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PREFACE

This report is the product of a committee convened in May 1980 by the National Research Council, at the request of the Secretary of the Air Force, to review Air Force plans for modernizing its Base Level Automation System. At the time of the Secretary's request, a plan for modernizing existing computer systems--called the Phase IV Program--was being reviewed by Congress, the General Accounting Office (GAO), and the General Services Administration (GSA). Appendix A of this report is a brief historical review of protracted Air Force efforts to modernize its base level automation system.

In response to the Secretary's request, the National Research Council established the Committee on Modernization of the U.S. Air Force Base Level Automation System. While the committee was being organized, the Air Force reached agreement with the federal review agencies on a redirection of the Phase IV Program, the plan that is now being implemented. Accordingly, the committee shifted its emphasis to the longer range aspects of Air Force base level automation planning.

The committee comprised members with expertise in a variety of complementary areas related to the planning, development, and operation of large, complex information systems. The members' backgrounds embraced such fields as information system planning and development, software technology, computer network design, information system management and operation, and system privacy and security.

The committee's review involved extensive briefings at Air Force headquarters in Washington, D.C., as well as during visits to representative Air Force bases. These included the Tactical Air Command headquarters at Langley Air Force Base, Virginia; the Air Training Command headquarters at Randolph Air Force Base, San Antonio, Texas (where committee members were briefed on the San Antonio Data Services Center and the Air Force Manpower and Personnel Center); and the Air Force Data Systems Design Center at Montgomery, Alabama.

The committee met as a group seven times for briefings and discussion. Between meetings, members reviewed materials, conducted interviews, and prepared report drafts as their full time responsibilities permitted. The combination of presentations, field visits, discussions, and background material gave the committee an insight into the Air Force planning effort and an understanding of the role of automated data processing in support of Air Force activities.

From this insight and understanding, the committee developed the judgments that are the subject of this report.

Several members requested assistance in the study from colleagues in their professional or business organizations. The committee is grateful, therefore, for the strong support that it received from John B. Campbell of the MITRE Corporation and William J. Hawkins of United Information Systems, Inc.

We have enjoyed the fullest cooperation and support, from then Air Force Secretary Mark in 1980 and from other Air Force officials, from the secretary's office to those at the Headquarters and in the field. In particular we appreciate the strong support that we received from Brigadier General Avon C. James, Director of Computer Resources, Headquarters, USAF, and his staff.

This committee, like others in the NRC whose members serve part time and without compensation, must depend heavily on its professional staff. In this regard, we are particularly grateful to R. V. Mrozinski and R. B. Marsten for their sustained support of our work.

A major committee effort like this imposes a heavy burden on its secretary. It is a pleasure to acknowledge the assistance of Linda E. Jones, who cheerfully typed what must have seemed endless report drafts and carried out other essential administrative activities.

Finally, as the committee's chairman, I want to express my sincere thanks to its members for their dedicated efforts.

Brockway McMillan

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Chapter 1

INTRODUCTION, CONCLUSIONS, AND RECOMMENDATIONS

INTRODUCTION

The Air Force today operates a system of 267 medium-size computers, collectively known as the Base Level Automation System, at 115 air bases throughout the world. At most bases, these computers operate 20 or 21 shifts per week. The bulk of the processing is done in the batch mode. This system evolved in the 1960s from earlier systems developed within individual Air Force commands to support management at each base. They processed data for such offices as Supply, Maintenance, Personnel, Accounting, and Finance. Today, the Base Level Automation System (as it will be referred to here) also provides data processing services for many other offices and users at these bases.

The computers in the Base Level Automation System come from two different manufacturers. They represent hardware designs nearly 20 years old. The Air Force has embarked on a program to replace them with machines of modern design. The replacement program, for historical reasons, is known as Phase IV. Phase IV has the following important features:

- Replacement of the present computers from one vendor, yet to be chosen.
  - Some 105 bases will have their own installations; the ten others will be served remotely.
  - Different bases will have installations of different sizes but with a standard architecture, depending on the expected load. All installations will be expandable with compatible equipment.
- Immediate transfer of major elements of the present software to the new machines.
  - The transferred software, as seen by the user, will emulate the operation of the present system.
  - Over the longer term, the services of the Base Level Automation System will be expanded and modernized, and new software will be written as required.

- Installation of the new equipment and rewritten software from 1983 to 1985.
- A competitive procurement (now in progress).
  - Two vendors have been selected to propose specific equipment configurations.
  - Each vendor and subcontractor team will write software for a representative sample, chosen by the Air Force, of functions now carried out by the Base Level Automation System.
  - The two vendors will run their software, on a standard configuration of their proposed equipment, with a series of tasks designed by the Air Force. Based on specified performance criteria and cost, a winning vendor will be selected.
- A 20-year planning horizon based on delegation of procurement authority from the U.S. General Services Administration (GSA) for the resulting system, with specific decision points, agreed to between the Air Force and the GSA, at which hardware compatible with the system then in being can be procured.

The committee has focused its attention on the following:

- Phase IV as a basis for modernizing and expanding services provided by the Base Level Automation System over the long run.
- Shorter term problems the Air Force may encounter in the transition to Phase IV and in later modernization.
- Basic technical and economic factors that bear on the future evolution of computer-based systems.
- Problems that the Air Force may encounter in taking advantage of modern computers and automation.

GENERAL CONCLUSIONS

Four principal themes run through the committee's conclusions and recommendations. These themes are so fundamental that they merit independent statements as separate conclusions.

Change Is Inevitable

Computer and communications hardware and techniques are evolving rapidly. Even since the present base level automation program was adopted, dramatic changes have occurred in the economic factors that affect the design and architecture of data processing and computer/communications systems. They also affect the extent to which these systems can economically replace labor and improve management. This rapid evolution will continue in the future.

Phase IV Is a Good Beginning

In Phase IV's capital replacement program and in the overall plan (of which Phase IV is a part) for modernizing the Base Level Automation System, the Air Force is establishing a sound basis for taking advantage of the improved economies and services that technical evolution will continue to make possible.

Progress Is Not Automatic

Even given Phase IV, full advantage of new techniques and new technology will not accrue automatically to the Base Level Automation System. New equipment will lower costs, operate faster, and improve maintenance to extents that by themselves would justify the program. However, other major gains are possible. To enjoy them, the Air Force must be alert to new possibilities, plan for their evolutionary attainment, and exert expert leadership and managerial control to bring them about. Without a cogent plan and clear leadership, data automation at the base level can fail to realize the capabilities and economies potentially available, and could become a hodgepodge of isolated functions.

It Is Later Than You Think

Minicomputers and microcomputers of impressive power are commercially available. Potential users in the Air Force see, clearly and correctly, that such equipment will improve the effectiveness and economy of Air Force operations. If Phase IV takes too long to achieve its potential effectiveness and economy, a now-latent potential for service to base level offices will be met by minicomputer- and microprocessor-based systems and therefore will be lost to the Base Level Automation System. The cost to the Air Force will be in the proliferation of isolated installations, individually useful but collectively less efficient than a well-planned and integrated system.

SPECIFIC CONCLUSIONS

1. Modernizing the computers of the present Base Level Automation System is essential.

- Maintaining the current obsolete hardware is already burdensome and will become more so.
- More importantly, the current computers can neither support the needed increase in capacity nor provide the improved service and economy that is possible with more modern equipment.

2. The Air Force has made a sound decision in treating the Phase IV procurement as a capital replacement program.

- This approach will hasten a much-needed modernization.
- Risks are reduced, since the complexities of procedural changes and of modifications to software are minimized during conversion to new hardware.
- Conversion will be speeded up and the costs of operating two systems during the transition will be reduced.

3. Phase IV allows the Air Force the flexibility to take advantage of future opportunities for improved service and economy. Phase IV should be regarded as a vehicle for maintaining the information system at the leading edge of technology and for offering greatly improved and better integrated services to Air Force management at each base.

- After three decades, data processing hardware continues to evolve rapidly in capability and economy.
- The architecture of computer systems and the resulting service to users are evolving to take advantage of advances in hardware and software.

4. The hardware (computers and peripheral gear) that will be available in Phase IV, from either potential vendor, can meet the Air Force's forecasts of future demand. It can also provide a basis for new, improved, and more efficient services to present and potential users. It can even permit expansion, if needed, to meet much greater demand than is now forecast by the Air Force (see below.)

5. The Phase IV capital replacement will, in itself, modernize only equipment, not services.

- The present base level system uses manpower inefficiently, places unnecessary demands on users, and lacks the capacity to meet latent demands from new users.
- Adapting the present software to new hardware will provide more reliable service and more capacity, but may not improve the use of manpower or the system's simplicity as seen by its users.

6. Modern hardware provides opportunities for expanded services to users of the Base Level Automation System in ways that will improve the efficiency of their own manpower. Improvements will not come automatically, but will depend on the development of the necessary software. Planning will be required both for that development and for the necessary terminals and communications.

- Savings in manpower and increased overall productivity can result, for example, from eliminating punched cards as a medium for input, output, and transfer of data.

- "Intelligent terminals" available today, when supported by appropriate software, make it easy for an almost untrained operator to enter data in the proper format or to frame a query and understand a computer's response.

7. The Air Force has underestimated the future demand for services from the Base Level Automation System by underestimating the degree to which modern hardware, software, and systems architecture will make new applications economically attractive. Fortunately, under the Phase IV program, the Air Force has the flexibility to increase the capacity and the range of functions of its computers, if needed, and to acquire new equipment to meet rising demand (conclusions 3 and 4).

- Present users will find it economical to increase the scope of the data processing operations they assign to the Base Level Automation System.
- New users will turn to the Base Level Automation System for functions not previously automated because of greater efficiency or improvements in their own operations that will result.

8. The key to new, expanded, and improved services is software. The planning, development, and acquisition of new software will probably limit the rate at which the Base Level Automation System can be modernized to accommodate new users.

- This has been the experience in almost all automated data processing systems.
- The quality of system-design and programming personnel will become critical, as will the productivity of programmers.
- Industry broadly has developed techniques, supporting facilities, and software to improve programmer productivity. The Air Force should take advantage of these aids.
- Under appropriate guidance and standards, and with good tools and assistance, users of the Base Level Automation System can share the burden of expanding and modernizing its services.

