each result reported by the laboratory staff. The Joint Commission on Accreditation of Hospitals (JCAH) requires that

the laboratory director² or a designee review these results at least daily, and preferably prior to reporting them [22, p. 149]. Since this duty is often delegated to subordinates, the supervisor must be confident of the quality control procedures in place in the laboratory. Most of these procedures are local implementations of those dictated by

- (1) the College of American Pathologists (CAP),
- (2) the JCAH,
- (3) the Department of Defense (DoD),
- (4) the Air Force,
- (5) the Major Command (MAJCOM), and/or
- (6) the hospital.

Formal application of a quality control procedure is only required if it is applicable to the individual laboratory [22, pp. ix, 141-161]. Also, most of the DoD and Air Force regulations are based on the CAP. In any case, the methods of quality control employed by a given laboratory are typically selected to be most efficient for that particular laboratory. Whatever the methods, a quality-control information system should be flexible enough to sat-

²The Laboratory Director is defined by the JCAH to be one of the following, in order of preference:

- (1) A pathologist on the medical staff,
- (2) A nonpathologist physician on the medical staff who is knowledgeable in laboratory procedures, or
- (3) A doctoral scientist with his degree in a laboratory discipline [22, pp. 141-142].

isfy both the manager and those who evaluate the performance of the laboratory. Also, it should be simple and consistent enough to have its data supplied by the technicians.

In addition to technical quality control, the military laboratory manager should have a tool available to assist in nonmedical supervisory duties. These duties roughly include the automated assistance expected by any small business, with the possible exception of accounts receivable. Budgeting, correspondence, personnel management, workload forecasting, periodic reports and requirements, inventory, modeling³, and extra unrelated assigned duties are all subject to improvement through the use of more efficient methods.

Finally, automation of some of the purely professional work of the laboratory manager may be useful. If the laboratory is involved with active research, the business abilities cited above would likely prove to be very valuable when used with newly developed databases; the organization of standard references could also be added to

³Modeling in the computer sense is a method by which a computer is programmed to mimic the activity of some task, situation, or sequence of events, allowing the operator to view the likely outcome without actually undertaking the task.

the list. Computer-aided diagnosis is another possibility, both as a tool for the laboratory and as a resource for physicians who request a consult.

History of Laboratory Computing

It is not difficult to picture the enthusiasm with which laboratorians embraced the concept of laboratory automation. They are, after all, known properly as Medical Technologists⁴. As the volume of test requests increased, the thought of replacing the drudgery of manually performing sensitive, complicated, and labor-intensive procedures on seemingly endless streams of specimens with instrumentation became increasingly attractive. With this new capability, not only could the work be more enjoyable, but the results would be more consistent; variations between technologists and inherent human imprecision would be eliminated. Many such instruments have been developed and

⁴There is a significant difference between a Medical Technologist and a Medical Laboratory Technician, the former requiring a degree from an approved School of Medical Technology. In the Air Force setting, laboratory officers (managers) are Medical Technologists. Technicians must complete a year-long, two-phase training program before working in the laboratory. This training is approximately equivalent to that of a civilian Medical Laboratory Technician. In this paper, a "technologist" generally refers to a member of either group.

improved upon; those which did not meet these lofty expectations were not accepted. Until the advent of the microprocessor, an instrument could best be described as just another piece of expensive equipment which the technologist wielded. Instruments would not operate unattended or make decisions based on their analyses. But automation did facilitate much higher throughput for the laboratory, and eventually the relative overall cost per procedure started to come down.

The idea of placing a computer in charge of the instrument was met with somewhat less enthusiasm [45, p. 149]. Would Medical Technologists become nothing more than phlebotomists and specimen pushers? Could they, or the physicians, trust the results? And what would happen if the machine broke down? After all, the heart of the system was to be a computer, that ethereal monster whose workings were to be understood by only the mightiest of minds. But the frontier was open and several established instruments started to incorporate microprocessor control into their operations. These instruments had all the weaknesses of the early computers--they were costly and proved too unreliable for medical equipment. Also, they were not powerful enough to offer any great advantage over previous instruments.

By the early 1970s, computers had outgrown some of their weaknesses and were again considered for inclusion in medical laboratory instrumentation. In the early 1960s, the AutoAnalyzer⁵ [36, p. 157] (figures 1.1 and 1.2) and the Coulter Counter⁶ [40, p. 192] (figures 1.3 and 1.4) established industry standards in automated chemistry and hematology analyses, respectively. The high volumes of work these and similar instruments could handle made systems to sort the data become attractive. Information systems, such as MEDLAB, MEDITECH, CHC, and LABFORCE, were already available for laboratories [7, p. 48]. These could generally handle much of the paperwork associated with the specimens, including workload lists, quality control data, patient demographics, and reports, but they were primarily intended to serve the entire hospital with laboratory order entry and retrieval.

In the 1980s, it is rare to find a laboratory of any size which has no computerized instrumentation. The overall cost of medical care has had a profound effect on the laboratory. In a hospital, the laboratory is typically one of the top revenue-producing departments and its gen-

⁵Technicon Corporation, Tarrytown, New York.

⁶Coulter Electronics, Inc., Hialeah, Florida.



Figure 1.1. An early SMA 12/60 AutoAnalyzer [18, p. 153].

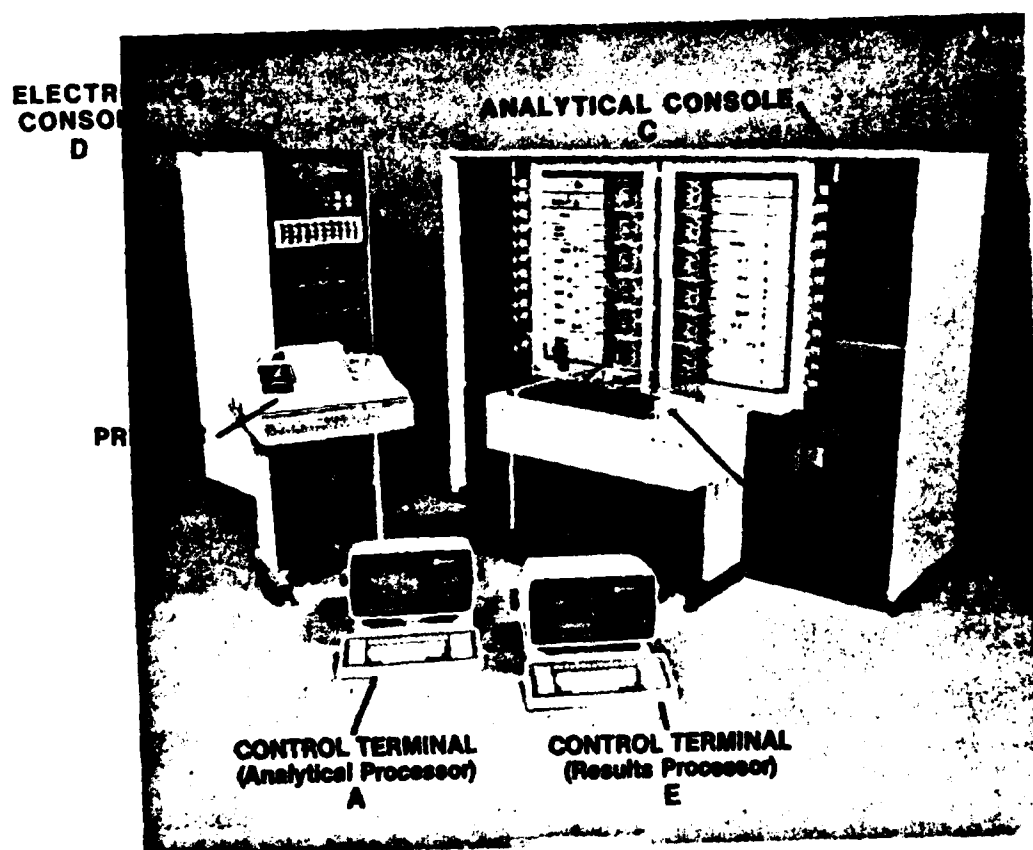


Figure 1.2. A computerized SMAC II AutoAnalyzer [27, p. 272].

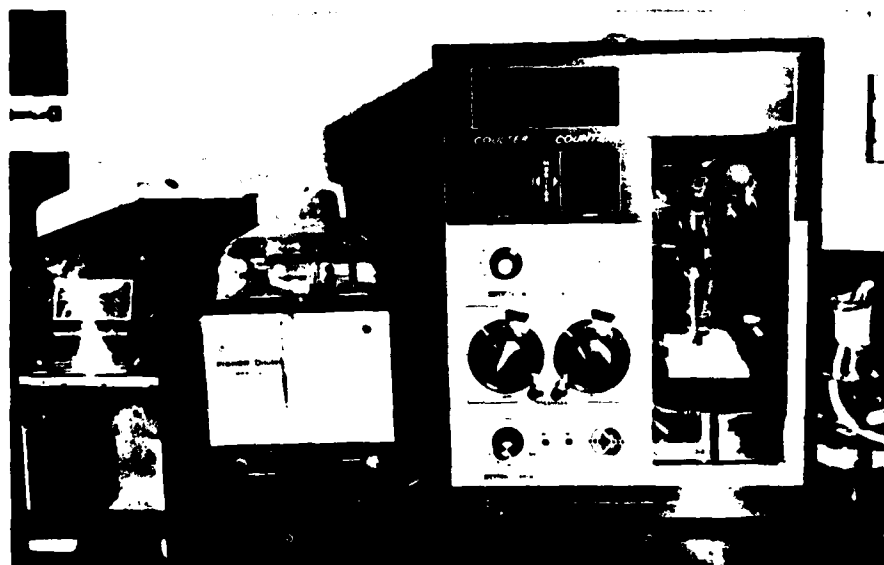


Figure 1.3. A Model Z Coulter Counter [33, p. 1087].

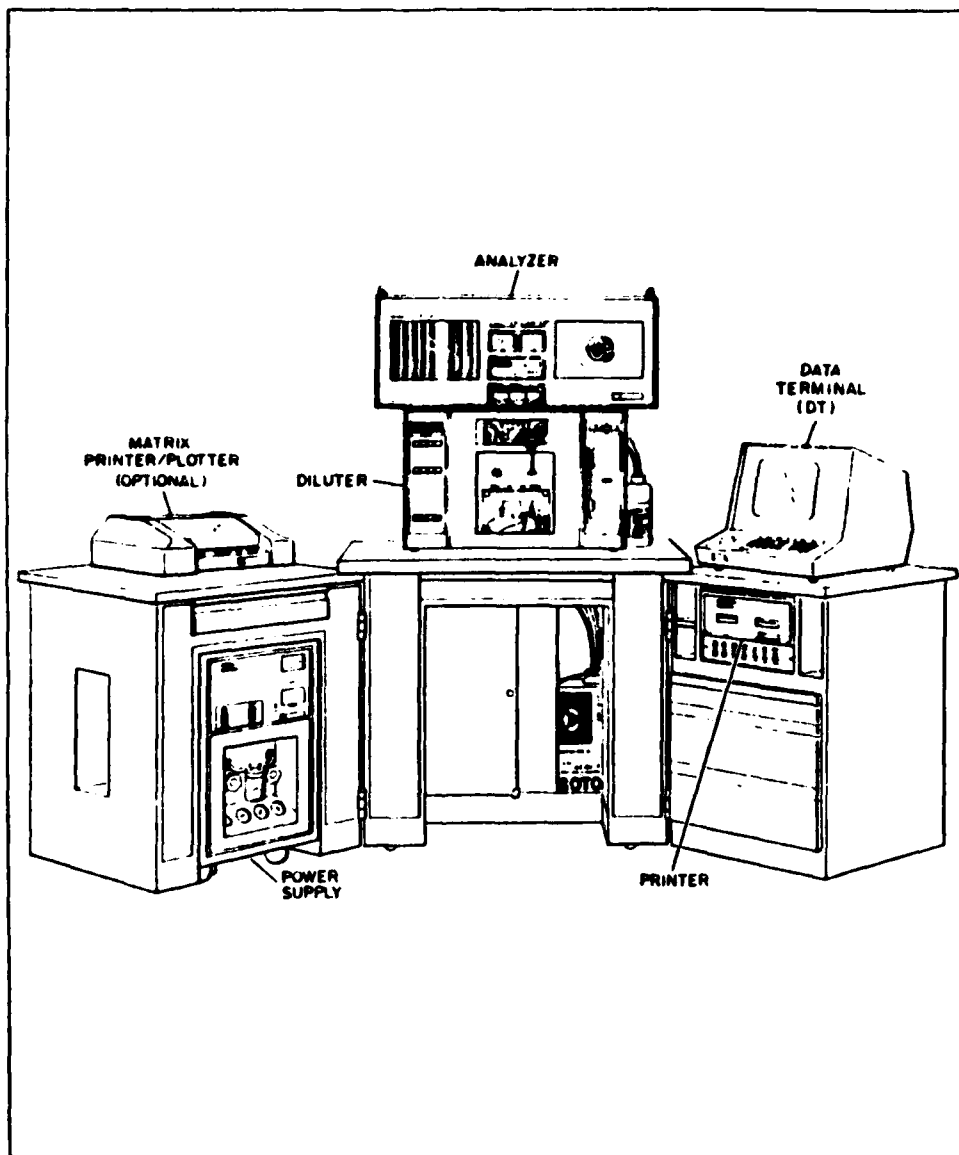


Figure 1.4. A computerized Model S-Plus IV Coulter Counter [9, p. xii].

erous use by physicians has always been encouraged. The luxury of abundant laboratory data concerning a patient quickly became the norm. The advent of diagnosis-related groups⁷ (DRGs), however, has threatened this bastion of defensive medicine unless the cost per test can be further reduced [3, p. 31]. Instruments today are designed for high-volume, low-attention work. The larger ones often contain their own information system to monitor and direct their operations on-line. They can generate and maintain quality control data and verify each test against this data, perform periodic calibrations automatically, detect and diagnose failures and direct the operator in the repair, and even communicate with similar systems elsewhere to maintain uniformity. Most will interface readily with other on-site computer systems. This "walk-away" capability is now very much in demand, allowing technologists to perform multiple simultaneous tasks. It is clear that computer knowledge will soon be a requirement for graduating medical technologists; indeed, many continuing medical education programs include computer seminars [39, p. 885],

⁷Diagnosis-related groups are means by which Medicare reimbursements to a hospital are based on expenses typically incurred for a patient with a given diagnosis. Costs beyond this standard for a given patient must often be absorbed by the hospital.

and schools of medical technology are requiring computer-oriented study with increasing regularity [43, p. 663].