9. The technical boundaries between data processing and communications are becoming blurred, and thus comparative costs are changing.

- Now, with microprocessor applications and other developments, data processing costs are decreasing faster than those of data transmission.
- The amount of data processing at sources, nodes, and terminals can be economically increased to reduce the bandwidths of, or the loads on, communications links.
- These considerations affect both the structure of the automatic data processing system within an air base and communications among bases.

10. Communications requirements should be identified and planned for now. Economy, service, and flexibility will require economically sound communications, both within and among bases, when each new equipment, service, or feature goes on line. The Air Force should pay considerably more attention to communications within its Base Level Automation System.

11. The Committee considers it possible that, when the final quotations are available from the vendors competing for Phase IV, the Air Force may find that even the limited extent to which the current Phase IV plan centralizes computation and serves some bases remotely ("regionalization") is too great.

- Economies can result from dispersed operations because computers are now available in a range of sizes and can be selected to serve the specific needs of a base economically.
- When costs of centralized and more distributed systems are nearly equal, the ability of a distributed system to operate at each base autonomously, if necessary, offers significant flexibility against natural disaster, sabotage, or military action.
- Before a final decision is made to operate Phase IV regional centers, the Air Force should examine its pros and cons carefully, including costs. Thus, if regionalization is not economically justified, the implementation plan should be modified accordingly.

12. Large, central data processors or complexes of specialized processors, linked to many and varied terminals at a base, will remain important in providing economical data processing. However, not all data processing needs are necessarily best served in this way. The Air Force will likely find it economical to serve some users or functions with remote or dedicated processors tied only loosely, if at all, to the main network.

- Automated data processing seeks to help users do their jobs economically and effectively. The task of the data automation community is to see that this in fact takes place.
- The overall economy and effectiveness of the Air Force is the matter at issue, not the integrity or uniqueness of a particular network of computers.

13. The Air Force may want to implement certain functional capabilities at particular bases on small, stand-alone computer systems. For such capabilities, information flow must be analyzed to identify all interfaces to be accommodated.

- Technology itself is not the paramount problem, even though there are technical aspects of data exchange among computer subsystems. The paramount problem is understanding how information is used at different hierarchical levels in the system and the details of the information flows among those levels.

- Information flow for stand-alone applications common to a number of bases should be handled uniformly at all such bases. The Air Force should maintain some level of overall control to prevent proliferation of stand-alone systems and different versions of common applications.

14. To control the proliferation of small systems, the Air Force Data Systems Design Center (AFDSDC) could design prototypes, for widespread use at all appropriate bases, from small-systems designs developed by local users.

- This technique will require leadership from the AFDSDC.
- A particular base could be designated as a "prototype environment" base to illustrate how such prototype designs could be applied in normal base operations.
- The "prototype environment" base could also illustrate how evolutionary changes to Phase IV systems are applied in normal base operations.

15. The Air Force should regard the Base Level Automation System, coupled with its supporting agencies, as a single entity that includes the Air Force Data Systems Design Center, other software development activities, and the data processing installations at air bases. Together, they should supply broader services than are now typical.

- These include services now being supplied (i.e., machines, including their operation and maintenance, and the writing of software for Air Force standard data systems).
- The primary service, however, is to assist users in acquiring the data processing support that best meets their needs and those of the Air Force. Some, or even most, of this data processing may be done most efficiently on specialized or dedicated equipment. In addition, the Base Level Automation System's users should contribute to its planning.
- The Air Force Data Systems Design Center and the data processing installations can provide the following services:

  - Help users define their needs, evaluate alternatives, develop specific requirements for facilities and software, and deal with vendors.
  - Promulgate standards for hardware, software, and interfaces. Without such standards confusion will reign and the Air Force's needs will not be served economically.
  - Train users in the use of tools for application software development.

- Make such tools available to users. Good, easily available tools will improve efficiency and economy, and promote compliance with standards.
- Direct assistance in developing needed software. Such assistance will attract users with only small professional staffs.

16. The Air Force needs to continue its broad and basic technical planning for the evolution of the Base Level Automation System and its supporting communications.

- The Air Force is already committed to defining the future functions of the Base Level Automation System.
- As data processing and communications merge, in both technology and requirements, the Air Force will have to consider the communications needs of the Base Level Automation System jointly with its other aspects. Such considerations cut across organizational lines at local levels, but fortunately not at the level of the Air Force Communications Command to which the Air Force Data Systems Design Center reports.
- Many users of the Base Level Automation System are linked by interests in common sets of data. Techniques and systems for handling large data bases are evolving. The planning of data base requirements must begin from these technical facts and from a functional analysis of user needs.
- Standards of software languages and interfaces will significantly affect future decisions. Such standards should derive from adequate planning for the system's growth.

17. The Air Force should reexamine functions assigned to the base-level systems in peacetime to determine how critical they will be during wartime. From the hundreds of functions performed, it is essential to identify those that are vital to the Air Force's wartime mission.

- The Phase IV system is primarily a peacetime system. Most material presented to the Committee concerned peacetime operations. It was clear to the Committee that the Air Force has not yet devoted as much attention to how the system would or should operate in the event of a war as to the peacetime aspects of Phase IV.
- Vital wartime functions must be strengthened or given backup equipment to ensure that they can continue to operate after an attack.

18. With forethought and continued good planning, the Air Force can avoid the trauma of another major capital replacement program like Phase IV. The Base Level Automation System can grow by evolution.

- Hardware is increasing in modularity and in the range of sizes and capacities available in software-compatible lines.
- Specialized systems for basic functions (e.g., data base handling) are becoming available. These can relieve general equipment of certain specialized tasks, making it possible to increase capacity and improve performance without major changes in software, in procedures, or in other parts of the system.

19. The Air Force needs to become better prepared to compete for trained data processing personnel.

- There are no realistic, accepted, and uniformly applied manpower standards* for Air Force data processing personnel.
- Compared to the current situation in private industry (which is by no means ideal) the Air Force is dramatically short of experienced people, especially in software development.
- The re-enlistment rate of military personnel trained in data processing specialties is below that in most other specialties.
- Re-enlistment incentives are not adequate in the Electronic Computer and Crypto Equipment Systems Specialist career field. Incentives in other enlisted data processing fields need a specific review relative to competing requirements for selective re-enlistment bonuses.
- The experience level of officers in data processing is critically low and dropping. In fiscal year 1980, 48 percent of the data processing officers were lieutenants, compared to 28 percent of Air Force officers as a whole.
- Junior officer retention in data processing is critical. The loss rate of captains in data processing is 50 percent higher than the Air Force average.
- Key civilian positions experience a greater vacancy rate than similar military positions. Lack of a centralized recruiting, training, and assignment function may be a contributor to this, along with the great need for experienced civilian data processing personnel in other federal agencies.

SUMMARY OF RECOMMENDATIONS

Most of the committee's recommendations are general in nature and are already almost explicit in the conclusions as they have been

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*"Manpower standard" is the Air Force term for fitting the size of an organization to the job to be done.

stated. They are repeated here for emphasis. Since they generally depend on arguments scattered throughout the text, several are not repeated in the text itself.

1. Expedite Phase IV--get the equipment on line and providing service as soon as possible.

2. Plan and build for the future.

- Plan for growth in load that may well exceed present estimates.
- Modernize present services and their software where economically justified.
- Encourage automation of processes presently carried out manually.
- Plan for new functional applications and for services not now in the system, wherever economically justifiable.
- Keep abreast of new developments in hardware and software, in machines and techniques for data base management, and in networking technology.
- Address modernized and new services as part of an integrated plan of growth.
- Provide facilities and techniques for improving the productivity of programmers.
- Enlist the aid of users in developing the services they need.
- At all times, keep in mind the final objective: service that improves the Air Force's effectiveness and economy.
- Be alert to the proliferation of microprocessors that may impose additional load on or interfaces with the presently planned Phase IV equipment.

3. Grow and keep modern by evolutionary processes to avoid another major capital replacement. In addition to maintaining technical and managerial modernity, the Air Force should adjust its procurement and decision making processes to accommodate the rapid evolution of data processing and computer/communications technologies. GSA cooperation is essential to the success of such adjustment.

4. Provide aggressive leadership from the Air Force Data Systems Design Center, as the designated manager of the Base Level Automation Program, for the coordination of all base level computing activities. The Center, the data processing installations at each base, and the Base Level Automation Program itself should provide users with a full range of data processing services, including the following:

- Data services and programming.
- Guidance to users in determining the best way to meet their needs.
- Guidance to users who elect to meet their needs with microprocessor systems that stand alone.

- Standards.
- Facilities and tools for program development, and training in their use.
- Prototype designs for widespread use at all appropriate bases.

5. Evolve toward a system in which users can operate terminals on their own premises without being specially trained in their operation.

6. Eliminate manual transcription and entry of data wherever automated data recording (e.g., of engine hours and temperatures) can be made available.

7. Equip the Air Force Data Systems Design Center with modern tools and facilities for software development.

- The Center should prepare guidance and training materials for users, so that they can avail themselves of similar aids.
- In the end, users should have access to the same kinds of facilities as those used by the Center.

8. Initiate a comprehensive program to build quality and experience into the Air Force data automation community.

- Develop and implement quantitative manpower standards (see footnote, p. 9).
- Establish standards of quality for data processing personnel.
- Establish as an objective some reasonable limit on the number of enlisted personnel with less than four years of data automation experience.
- Place priority on retaining experienced junior officers and enlisted personnel.
- Centralize the direction of recruiting and training of civilian data processing personnel.

9. Address more aggressively the problem of data processing needs during wartime.

- Determine the essential needs of units deployed in combat.
- Examine the changes in load that will be placed on the Phase IV system in wartime.
- Determine the need for backup equipment and data bases to maintain continuity of essential functions.

Chapter 2

THE PHASE IV CAPITAL REPLACEMENT PROGRAM

The Air Force has decided to treat Phase IV procurement as a capital replacement program. The Committee supports that decision completely. The program properly emphasizes the much-needed modernization of the data processing equipment used to provide base level services. The Air Force's current equipment is aging, obsolescent, and more than a decade behind that used to provide comparable services to industry. Its continued use would increase the already high costs for programming, operation, and maintenance, and would not permit the expansion of capacity and capabilities needed for improved services.