Overview of Following Chapters

Throughout this paper, particular attention is focussed on typical small Air Force hospital and clinic laboratories. These laboratories employ about five to twenty persons. The larger ones are usually headed by an officer holding the credentials of a Medical Technologist, the rest by relatively senior enlisted personnel. Despite the differences in size and leadership, all of them share many of the same management problems. Most of these problems are common to all departments of clinical pathology, but some are unique to the Air Force.

Chapter Two discusses some of the systems currently used to perform the routine information-related tasks required of the laboratory. The strengths and weaknesses of laboratory systems in the DoD are explored, along with the management needs they support. For those systems still not fully implemented, some predictive usefulness will be involved.

Chapter Three is involved with the other tasks which would be very useful to the laboratory if they were sup-

ported by the information system. Some of these tasks are obvious, but they are seldom, if ever, integrated into the systems discussed in Chapter Two.

Chapter Four is concerned with the systems analysis of the proposed stand-alone system. A typical laboratory data flow description is presented along with the environmental factors, both physical and work related, which must be considered. Some of the hardware and software currently available which will support this analysis is discussed in this chapter.

Justification for various configurations supporting the established requirements is presented in Chapter Five. Hardware and software availability, cost, and implementation time are explored. These attributes are compared to those related to systems currently under development. The utility of the stand-alone system by the local laboratory management is particularly emphasized.

Chapter Six discusses the physical implementation of the proposed system and its impact on the laboratory. It covers acquiring the system under existing governmental standards, testing the hardware and software, and the training involved with the conversion from the present system. Maintenance and reliability are addressed here, also.

Chapter Seven comprises the author's conclusions and recommendations for further study.

CHAPTER II

CURRENT SYSTEMS

Manual Methods

The standard method for technical and managerial duties has always been to document these performances by hand. A writing instrument, paper, a correction method, and sometimes a typewriter were the basic pieces of equipment. The local laboratory could, and generally did, develop its own conventions, such as using red ink for entering stat¹ requests on the work logs. Regardless of the method employed, there can be no argument that records of virtually every activity of the laboratory must be created and maintained. Every accrediting agency, as well as common sense and good defensive medicine, makes this abso-

¹Stat is accepted medical jargon designating those actions which should be given priority over other activities because of medical urgency. Technically, it should be written stat., an abbreviation for the Latin statim, meaning "immediately." Although its use is often abused as a convenience, it is reserved for those cases where delay would likely result in loss of life, limb, or cause undue suffering. The jargon permits its use as an adverb ("Do it stat!"), as an adjective ("a stat glucose"), or as a noun ("Has the stat arrived yet?").

lutely clear. In addition, many of these records, such as procedure manuals and daily work logs, must be created in a relatively standard way to make it easy to consult them when necessary. Others, such as Airman Performance Reports (APRs) and Officer Effectiveness Reports (OERs) have exacting standards dictated by appropriate rules or regulations [12, p. 12]. The result of all this is a separation of the actual performance of the testing procedures from its associated documentation. Nevertheless, both must be completed, together with the required certification, before the job can be considered finished. Consequently, much of the paperwork is such that it cannot be left to be done as a batch job.

The actual pencil-and-paper creation of this documentation typically takes many forms. Most formal correspondence is typewritten; orders, notes, and record entries are usually handwritten and may later be transcribed by a typing pool. Some laboratories may have the luxury of dictation support, but this is rare and virtually nonexistent in the small laboratories. Procedure manuals must be typed, but must also be reviewed at least annually by the department head; his corrections and updates are pen-and-ink, and every procedure must bear his initials and the date of review. Work logs are standard forms onto which

patient demographics and results are transcribed; some automated instruments will generate these forms automatically after the information is typed into the integral console on the instrument. These logs eventually become the archival records. They and the laboratory's copy of the completed request form typically represent the only documentation held by the laboratory for a given test. Copies are provided for the patients' charts and for the requesting physician, but these are distributed and maintained outside the laboratory. Retrieval of this archived information involves a manual chronological file search using the patient and the requested test(s) as a concatenated key. The request for such a search must be person-to-person, either in writing or by voice. Quality control data contained on these logs must be transcribed by hand to separate computational logs or to the standard forms provided by third-party vendors. Typing is usually required to complete the standard forms of recurring reports. Methods for managing activities such as inventory, shipping and receiving, cost center data, and personnel must also be developed and records maintained in accordance with appropriate regulations and local convenience.

Each of the documentation activities mentioned above will result in its own file, the maintenance of which is

itself subject to control. Storage protocols, physical security, access control, and the privacy act must all be considered and are mandated to some extent by regulation. (Fortunately, laboratories do not have a need to maintain classified documents for any length of time.) Each of these files provides the legal protection and required documentation for the activities of the laboratory, but are accessible only through a physical search. They are also subject to common problems associated with such a file, such as illegibility, transcription errors, misplacement, lack of storage space, and accidental damage or destruction due to frequent or aggressive access. Eliminating these problems and the time and effort required to generate and search the files are the major attractions of an automated system.

Automated Methods

Automated laboratory information systems have received considerable attention by instrument manufacturers for some time. At first, the systems were designed to work with a specific instrument supplied or supported by the company. As laboratories acquired various instruments, each with its own information management system,

the laboratory was forced to alter or develop record-keeping procedures to conform with the information produced by these instruments. Although the types of information were reasonably standard due to written guidelines and tradition, the means by which the information was presented varied considerably. These variations made comparisons between the different instruments and operators difficult.

Because of the relatively standard data generation and information requirements of a typical laboratory, developing a system to integrate the various forms of data into useful information was not especially difficult. However, gathering and inputting the data presented some challenges. Manually entering the outputs of the various instruments into the integrated system was a task to be avoided unless the benefits derived from the system were determined to justify this duplication of effort. Collecting the data directly from the instrument (on-line) was the obvious solution, and as soon as the instruments were designed to interface with external systems, this level of integration became possible. The emergence of somewhat standard data transfer protocols, such as RS-232, made interfacing much easier, although hardware and/or software interfaces are still typically necessary. The host system must still accept manual input, for it is a

rare laboratory which has no manual testing procedures. Also, operator intervention will usually be required when unusual circumstances arise, such as error recovery or special treatment of specific samples.

Centralized laboratory management systems are still designed to handle laboratory information according to the traditional methods with which nearly all laboratorians are familiar. The end product still is usually a log which the machine generates and will be filed in the usual way. The difference is that automated systems can also generate machine-readable archives which are quickly searched, eliminating the need for a paper search. Of course, memory constraints require that old archive entries be removed from the automated system after some established period of time and stored in the conventional manner. These logs and archives can be composites of all the departments of the laboratory, minimizing the duplication of patient demographics and making it possible to correlate all results derived throughout the laboratory for a given patient. Comparisons of methods, instruments, and technologists are much easier and more meaningful when the data are uniformly formatted. Therefore, maintaining current management methods and standard documentation systems is the goal of both manual and automated information

systems. The end results are essentially the same. Hopefully, however, the automated systems can achieve the goal with much greater efficiency.

Automated Systems in the DoD

The DoD has invested considerable time, effort, and money in the interest of developing a standard system to accomplish the purposes set forth above. In 1972, a group of about 100 persons gathered at Gunter AFB, Alabama, to develop the specifications for the New Generation Hospital Project. This idea was to create, as a prototype, the most modern medical treatment facility (MTF) possible at Travis AFB, California. Although funding for this project was later stopped by Congress, the Tri-Service Medical Information System (TRIMIS) system emerged from the residue of its efforts and from the work of other services [29]. On July 11, 1974, the TRIMIS Programs Tasking Assignment was made [42, p. 1-1]. The TRIMIS system which evolved is beyond the scope of this paper, but the reader is referred to Packman [31] for a thorough discussion. The intent was to develop a complete medical information system for general use throughout the DoD, with each MTF accessing a common database which would contain the medi-

cal records of each patient. This would make any civilian system currently in use at a military laboratory immediately inadequate. As a result of this interest, four laboratory systems have been researched, two of which are currently in place. These are the Regenstrief Clinical Laboratory System (RCLS), TRILAB, the Veterans Administration Decentralized Hospital Computer Program (VADHCP), and the Composite Health Care System (CHCS).

RCLS

The RCLS concentrates on maintaining a maximum amount of patient data in a minimum of space, allowing data to remain available for a maximum length of time. This is accomplished by using "a true database management system" and packing data for storage. Coding permits almost any data, including common text responses, to be stored in only 16 bits, and "only the most clinically relevant information" is stored on-line. The remainder is stored using other archiving methods. Redundancy is eliminated by merging, and the result is "over five years of laboratory

work for over 30,000 patients using under 200,000 bytes of storage. . .² [26, p. 254].

The system also emphasizes making the system easily accessible by the physician and information is formatted according to his needs. He can use the database directly with a query language called CARE, which is easy to learn and also incorporates "ideal rules of care" which are used to flag questionable or unnecessary requests as well as to avoid overlooking important information. Screens have been designed to be easily understood by unskilled users, both for input and for retrieval.

The system supports management uses by "modifying the system without programming." Standard database commands are consolidated with given modules to produce a command language. This can be used to generate ad hoc reports or to maintain the database. Workload lists, billing, and quality control statistics are also produced [26, pp. 255-256].

The RCLS was installed in 1975 at Wishard Memorial Hospital in Indianapolis, Indiana, and at Wilford Hall

²This statement implies that a typical patient's demographics and five-year laboratory history can be contained in less than 7 bytes (54 bits). This is obviously not really possible. The statement probably refers to a 200,000-byte memory-resident directory to the much larger archives stored on large disk packs.

Medical Center, San Antonio, Texas, in 1981. Currently, Wilford Hall is the only Air Force facility running it. It is designed to run on VAX computers from Digital Equipment Corporation (DEC) and is written in compiled VAX BASIC [26, p. 256].

TRILAB

TRILAB³ is related to the MEDITECH system already noted in Chapter One. The first Air Force installation was at Wright-Patterson AFB, Ohio, in 1981. TRILAB currently is also in operation at Andrews AFB, Maryland; Sheppard AFB, Texas; Scott AFB, Illinois; and seven other non-Air Force DoD facilities. No other Air Force installations are scheduled to receive TRILAB, although smaller laboratories can be indirectly served by it. Sheppard AFB, for instance, serves as a reference laboratory for the laboratory at Altus AFB. Through a modem link and voice recognition equipment, the Altus staff can monitor and receive the results for the samples sent to Sheppard.

TRILAB is an integrated laboratory management system which provides most of the management tools available with

³Medical Information Technology, Inc., Cambridge, Massachusetts.

other packages, such as the RCLS. It is written in the MUMPS language⁴, which was originally designed to allow the program to be easily changed to meet special needs, but TRILAB removes this option. It also forces the laboratory to buy instrument interfaces from the vendor, even if no hardware is involved [32, p. 1]. A comparison of TRILAB and the RCLS [32, p. 2] notes that in TRILAB "CAP workload procedures is [sic] probably the best available" and the "method of handling optional tests in batteries⁵ . . . is exceptionally good." However, although most of the desired laboratory information handling is supported, there exist some aspects where the support is less than should be expected⁶ [32, pp. 1-2].

- (1) "System evolution" has not progressed as fast as a typical commercial product should have.
- (2) Documentation is poor.
- (3) The heirarchical, menu-driven command structure can be cumbersome.

⁴MUMPS is an acronym for the computer operating system and language known as the Massachusetts General Hospital Utility Multi-Programming System.

⁵A battery is a group of individual, related tests which can be ordered as if they were a single test. For instance, a liver function test (LFT) may consist of discrete analyses for several different liver enzymes.

⁶Since this list is from a comparison of TRILAB and the RCLS, it can be assumed that the RCLS does not suffer from the listed weaknesses. However, this does not imply that the RCLS is exceptionally strong in these areas.

- (4) Reports do not spool.
- (5) The microbiology subsystem is separate from the main system and does not operate in a completely parallel way.
- (6) Only a single name for a test is allowed, e.g., SGOT, GOT, OT, and AST⁷ would all be considered separate tests.
- (7) Multiple-file structure reduces the flexibility of queries relating to patients.

VADHCP

The Veterans Administration Decentralized Hospital Computer System began as the work of a group of loosely-organized VA programmers who saw the need for hospital information systems. Their work progressed until formal recognition was granted when "a VA Executive Order established the Medical Information Resources Management Office (MIRMO) and the Decentralized Hospital Computer Program (DHCP)" [28, p. 1]. Many programmers participated in the development of the various modules, and there eventually emerged two factions possessing "philosophical differences." One group favored "a loosely controled [sic] pro-

⁷GOT is an acronym for glutamate oxalacetate transaminase, a liver enzyme. The prefix S indicates that the sample is blood serum, by far the most commonly-used source, and is frequently omitted. OT is sometimes used when there is no ambiguity possible. AST stands for aspartate aminotransferase, another descriptive name for the same enzyme. The interested reader is referred to Tietz [41, pp. 672-682].

cess allowing great latitude in local hospital design of systems, the DHCP" [28, p. 1]. The other advocated "a more centralized approach similar to that of the TRIMIS program--commercial procurement of vendor developed hospital information systems" [28, p. 2]. This was eventually resolved by legislation in December of 1982 mandating the implementation of the DHCP approach [28, p. 1]. When the TRIMIS Program Office (TPO) announced in May of 1984 that the DoD would concentrate its efforts on the CHCS (a centralized system) only, the Chairman of the House Veterans Affairs Committee, G. V. Montgomery, advocated the use of the DHCP as being more cost effective. His increasing criticism of the TRIMIS program eventually resulted in the hiring of the MITRE Corporation to assess "the feasibility of using the VA DHCP in the TRIMIS program" and in permission and funding to test the DHCP at March Air Force Base by the Arthur D. Little Corporation [28, pp. 2-3].

Both reports showed deficiencies. The MITRE report, released in January of 1985, concluded that "there was a 30 percent match with the CHCS functional requirements . . . and a 65 percent match with the technical requirements. . ." [28, p. 3]. The Little report, issued in May of 1985, indicated that "users were satisfied" and "functionality was adequate" but suggested that appoint-

ment scheduling was "time consuming" and "cumbersome" and that its use ". . . in a large clinic with many providers and volatile provider schedules may be problematic" [30, p. 1]. Representative Montgomery was critical of both reports and attempted to halt the CHCS. The result was an amendment in August of 1985 to the Fiscal Year (FY) 1985 Defense Authorization Act which mandated [30, pp. 1-2]:

Expanded test at March and one other DoD hospital of significantly larger size;

Test to commence not later than 1 March 1986 for six month period;

Must include all currently available software packages of the DHCP;

Must assess the feasibility and cost advantage that would accrue from the short term implementation of the DHCP in lieu of the cost of the longer term "higher risk" procurement of the CHCS; and

TPO cannot make final contractor selection for the CHCS until the Comptroller General files a final report on the evaluation and the Congress makes its final determination of which of the two systems will be used.

It must be noted that the laboratory module was not a part of the system described by the MITRE and Little reports, but the module is included in the current testing at March, as directed. The length of the testing time was recently extended to December of 1986.

The actual laboratory functions of the VADHCP are similar in purpose to the other systems previously discussed [23, pp. 3-4]. Like TRILAB, it is written in MUMPS, but the inaccessibility of the TRILAB code has been largely avoided. The VADHCP is also very similar to TRILAB in its design, operation, and use. Interestingly, it is likely to become more like TRILAB as testing continues and modules are modified by individuals familiar with TRILAB's operation. At the same time, this familiarity may avoid some of the perceived weaknesses of TRILAB.

CHCS

The CHCS represents the single information system designed for use by all Air Force medical treatment facilities. The CHCS is not limited to laboratory use, but is intended to be a total health care information system. However, the laboratory module can be discussed individually and the functional descriptions (FDs) for this single module have been formulated [42, pp. 3-1 - 3-41]. This module is part of phase two of a three-phase installation, the first of which is scheduled to take place at Sheppard AFB, Texas, by 1 September 1987. Phase two is scheduled to commence at Sheppard on 1 March 1988. At the time of

this writing, bids are still being solicited for development of the system. The following discussion, therefore, is based on the functional descriptions alone; no evaluation can be made about whether or how well the system satisfies the FDs.

Since the CHCS is intended to eventually be part of every laboratory, it is important to note the objectives of the program. The CHCS will likely be the integrated system which will be augmented by the stand-alone system this paper recommends. Figures 2.1 and 2.2 list these objectives. The objectives appear to address approximately the same activities as most of the predecessors of the CHCS. Particular emphasis is placed on minimizing paper handling in the laboratory, thereby eliminating many human documentation errors. Experienced laboratory managers will recognize that some thought was given to management of tangentially related duties, since support for the Drug Testing Program⁸ is to be provided.

⁸The Air Force Drug Testing Program involves collection and shipment of urine samples from Air Force members under strictly defined conditions. Since collection and shipment of body fluids logically falls to the laboratory, the laboratory is tasked with much of the administration of the program. The nature of this program tends to make the activity more a legal responsibility than a medical one, and the required management practices associated with the program do not conform easily with established laboratory protocols.

- a. Share core functions among all authorized users in the MTF work centers.
- b. Standardize functional communications throughout the MTF.
- c. Provide a flexible and powerful framework for the growth, development, and evaluation of functions and workload.
- d. Provide high system reliability with graceful failure of functions.
- e. Share patient administrative and clinical data with all authorized users within the MTF.
- f. Integrate the functional medical information and requirements of various work centers to ensure the capabilities to collect, store, modify, retrieve, and report MTF level patient and management transaction data.
- g. Limit redundant collection of data to the extent required by the MTF.
- h. Provide for standardized order entry and results reporting for all medical information within the system.
- i. Protect the security and privacy of patient and staff information.
- j. Collect administrative data as a by-product of health care delivery for purposes such as UCA, budgeting, QA [Quality Assurance], etc.
- k. Improve the quality of patient care as a result of more thorough collection, better organization, and more timely and accurate availability of patient information.
- l. Reduce the time to transmit information on admissions, dispositions, transfers, patient status, patient care orders, and diagnostic results within the MTF.
- m. Interface with non-CHCS systems which share or require information from the CHCS work centers.
- n. Provide interface to non-CHCS systems such as DEERS [Defense Enrollment Eligibility Reporting System], Food, Logistics, without active involvement of MTF staff in routine interactions.
- o. Prevent the loss or degradation of functional medical information through the provision of standard failure contingency and security capabilities.

Figure 2.1. CHCS objectives [42, p. 2-2].

- a. Provide a totally integrated data management capability that supports Clinical Pathology, Anatomical Pathology, and Blood Bank services.
- b. Reduce transcription and transcription errors.
- c. Provide for early accountability for laboratory orders.
- d. Reduce the amount of clerical tasks performed by technicians by automatically preparing work documents, labels and other products.
- e. Reduce the preparation required to produce workload statistical and management reports.
- f. Make test result and status data available in a more timely manner and in a format compatible with a user's requirements.
- g. Provide information for more efficient operation of the Laboratory, such as uncertified results reports, uncollected specimen reports, etc.
- h. Provide consistent identification of patient results.
- i. Facilitate the accuracy of test results by providing drug/Laboratory interaction data and the flagging of results outside the normal range of values.
- j. Provide more extensive quality control reports with less user intervention.
- k. Facilitate reduction of the number of outdated blood product inventory control.
- l. Improve blood donor services by providing on-line donor files and reports.
- m. Improve the control of blood product distribution by providing on-line, detailed data about the donor, blood product and patient.
- n. Provide more accurate tracking of Tumor Registry reporting capability.
- o. Provide support for the Drug Testing Program.

Figure 2.2. CHCS laboratory objectives [42, p. 2-3].

CHAPTER III

REQUIREMENTS YET TO BE FULLY SUPPORTED

In spite of the emphasis placed on the development of laboratory systems, there remain several important requirements which have not yet been fully supported by the systems. Some of these requirements appear to have been overlooked completely, while others address the issue but fail to be powerful or flexible enough to handle the problems as they typically occur. Both the VADHCP and the CHCS represent great strides in recognizing these requirements and will be the major focus of attention in the following discussions, since one of these two systems will most likely be the one Air Force laboratories will be using. The requirements listed represent those that even these two systems fall short of supporting, as determined by the FDs. Obviously, laboratory managers may find other requirements which the systems do not adequately support when the systems are subjected to real-life use and this fact must always be considered. It must also be recognized that at the time of this writing, most Air Force laboratories have no computer support at all and will not

have any for several years, until either the VADHCP or the CHCS is installed and running smoothly. Therefore, all the other functions beyond those listed explicitly in this chapter also comprise unmet requirements for these laboratories. The stand-alone system recommended by this paper represents the only laboratory information system available in the interim.

Laboratory Management

With the advent of more powerful computers and the lessons learned with each new generation of laboratory computer systems, successive systems are able to incorporate more modules designed to assist in laboratory administration. A good example of this is the improvement of the ad hoc report generation capabilities in the VADHCP relative to TRILAB. The ever-increasing flexibility of each new system is evidence of the designers' recognition that the programs cannot anticipate every use a particular laboratory may have for the system. Allowing access to the program and to its associated databases may allow the end user to solve many of the problems inherent in older systems, but this presumes the presence of a user who understands both the system and the problems well enough to

make the proper modifications without compromising the system as a whole. This access also presumes that the system has the basic abilities necessary to support the modifications. Very few, if any, laboratories currently have access to both of these resources. Whether each laboratory will have them in the future is speculative, but it is safe to assume that each laboratory has need of them now.

In examining some of the tools which are useful to the laboratory management, consideration must be given to what is currently available and what is expected to be available in the future. It has already been established that the typical military laboratory has much in common with civilian facilities in terms of daily tasks and that there also exist some tasks unique to the function of a military laboratory. With a few notable exceptions, such as the proposed support for the Drug Testing Program support available with the CHCS, the large systems are being designed much like civilian hospital support systems. It is left to the user and local creativity to handle extraordinary military circumstances. Such circumstances seldom have anything to do with the laboratory and would not even be construed to be part of a laboratorian's job in the civilian world; in the military, however, one's

laboratory duties are subordinate to duties as defined by higher authority. In this way, the laboratory and its technologists can become an Office of Primary Responsibility (OPR) for any number or type of extra duties. Examples might include being designated as project officer for solicitation drives such as the Combined Federal Campaign, as a disaster preparedness team chief, or as the manager of the local emergency shelter. A truly responsive laboratory information system, then, should be a tool in managing these completely unrelated duties, if desired, as well as laboratory responsibilities.

Personnel

One of the most interesting, and often most frustrating, activities of a laboratory manager is the scheduling of the laboratory manpower. As in a civilian laboratory, care must be taken to insure fair and equal treatment of the staff. For example, the manager must make the typical decisions regarding ability, competency, compatibility of co-workers, seniority, periodic rotations, scheduled continuing medical education (CME), personal preferences, and emergencies. In addition, however, the manager must con-

sider leave¹, sick time², scheduled military training, temporary duty (TDY) elsewhere, and frequent changes to the staff as a result of transfers to and from other installations (PCS--permanent change of station). Fortunately, payroll seldom comes into play, since all military workers are salaried. However, the pay, benefits, and hours worked by civilian government employees are regulated by law and by union agreements and must be carefully controlled. With all this to consider, developing a periodic manpower schedule becomes difficult, and an error will generally translate into extra work for someone. A properly designed information system appropriate to the personnel requirements of the laboratory will not only maintain data such as appointments and scheduled absences, current leave balances, projected gains and losses, indi-

¹By law, every active duty member accrues 2.5 days of leave (paid vacation) per month on active duty. He can carry no more than 60 days into the next fiscal year, which currently begins on 1 October of each year; any excess is lost forever. Any such loss requires thorough justification. The member and his supervisor are equally responsible for seeing that no leave is lost.

²Sick time is not an accrued benefit for military members. If a member is declared unable to work by competent medical authority, or if such authority declares that the work routine must be altered, these declarations are carried out. There are no alterations to the member's pay or benefits; the only effect on the laboratory is the extra workload placed on the remaining technologists.

vidual competencies, and working times available for each technologist, but will also design suitable work schedules using this data.

Of the four laboratory systems discussed in Chapter Two, only the CHCS makes any mention of personnel scheduling support [42, p. 2-14].

2.4.9 Administrative Support. These capabilities will provide the workload statistics to meet the Uniform Chart of Accounts (UCA), and the CAP (College of American Pathology [sic]) workload reporting requirements. UCA weighted procedures totals will be provided for Clinical Pathology, Anatomical Pathology, and Blood Bank. The system will produce CAP Detail, Summary, and Comparison Reports for a user-specified time period. Service-unique manpower reporting requirements (e.g. [sic], ARMY Schedule X) and personnel scheduling will also be supported by the system.

There is obviously no indication as to the degree of support the system offers, but among the related output requirements are found "LAB-PERSONNEL-SCHEDULE" and "LAB-SCHEDULE-TEMPLATE-DISPLAY" [42, p. 3-4].