The committee's support of the Air Force's present emphasis on hardware replacement, implying a corresponding postponement of software redesign, is an expression of realism rather than enthusiasm. The complexities and delays inherent in the procurement of data processing equipment by the U.S. government are well known. In a project the size of Phase IV, adding the complication of software change would have thrown additional obstacles in the path of the long overdue modernization effort.

However, as will become clear, the full potential of the new equipment lies in its ability to provide information services in ways very different from the present software-hardware combination. Once the Air Force has adapted its current software to the new equipment, it can use the latter to provide many new services that are not now economic.

An important conclusion of the committee should be recorded: because of trends in technology, the Air Force will probably be able to make future capital improvements by incremental rather than wholesale investments. The equipment proposed by either of the current Phase IV contractors will be compatible with evolutionary growth and change. By following such an evolutionary pattern, the Air Force's information services at the base level can benefit from continuing decreases in hardware costs, as have information services in industry.

Thus, the economic forces that have in the past dictated high-cost, centralized approaches to computing will no longer exist. Processors with the capacity and power of the medium-sized systems now in use at Air Force bases can even now be built on just a few silicon chips.

When this revolution has finally run its course, it will be possible to create functionally distributed processing systems of great power and low cost. Because of their modular character, the Phase IV systems will probably never need to be totally replaced. The Air Force should aim to avoid another complete capital replacement, especially in view of the difficulties of the past decade (see Appendix A).

ADEQUACY OF THE PROPOSED EQUIPMENT CONFIGURATIONS

The family of computing equipment proposed by each of the potential contractors in Phase IV meets the Air Force's needs. Each offers substantial modularity of function and a range of options for processing, input-output control, and storage. It should be possible to select with much greater precision than before the exact amount of processing power required at a given installation. It should also be possible to expand the systems into substantial aggregations of processing and filing power capable of handling many times the presently anticipated load. Data communications interfaces appear reasonably straightforward. This is an important prerequisite to developing an effective network or system of distributed functions. Many issues involving standardization of communications protocols will, of course, have to be addressed as the system develops.

It is fortunate that modern computer systems have a wide range of processing options because the Air Force may have underestimated the potential future need for computer services. The forecasts shown to the committee seem to project a computing load growing roughly linearly with time. Industry, however, has experienced more nearly exponential growth, though without the artificial constraints characteristic of the Air Force's older base level systems. When Phase IV's more flexible, capable, and economical systems are introduced, new applications will become not only possible but also economically justified through superior service to users. Therefore, the committee believes that demand will be substantially heavier than forecast by straight-line methods.

Phase IV will share resources wherever justified to cut costs. Some bases will use computing services provided by data processing installations located at regional centers, thus reducing duplication of equipment, facilities, and personnel. These savings will be offset by added communications costs. Whether regionalization can reduce overall costs will depend on the specific costs of people, computers, and communications. However, the economics that have justified regionalization in the past are becoming less valid with time. In earlier generation computers, the high costs of central processors and high-speed memories dictated centralizing of computing resources. With new technology, processors and high-speed memories cost much less. This allows processing to be performed where data files are logically maintained. Lower cost of high-speed memories allows more sophisticated operating systems to be used, even by smaller processors. Software systems that rely less on batch processing techniques will reduce manpower requirements. The Air Force should analyze costs and their trends to determine how much regionalization to adopt under Phase IV.

THE PHASE IV PROGRAM BEYOND TRANSITION

The Phase IV program management should be able to deliver operational sets of the transition software on both competing systems. It should also be able to convert the remaining software expeditiously, using a variety of automated tools. When the transition is complete, the Air Force will have acquired contemporary equipment.

However, except for some software modernization achieved by the Phase IV vendors, the Air Force will be using programs originally designed for outdated hardware. Longer term use of these old programs will prevent the new equipment from being operated as efficiently as possible, as well as probably requiring more manpower. For example, in the desire to minimize software changes in the transition systems, operations that still depend on punched cards and magnetic tape or other sequential file structures may be retained even though on-line access and data base management systems would offer better service at lower costs. The transition systems will probably continue to rely significantly on batch processing. Thus, they may continue to require more manpower than would be needed if the applications were reprogrammed to serve users interactively directly from remote terminals.

The Phase IV system's technological capabilities should not be the reason, however, for redesigning all the software. Many existing applications, which produce periodic reports, should probably be kept. Unless it would either lower costs (e.g., by reducing paper handling or personnel) or improve services to users (e.g., by giving supply and maintenance personnel access to common computer files), software redesign should not be undertaken. Programmers are a costly resource in short supply.

Phase IV software will be covered later in this report. It is important to recognize, however, that the Phase IV systems, once installed, can and will provide the basis for greater efficiency and management responsiveness. The new systems can connect to and communicate with other information systems, both on the base and at other locations, with low additional investments in equipment. The new Phase IV computers will lend themselves to distribution of computing functions and local area networking--both important evolutionary steps to prevent the need for another capital replacement.

The Promise and Challenge of New Technology

Information processing is changing more rapidly than almost any other technical endeavor. Because of continual innovations in hardware and software design, computer systems put into service as recently as five years ago may be functionally obsolete today. For example, the hand calculator--a radical innovation in the early 1970's--could perform many computer functions for less than $300. It made its mechanical predecessors obsolete. Today's hand calculator of equivalent power costs less than $30, most of that for the display and keyboard. Next year, the same $30 might buy a combined digital watch and programmable calculator.

Thus, technological trends need to be considered in planning for future information systems. Manufacturing processes using very large scale integration (VLSI) techniques can produce the same logic on three small silicon chips that now exists in a medium-sized "mainframe" computer. The $1,000 "mainframe" computer is now in sight and will probably shrink to a $100 mainframe later in the 1980s. VLSI techniques have also radically decreased the costs of main computer memories. In earlier generation systems, the high cost of memory tended to limit the number of applications or of simultaneous users a processor could handle. Now, even inexpensive computer systems can implement sophisticated operating software for multi-user applications. Though the mainframe costs alone do not define total system costs, this drastic rewriting of the cost/performance rules will revolutionize information systems. The current practice of centralizing computing hardware in one room can hardly be justified when the same power can be distributed in quantity at very low cost to locations where the processing is needed (e.g., the finance office, maintenance shop, flight line, or supply room).

It may be difficult to understand the relevance of the "number of computers at a base" when they are counted in dozens and priced in the hundreds of dollars each. When processors can be obtained that have the cost and size of today's hand calculators, but the power of a current mainframe, then functions can be added to a system by procuring additional specialized subsystems each having low cost and high capability.

Planning for systems of this type is underway in the business community. Local area data networks (e.g., Ethernet, Wang Net, or Hyperchannel) promise effective and economical integration of dissimilar specialized processors into a flexible aggregate.

Moreover, this revolution is not confined to hardware. Software systems will evolve to include functions such as data management and retrieval as parts of their own processors. They will also perform these functions for other processors communicating with the same data bases. Finally, the processors need not all be made by the same manufacturer or be located in the same room. Thus, they will have a potential for evolutionary growth toward highly flexible base level systems whose components can be tailored to service the needs of a given base.

The Air Force must recognize these trends as inevitable and desirable, and should meet them head on. Without a coherent plan, information processing at the base level might drift into an uncontrolled and uncoordinated proliferation of independent miniprocessors and microprocessors in the personal computer class. Because of their low cost, these appear highly effective for satisfying user needs, but they must be regarded as part of an integrated base-level system and added within the framework of a coherent plan.

For example, word processing systems containing shared logic and terminals will undoubtedly acquire more powerful computational capability. Once capital replacement is complete, Phase IV computers could serve as hosts for integrated base level systems. The emerging technology of distributed processing, coupled with high-performance local data networks, could connect functionally specialized systems at low cost into cooperating base networks. If this opportunity is missed, Phase IV systems could become splendid relics unable to adapt to changing times. Phase IV should be regarded as a vehicle to maintain the information systems at the leading edge of technology and to offer greatly improved and better integrated services to base level management.

The need for closer coupling between data automation and communications deserves special attention. In a distributed system, communications is part of the system rather than a necessary but separate function, as it is now.

It will be difficult to connect separate processing elements into a local, base level distribution network unless the data automation and communications communities jointly define the system characteristics. There will, of course, continue to be a need for centralized host computers; these will continue to communicate with higher echelons or with remote centers, such as the Air Force's Manpower and Personnel Center or the Accounting and Finance Center.

Intra-base networks can be created to distribute data by combining conventional and advanced techniques. Today's point-to-point wiring may give way to more flexible switched connections using digital private automatic branch exchanges (PABX). Using coaxial or fiber optic cables, processors will be connected with terminals on a common data bus at high speed and relatively low cost.

The Air Force may have to consider new organizational approaches to defining composite requirements for local systems that integrate host processing (Phase IV equipment), word processors and electronic mail services, and a pervasive local data network. At present, these are the domains of three relatively independent communities, but the interests of these communities will tend to merge as an outgrowth of the new technology.

Personnel

Without exception, both the system users and the data automation community within the Air Force have many dedicated and knowledgeable professionals. They are producing workable software systems despite cumbersome batch operations, too few terminals, and the absence of modern software development tools. Users in all functional areas seem well aware of the limitations of the present systems, but have adapted to them and are enthusiastic at the prospects of a modernized system.

However, contemporary equipment and improved capability will highlight the Air Force's critical problem of too few highly trained personnel. This gap would prevent the Air Force from realizing the full potential of the Phase IV system. For their definition, development, and effective use, new services and applications will require a cadre of software specialists, fully trained in modern information systems.

The Air Force should examine its training programs, reenlistment incentives, and recruiting practices to improve the retention rates for data automation specialists at all levels. The emphasis should shift from filling slots to building quality and experience. Obtaining high-quality graduates, particularly in computer science, should receive more emphasis in officer recruiting. Crossflow from other specialties into data automation should be viewed as less desirable than retention of experienced enlisted personnel.