In addition to personnel scheduling is the maintenance of the local personnel files. None of the systems discussed thus far offers any direct support of this function. Although only a small part of a member's personnel file is maintained in the laboratory, it is the most dynamic part. This file will contain the member's on-the-job-training (OJT) record, certifications records, CME

documentation, performance evaluations, documentation of counseling sessions, laboratory assignments, commendations, and any other information which the supervisor wishes to keep. None of the information will be classified, of course, but it should be considered confidential. Good management practices generally dictate that activities such as evaluations, counseling, and training be performed regularly as well as on an as-needed basis. At the discretion of the manager, the laboratory information system should be capable of providing notification that such activities are coming due, and even provide time for them in the schedule, if desired. The system should also be able to maintain this information in a file or database which is appropriately secure from unauthorized access.

Cost Analysis and Justification

When consideration is given to acquiring new instrumentation, making a new test available, discontinuing an expensive or seldom-requested procedure, altering an established procedure, or requesting additional personnel to alleviate a manpower shortage, the entire process ultimately boils down to a discussion of need versus cost versus benefit. Sometimes this process is relatively simple,

such as using the FASCAP program to acquire a piece of equipment which pays for itself by fulfilling an existing function less expensively. In this case, the need is already established, the relative cost will be zero or less, and the benefit is left to the laboratory to determine. More often, however, the manager finds himself having to justify all three of these parameters. Usually, documenting the need for a new item is the most difficult of the tasks. The military is unique in that an item must be needed before it can be pursued; a projected requirement is of little or no worth. This situation makes it easy to rationalize that if the laboratory has "needed" the item for the past year but has somehow managed to get along without it, no need really existed. As a result, this need must usually be documented by translation to a cost savings.

The FD for the CHCS specifies that the CHCS be able to maintain inventory data for the laboratory, including the costs of supplies [42, p. 3-39]; no such specification exists for the VADHCP. Presumably, such information as cost per test and net worth could be derived using inventory, workload, and procedure data, but this would represent only historical information. Extrapolation of anticipated future performance, modeling of new procedures un-

der consideration, and comparisons of the related studies would still have to be done externally. In describing a stand-alone program used to derive the actual cost of a given test, Sealfon lists 20 items which should be considered [37, p. 426].

1. Price per kit or total reagent³ costs.
2. Number of tests per kit or total reagent volume.
3. Number of controls⁴ per run.
4. Number of standards⁵ per run.
5. Single or replicate analysis.
6. Price for expendable items per batch.
7. Price for expendable items per specimen.
8. Specimen collection and/or processing costs.
9. Maximum batch size (instrument-dependent).
10. Calculated time per analytical result or CAP workload factor.
11. Technologist hourly salary.
12. Reference laboratory or selected comparison price.
13. Frequency of calibration.
14. Number of replicate calibrators required for calibration.
15. Number of actual work days per month.
16. Initial instrument purchase price.
17. Instrument useful life span (years).
18. Instrument salvage value.

³Reagents are the chemicals required to do the test.

⁴Controls are laboratory samples which are tested at the same time and in the same way as the patient samples, and whose values must fall into a statistically determined range for the test to be considered valid.

⁵Standards are samples of known value tested with the patient and control samples. The values of the control and patient samples can be calculated using this known standard value and the raw data from the testing environment.

19. Total number of different analytes⁶ performed daily on the instrument.
20. Yearly maintenance costs (service contract).

It can be seen that some of these may not be immediately available to the CHCS database, which would require external manipulation.

Computer-Aided Instruction

Computer-aided instruction (CAI) has only recently been considered as appropriate for laboratory instructional use. According to Burson, "Computer Assisted Instruction (CAI), in its simplest 'definition' sense, is an interactive learning environment in which the computer makes, facilitates and implements the final information presentation based on input from the learner" [5, p. 886]. It is easily recognized that a modern Medical Technologist "must understand the basics of computer science as they relate to the medical laboratory" [43, p. 663]. But using computers as substitutes, at least to some extent, for traditional lectures and programmed learning texts appeared to be a somewhat radical way to introduce students

⁶The analyte is the particular substance in the sample being tested for. For example, glucose is the analyte of a blood sugar test.

to computers. However, CAI in the laboratory training environment appears to be successful. In one study comparing CAI to lectures and programmed learning texts [10], those students using CAI

- (1) were less likely to be bored,
- (2) showed increased achievement,
- (3) had considerably lower failure rates, and
- (4) saved a lot of time.

None of the four military laboratory systems has or is anticipated to have a documented CAI capability, but it is arguable that CAI could be emulated through clever manipulation of specialized databases, report generation, and data input. Only a few laboratories actively train technologists and technicians, but all laboratories have a need for continuing education and for indoctrination of recently-arrived technologists.

Correspondence

In addition to the many reports which a laboratory manager must submit, there will forever exist a tremendous amount of information which must be transmitted using printed prose. Very few laboratories have their own secretarial support and, unfortunately, laboratory correspondence seldom receives high priority when submit-

ted to a typing pool. Especially in the smaller laboratory, a document requiring typing must either be typed by the originating individual or created in draft form to be typed by an assigned laboratorian if deadlines are to be met.

The advent of word processing has drastically reduced the amount of time needed to produce a correct final copy of a document. There is of course no speed advantage in the actual typing of the document, since that speed is dependent on the abilities of the typist. However, making an error does not require restarting the entire page. The abilities of a full-featured word processor make composition at the keyboard and later revisions easy, eliminating the time needed to create a draft. Sizing text to fit into a defined area, as on an APR or OER, becomes much less of a chore and much faster. The final product will often be more professional as a result of on-line thesauri and spell-checking routines.

Another advantage realized when using word processing is that of maintaining large documents on quickly accessible media. Much time and effort can be saved, for example, by producing and keeping procedure manuals on magnetic disks as well as on paper at the work areas. Whenever a procedure requires a change, the source document

can be quickly retrieved from the disk, updated, edited, and replaced on the disk. The computer then prints the updated pages to replace the ones at the work area after review by the laboratory manager. Because of this ease in changing a source document, however, the Air Force does not recognize the storage medium as a copy of a document. Thus, for those documents requiring a file copy, multiple copies of the document must be printed with the original.

Automatic Notification

As in most modern enterprises, there exists in the laboratory a plethora of dates and times representing some required or desired action. Many of these were discussed above in conjunction with personnel management, but there remain many others. It is a very simple matter for a computer to be provided with these dates, times, and activities as data and give some sort of notification when action is due. Even better, it can prompt the user for interim checkpoints to avoid last-second rushes. Assigning a relative priority to each activity further enhances the computer's ability to assist in the manager's planning of daily, weekly, or monthly events. The system could then be used as a daily work-list generator for the manager in

much the same way as it generates work lists for the technologists. The list of activities is virtually endless, but would include all the recurring personnel management functions noted earlier, patient appointments, meetings, projects, suspenses, correspondence awaiting replies, obstetric patients' due dates, and even technologists' birthdays. Any event sufficiently important to the user can be included.

Many recurring activities in the processing area of the laboratory are required for accreditation and proper operation. The CHCS has a provision for documenting the routine scheduled preventive maintenance of equipment and maintain a repair log [42, p. 2-14], but there is no indication that the system will prompt the technologist when maintenance is due. Since these records are seldom consulted unless the instrument fails, such an ability will likely decrease the number of times routine maintenance is overlooked.

Professional Needs

Small computers offer many capabilities useful to a Medical Technologist as he performs consultations or other duties associated with his training in clinical pathology.

Many small Air Force hospitals and clinics do not have a pathologist on the staff and it falls upon the laboratory chief to provide such support, either by offering his own services to the extent his training and credentials allow or securing the services of a qualified reference pathologist. These services can be divided into at least two general categories, diagnosis and research.

Computer-Aided Diagnosis

Research in artificial intelligence has demonstrated that programs can be developed for computers which make these systems act as experts in some field of understanding. Rich defines such expert systems [35, p. 284].

There is a whole array of interesting tasks . . . that require a great deal of specialized knowledge that most people do not possess. These tasks can only be performed by experts who have accumulated the required knowledge. Examples of such tasks include medical diagnosis, electronic design, and scientific analysis. Programs to perform these tasks would be very useful since there is usually a shortage of qualified human experts. Programs that do perform some of these tasks have already been written. Such programs are called expert systems and the construction of them is referred to as knowledge engineering.

Among medical diagnosis systems, programs such as INTERN and MYCIN⁷ have served as templates for similar programs available now which run on microcomputers. Although physician acceptance of such diagnostic sources varies, such a system can offer valuable assistance to the laboratorian in explaining unusual laboratory values and suggesting confirmatory studies. It can also serve as a useful resource for any interested physician in his nonlaboratory-related diagnoses and as a diagnostic training tool.

No formal computer-aided diagnosis ability is part of any of the current or proposed military medical laboratory systems. Access to the databases is to be granted by the VADHCP and the CHCS, but neither the specialized knowledge bases nor the "analytical engine" required could be incorporated.

Research

Although funds for research are seldom granted to small laboratories, the Air Force encourages research at

⁷INTERN is a program which asks questions of the clinician and forms a differential diagnosis based on his responses and on its knowledge base. MYCIN is similar, but specializes in diagnosing bacterial infections.

all levels as a learning tool and a technical resource. Even the smallest laboratory will eventually be called upon to pursue unusual circumstances surrounding an occasional patient or assist a physician in writing a paper. A laboratorian may want to pursue an area of interest himself, perhaps in preparation for a presentation or publication of a paper. In any case, the abilities available with small computers can present options to the research not otherwise available.

During the course of the project, databases containing the associated information will be created. These databases may contain preparatory material or data gathered during the actual performance of the experimentation. Conceivably, the data-handling capabilities of the VADHCP or the CHCS could be tapped to perform this function. However, other sources of information must be manually entered. An example of this is access to MEDLINE⁸ or to an automated library cataloging system. A microcomputer equipped with an inexpensive modem could access such resources directly. This capability is not documented in the FDs for the major systems.

⁸MEDLINE is an automatic search system for medical journal entries. By using key words and Boolean logic ("and," "or," and "not"), papers relating to the desired topic can be selected.

CHAPTER IV

STAND-ALONE SYSTEM ANALYSIS

The production of a large-scale laboratory or hospital computer system obviously involves much planning and organizing before the system can be constructed. Weinberg calls these efforts the analysis phase, which is followed by the design and implementation phases if the project continues to its completion [44, pp. 10-11].

Analysis frequently is used to describe the front-end phase of the systems development life cycle prior to the design phase. In this phase, problems and objectives are defined, tentative solutions proposed, and costs and benefits evaluated.

One can debate whether the laboratory systems presented in Chapter Two are, or will be, the result of a proper analysis as defined by the experts. This paper will not enter into this debate other than to recognize that proper analysis is necessary to the success of the system. The existence of FDs for the CHCS indicates that an attempt was made.

One of the primary concerns of a systems analyst is to be familiar with the intended operations of the organi-

zation in question. One of his best sources for this information is the end user, the one who will be ultimately running the system and, hopefully, benefiting from its operations. In the case of the CHCS, the end user becomes generic because of the intended total integration of the system. To take into account the needs and desires of each end user of such a system becomes counterproductive. Therefore, the analysis keys upon the known equivalencies from laboratory to laboratory and specific augmentations are left to the creativity of the local management.

Data Flow in the Laboratory

One of the first aspects of the organization which the analyst attempts to understand is the kinds of data used, where the data come from, how they flow through the organization, how they are changed during this flow, and where they ultimately terminate. A tool used by the analyst to chart these properties is the data flow diagram (DFD)¹. Figure 4.1 is an extremely simplified DFD tracing some of the data associated with a typical physician's

¹Weinberg defines a DFD as "a graphic tool used to depict the logical flow of data through a program or system" [44, p. 55] and "a graphic tool that represents data flow and transforms in a process" [44, p. 311].

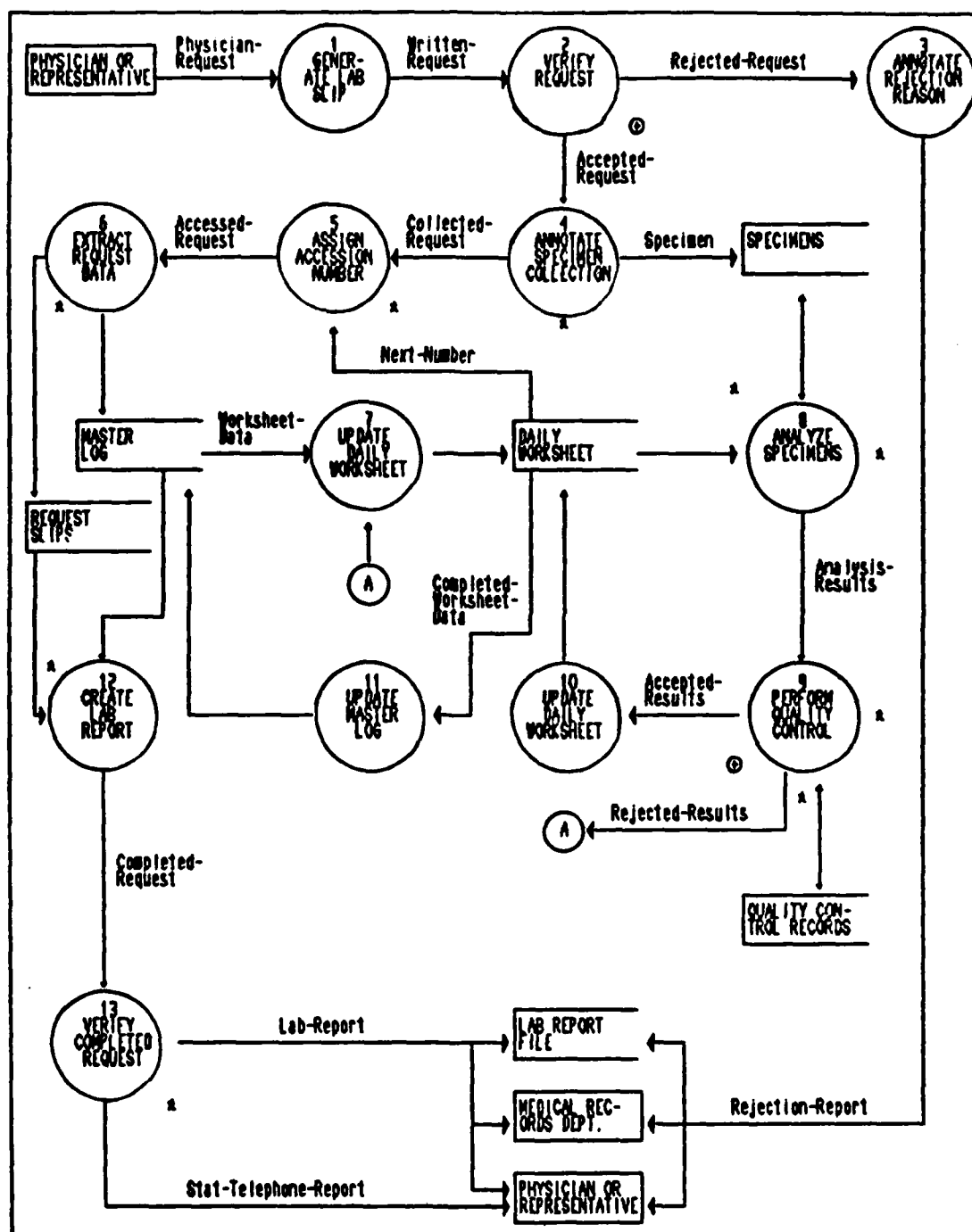


Figure 4.1. General top-level DFD for a laboratory analysis request.

order through a laboratory. Because Air Force laboratories conform to civilian accreditation requirements, this DFD applies to Air Force laboratories as well. It must be noted that there exist many extensions to this DFD which describe, for example, report generation, maintenance, specimen shipment and receipt of results, and inventory. In addition, the entire DFD can be depicted to many more levels². If extensions are then added to cover the data flows associated with the standard military operations of a DoD laboratory, one can conceive of the DFD which the CHCS (hopefully) has been designed to support.

In addition to the typical workload flow, every laboratory faces data which must be handled in a nonstandard or undefined way. Although the military attempts to standardize its operation as much as possible through the use and enforcement of documented regulations, a given manager is seldom familiar with those regulations outside his own realm. The regulations may also not cover a specific situation or may explicitly place the responsibility for the

²Each circle (known as a "transform" or "bubble") represents some activity performed to change the incoming data into the outgoing data. The methods by which this transformation takes place can also be represented by a DFD. Therefore, a DFD can be fully characterized to any desired degree of detail by successive descriptions of transforms. A level or layer, then, represents the next degree of detail in the DFD.

decision on the manager without further guidance. In any case, handling the flow of data associated with such crises essentially becomes the responsibility of the manager. As a result, a DFD describing this general situation cannot be any more detailed than the one in Figure 4.2. The layers and extensions of the transform literally do not exist until the situation occurs for the first time. Naturally, the number of options available to the manager as he approaches the problem will be greatly influenced by the flexibility of the tools he plans to use. And there can be no argument that the information systems in the laboratory are important tools.

Systems Design Considerations

"Systems design is concerned with the development of specifications for the proposed new system or subsystem which satisfy the demands identified during the systems analysis phase" [4, p. 373]. With this definition in mind, the analysis of the proposed stand-alone system must include any events or situations occurring in an Air Force laboratory which may affect the performance of the system.

The scope of this paper is limited to microcomputers running under the Microsoft Disk Operating System

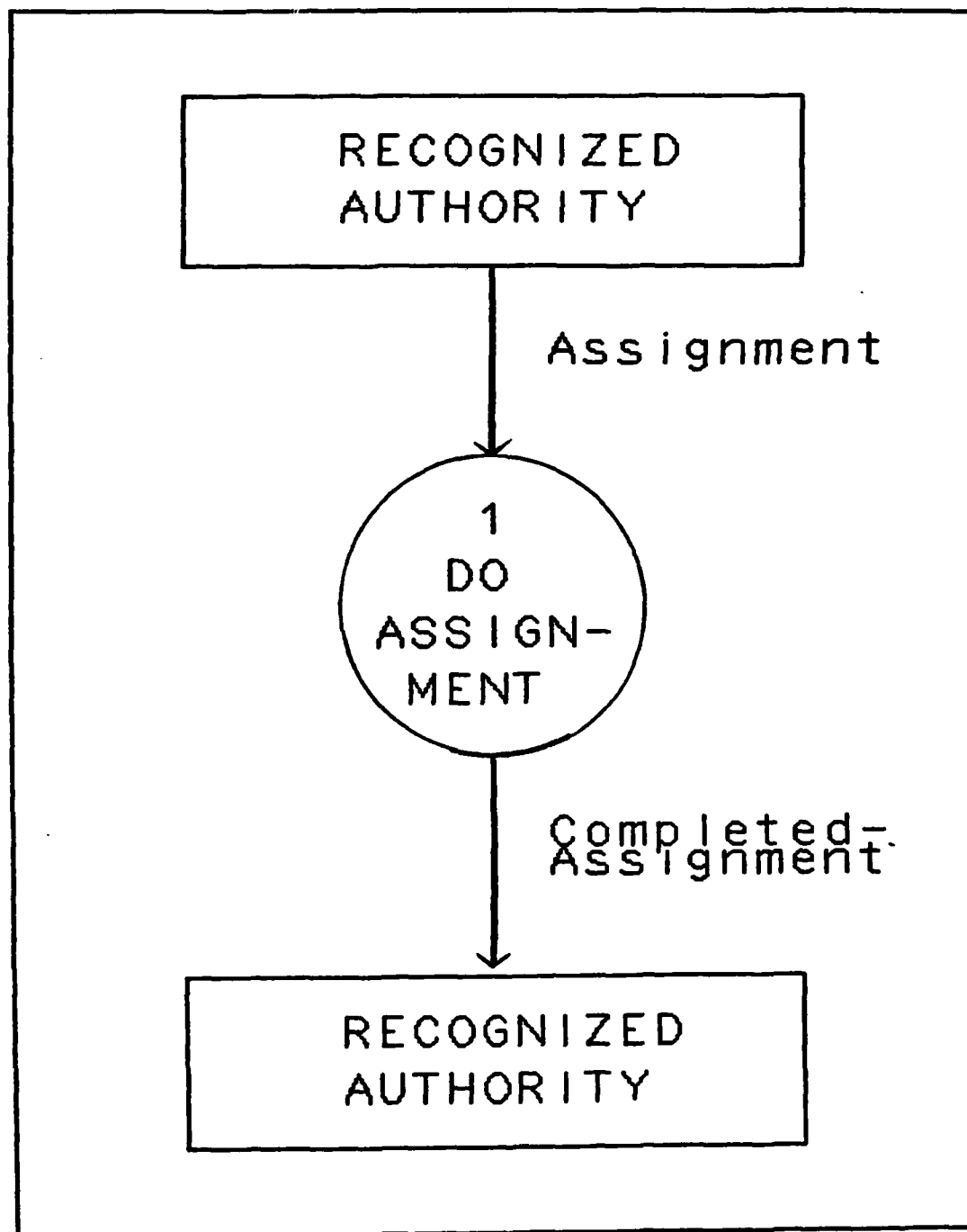


Figure 4.2. DFD for an atypical laboratory duty.

(MS-DOS³), which can loosely be considered to be the IBM⁴ Personal Computer (PC), the IBM PC/XT, the IBM Personal Computer AT⁵, and their true compatibles⁶. It should be noted here that the Zenith Z-248⁷, the "advanced computer system" for which the Air Force let a standard requirements contract in February of 1986, is required to be AT compatible [1, pp. 68-70]. This group of microcomputers is well established in the business world and have indeed created a de facto standard for microcomputers. For these

³Microsoft Corporation, Bellevue, Washington.

⁴International Business Machines Corporation, Boca Raton, Florida.

⁵The IBM PC is the basic microcomputer using Intel's 8088 microprocessor. The IBM PC/XT is essentially identical to the PC, but has the necessary modifications to easily support popular add-in options such as hard disk drives. The IBM Personal Computer AT is based on Intel's 80286 microprocessor, which runs at a higher clock speed and can directly address more memory. Since the instruction set of the 80286 is a superset of the 8088, it can run the same software as the 8088-based systems.

⁶Since the firmware-based routines (ROM BIOS) in the IBM machines are copyrighted, the compatibles (also known as clones) must emulate these routines in their own software or firmware. The success of this emulation varies from clone to clone with a concomitant variation in their abilities to run all the same software despite having identical microprocessors. On the positive side, many clones incorporate later microprocessor versions, such as the 8088-2 or 8088-3, which run at much higher clock speeds. Some AT clones will also accept the 80386, which will be widely available soon.

⁷Zenith Data Systems Corporation, Vienna, Virginia.

reasons, the reader is referred to other appropriate sources for information regarding their use in a nonlaboratory setting. In the laboratory, of course, some special precautions must be taken. However, with a few exceptions, these precautions will be very similar to those taken for other microprocessor-controlled instruments which are usually abundant in a modern laboratory.

Environment

The Air Force laboratory environment varies little when compared to its civilian counterparts. Both types suffer, or benefit, from constants such as the age of the facility, the state of repair of the building and fixtures, the amount of workspace available, and convenient access to the various departments. These constants then combine to affect the variables under which the system must operate, such as heat, humidity, vibration, proximity to liquid, gaseous, or microbial contamination, working light, glare, and electrical power stability. These same variables affect the daily work of a laboratory, not only in terms of sensitive equipment, but also in the biochemical processes themselves. Fortunate indeed is the labora-

torian whose quality control records do not show the results of an air conditioning failure.

A typical microcomputer and its peripherals will easily tolerate the normal conditions found in a laboratory with appropriate care. Figure 4.3 outlines some of the documented tolerances for a typical microcomputer system. Recently built laboratories are often devoid of exterior doors and windows and rely solely on their own air-handling systems to maintain the temperature and humidity within acceptable tolerances. To lessen the chance of contamination, the air-handling system for the laboratory ideally should be isolated from that of the rest of the hospital and should maintain a slightly negative pressure relative to the hospital. This certainly is not always the case, but it often contributes to a lessening of the ability of the air-conditioning system to dissipate the heat generated by all the laboratory equipment. In addition, large temperature variations can be expected in various parts of the laboratory, but drastic temperature changes can normally be considered unlikely. Since a laboratory can seldom tolerate temperatures outside a range of approximately 13-29°C (55.4-84.2°F) without experiencing some unacceptable degradation in performance, the microcomputer will be outside its tolerances only in extreme

Environmental Factor	Micro-computer	Mon-itor	Key-board	Printer
Power requirement (W)	300	30	2.5	100
Operating Temperature (°C)				
Minimum	10		0	5
Maximum	32		50	35
Storage Temperature (°C)				
Minimum			-40	-30
Maximum			55	70
Operating Relative Humidity (% noncondensing)				
Minimum	20		0	5
Maximum	80		95	90
Storage Relative Humidity (% noncondensing)				
Minimum				0
Maximum				95
Shock (G, 1 msec)				
Operating	*			1
Storage	*		40	2
Vibration (Hz)				
Operating	*		200	55
Storage	*			55
Vibration (G)				
Operating	*			0.25
Storage	*			0.5
Gas Concentration (ug/m ³)				
Hydrogen sulfide (H ₂ S)			5	
Sulfur dioxide (SO ₂)			1300	
Ozone (O ₃)			25	

*Varies--the limiting factor is typically the kinds of disk drives installed.

Figure 4.3. Typical hardware environmental tolerances [24, p. M-2; 21, pp. 2-4-3, 2-4-5; 6, p. 3; 47, p. 4; 46, p. 4].

laboratory emergencies. Laboratory humidity is typically higher than the ambient humidity for a given temperature, but seldom causes any problems for hardware unless condensation is present. In areas of low relative humidity, however, care must be taken to guard against static electricity discharges through the equipment, especially if the laboratory is successful at maintaining comfortably low temperatures. Special mats and touch plates are available for this purpose, and proper equipment grounding is mandatory in any case.

Laboratory contamination presents a unique problem for a microcomputer. If the system is situated in an office, as an example, it must be protected from snacks and pastimes of proximal humans. No laboratory, however, should permit eating, drinking, or smoking in analytical areas, so a system placed there should not be affected by consumable items. Without sacrificing user convenience, the system should be situated out of the way of accidental spills or splashes of any substance and away from any source of corrosive gases. Standard laboratory procedures minimize the likelihood of any of these situations occurring and define cleanup regimens, but accidents will always be part of laboratory life. Hardware such as a keyboard is notoriously difficult to clean, and circuit

boards and disks can be rendered permanently useless after exposure to these agents. In addition, proper laboratory technique must be maintained to avoid the keyboard becoming a vector for hand-borne contamination. Covering the equipment when not in use or during the performance of potentially messy procedures represents common-sense management.