In summary, because software rather than hardware will determine the success with which Phase IV and its successor systems provide efficient, versatile services to users, and since quality software can be produced only by highly trained and experienced specialists, it is now more important than ever that standards of quality and training be carefully examined and improved by all possible means.

In addition to ensuring continued availability of highly qualified computer professionals, the Air Force also needs to plan for a gradual change in how these people support base level automation. At present, data automators assume total responsibility for meeting the computing needs of the users located on an air base. Users are regarded as consumers, not creators, of services.

The evolutionary change that must be planned for will come about when users begin to acquire more independence in their own computing affairs. If the Air Force adopts an approach involving more autonomous, functionally distributed processing at base level, and if users can do some of their low-level programming on distributed small computers, data automators can begin acting as advisors and disseminators of programming techniques and useful software to help the users get the most out of their new autonomy.

Software: The Key to Improved Services

Current software systems that operate at base-level installations represent a substantial investment of human resources. After this software is adapted to the new equipment, many additional systems will be developed to meet expanded user needs.

The ability to implement new services will depend on the productivity of the data automation specialists. Like its counterparts in industry, the Air Force should emphasize programming productivity as the key to the successful creation of new and modern software systems capable of exploiting the new equipment. Because hardware costs will diminish over the life cycle of the Phase IV program, attention will increasingly focus on programming productivity and the maintainability of software systems. Personnel costs, not hardware costs, dominate today and will probably continue to do so.

Several aspects of software technology should be fully studied and exploited to contain the cost of developing and maintaining new systems. Some permit programmers to be more productive, some lower maintenance costs, and still others reduce software costs by enhancing interchange and sharing of software among commands. Base-level software systems should be produced with the aid of specialized software development facilities at the Air Force Data Systems Design Center and at major commands. These facilities should be linked in a network to permit software sharing. Also, structured programming techniques should be aggressively adhered to and data base software systems should be used for efficient file management. Finally, query and report generation languages should be improved to increase their use and thus reduce or eliminate the need for programmers in many of the simpler, user-specific applications.

Maintaining a Focus on Evolutionary Growth

Even without the problems imposed by the cumbersome and time consuming Federal procurement process, the Air Force has many reasons to avoid major capital replacement programs. Replacing large numbers of common computer systems worldwide can be prohibitively expensive, time consuming, and disruptive. Still, obsolete equipment no longer in production needs to be completely replaced. Because this equipment supports many data processing programs for different users at many locations, all are affected by the replacement.

With the new generation of computing equipment now being introduced, however, it will be possible to avoid such expensive traps. The key will be found in the drastic reduction of costs of processors, memories, and other electronic components. Entire collections of programs and services no longer need to be combined in the same central processor. Information processing is moving toward distribution of functions into separate, small pieces each performing a function for which it has been designed.

For example, communications are being handled now by specialized front-end processors. If communications networks should significantly improve, front-end processors might be exchanged for more capable models without affecting central processors or application programs. A wholesale capital improvement program might not be necessary to improve communications.

Similarly, recently introduced "back-end processors" or "data management engines" (specialized processors) can retrieve and manipulate data. They can thus relieve mainframe processors of that duty. Improved data structures or retrieval speed can be brought about by exchanging back-end processors, again without significantly altering other elements of the system.

Another opportunity for evolutionary growth will arise from a different kind of distributed processing. In addition to providing distributed computing processors (e.g., communication or data base), specialized processing can be distributed by user functions. For example, a specialized base level subsystem could be designed to support civil engineers. Such a system could be located close to and configured for their software. Because the subsystem would have local communications, it could be considered part of the base-level system. Such systems need not be expensive: a civil engineering system might cost $50,000, whereas a system to support the base pharmacy might be only $20,000 (hypothetical but possible figures). Neither of these hypothetical systems would require manpower per se. Each would be operated entirely by those who use its services on their jobs. The important issues are the overall cost of the system, including software, and its ability to support the users adequately.

Thus, the days of monolithic systems are, fortunately, numbered. Compatible processors from the Phase IV family will range from very small to very large. Processors from other vendors may be added to a base-level local network to support functions while communicating with others in the network, including the central host systems. The advantage to the Air Force is that this concept will permit orderly, nontraumatic growth and change; evolution will be possible by adding or changing functional processors in a less disruptive way.

Control over the base-level networks is a concern for managers. Presently, data automation and communications organizations are separate entities at each base. If distributed processing networks are introduced to replace the current centralized systems, data communication becomes part of the system rather than merely a service function. The data automation community will need to take the initiative for directing the orderly adoption of such network-based systems, while permitting users the flexibility that the system promises. Centralization of all applications on a big mainframe in a single computer room, once prized as offering economies of scale, should be regarded as contrary to evolutionary growth and not cost-effective.
It should be avoided in favor of distributed functions, local communications, and dissimilar but compatible small processing units.

Chapter 3

TRENDS AFFECTING THE BASE LEVEL AUTOMATION PROGRAM

The conclusions presented in the earlier parts of this report derive from the committee's review of the Phase IV program and from its judgments about some important technological trends and their applications to automated data processing. This chapter describes some of these trends and their implications more fully.

A central trend is the continuing rapid decrease in the physical size and cost of a machine to deliver a given amount of computing power. Not only are computers' direct costs dropping, but also with decreasing physical size come dramtic savings in other costs: space, power, cooling, and physical security. Examples, some forecasts, and further implications are given in section 1 of this chapter.

Changes in the pattern of costs have brought about the development of specialized computers and their supporting software. Examples are "intelligent" terminals that permit relatively untrained users to enter data or frame queries, and "front end," or communications, processors that facilitate the operation of systems having multiple terminals or processors. These are noted elsewhere in this report. A further important example, that of the specialized data-base management system, is discussed in section 2.

Given more computing power and speed, systems can be designed to respond more flexibly to users' needs and to maintain contact with multiple users simultaneously. For these reasons, a design philosophy embodied in so-called transaction-oriented systems, discussed in section 3, has developed.

Out of the trends described above has come a philosophy of design for automated data processing systems that can support administrative and management functions in large organizations. Computers, user terminals, and specialized processors such as data-base machines can communicate interactively under control of their own programs and according to instructions from the terminals. The facilities themselves are located wherever economy or convenience of operation dictates. Facilities are shared by users when sharing is economical, or for such specific functions as are most economically shared. Where economy or operational factors dictate, some users or functions may be served by dedicated machines. Software is written so that the user need not be concerned about the physical location of the computing facilities. A brief discussion of communications facilities for such a system appears in section 4. An illustrative system is sketched in section 5, based on typical practices in business organizations. Parallels with the Air Force are noted.

With the decreasing costs and increasing capabilities of computer hardware has come strong pressure to reduce the labor costs and time delays involved in writing programs. The art of program design has matured. Furthermore, a family of specialized computer systems and facilities has emerged to support program design and development and to improve the productivity of programmers. Those matters are discussed in section 6.

Small computers based on microprocessors are becoming available in a wide variety of sizes, prices, and capabilities. It is inevitable that these will offer substitutes for or additions to the services that the present base level system provides. Some implications are discussed in section 7.

Finally, section 8 comments on the differences between wartime and peacetime operations, and on their implications for the evolution of the base level ADP system beyond Phase IV.

1. SMALL HIGH-PERFORMANCE SYSTEMS

Techniques for fabricating the semiconductor devices that stand at the heart of every computer are expected to continue to evolve during the 1980's. Speed of operation will increase, and the number of active elements or logic devices that can be put on a single silicon chip will grow dramatically. By the late 1980's, it should be possible to put a million or more active elements on a single chip a few millimeters square, as compared, say, to a few tens of thousands in today's commercial practice, or to a few hundred ten years ago. Fabrication at these high densities is known, somewhat loosely, as very large scale integration (VLSI).

At such high densities, a complete central processing unit of 250,000 gates, complete with memory, power, and input/output lines, could be scaled down to a few chips. Further, if the chips used gallium arsenide as their primary semiconducting material, they could operate at a speed approximately an order of magnitude faster than those constructed by present techniques. Alternatively, if VLSI were used to implement the so-called Josephson junction technology, a complete central processor and expanded main memory, which now occupy several full size cabinets, could be reduced to 40 cubic inches. The resulting package, which would not be much larger than a hand-held calculator, could execute some 250 million instructions per second.

It seems unlikely that current designs of the large mainframe computers will continue to be made in smaller and smaller physical sizes. In the near term, advances in VLSI technology will probably provide another generation or two of more powerful, smaller, and more cost-effective processors. Over the longer term, however, large systems will undoubtedly evolve in a different direction, probably toward arrays of specialized devices functioning in parallel. Many current limitations on information formats and on addressing will then virtually disappear.

One of the continuing beneficiaries of the reduction in cost per unit of operation will be the growing line of personal computers. Present systems use microprocessors and are available with printers, keyboards, and full lines of software. They sell for less than $5,000. Of this, only about $1,000 is for the central processing unit; the rest is for the peripheral equipment. With its software, such a system can handle the needs of a small business. Significantly more powerful systems, which should sell for prices only a few times greater, have been studied experimentally for commercial development. These systems have the power of processors currently defined as small or medium in scale. (Small systems execute instructions at up to 200,000 per second; medium systems, at up to 1 million per second.)

As these small high-performance systems reach the market, they should develop much as hand calculators did during the 1970's. As their usefulness becomes apparent, cost becomes considerably less important in deciding whether to buy them. For many base level applications, the economies of scale that once led to a single, central computer system will be gone. A great deal of flexibility will be possible in matching equipment to its intended use. Freed from the constraints of hardware, planning is likely to focus on user needs.

Other benefits may also flow from the use of multiple, inexpensive, high-performance systems and subsystems. An Air Force base that can process its own critical applications is less vulnerable to attack than one that depends on a regional connection. Even within a single base, several systems deployed over a wide area would be less vulnerable than a single centralized system. Because costs are low enough, redundancy can be built into survivability and backup planning. Security and privacy are usually easier to handle on dedicated systems or subsystems than on those shared with many general users. Also, small systems are moved easily and can be powered by small generators, batteries, or even solar cells.