Electrical power considerations are generally self-evident, but some thought is necessary before system placement is decided upon. Surge-suppression techniques should always be employed. If continuous operation is essential, the system must be connected to a line to which emergency power is supplied in the event of an interruption of service. An uninterruptible power supply will probably be necessary to keep the system running during the transition phases. Although the power requirements of even a fully outfitted microcomputer system are generally too low to present an unacceptable drain on a good emergency power system, it may be sufficient to cause voltage fluctuations which may affect itself or other equipment on the same line. Conversely, the computer system may not tolerate fluctuations introduced by the other equipment. In addition, care must be taken to consider the effects, if any, of the electromagnetic radiation produced by elec-

trical systems on or from other equipment. An IBM PC, for example, interferes with a nearby television set.

Finally, the system should be situated in a stable, comfortable work area which is not subject to excessive shock or vibration. Sufficient light must be available without producing undue glare on the screen. It is obvious that the workbench or desk upon which the system is placed should be able to support its weight plus a good bit more. But regardless of the stability, it would be unwise to have the system share a bench top with a centrifuge, for example. Even a well-balanced centrifuge produces sufficient vibration to make work unpleasant; an unbalanced one could be disastrous for the hardware, especially an operating hard disk.

Security

The Air Force policy on small computer systems security is influenced by several regulations⁸. It briefly

⁸Air Force Regulation (AFR) 12-35, Air Force Privacy Act Program; AFR 30-30, Standards of Conduct; AFR 123-2, Air Force Fraud, Waste and Abuse (FW&A) Prevention and Detection; AFR 125-37, The Resource Protection Program; AFR 205-16, Automatic Data Processing (ADP) Security Policy, Procedures and Responsibilities; AFR 700-10, Information Systems Security; and AFR 700-26, Acquisition and Management of Small Computers [20, p. 1].

states that the system is to be used properly and to full advantage [20, p. 1].

POLICY. (Organization name) personnel will safeguard and prevent abuse of small computer systems and associated resources consistent with established security policy defined in this and higher level directives, including the reporting of any suspected instances of fraudulent [sic] or unauthorized uses or practices to the proper authority.

a. Small computer systems and the information processed on those systems will be protected against improper use, alteration, manipulation, or unauthorized disclosure in accordance with governing regulations.

b. Small computer systems will be utilized to the fullest extent possible and only for their intended purpose.

This policy could easily be applied to any other instruments in the laboratory as well, and most of the applicable security precautions for a microcomputer are identical to those taken for other electronic equipment. But it must be noted that a microcomputer is a far more useful item outside the laboratory than is an electrolyte analyzer⁹, for instance, even though the latter may be worth five times the value of the computer. Hence, the computer may be more attractive to a would-be thief.

⁹A typical electrolyte analyzer measures the concentrations of sodium (Na^+), potassium (K^+), chloride (Cl^-), and total carbon dioxide ($\text{HCO}_3^- + \text{CO}_2$) in blood or other fluids.

Basic to system security is what Burch calls "physical controlled access" because "if a potential penetrator cannot gain entry to the computer facilities, then the chance for harm is reduced considerably" [4, p. 466]. It goes without saying that the laboratory should remain locked when unoccupied [20, p. 1], but some procedures must be adopted to limit access at any time to only those individuals to whom authorization has been given and who pose no threat to the system. Intelligent location of the system, in an easily controlled place which is sufficiently isolated to avoid advertising its existence but is conveniently accessible to its users, will enhance physical security.

Data security logically demands that hardware, disks, and other storage media be subject to the same protection mechanisms as have been previously described. Indeed, Batson feels that physical security is still the best means of data security [2, p. 172].

The most secure and best understood ways of protecting computers and their data are the oldest. Physical measures such as locks and alarm systems often do the best job. Keeping a computer system in a secure place and preventing outside access such as dial-in phone lines often protect a machine much better than several layers of clever programming. As a bonus, such arrangements also help prevent some "low-tech" hazards, such as fire damage and outright theft of expensive computer hardware.

But the data on the media or in memory is often much more valuable than the hardware, and some form of data protection must always be employed. At the very least, duplication of copyrighted software must be prevented; on the other end of the scale lies the prevention of any kind of disclosure during or after the manipulation of classified material.¹⁰ Patients' sensitive medical information, which is affected by the Privacy Act, falls somewhere in between these two extremes. The type of data protection chosen will necessarily be influenced by the types of data used. Some authorized system users may have to be denied access to certain data in the system, and passwords or protective software such as WATCHDOG¹¹ will be useful in this regard. Generally, however, this problem is most easily solved by maintaining the information on removable media which are stored in a secure area to which only the

¹⁰When handling classified data, care must be taken to eliminate any possibility of compromising the data. Besides remaining out of sight of onlookers and shielding against any form of electromagnetic eavesdropping [38], all vestiges of the data must be removed and properly stored afterward. These include, but are not limited to, diskettes, tapes, notes, papers, printer output, and printer ribbon. In addition, all memory and buffer contents must be destroyed, and monitor burn-in must be ruled out. Since data are not usually removed from a disk upon erasure of the file, classified data should not be placed on an unsecurable hard disk.

¹¹Fischer Innis Systems Corporation, Naples, Florida.

specified users have access. The importance of creating and maintaining backup data cannot be overstated, and the backups must be accorded security at least as tight as that of the original. Adherence to the environmental guidelines presented previously also contributes to data security by protecting the system, its data, and the storage media from unexpected hazards.

A discussion on Air Force small computer security is not complete without mentioning fraud, waste, and abuse. As with all other Air Force equipment, the computer is intended for official use only. Technically, this precludes its use for personal or nonduty projects, even if the projects are undertaken entirely during idle periods and while the operator is off duty. Also prohibited are borderline situations, such as managing the database for the base Morale, Welfare, and Recreation (MWR) bowling league [25]. Hopefully, sufficient authority and responsibility can be granted to the manager of the computer system to judge and approve each proposed project on its own merits. Only in this way can a microcomputer "be utilized to the fullest extent possible" [20, p. 1].

Interfacing

In order for any computer system to perform useful work, it must have a means of acquiring data from a source and outputting the manipulated data or information. This means is referred to as an interface, defined by Weinberg as "a common boundary between two devices, subsystems, programs, or modules" [44, p. 314]. It can be thought of as a line of communication between the computer and some entity exterior to it. The data exchange along this line must take place using some protocol understood by both the computer and the external device. The stand-alone laboratory microcomputer system will definitely have to interface with humans, and may also do so with laboratory analytical instruments and/or any other operating computer systems.

A computer typically communicates with its human operators through the written or typed word. The exact language used may be one of many and is irrelevant for this discussion, provided both the computer and the operator understand the language. In this regard, interaction with laboratorians is no different for the computer than that with nonlaboratorians. The typical operator "speaks" with

the keyboard and the computer replies on the monitor or printer.¹²

Interfacing a microcomputer with automated laboratory instruments presents much more of a challenge, but results in dramatic increases in efficiency if properly done. The advent of relatively standard data transmission protocols, such as RS-232 serial transfer, has greatly improved the ease with which the connections can be made. Most modern microprocessor-controlled laboratory instruments have ports available for this purpose. Nevertheless, specialized software is still usually necessary to allow the two devices to recognize each other. Medlink¹³, for example, requires separate software interfaces be purchased for each instrument the user wishes to include in the system [15]. Although the ability to link the microcomputer with laboratory instruments is attractive on the surface, the high cost and subsequent loss of system availability must

¹²Other common input devices are the light pen and the mouse. Some sophisticated systems employ voice-recognition techniques allowing them to accept spoken instructions and reply verbally.

¹³Eastman Kodak Company, Rochester, New York. Medlink is the name of Kodak's Data Management Network for the laboratory. It runs on the IBM PC/XT or IBM Personal Computer AT.

be weighed against the immediate gains realized and the restructuring necessary with the installation of the CHCS.

The final consideration is whether the computer can interface with other laboratory computers which may be currently running. As with the laboratory instruments just discussed, if linkage of the two computers is feasible, hardware and/or software interfaces will likely be required. However, alternatives do exist. Both TRILAB and the VADHCP are provided with modems¹⁴ through which access to the system can be achieved after proper validation; presumably, the CHCS will have one as well. Data transfer is much slower using this method, but should prove to be adequate since the host machine can be called upon to do some of the processing. Although software is required to drive the modem, several excellent packages are available in the public domain. Another interfacing alternative is through the use of shared media, but it is unlikely that two very different computers can produce diskettes, for example, with identical formats and data-storage protocols. Once again, the perceived benefits must be explored before a computer-computer linkage is at-

¹⁴Modem is an acronym for modulator-demodulator, a device necessary to send data over common carrier lines, usually telephone lines.

tempted. However, modems and shared media provide an excellent way for occasional interlaboratory communications to take place.

Software Support

The emergence of the IBM PC as the recognized industry standard microcomputer enticed developers to write a plethora of software for it. As a result, the chance of finding an appropriate package for virtually any given purpose is high. Competition has been stimulated, and comparative reviews are abundant. Most individuals who use an MS-DOS computer already have a favorite word processor or spreadsheet, a fact which will ultimately influence the selection of software for the laboratory stand-alone system.

Business software can be loosely categorized into five groups: word processors, spreadsheets, database management systems, communications programs, and programming environments. Some well-known examples of these groups

are WordStar¹⁵, Lotus 1-2-3¹⁶, dBase III¹⁷, Smartcom II¹⁸, and Turbo Pascal¹⁹, respectively. Some packages combine these five areas into a single program. Although this integration is convenient in that the applications are immediately available and data are easily shared among them, these programs require more memory and any given application is seldom as powerful as a single dedicated program. The most popular example of such an integrated package is Symphony²⁰, but another example, Enable²¹, is to be offered as part of the standard requirements contract [1, p. 37]. Many full-featured programs have list prices of \$695 or more, although volume outlets usually offer much better prices. In addition, outstanding no-cost programs which also cover these five areas, among many others, can

¹⁵MicroPro International Corporation, San Rafael, California.

¹⁶Lotus Development Corporation, Cambridge, Massachusetts.

¹⁷Ashton-Tate, Torrance, California.

¹⁸Hayes Microcomputer Products, Inc., Norcross, Georgia.

¹⁹Borland International Inc., Scotts Valley, California.

²⁰Lotus Development Corporation, Cambridge, Massachusetts.

²¹The Software Group, Ballston Lake, New York.

be found in the public domain, although some sacrifices in support, documentation, power, features, and standard usage may have to be made.

The selection or development of software for the proposed stand-alone system should naturally be driven by the projects for which the system is to be a tool. Emphasis should be placed on those needs which are not currently supported and will likely still not be available even after the installation of the CHCS (see Chapter Three). By considering currently available software packages, the entire stand-alone system can be developed as quickly as the military procurement system allows, and be provided with software which has already been tested and documented.

CHAPTER V

JUSTIFICATION

Despite all the nice things that can be said about having a stand-alone microcomputer system available in the laboratory, tangible benefits must be documented to justify its acquisition. After having shown the need for the system to exist (Chapter Three) and that the proposed microcomputer can fulfill the need (Chapter Four), some discussion must take place regarding its relative worth. Since the common denominator of worth to the government is money, a translation of benefits to dollars must usually take place. However, this opens the door to individual interpretations. How much more is the value of a word processor, for example, to a poor typist as opposed to a good one, all else being equal? Using a conventional typewriter, the good typist will likely make fewer errors, and he will have to invest much less of his time in redoing any given error. Therefore, the word processor becomes more justifiable (worth more dollars) to the poorer typist, but the machine and its associated costs are identical in either case. For this reason, equating monetary

quantities with specific value judgments will be avoided in this paper; the inherent differences among laboratories and their staffs, however small these differences may be, will vary the relative worths of their respective computers.

Although the worth of a given laboratory microcomputer can best be determined by the local management, even general data can be used to show that the cost of such a system can be quickly recaptured in essentially every laboratory based on time savings alone. In a typical small laboratory, a \$3,000 microcomputer system can pay for itself in the first year by saving each staff member an average of less than 5 minutes per day¹. Reaching a general monetary break-even point will not take more than a year

¹A Captain with 5 years of service receives approximately \$38,784.05 in total annual compensation [13, p. 1]. If the laboratory also has 14 technicians and each is assumed to be compensated at only half the rate of the Captain (very conservative), total annual compensation for the laboratory is \$310,272.40. Depending on the year and how each staff member chooses to take his leave time, he may work from 219 to 251 days in a year; the mean is 235 days. Authorized absences other than leave, such as TDY and sick time, are not considered. Hence, the laboratory works 3,525 person-days in a typical year, or 28,200 person-hours if an 8-hour day is assumed (seldom factual, but sufficient for comparison), thereby averaging about \$11.00 per hour. It therefore requires about 272.7 person-hours of work to make \$3,000, or about 4 minutes and 39 seconds per person for each of 235 days [19, pp. MC43-050-107 - MC43-050-108].

or two for any laboratory, and will frequently be attained much sooner.

System Alternatives

Although many of the requirements of different laboratories for microcomputer support are alike, laboratory sizes and scopes vary greatly. As a result, the configuration of the stand-alone system may also vary according to the differences in size and scope of the requirements. In addition, more than one microcomputer may be required, and if so, it may be necessary to link them together into a network. Careful consideration of the mission of the individual laboratory, as well as the duties and preferences of its staff, must be a part of the system design process.

In much the same way as the addition of options to a car make it much more useful and pleasant to drive than another which is outwardly identical, the performance (and price) of a microcomputer is greatly affected by the installed extras. The standard IBM PC, PC/XT, or compatible of just three years ago is no longer sufficient to handle the needs of most users. The dramatic decrease in price

of memory chips in the last 18 months has made the 64K² and even 256K machines less common, since the cost of expansion to the (present) limit of MS-DOS or PC-DOS (hereafter referred to simply as DOS) of 640K is extremely reasonable. With more memory came the need for more storage space, and most computers are now configured with at least two 360K floppy diskette³ drives. Today, hard disk drives, also known as fixed disks, are very common. They typically hold up to 30M⁴ of data and are about twenty times faster than floppies. Since added memory and storage are usually much less expensive than the cost of highly

²k is a symbol for the prefix kilo-, meaning 10³ or 1,000. In computer jargon, it is often written as K when there is no possibility of confusion with degrees Kelvin. Since computers are binary, the computer K actually denotes 2¹⁰ or 1,024. Unless otherwise specified, the product refers to a number of bytes, each consisting of 8 bits (binary digits--0s or 1s), and may also be written as kb, kB, or KB. A byte can be thought of as the amount of memory required to store one character of information.

³Floppy diskettes, also known as floppies or disks when no confusion can result, are the familiar 5.25-inch nonrigid disks used by most MS-DOS computers. When formatted under versions 2.0 and later of DOS, each disk contains a maximum of 2 sides of 40 tracks each of 9 sectors each of 512 bytes each, for a total of 360K (368,640 bytes) of storage. Some of the space is used by DOS for housekeeping, leaving 354K (362,496 bytes) of usable disk space.

⁴This is a symbol for the prefix mega-, denoting 10⁶. The computer M means 2²⁰ or 1,048,576 and is used in the same way as K.

optimized software, much of the newest software is being written with the assumption that the extra operating space will be present; indeed, many packages require it. Symphony, for example, requires at least a 320K system with two floppy drives or one floppy drive and a hard drive; the latter is recommended [17, p. 45].

Although technically considered an option, including a printer in the system is an absolute necessity in light of the established importance of word processing capabilities in the stand-alone system. On the other hand, the ability to communicate with other computers over standard transmission lines (including Autovon⁵) requires the presence of a modem and software to support it. The value to a laboratory of having instantaneous access to data from any other laboratory or from another computer must be carefully weighed. Since more and more military laboratorians are being trained in computer technology, and still more are already familiar with DOS systems, it is anticipated that there will be many programs written by local personnel. Programs written in this way are in the public

⁵Autovon is an acronym for the Automatic Voice Network, a system of telephone lines maintained by the DoD which connects most military telephones throughout the world and thus permits easy and relatively inexpensive global telephone communications.

domain of other government agencies and access to them would become important. Including a modem in the laboratory system, then, is strictly optional, but it would likely soon become sorely missed if foregone.

Several hardware options do little to alter the underlying abilities of the microcomputer system, but nevertheless may be great conveniences and serve to make human interfacing more effective. An example of such a convenience is the inclusion of a clock which keeps time continuously (even when the system is off or disconnected by use of a rechargeable battery) and automatically loads the proper time and date into DOS when the system is started, eliminating the need for manually entering this data every time. Another example is the selection of a screen display. Options include a monochrome adapter, a standard color graphics adapter (CGA), and an enhanced color graphics adapter (EGA), along with an appropriate monitor. At least one of the display options must be included, of course, but the one selected is largely left to the discretion of the users. Selection of the EGA system will offer the most utility in the future, though.

System Availability

In keeping with the premise upon which this paper is based, no piece of hardware or software which is not a current "off-the-shelf" product has been considered as an option. In this sense, availability refers to the likelihood of successfully obtaining the desired system and its options under the constraints of the military procurement system. It also refers to the likelihood of the procured system components operating properly in concert with one another.

A great step toward relatively easy access to microcomputer systems was taken with the letting of the previously mentioned standard requirements contract with Zenith Data Systems. Although justification is still required, many of the bureaucratic evaluation and approval processes previously associated with microcomputer purchases have already been accomplished and need not be repeated. It is conceivable that the purchase of such a system may now be no more involved than that of a new analytical laboratory instrument. With this in mind, it is all the more important to order the computer already outfitted with the desired options rather than having to justify individual

purchases of software, expansion boards, and peripheral equipment later on.

It is important to note that add-in hardware is available from many manufacturers and the equipment is necessarily different. Software packages, however, are written to run on particular types of hardware and may not support that of certain manufacturers. Although software developers make every effort to support the most popular types of hardware, there are a few names which are ubiquitously supported. Although a higher price is generally associated with these names, they have become industry standards and compatibility with the software packages the laboratory selects is virtually assured. Obvious examples of these standards are IBM for computers, Epson⁶ for printers, and Hayes⁷ for modems. Many companies emulate these standards and claim to be compatible, but extreme care should be exercised when considering such a purchase.

⁶Epson America, Inc., Torrance, California.

⁷Hayes Microcomputer Products, Inc., Norcross, Georgia.

Relative Cost

To compare the cost of a microcomputer with that of a large integrated laboratory information system, such as the CHCS, is neither fair nor useful. Obviously, the smaller system will cost a great deal less, but there is no intention of using it to replace the larger one. Although each system can likely mimic the other to some degree, the designs are intended to complement each other. It would make more sense to include the microcomputer systems in the total cost of the CHCS, but this will certainly not happen. Laboratories will be forced to deal with the cost of the small systems on their own.

A great deal of money can be saved by purchasing hardware clones, providing nothing is lost due to incompatibility problems as discussed previously. The advanced Zenith system, for example, at \$1,658 [1, p. 8] will be roughly one third the cost of a comparably equipped IBM system. In addition, the identical item is often available at a greatly reduced price from certain suppliers. To assume that the published list price of a piece of hardware or software is representative of the actual price is naive. WordStar Professional, for example, has a list price of \$495 [14, p. 96] but can be obtained for as lit-

tle as \$230 from some distributors and for \$130 from the standard requirements contract [1, p. 37]. A similar cost differential is usually associated with hardware as well.

System Utility

Although the idea of flexibility has already been mentioned as a key positive aspect of a stand-alone laboratory information system, it bears reiteration here as part of the justification. The avenues by which the laboratory staff can take advantage of an open system must be addressed.

Management Options

The management has total control of the microcomputer information system, within the confines of the Air Force regulations. Management is free to select and use the software and hardware which they feel will be most productive for the given laboratory and staff. Databases can be designed to in-house specifications and need contain only locally relevant information. Only if the data are intended to be shared need they conform to any previously

defined specifications, which can easily be set apart either through regulation or informal agreement.

The other advantage of total management control is the independence a stand-alone system offers. The system will not be tied up gathering data from instruments, unless these interfaces are deemed useful, and will hence be available for use when needed. Access to the system can be controlled by the laboratory management, including any prioritizing required. And the time may come when the laboratory management will be given sufficient authority over access and job authorization that the system can be utilized to its fullest.

Use of Local Computer Expertise

Although relatively few have been formally trained in computer operations, there can be no doubt that many laboratorians are familiar with computers. Because of the standard set by MS-DOS machines, many of these persons are particularly adept at handling IBM PCs and their compatibles. This fact alone represents a tremendous resource already available to laboratory management which remains untapped until the proper tools are available. Eventually, every Air Force laboratorian will become knowledge-

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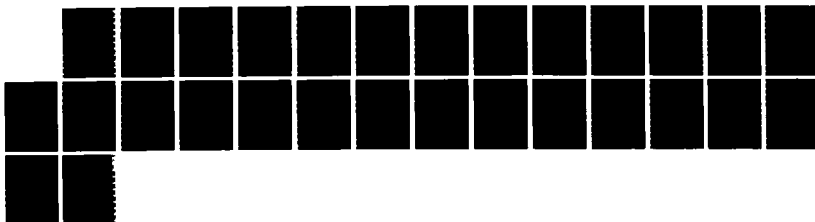
A STAND-ALONE INFORMATION SYSTEM FOR SMALL AIR FORCE
HOSPITAL LABORATORIES(U) AIR FORCE INST OF TECH
WRIGHT-PATTERSON AFB OH W P FITCH 1986
AFIT/CI/NR-86-158T

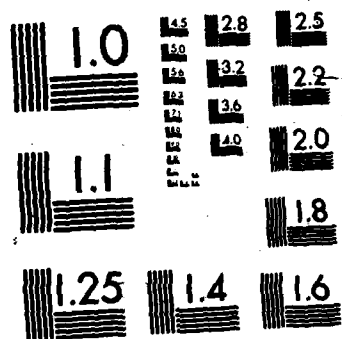
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able regarding the CHCS in whatever form it appears, but laboratorians' current abilities with standard systems will not represent a large asset when initially dealing with the uniqueness of the CHCS.

Acquisition Time

Off-the-shelf software and hardware have the advantage of already being available and to a great extent have already undergone much of the testing and practical usage which must follow the implementation of a newly designed system. As a result, the microcomputer and its associated software can be purchased and set up in the minimum time allowed by regulations, minimizing the likelihood of pre-purchase obsolescence.

Although laboratory computer support should have been a part of the Air Force years ago, the first such support available to most laboratories will be the CHCS. The installation of the CHCS may not take place until June of 1994 [16, p. G-12] for some hospitals, a date which current delays already threaten. The stand-alone system will then serve as an interim information system for these sites. Properly equipped, these microcomputers will also serve as terminals for limited access to CHCS systems in

supporting laboratories when the first CHCS systems become functional. With the current availability, there really exists no excuse for any Air Force laboratory not to have the support of this stand-alone information system within a few months.

CHAPTER VI

IMPLEMENTATION

Having completed the analysis of the stand-alone information system and addressed its design to the extent of exploring the available configurations, the physical effort involved in bringing the concept to fruition begins. Weinberg calls this effort the "implementation phase" [44, p. 11]. It deals with the plans and activities necessary to translate the design into a functioning unit. In Air Force terms, it means documenting the analysis and design of the proposed system as a justified request for purchase, followed by the requirements to turn the machine into the tool it was intended to be.

Acquisition

Because of the standard requirements contract discussed above, the actual purchase of the small computer is not much different from the purchase of a piece of laboratory equipment. However, the computer is much less likely to exceed the \$3,000 threshold which separates normal pur-

chases from investment equipment. Hence, the decision and money will be largely controlled in the local hospital; the microcomputer will have to compete against other equipment requests from all departments in the hospital.

The actual steps involved in acquiring the microcomputer system are outlined explicitly in AFR 700-26 [11, pp. 3, 5].

a. Identify a requirement for which automation may be appropriate. . . .

b. Confirm the operational validity of the requirement by having it approved at the appropriate level in the user's chain of command.

c. Contact the ISSO¹ for assistance in developing and processing the requirements document, (ISR², SON³, AF Form 601⁴) and identifying a potential technical solution. If the potential technical solution involves a small computer to process classified data (TEMPEST), special attention must be paid to security requirements and to developing or selecting a maintenance concept that protects the TEMPEST integrity of the small computer.

d. Along with the ISSO, process the requirements document through the ISRB⁵ and, when

¹"The local ISSO [Information System Staff Officer] is the base focal point for small computer user assistance. . ." [11, p. 10].

²Information Systems Requirements Document.

³Statement of Need.

⁴This is the standard requisition form for equipment.

⁵"All small computers will have a requirements document approved by an Information Systems Requirements Board (ISRB)" [11, p. 3].

appropriate, specify that a small computer is the preferred technical solution. . . .

e. After the requirements document is approved, begin the process of acquiring the small computer with assistance from the local ISSO. Note that standard small computers and software on standard requirements contract are requisitioned from the supply system. Software not on standard requirements contracts is acquired through normal contractual actions. . . .

f. Prepare for delivery by setting up the location, obtaining the required supplies, arranging for training, and making sure of compliance with appropriate security measures.

g. Enter the equipment into the supply inventory and automatic data processing equipment (ADPE) reporting system with the assistance of the local ISSO and the base supply Equipment Management Office.

Paragraphs a and c require some effort on the part of the laboratory manager. This paper has documented several needs common to laboratories in the Air Force, but has by no means addressed all the requirements of any given laboratory. Indeed, the individual manager may find local needs more acute than any discussed or speculated on here. Paragraphs b and d may require some diplomacy and well-directed persuasion. Whenever interpersonal relationships come into play, the experience of the individual laboratory representative becomes paramount in the success of the endeavor.

If the requirements document specifies the Z-248 as an appropriate computer, the system can be ordered directly through supply channels using AF Form 601 as in

paragraph e. This is the same form used for other relatively inexpensive laboratory equipment and is outwardly the easiest and most familiar route for a laboratory manager to follow. If for some reason (which obviously cannot be identified here) equipment or software not offered on the standard requirements contract is needed, other avenues must be explored. In general, however, such an undertaking appears not to be justified, assuming the Z-248 conforms to the contractual requirements.