2. DATA BASE MANAGEMENT SYSTEMS

Over the last few years, the data processing industry has developed systems that use specialized data base management techniques and software. The results are clear: data base management systems (DBMS) can significantly benefit users, programmers, and maintainers. DBMS software that is currently available for all large mainframes and for many minicomputers often includes software for managing data communications, for inquiry and retrieval, and for assisting software development. Already such DBMS software is proving to be stable, efficient, and economical of resources; some form of it will probably become standard in future large systems.

Since its beginnings in the early 1970's, data base technology has grown rapidly. Its development has been encouraged by declining costs for random-access storage devices and by a recognition that integrating all data being handled by individual programs into one common pool can often improve efficiency.

Today, data files at each Air Force base are associated with specific programs that process them in accordance with the organization of the records in the files. A given data element (e.g., a supply stock number, aircraft tail number, or Air Force specialty code) may exist in many files; it must be altered in each separate file whenever a change is made. Any format change (e.g., switching from a numeric to an alphanumeric designation, or changing from a five- to a six-digit identifier) requires changing every program code that uses the data element and rewriting all files with the new record structure. Were the data in a common file, accessed by all programs that use it, the overhead in maintaining the common file could be significantly less than that in carrying separate files for each program.

Contemporary data base management systems are characterized by (1) integrated collections of data available to wide varieties of users; (2) data definition in the form of centralized and accessible descriptions of the names of all data elements, their properties (such as character or numerical type), and their relationships to other elements—relationships that can involve complex groups and hierarchies; (3) centralized control over data descriptions by data administrators; and (4) compatible inquiry and retrieval languages that can specify a variety of logical operations and output formats, thereby permitting nonspecialists to write simple retrieval and reporting programs for their particular requirements.

Data definition is the cornerstone of DBMS. By controlling definition, data administrators can successfully adopt a family of programs using shared data. The data administrator can publish a data dictionary, available to all programmers, that contains the names, formats, definitions, and relationships of all data elements. In most systems, programmers or ad hoc users can have access to such dictionaries to determine correct data names.

In a well-designed DBMS, neither programmers nor ad hoc users of query systems can alter the physical or logical relationships among data elements. Programmers are prevented from defining new elements to be included in the data base, and all programs use common data definitions. Any new program can then retrieve or update data easily, formats can be changed without affecting multiple files or programs, and storage and retrieval mechanisms, hidden from programmers, can be made more efficient.

A well-designed DBMS also serves to maintain data quality. Failure or inadvertent misuse of a processing program may result in incorrect values being written into the data base. This error must be corrected or its effects undone, lest other programs use the incorrect values. Back-out facilities for doing this are usually provided by modern DBMS packages, along with complete facilities for producing and reloading safe copies of backup files.

Considerations of privacy and security are somewhat more important in data base management systems than in those in which files are maintained by individual programs. Because all users know that shared data exists, a DBMS must be able to protect the data from unauthorized access or disclosure. Privacy is usually achieved through a security mechanism, typically a password. Data administrators determine which users have access to what data. Audit trails are maintained to identify who gained access to what data under what conditions. Some of these techniques are at present only partially developed, but they are certain to receive a great deal more attention in the future development of DBMS software.

For the purposes of the Base Level Automation Program, data base management systems can greatly reduce programming and maintenance costs. Much of the source code of a typical COBOL program consists of definitions of data elements being read and produced by the program. When a data base is used, the DBMS software conveys data definitions to the program through a variety of linkages. When data descriptions change, all using programs can accommodate the change with little effort.

Ad hoc query languages supplied with most contemporary DBMS packages can contribute significantly to a system's utility. In the current Phase IV system, when a user requires a new report to be produced from existing files, a programming effort is frequently required. Under a DBMS, simple requests may frequently be accommodated without programmers, since the query language is usually an English-like representation of logical relationships, simple arithmetical operations, and report format descriptions. Users may be able to train low-level programmers to meet many of the ad hoc processing requirements that today go unfilled due to the shortage of experienced programmers needed for the simplest of programs.

3. FROM BATCH TO TRANSACTION PROCESSING

Managers have always used periodic "snapshot" reports on, for example, the states of inventories or cash balances. Such reports have generally been the best available, given the accounting and reporting procedures with which managers have had to operate. Thus, current base level computers are so configured that many of the important operations are done by batch processing. Consequently, files and reports drawn from them are current only at intervals.

Modern ADP systems, like those the Base Level Automation System hardware with appropriate terminals and software can create, have sufficient flexibility and power so that files can be continuously updated. Each transaction can be taken care of as it occurs (hence the term "transaction-oriented"). Moreover, the current status of any particular balance or inventory can be reported on demand. With large memories and rapidly accessible mass storage (on-line discs and so-called "virtual memory" techniques), and with well-designed data base software, the computer can immediately evaluate and respond to a new entry and update the data base accordingly. Indeed, if data are captured at the source by a monitoring or sensing device connected to the computer, the status of that particular application can be kept current in essentially "real time."

Transaction-oriented systems have changed the ways many businesses operate, for example, by reducing requirements on inventories and cash balances, by conserving managers' time, and by increasing the efficiency and productivity of workers whose output depends on information derived from the data system. The Air Force could realize these advantages by moving toward a transaction-oriented system. At the same time, it could reduce clerical and other labor costs now required for batch processing. The Committee understands that the Air Force has been moving from batch to on-line operations for such functions as accounting, maintenance, and personnel. The transition will make transaction processing possible for such functions when the Phase IV system begins operation.

4. LOCAL COMMUNICATIONS SYSTEMS

A variety of developing technologies can provide flexible communications links within an air base. Perhaps the most readily available, taking into consideration existing facilities, is a computer-controlled telephone switching sytem. These private automatic branch exchanges (PABX) transmit both voice and data over the same wires. Regardless of whether the information is converted to an all-digital or an all-analog format, the computer that controls the switching function provides a flexible communications medium. Voice and data equipment are easily connected and accessed from any point in the system, and are readily linked to external telephone networks. Although limited to data transfer rates typical of terminal devices, a modern PABX is easily implemented and can share its investment costs with a voice system.

Local transmission systems that handle data at rates much higher than those accommodated by telephone lines are now commercially available. Both point-to-point and netted systems are possible.

Private industry is developing interface and protocol standards to control data transmissions in such local systems. As these standards become more widely accepted, more product and software support will become available for connections to conforming systems. Location, function, and speed will not be difficult problems in establishing communications between machines. These developments will considerably expand the definition of data processing systems, because access to the systems can be made available almost anywhere that it is required.

Communications can effectively serve data entry devices. In many present base-level systems, information is transferred in a series of steps from its sources to punched cards that are eventually entered into a computer. The process is slow, subject to handling errors, and rigid in format. For less than the lifetime costs of a keypunch, terminal devices for entering data can be located whereever needed and connected by a local communications system directly to the computer. And because of the low cost of microprocessors, the terminals can process data locally as it is entered, for example, checking for format conformity or data value ranges.

While most logic and memory devices continue to drop in price, those that connect operators to computer systems are not decreasing in cost as quickly. High-speed printers or plotters, for example, are built out of parts from technologies that are developing at different rates. For these, equipment costs remain high. However, easy connection to local communications systems provides a means of sharing costs and capabilities.

Advances in local communications allow for a broadened concept of computer systems and a larger community of users. The benefits of automation can now be extended to whole processes rather than being restricted to individual intermediate steps.

5. THE DISPERSAL OF PROCESSING POWER

With computers available in a wide range of sizes and speeds, with a variety of convenient terminal devices, and with facilities for communicating among these under computer control, organizations can fashion automated data processing systems to fit their operational and organizational requirements. Many companies have developed their own approaches, but certain general characteristics can be observed:

- There is strong interest in capturing data at its source, automatically if possible, or as an automatic feature of other operations that must be performed in any case.
- Data terminals reduce the processing and communications load on the rest of the system by checking and editing data and putting it into a standard format before transmission, and by storing and transmitting it when the host computer is ready.
- Sometimes there is no single, large host computer. Even when there is, it usually is a complex of special-purpose machines (communiations processors, data base "engines", vector processors, etc.). These can provide functional dispersal of the processing load.
- Organizations that are widely dispersed geographically save communications costs by distributing or dispersing their processing capacity to centers of major activity or to geographically concentrated clusters of terminals. A lateral dispersal of this kind is effective when each center or cluster deals largely with data needed primarily in that center or cluster. This kind of lateral dispersal may often be accompanied by a higher level of functional dispersal as well (e.g., to supply and accounting), since each function tends to be housed together.
- Another kind of functional dispersal or distribution tends to follow the managerial hierarchy. At higher levels of the organization, the data of interest tend to be of a strategic or global nature. At lower levels, detailed data concerning local operations (such as the location of an item in a warehouse) may be required. Yet the fact that the item is

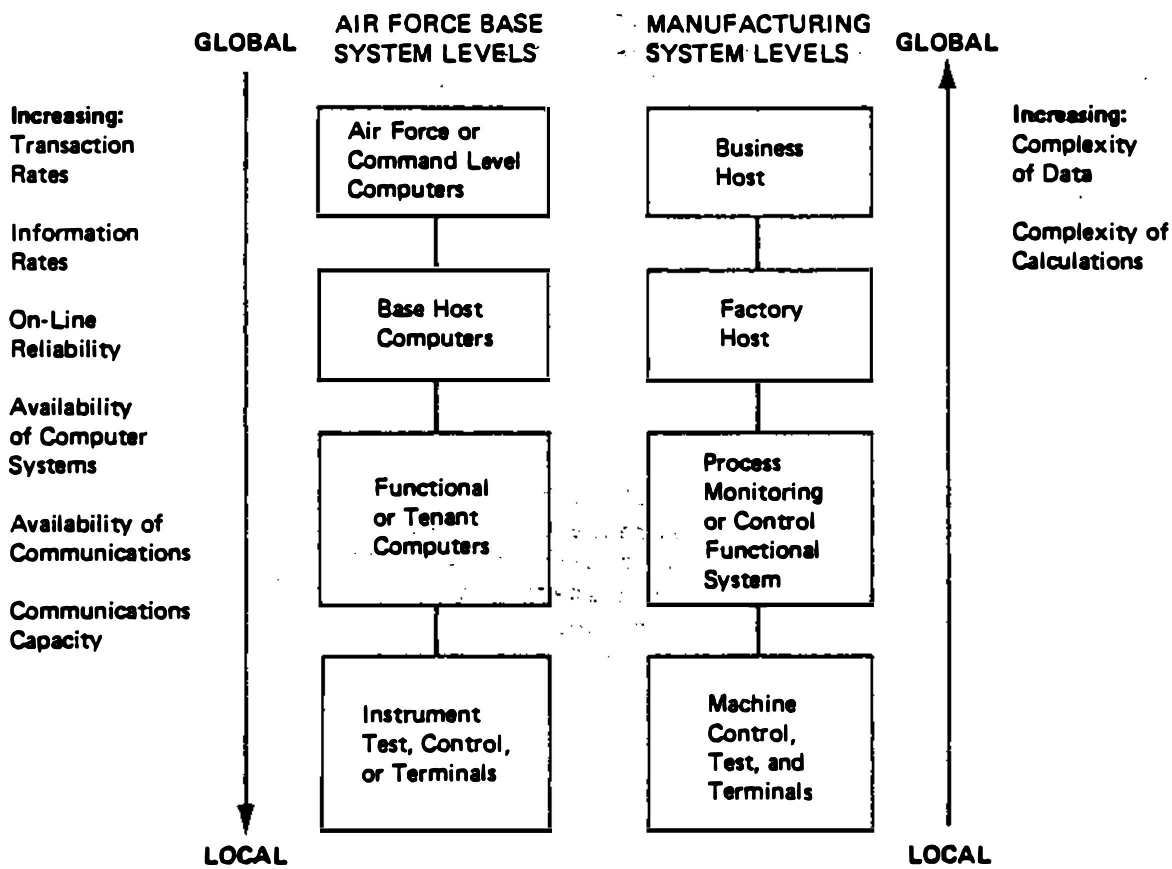
there may be of global interest and the sum of the items in all warehouses may be of strategic interest. Because the data required at higher levels are different in kind and typically simpler in detail, but may be processed or summarized in complex ways, it is convenient and often economical to treat this hierarchical dispersal as one would treat a functional or geographic one, with host computers chosen or configured to serve a particular organizational level efficiently.

- As processing capability becomes cheaper and available in a wider range of modular sizes, it becomes economical to disperse or distribute processing more widely. Similar considerations apply to functional and hierarchical dispersal. Dispersed or distributed processors may be linked by any or all of a variety of means, including coaxial or fiber-optic cables, microwave links, or satellite communications. In fact, the Air Force has already settled on a structure for the Base Level Automation System that is widely dispersed geographically. In the future, greater dispersal even at a single air base may prove economical and operationally desirable.

Figure 1 illustrates a model automated data processing system embodying these principles of dispersal or distribution, keyed to the hierarchical structure of a manufacturing organization or, in a parallel display, to operations at an air base.

Some further properties and requirements of such a system are:

- There may be multiple computers at each level, especially at upper levels.
- Communications between offices may be by telecommunications, magnetic tape, or other medium. They should, however, be in machine-readable form.
- The data bases on different computers may be related. Consequently, maintaining data integrity over distributed data bases is essential.
- Individual components of the information system are distributed to where they are needed. They should be able to cope with communications links that are temporarily cut. Enough buffering should exist in each local system to maintain essential short-term operations and restore data bases.
- Simplicity and reliability are achieved by allocating functions to specific and perhaps specialized hardware. In addition, where reliability and availability are essential, dual and/or fail-safe equipment can be installed.
- Sending only the information needed at a given level minimizes communications requirements.
- When lower-level organizations on different branches need to communicate, this can be done by going down the organizational tree and then up. In hierarchical structures, this is rarely needed.



ALL LEVELS: Integrity of data, good recovery and restart, high information transfer rates.

FIGURE 1

In addition to technical considerations already touched upon, factors of personality and management style are important. For example, managers may not want the next higher levels of management to control or have access to their entire data bases, preferring to retain control of their total resources. Such nontechnical factors tend also to favor distributed systems.

Most of the above reasoning appears to apply to Air Force information systems. Because of the Air Force's mission, the final system may be more distributed than that planned for the initial implementation of Phase IV.

However, it is certainly not true of operational units, such as combat units that may be moved almost anywhere in the world on very short notice. Most locations, for example, lack the base support systems available at major air bases in the United States. In addition, remote locations may lack communications and computing facilities, or such facilities may be damaged or destroyed in war. Under such circumstances, each potentially mobile unit could profitably have the hardware, software, and data bases to support its operations. The technical means to do this is either here or just around the corner. In the future, each aircraft wing, for example, will probably be able to take its own information system along when it deploys to another base. The host computers at each major base in Phase IV should be able to support such mobile information systems.

As the Base Level Automation System evolves, intelligent automated data gathering, intelligent terminals, and microcomputers will probably reach much farther down in the base support/tenant hierarchy. For example, recording flight and engine histories in machine-readable form is presently feasible at a cost in weight and power that will undoubtedly decrease in the future. Voice input may be used to capture the details of maintenance functions, and voice output to coach a technician in a specialized task. The use of computer terminals by maintenance personnel could give them ready access to current technical data and guidance. These few suggestions illustrate the many ways in which the Base Level Automation System may well extend its services.

Nevertheless, the system's structure will continue to need centralized host data processing, even where many computing elements already function. These needs include:

- The consolidation of common and/or global data.
- General-purpose batch, time-sharing, and transaction processing.
- The provision of a centralized software engineering environment and the establishment and control of interface, data base, and development standards.
- The integration of maintenance activities throughout the hierarchy.
- Specialized software and hardware.

6. SOFTWARE TRENDS

While current software systems can be adapted for the transition into the Phase IV Base Level Automation System, new programs will surely be needed as applications are modified, replaced, or upgraded during the program's later stages. In this regard, the software used in the middle to late 1980's should not be constrained by whatever temporary expedients may have been necessary for the transition phase. Failure to match software to hardware for best program results will hamper development and increase maintenance costs. It is precisely these costs that dominate in all large data processing systems.

The programs for the current base level system, including those that are unique to specific Air Force commands, have been developed over a long time. They represent about 5 million to 6 million lines of code. The significance of the software problem can be put into perspective by performing the arithmetic implied by the following commonly recognized rules of thumb:

- Producing a new program costs more than $20 per line of source code.
- Maintaining a program over its lifetime can cost four times the original development costs.
- Current programmer productivity is about 10-20 lines per day.

While computer hardware costs have dropped sharply, there has not been a corresponding sharp decrease in the cost of producing computer programs. Programming costs have risen more rapidly than the rate of general inflation and in many systems are several times more than the hardware costs. The implications of this fact are not confined to the Air Force's Base Level Automation System. Users and developers of data processing systems throughout the world face escalating software costs coupled with a very slow rise in programmer productivity.

In an effort to improve programmer productivity, a number of techniques have evolved. In general, one attempts to bring more discipline into the management aspects of software development teams and to frame the computer program itself in some very orderly structure. Recent developments include:

- Structured programming (a categoric term for any approach that imposes an orderly process on the management of development teams or on the details of the program itself).
- Top-down design (building a computer program by starting at the most general level and gradually extending the program downward into more detail), with provision for the next step in the design at each level of progression into detail.
- The use of chief programmer teams that attempt to divide each large program into a number of smaller modules, each sized to be manageable by a small team of three to five members headed by a very experienced and competent chief programmer. The notion is to keep the teams small enough to

ease communication among their members and, at the same time, keep their programming tasks modest enough that the basic structure of each task can readily be kept in the minds of the appropriate team members.

- Hierarchy plus input-processing-output (HIPO), an aspect of top-down design in a structured sytem. Originally a documentation tool, it has become a technique for describing each function or module of a large program in terms of its inputs and outputs.

Each of the techniques above is described fully in the literature and is, therefore, not described in depth here. The important point is that techniques for structuring and organizing complex computer programs and approaches for managing the teams and organizations to develop them have progressed significantly throughout the 1970s. Organizations that have been in program development for longer than a decade or so tend to remember the old ways of doing things and may not actively exploit the most productive new ways to conceptualize and structure complex programs.

Users as Programmers

The first users of digital computers were scientists who could translate mathematical concepts into detailed sequences of instructions for computers to follow. As time has progressed, a class of professional programmers has gradually merged who build complex computer programs in response to detailed statements of requirements from end users.

Today, programming involves an intricate set of repeated interactions among programming organizations, end-user organizations, testing organizations, and sometimes still others. Typically, ultimate users cannot describe their requirements precisely enough to enable a program, when first completed, to meet their needs. Therefore, the various players in the process interact repeatedly as the program moves toward completion, consuming the time of both programmers and users.

With the emergence of programming as a professional skill has come a progression of so-called higher order languages. Such languages permit users to state needs at a more abstract and general level. Among such languages are FORTRAN, COBOL, PL-1, PASCAL, and ADA, each of which is intended to improve programming productivity by raising the level of abstraction at which programmers could function. Concurrently, computer costs have dropped dramatically. Today, then, there is less emphasis on producing programs that are extremely efficient and make best use of computer resources.

As a consequence of these trends, it has been possible in many commercial applications of ADP to write the basic software so that users themselves can program specific applications to meet their needs. This practice is particularly effective when users are also given access to program libraries and to good software development tools, such as discussed below.

Programming Cost Problems in Large Systems

In the Base Level Automation System, like many of its civil counterparts, personnel costs greatly exceed those for equipment. In addition to a corps of 610 in a centralized facility that develops most software (the Air Force Data Systems Design Center), the Air Force has approximately 40 people at every base assigned to computer operations, support, and management. This total cadre of 4555 people operates the base computer system at shift levels exceeding 15—at many bases at levels of 20 or 21—per week. In addition to the management and program structuring techniques that are intended to increase the productivity of programmers and users, there is also the question of the work environment. In the past, programs were written out laboriously on paper and then transcribed onto punched cards that were read into a computer for execution.

In the best of today's program development environments, the programmer—professional or not--works at a terminal coupled directly to a computer. He keys instructions directly into the computer. The best environments also include features for verifying the work and remedying the more common or obvious mistakes. Finally, when a program is ready for trial execution, it can be submitted directly to the computer through the terminal. When the job is completed, the results can also be verified through the terminal.