Accomplishing these requirements documents the approval of the system and places it in the prioritized queue of requested hospital equipment. At this point, the manager's active and diplomatic participation in the Local Purchase Board⁶ will usually be required for the purchase of the system. Here again, the documents produced during a proper analysis are invaluable.

⁶Although it may be known by other titles, each hospital periodically convenes a board of representatives from the various departments of the hospital to prioritize the approved equipment requests for purchase. Medical urgency, rank of representatives, individual enthusiasm, and political manipulation all play a part in these sessions. For all his efforts, the laboratory representative will likely not be successful in establishing a stand-alone laboratory information system if the available dollar amount will not cover the computer and the equipment preceding it in the queue.

Assuming that funds are allocated for the purchase of the system, site preparation can begin per paragraph f. All the previously discussed considerations for environment, security, and intended interfacing with humans and with instruments must now be put into operation. Having the site ready for installation will make the transition much easier and faster. Delivery speed will also be enhanced by careful monitoring of the requisition as it travels through supply channels. If each of several agencies takes the maximum time allowed to process the requisition, much time will be lost.

AFR 700-26 makes it clear that the responsibility for the small computer system lies with the user [11, p. 3-4]. He must provide for its requisition, receipt, setup, testing, training, use, and maintenance. As a result, the laboratory manager will be in charge of the installation of the newly arrived system with the assistance of the ISSO. If laboratory instruments are to be interfaced with it, technical representatives from the vendors may have to be contacted. In addition, various requirements regarding labeling of the equipment, entry into identification logs, and assignment of a serial number must be satisfied [11, p. 5].

Testing

The laboratory staff is also responsible for testing the newly arrived hardware and software. One might be led to assume that since no specific requirement and little guidance is given on this subject that it is relatively unimportant. Burch comments on this fallacy [4, p. 513].

Testing the newly developed or modified system is one of the most important activities in the systems development methodology. It is an implementation activity that, similar to training personnel, requires careful planning and application. The goal of testing is to verify the logical and physical operation of all design blocks to determine that they operate as intended. Often, testing is given lip service, or is abridged as cost overruns occur or schedules slip. Inevitably, failure to test adequately leads to problems with the systems operation.

Indeed, AFR 700-26 mentions testing only in passing, stating that "the equipment should be used extensively prior to warranty expiration to make sure it is in proper operating condition" [11, p. 5].

Since only off-the-shelf hardware and software are espoused here, it is logical to believe that all of it has undergone some degree of aggressive testing already, both during development and through actual use in the field. In this regard, there is little the laboratory manager can do to check the system other than running various diagnos-

tic programs and noting obvious damage. However, any data or software developed by the laboratory must be checked appropriately according to its importance to the user.

Personnel Training

The laboratory will also be individually responsible for any system training necessary, although the help of the ISSO can be enlisted [11, p. 3]. The tendency in such a situation is to evolve into a predicament as described by Riccabona [34, p. MC55-300-101].

In the past, microcomputer training had been approached on a purely informal basis. Users would teach themselves using the documentation which accompanied the hardware or software. Since microcomputer users were typically knowledgeable hobbyists, or a least enthusiastic about becoming knowledgeable, the standard user's guide proved to be sufficient.

Assuming all of the laboratory staff to possess the enthusiasm of a hobbyist is likely to result in the creation of a faction in the laboratory which shuns the computer altogether. The manager's goal, then, is not only to teach the staff how to use the system, but also to stimulate a desire to want to understand and use it.

Burch maintains that "the first step in determining training requirements and training approaches is to com-

pile a list of all the tasks required by the new system and the skills needed to perform them" [4, p. 511]. Obviously, the overall purpose of the information system will have a bearing here. If the system is interfaced with instrumentation and is the heart of the data management system in the laboratory, every staff member must be familiar with its operation. On the other hand, if the system is provided as a more efficient alternative to other acceptable methods, such as word processing, more latitude can be granted. Still, laboratory management will want to encourage more efficiency. The list of skills will be most easily managed by appending them to in-house on-the-job training records and to the indoctrination protocol for newly arrived personnel.

The initial training forum should be at the laboratory training sessions which are required to be held regularly. This can begin long before the arrival of the computer, in much the same way as the staff discusses in advance the need for and use of a new laboratory instrument. Many unpleasant surprises can be avoided in this way.

Upon arrival of the equipment, hands-on training schedules can begin. One of the advantages of a stand-alone system is its independence. Within reasonable limitations, the user is free to experiment without worry of

causing significant damage. Tutorials provide an enjoyable atmosphere for learning, and the framers of the Zenith contract wisely mandated that these be provided [1, pp. 85-87].

The contractor shall provide technical services and materials to train Government personnel. Contractor must provide a Computer Assisted Instruction (CAI) package. . . . CAI courses must be delivered on 5.25-inch floppy disks, interactive, and user friendly. Each course must be supplied with the normal commercial documentation. Students taking these courses will be functional users with little or no computer expertise.

The costs for the courses mentioned are very reasonable and their successful completion by each staff member provides a convenient documentation method for training records. In addition, the initial heavy use of the computer system effected by the mandatory completion of the tutorials provides an excellent testing medium for the new system.

Conversion from Current Methods

Although relatively few medical technologists or technicians have any fear or anxiety associated with computers or automation, many exhibit a definite resistance to change. Encouraging the use of the new system instead

of older routines with which the staff members have become comfortable may present a unique challenge to the laboratory management. It is important to initiate the change to the new system by having a workable conversion plan before the new system is installed. The success of the conversion will have a major bearing on the credibility of the system and the impression it leaves with the laboratory staff.

There are various ways to approach change from one system to another, each with advantages and disadvantages and each being better suited to some situations than others. Four basic conversion methods are outlined by Burch [4, pp. 522-524].

1. Direct Conversion. A direct conversion is the implementation of the new system and the immediate discontinuance of the old system, sometimes called the "cold turkey" approach. . . .
2. Parallel Conversion. Parallel conversion is an approach wherein both the old and the new system operate simultaneously for some period of time. . . .
3. Modular Conversion. Modular conversion, sometimes termed the "pilot approach," refers to the implementation of a system into the organization on a piecemeal basis. . . .
4. Phase-in Conversion. The phase-in approach is similar to the modular approach. This approach differs, however, in that the system itself is segmented, and not the organization.

Of these approaches, direct conversion is most likely to fail and neither modular nor phase-in conversion fit well

in a single-laboratory setting. Parallel conversion is the best candidate since it conforms to other conversion processes with which the laboratory is already familiar, such as conversion to a new lot of reference standards.⁷ Indeed, documentation of the temporary duplication of effort serves to test the system in the same way that the output of a new laboratory instrument must be reconciled with the previous results. It also offers the staff the opportunity of seeing the advantages of the computer system over the previous methods.

Because the user, in this case the laboratory manager, has the primary responsibility for implementing a small computer system in the Air Force setting, all of the associated activities are his to perform. He may or may not have the assistance of an individual experienced in setting up small laboratory systems. With this in mind, Burch emphasizes the importance of parallel conversion [4, p. 523].

. . . Conversion projects are often burdened with additional tasks of training, testing, procedure and documentation rewrites, file

⁷When a new lot of reference material is received, it is repeatedly tested as a sample using the old lot as the reference. By documenting that the tested values of the new lot correspond to their stated values based on the old lot, continuity of the testing environment from one lot to the next is shown. This is known as parallel testing.

changes, attempts at retrofitting controls, and major computer configuration adjustments. If this is the case, then parallel conversion is really the only sensible approach to use.

Maintenance

As with any other laboratory instrument, the stand-alone information system must be maintained in conformance with established standards. Documentation of this maintenance must satisfy the requirements of the Air Force as well as those of the agencies granting accreditation to the laboratory.

Air Force maintenance requirements are relatively simple but not yet completely standard. Essentially, "maintenance concepts" are developed at the MAJCOM level. Local ISSOs develop procedures to implement the concepts and monitor the users' compliance with the procedures [11, p. 6]. Special considerations are given to computers handling classified data. The thrust of these procedures is obtaining service when the system is down.

Whether the laboratory purchases a maintenance contract for the system must be decided based on the reliance of the laboratory on the computer or software, the cost, and the availability of repairs locally. The Zenith con-

tract allows purchasers of these systems to obtain repair service in any of three ways and the cost for each is very reasonable. Typically, a postwarranty maintenance contract for a laboratory instrument costs 10 to 20 percent of the purchase price annually. Under the Zenith contract, on-site service costs \$135.00 for the advanced system with a purchase price of \$1658.00, or about 8 percent. Mail-in service for the same system costs \$44.00; the user can also maintain the system himself using spare parts and telephone assistance [1, pp. 8, 83-84, 87-88].

In addition to repair procedures, the laboratory maintenance procedure should include all recommended maintenance in the operations and technical reference manuals as well as the rules of common sense discussed in Chapter Four. Instructions for performing and documenting periodic activities, such as running the diagnostic programs, routine cleaning, and creating backups, must be included. The laboratory environment may necessitate certain preventive maintenance activities be performed more frequently than the minimum recommended in the references. Also, the amount of use the system sustains will be a factor; unnecessary cleaning of the read/write heads of a floppy disk drive, for example, can be as damaging as running them dirty.

Software and data maintenance also includes many common-sense activities. Foremost among these activities is to establish and hold to a rigorous backup program. Original program disks should never be used for routine operations. The specifications for the Zenith contract require an unlimited number of identical copies of the original software may be produced and that the copies operate "in the same environment and independent of the originally supplied materials" [1, p. 61]. This obvious advantage may not be available if software is procured from other sources, however. Also, procedures must be established to assure that users understand and adhere to the proper handling and storage of diskettes.

CHAPTER VII

CONCLUDING REMARKS

Conclusions

In the course of this study, several of the author's previous impressions have been substantiated. The concept of the military providing computerized hospital information systems on a worldwide basis in and of itself is highly laudable and more than worthy of continued pursuit. However, past efforts have indeed been directed too much at development and not enough at usefulness. Time and money have been wasted for various reasons, not all of which can be attributed to DoD faults. Lack of Congressional support, crossed purposes, too much or too little leadership, and a lack of involvement of the end users have all contributed to inadequate analysis and implementation. The resulting, embarrassing travesty is that after twenty years and billions of dollars, only a tiny percentage of military laboratorians have any computer support at all in their work today. Furthermore, the little support that is available is incomplete and inflexible.

Fortunately, these shortcomings have not been entirely without benefits and some very positive attitudes toward potential systems have been developed by the author. TRILAB is the result of some of the lessons learned in the past and, with some exceptions, functions well. The VADHCP is also a good system, despite its unorthodox development. The fact that it may satisfy the FDs for the CHCS speaks very highly of the system. Although the CHCS still exists only on paper, it is impressive. Perceived or actual weaknesses of previous systems appear to have been specifically addressed. The author is genuinely excited and looks forward to its implementation.

But, no current or foreseeable integrated package can anticipate all the needs of every laboratory it is intended to support. That day may come. Until then, the individual laboratory, with its own technologists and technicians, must deal with the unusual or unsupported situations as best it can. It is here that the intelligence of the end user becomes the most valuable resource in the Air Force. To contend with these situations requires that the person be in control and be able to wield the tools given him in the way he reasons to be most advantageous.

After all the research associated with this paper, the author is more convinced than ever that stand-alone information systems based on standard microcomputers is an absolutely indispensable tool for the laboratorian. It cannot and should not replace the large integrated system represented by the CHCS. Laboratory support is only a small part of the CHCS; the stand-alone system is to be totally dedicated to the laboratory. Nevertheless, until the CHCS is in place, the stand-alone system is capable of handling most of the laboratory functions of the CHCS.

Based on this research, it is concluded that the laboratory is best served by adhering to the standard requirements and obtaining the advanced computer system as described in the standard requirements contract. This paper has shown that such a system is capable of operating efficiently in a medical laboratory environment and of filling many of the voids left by the current and proposed integrated systems. It should be augmented with whatever hardware and software is deemed appropriate, using knowledge of local needs, solicited expert laboratory advice, and this paper as guidelines. These augmentations include support for word processing, cost analysis, research, instruction, and many other applications which the users can derive as needed. The system can be obtained, imple-

mented, and maintained in much the same way as other laboratory equipment and for a very reasonable price, which can easily be justified based on time savings alone.

Recommendations for Further Research

As further enhancements are considered for the CHCS or any future system, methods by which the user can access the capabilities of the system should be developed. This should go well beyond the current attempts at flexibility such as customized report generation. Using an operating system which supports the virtual machine concept, for example, would allow access to the "machine" and selected data without affecting any other operations.

Finally, the needs, ideas, and suggestions of the laboratorians must be ascertained. To involve every one of them in the complete analysis process is impossible, but surveys can be conducted at various points in the process. Beginning with the evaluations of the CHCS upon its initial installation, comments from its new users should be solicited, compiled, and studied. The insight so gained will not only supply information which will be valuable in a future analysis, but will identify individuals who have previously unknown computer expertise. The

pool of Pathologists, Medical Technologists, and Clinical Laboratory Technicians constitutes the greatest clinical pathology database available to the Air Force, and must no longer remain untapped.

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