The on-line development of computer programs is an enormous boon to a programmer's productivity. It not only allows him to communicate more directly with the machine, but it also supports him with a wide variety of aids that take care of some programming details automatically, check for mistakes, and facilitate searches for other errors that are latent in the programs. Thus, the Air Force Data Systems Design Center, a large, professional, systems developmetn organization, needs the most modern software development facilities available for its personnel. Most vendors of contemporary computer systems include such capabilities in their product lines. It is even possible to get a program development facility from one vendor that can be used to produce programs for computers of other vendors.

The payoff that an organization expects from an appropriate program development environment includes faster interaction of programmer and computer, automatic scanning for some errors, automatic debugging and testing, automatic handling of some programming details, and (perhaps more important than anything else) an environment in which the programmer can accomplish his complex, highly detailed job more effeciently.

The characteristics normally demanded of a high-performance software development configuration include:

- The ability to support simultaneously multiple CRT terminals, operating with full-screen editing.
- Subsecond response times for most commands.
- Powerful text editors capable of string manipulation.
- Hard copy production of source listings.

- Directory and file manipulation, including file sharing and communications among users.
- Job submission capabilities to another production systems, if different from the development system.
- Source code control commands that permit successive versions of source program modules to be controlled, maintained, and retrieved, so that every change can be accounted for and linked to version numbers of released systems.

Computers that handle the normal day-to-day operational workload frequently lack features that are essential to a high-quality program development environment. To solve this problem, one option is to add a so-called overhead computer, an additional machine equipped with an appropriate terminal-oriented environment and used only for program development. However, features can also be implemented very efficiently on minicomputers to support dozens of simultaneous users and produce end programs for a Phase IV machine.

7. EVOLVING USES OF MICROCOMPUTERS AND MINICOMPUTERS

There is a number of reasons for the growing use of small systems utilizing microcomputers. For example, there are data processing tasks small enough to be carried out by a microsystem. The advantages of doing so include:

- Favorable cost (perhaps).
- Users having their own computing capabilities.
- No dependence on communications.
- Avoidance of the overhead involved in running a large central system.
- Avoidance of large-scale breakdowns.
- Encouragement of users to be innovative in exploiting computer technology for better efficiency and effectiveness.

The one disadvantage--potential loss of discipline through proliferation of small systems--can be controlled by the Air Force through prototype designs from the Air Force Data Systems Design Center (p. 35).

Whatever the reasons why small computers will have growing importance at Air Force bases, it is likely that any such applications will have information interfaces with the Phase IV base-level installations, raising both hardware and software questions. For example, a Base Level Automation Program site might need the ability to either read or write 5-inch or 8-inch floppy discs, or the ability to produce a subset of a master file for the use only of the personnel of a deploying aircraft wing. Quite aside from the hardware and software questions there are important system-level questions.

Suppose, for example, tht the Air Force wanted to automate the handling of travel vouchers on a small, stand-alone system. Offhand, it would appear to be a self-contained application, but there are many interconnections that must be made. For example, there is the matter of overall budget control. Further, a local travel voucher system might share just a portion of some larger data base dealing with the same issue. Thus, there is a system-level question involving the information interface between a satellite, a stand-alone computer and a central one. What might, should, or must be kept in the small computer to accomplish the local objectives? What must be kept centrally to satisfy such requirements as audit trails, overall fiscal accountability, and reporting to higher headquarters? There might be some data that should or could be kept in both places; but, if so, the master file might have to be updated from the local file, and the Air Force would have to determine how frequently that must be done. What information must be passed to higher echelons or laterally to corresponding users at other bases?

Thus, an information flow analysis should be conducted for any functional capability proposed for a small stand-alone computer, to identify all the interfaces that need be accommodated. The organization proposing a local capability probably could not do such an analysis, simply because it might not be aware of the overall Air Force context in which its particular activity is embedded. Technology itself is not the paramount problem, even though there are technical aspects of data exchange among computer systems (e.g., data formats, disc details). Rather, it is an understanding of how information is used at local, central, and higher echelons, together with all of the details of such flows.

A related issue is that of software life-cycle support. Continuing the travel voucher example, the Air Force would want to ensure that it would be done uniformly at all bases. Even if one base were to take the lead in designing and developing such a system, that same base should not necessarily be forever responsible for supporting the software. The senior authority for the functional area in question might undertaken such support (e.g., the Air Force Accounting and Finance Center for anything involving financial transactions). But there may not be an appropriate senior authority for some stand-alone applications that might be desirable, or the appropriate authority may not desire the additional burden. Thus, there are aspects of proliferating small stand-alone computer systems that could create problems for the Air Force unless some level of overall control is maintained.

A possible technique for this, and for leadership from the Air Force Data Systems Design Center, is to have the Center make prototype designs, for widespread use at all appropriate bases, from small-system designs developed by local users. Alternatively, some particular base could be selected to be a "prototype environment" base, to illustrate the ways in which evolutionary changes to Phase IV systems are applied in normal base operations.

Office Automation as Related to Base Systems

An important use for small computers at base level is bound up in the ubiquitous word processor, which can grow into a more fully capable office support system that has interfaces with other base services.

Almost from the beginning, on-line computer systems included text editors used to develop programs. These editors were soon enhanced by the addition of routines that standardized output. Thus, computers could process text as readily as numbers. Somewhat in parallel, typewriters were connected to simple memory devices like magnetic cards. With the advent of microprocessors, these memory typewriters quickly evolved into word processors that could not only handle text, but could also process or compute numbers. Now, communications link computers and word processors.

This marriage of computing, word processing, and communications has given rise to the concept of the automated office. Information of all kinds can easily be transmitted locally or globally, and it can be processed mathematically or editorially. This has led to such services as "electronic mail" and "paperless processes," which are beginning to appear in the commercial marketplace.

Electronic mail's significance does not come from transmitting information by electrical signals. That basic capability had been available for a long time. Rather, its significance is that information can be both transmitted and processed by a variety of equipment. Prescribed formats no longer hinder informtion flow or arbitrarily limit its content. A high degree of local autonomy is possible because necessary data can easily be extracted, recombined, manipulated, and displayed as required by each user.

Typically, office automation begins with a word processor. Even for skilled typists, word processors can improve productivity, particularly in preparing a lengthy document to which a number of people make contributions, and in which various sections must be revised and re-revised. As a second step, the word processor can be connected to other word processors or computers through the telephone system or other communications network.

From this point on, the benefits of office automation accrue in proportion to the degree of management planning and user feedback. Step-by-step implementation is a practical approach, but it must be developed in the context of an overall plan. The advantage is that data once entered into the system need never be entered again. It is free to be moved and transformed to serve the needs of management where and as required. This can led to integrated, end-to-end processes that considerably improve the performances of the functions they control.

Thus, office automation is not a single system or event; it is the long-term application of computing, communications, and office machine technology to business processes. Just as computers relieved people from the drudgery and limitations of manual arithmetic, so too can office automation relieve the drudgery and limitations of many clerical tasks. It not only improves the productivity of clerical workers, but it should materially improve the quality of the process as well.

The Air Force Data Systems Design Center might well have a significant role in the growth of office automation in the Air Force, especially since the Center is part of the Air Force Communications Command. Among its functions, the Center supplies all the on-base communications to support office automation networks, in addition to communications in support of the Phase IV installation and networking of microprocessors.

8. BASE LEVEL SYSTEMS IN WARTIME

In peacetime, the Air Force emphasizes efficiency and minimum costs. In wartime, the emphasis switches to such criteria as combat readiness, maximum availability of aircraft, and prompt maintenance.

The base information infrastructure will have to accommodate two directions of change. First, the information-handling demand on base is likely to change dramatically by the 1990's. Second, the base must be ready to move whenever necessary from a peacetime status to one of military action promptly and smoothly. In this context, military action can mean anything from full-scale nuclear warfare, through theater operations (e.g., in Europe), to potential crisis involvement in any country of the world.

Thus, in planning its future base level information handling, the Air Force must ensure enough flexibility in its information systems to accommodate the variety of bases from which it operates. Its plans also have to accommodate the transition of some or all bases into military-action status at any time.

While there is an awareness of wartime planning and there are exercises for practicing contingencies, the fact is that peacetime operation tends to dominate attitudes, thinking, and planning. In peacetime, motivations are those of efficiency, minimum cost, budget consciousness, and federal government funding cycles. During a military action, motivations will be reoriented toward such things as overall effectiveness, quick turnaround of sorties, maximum availability of aircraft, and prompt maintenance.

Information flows—who transmits what data to whom, and why—are very likely to change correspondingly. The pattern of information exchange that characterizes a base during peacetime will be different during military action. New data may have to be collected, maintained, or manipulated; new uses for data may appear, or new users of data may materialize. The quantity of data flowing among established users may surge or, in some cases, vanish.

For example, to offset an impaired flow of spare parts, some aircraft may be cannibalized to keep others flying. New data handling demands could arise from such circumstances. Similarly, it might prove desirable in a wartime emergency to exchange spare parts among bases; if so, a substantial lateral flow of data could develop.

The Air Force, of course, does its best to estimate what data systems will be needed in wartime. Presumably, it also will seek to estimate how wartime information needs will differ from those of peace. However, there is something of an unspoken assumption that war or other military actions will be like peace insofar as data requirements are concerned. And, to the extent that it is not, the prevailing philosophy seems to be, "We will make it work."

When information was handled manually at each base, it was possible to innovate with alacrity and to create new recordkeeping processes with reasonable speed. At a time, however, when much of record handling has been computerized, innovative actions to accommodate deficiencies that appear only during wartime will at best be difficult and may be impossible. Air Force bases might find themselves in a major administrative problem.

In addition, the data processing installations at most Air Force bases in Europe and the Pacific have not been adequately protected against wartime threats. They are vulnerable to damage, disruption, or destruction by air attack, electromagnetic pulse, sabotage, or ground assult. The likelihood of continuity of normal processing in the face of these threats is quite low.

The Committee has been made aware of Air Force plans to make the Base Level Automation System combat-ready and encourages the Air Force to give this planning a high priority. The Committee was told of plans to develop a combat supply system that would assume many of the supply functions performed by the Base Level Automation System, but would operate on small scale computers that could be deployed with fighting to satisfy all wartime support responsibilities. One particular concern to the Committee, for example, is the engine tracking system, which is vital for combat readiness of squadron aircraft. That system depends on a computer system that may not survive an attack or redeployment. A wartime equivalent or substitute for that system, implemented on an appropriate system that is transportable and survivable, would probably be justified because of its value to the operational readiness of a deployed combat wing.

Other wartime contingency measures being undertaken by the Air Force include the following:

- A comprehensive analysis, managed by the Air Force Data Systems Design Center, to examine contingency planning requirements in Europe, the Pacific, and the Tactical Air Command (for rapid deployment force requirements).
- Development of improved methods for reducing the vulnerability of base-level computer systems to enemy attack. This effort has included a MITRE study that recommended specific plants to develop "transportable" and survivable computer systems that are packaged in small enough containers to be moved readily by air for long-term support requirements (60-90 days after deployment).
- Acquisition of a small computer system to support combat supply requirements that can be easily moved with deploying forces in the very early stages of conflict. Additional systems may be acquired to support other functional users.

These actions are all necessary to the development of an adequate wartime ADP system for supporting essential administrative and operational functions. The Committee has not, however, seen enough detail to assure it that a comprehensive approach is being taken to the planning of a system adequate for wartime operations. Although the Committee has not pursued this matter further, it must strongly recommend that the Air Force conduct comprehensive planning to assure the adequacy of the base-level system to wartime as well as peacetime operations.

Appendix A

AIR FORCE PLANNING LEADING TO PHASE IV

The Air Force launched several independent studies, beginning in the early 1970's, to determine its future base level data automation requirements. These included STALOG (Study of the Automation of the Logistic System at Base Level), SADPR-85 (Support of Air Force Automatic Data Processing Requirements through the 1980's), and BASE-TOP (Base Automated Systems for Total Operations Program).

In commissioning these studies, the Air Force was concerned with the growing obsolescence of the computers it used to support administrative operations on 115 air bases worldwide. The computers included the Univac U1050-II, a second-generation computer used by the Air Force since 1965, and the Burroughs B3500, in use since 1969. The Air Force was concerned that as the computers became older, their failure rates would increase and adversely affect Air Force operational effectiveness. Further, the government-owned components of the Univac computers could not be replaced by the supplier. Even where parts were replaceable, replacement prolonged the computers' original capabilities without taking advantage of rapid advances in data processing technology.

STALOG

The STALOG study, published in mid-1973, sought to determine how best to satisfy data automation requirements for logistics at each air base at minimum cost. The study analyzed five hardware alternatives for an integrated system concept that entailed large-scale development of functional software. The study recommended replacing the Univac and Burroughs computers with a single computer system at each air base as the most economical course, since it consolidated two separate computer systems into one.

SADPR-85

The SADPR-85 study was initiated in October 1973. The Assistant Secretary of the Air Force (Financial Management) stressed the need to determine total ADP support at base level, beyond that examined in

STALOG. The two major alternatives considered in this study were: (1) an on-base computer system at each installation, and (2) regionalization. The study found that regionalization was the more economical plan, but also the one with the greater technical risk. In May 1974, the SADPR-85 steering committee at Air Force Headquarters adopted the on-base computer system strategy.

BASE-TOP

Meanwhile, the Office of the Secretary of Defense restricted future funding of STALOG development in December 1973 to the then current level until the Air Force developed a comprehensive plan to satisfy total base level ADP requirements. In response, the Air Force established BASE-TOP to prepare this plan and manage the acquisition of new base level systems to satisfy all requirements, including STALOG.

During the fall of 1974, Air Force Headquarters recognized the risk of simultaneously implementing major changes to hardware, software, and information systems. As an alternative, a modular, incremental development plan was begun. This approach, however, raised significant hardware integration problems. Thus, this plan required significant amounts of new ADP equipment for short-term improvements before the aging Univac and Burroughs equipments were replaced. In addition, the plan posed serious technical problems in interfacing a second-generation computer with more modern equipment.

DIRECTION FROM THE OFFICE OF THE SECRETARY OF DEFENSE

In its October 1975 internal budget review, the Department of Defense (DOD) determined that the evolutionary approach being developed under BASE-TOP/STALOG raised significant problems related to hardware acquisition, software development, and system implementation. The department felt that these problems were not solvable prior to the start of fiscal year 1977. DOD also noted that the Air Force had not fully complied with the December 1973 directive to submit a plan satisfying total base level ADP requirements. As a result, the department limited fiscal year 1977 funds for computer hardware to the level of the previous year. The department also directed the Air Force to submit a plan satisfying all base operating functions through competitive selection of computer systems from a single manufacturer with modular, add-on capability to accommodate different workloads and mobility requirements.

REDIRECTION OF THE BASE-TOP/STALOG PROGRAMS

In December 1975, the Air Force logistics community reevaluated the automation requirements of the STALOG program, with the result that a large portion of the logistic automation requirements were removed. Functional requirements were also reviewed and significantly reduced.

INITIATION OF THE PHASE IV PROGRAM

In the spring of 1976, the Air Force's Director of Data Automation won acceptance of the idea of discontinuing the BASE-TOP/STALOG programs in favor of a base-level program for capital replacement of the Univac and Burroughs equipment. This separated the development of application systems from acquisition of hardware to replace existing equipment. Thus was begun the planning for the capital replacement program known as Phase IV.

A serious concern was the ability of the Univac equipment to support supply requirements until Phase IV could be implemented. An ADP acquisition team was established to determine how to implement Phase IV in the shortest time at the lowest risk. The team concluded that the "system contractor" approach was best. That approach involved:

- Contracting the transition of high-risk software to two competing contractors.
- Conducting a full range of testing, including a Qualification Operational Test and Evaluation conducted by the Air Force Test and Evaluation Center.
- Awarding a production contract to a single vendor.
- Implementing the computer systems in a phased conversion, replacing the Univac U1050 first and then the Burroughs B3500.

REVIEW OF THE PHASE IV PROGRAM

The Phase IV Program underwent an extensive series of reviews both within the Air Force and in the Office of the Secretary of Defense. Other reviews were conducted by the Office of Management and Budget (OMB), the Office of Federal Procurement Policy, the Senate Committee on Appropriations, and the House Committees on Appropriations and on Government Operations.

In March 1979, the chairman of the House Committee on Government Operations requested a General Accounting Office (GAO) review of the Phase IV program. On October 10-11, 1979, congressional hearings on the Phase IV program were held, with testimony by the GAO, the Air Force, the Department of Defense, and the General Services Administration (GSA). On October 26, 1979, the GAO released its formal report, recommending cancellation of the Phase IV program. On November 28, 1979, the Secretary of the Air Force replied to the GAO report, indicating that the recommendation was too drastic.

On November 2, 1979, the General Services Administration suspended the Delegation of Procurement Authority for Phase IV pending its review of the program. Extensive discussions were held between Air Force and GSA officials, and senior members of the GSA staff visited several bases to review Air Force requirements and to assess the effect of canceling the Phase IV program.

On March 28, 1980, the Secretary of the Air Force notified the Chairman of the House Committee on Government Operations that, after coordination with the GSA, the Phase IV program had been redirected to resolve the concerns raised by GAO and the House Committee on Government Operations. GSA reinstated the Delegation of Procurement Authority for Phase IV on April 3, 1980. Contracts were awarded on December 1, 1980, to the Burroughs Corporation and to Sperry Univac for the initial software transition portion of the Phase IV program.

Software transition and testing activity is under way as of mid-1981. The Air Force plans to select the final Phase IV vendor and to begin installation of new computers in February 1983.

Appendix B

GLOSSARY

ARCHITECTURE: The design of the components of a computer system.
AUTOMATED DATA PROCESSING: The process by which data is assembled, processed, stored, recombined, and retrieved by automatic means using a computer system.
BATCH: A group of jobs to be run on a computer at one time with the same program.
BUG: A mistake or malfunction.
CHANNEL: A path along which data passes or along which data may be stored serially in a computer.
COAXIAL CABLE: A transmission line that consists of a tube of electrically conducting material surrounding a central conductor held in place by insulators; used to transmit telegraph, telephone, and television signals of high frequency.
COMMAND LANGUAGE: A source language consisting primarily of procedures capable of invoking a function to be executed.
DATA BANK: A collection of data organized for rapid search and retrieval by computer.
DATA BASE: A set or collection of information that is sufficient for a given purpose or given data processing system.
DATA PROCESSING: The converting by computer of crude information into useable or storable form.
FILE: A collection of related records treated as a unit.
FLOWCHART: A graphical representation for the definition, analysis, or solution of a problem.
HARDWARE: The physical equipment of a computer system.
MAINFRAME: The computer itself and its cabinet, as distinguished from peripheral devices connected with it.
MICRON: A unit of length equal to one-millionth of a meter.
MODEM: A device that processes signals transmitted over communications facilities.
OFF-LINE: Not under the direct control of a computer.
ON-LINE: Controlled directly by or in direct communication with a computer.
PROGRAM LIBRARY: A collection of computer programs and routines.
REAL TIME: The actual time during which a physical process controlled by a computer occurs.

SOFTWARE: The entire set of programs, procedures, and related documentation associated with a computer system.

STRING MANIPULATION: Characters in a computer program to be changed.

TERMINAL: A point or device in a computer systems at which data can either enter or leave.

WORKBENCH: A specialized high-performance computer system that allows programmers to edit and control modifications.

Appendix C

ACRONYMS

ADP: Automatic data processing

AFDSDC: Air Force Data Systems Design Center

CPU: Central processing unit

DBMS: Data base management system

DOD: Department of Defense

DPI: Data processing installation

GAO: General Accounting Office

GSA: General Services Administration

HIPO: Hierarchy plus input-processing output

LSI: Large scale integration

MIPS: Million instructions per second

NRC: National Research Council

OMB: Office of Management and Budget

PABX: Private automatic branch exchange

PPL: Programming production library

RJE: Remote job entry

VHSIC: Very high speed integrated circuits

VLSI: Very large scale integration

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