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General Accounting Office

Tactical Operations System Development Program Should Not Continue As Planned

The Army has been attempting to develop a system to provide automation support for tactical command and control operations for over 20 years. The current effort is the division-level Tactical Operations System. The Army is also planning a corps level and below effort.

This $4 billion program has unresolved issues, including the need to fully identify functional requirements and the need to study alternative system designs. Ongoing studies in the command and control arena should better define the functions and design for the system. For this reason, the Army's efforts should be delayed until the studies are completed.

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Logistics and
Communications
Division

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The Honorable Harold Brown
The Secretary of Defense

Dear Mr. Secretary:

This report presents the results of our review of the Army's Tactical Operations System (TOS) program. Our findings, conclusions, and recommendations are summarized below. A detailed discussion of the results of our review is provided in the appendix.

After some 20 years at trying to develop a system that would use automation to assist battlefield commanders in making tactical command and control decisions, collectively referred to as the TOS program, the Army still has not fielded a system.

The current development, which started in 1971 as a test bed, has not been very successful. The Army overlooked the following key aspects of sound system management.

--Basic system development practices, specified in acquisition policy directives, were not adhered to or effectively conducted--alternative system design concepts were not explored; test objectives were not met and proposed solutions were accepted without further testing; and the cost effectiveness of the proposed solutions was not proven.

--The requirements process, which must identify and substantiate the information that could or should be automated, did not receive timely input from the primary users and still remains incomplete.

--System design was tied to preselected hardware (now outdated) and software and did not adequately consider the severe battlefield environment in which the system must operate with its requirement for military use.

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The test bed development resulted in a system that was difficult to operate and doubtful as to its military use. However, based on design changes proposed by the system developer, the Army approved and advanced division TOS to the next phase of the acquisition process--full-scale engineering development.

Representatives of the Office of the Under Secretary of Defense (Research and Engineering), however, were not convinced that the Army had adequately completed advanced development and questioned the validity of some of the above aspects of division TOS. Thus, the Army was directed to retain the system in advanced development while demonstrating, with test results, its military use. We, too, believe the Army did not have an adequate basis to make the full-scale development decision because it had not performed all of the development practices that should precede such a decision to reduce the risk of further costly delays and incomplete, inconclusive, and inadequate program results.

In this regard, the Department of Defense's direction of division TOS, while appropriate at the time, did not correct other deficiencies in the development effort. The Army has not been directed to explore alternative system design concepts nor to complete the requirements identification process, two important aspects that affect the military use and cost effectiveness, for division TOS.

In our opinion, the Army needs a complete statement of functional requirements in order to identify and substantiate the information needs of the system's primary users. In this regard, two ongoing Army studies--the command and control master plan and the corps and subordinate echelons' requirements--should result in a complete definition of functional requirements for a division command and control system. The corps study would also be a good basis for exploring alternative system design concepts using state-of-the-art computer technology. These opportunities were not previously available to the Army, and, for the first time, division TOS can be viewed within the context of a complete command and control automation architecture.

Also, the Army is planning a field experimentation test for the corps and subordinate echelons' development program involving the use of division TOS hardware and software. We believe this experimentation represents a premature commitment to design, and the same set of conditions that limited division TOS design could also apply to the corps' effort.

AGENCY COMMENTS

We discussed the matters in this report with Army and Department of Defense officials responsible for program actions.

Army officials, recognizing that the TOS program developments have taken a long time, are anxious to keep the current program moving. Stressing the need for automated support to assist command and control, they believe the Army can develop an acceptable system by incorporating design and hardware changes and by early fielding of that system in Europe. They believe that the functional requirements definition of the system now being developed is complete. They recognize that additional functional requirements will be identified for the system, but believe that the European fielding will provide the definition needed. Officials from the Office of the Under Secretary of Defense (Research and Engineering) support this "evolutionary approach" to division TOS development. However, this approach has not been successful in other Defense Department and Army programs--the World Wide Military Command and Control System and the Tri-Service Medical Information System to name two. The division TOS test bed was also a product of evolutionary development and it was not successful.

CONCLUSIONS

The Army's 20 years of lessons learned is more than sufficient time to implement sound management and system development practices. It seems evident from the Army's experience that the TOS program will forever be "evolving" if information requirements are not clearly defined before proceeding with development.

The Army's plans to continue development by fielding one system in Europe will require additional funding of over $100 million. At best, this early fielding will be an interim system which can be expected to be rendered inadequate by corps-level requirements and system development efforts. With the opportunity that the corps-level system presents to provide a full identification of requirements and state-of-the-art technology, in our opinion, little would be gained from a developmental point of view by continuing with the division-level development effort at this time.

While there is a need for some form of automated assistance to support command and control, the Army, in our opinion, is not in a position to make major commitments

to division TOS. Several unknowns exist about requirements, other system developments, concept developments, technology, system effectiveness, and system interfaces which should be considered in deciding the future of the entire TOS program. The ongoing corps-level study is intended to provide the design needed, and the Army should not make investments in hardware or software until these requirements are known and the system design is established.

RECOMMENDATIONS

We recommend that you direct the Secretary of the Army to delay the division TOS development effort until the results of the master plan and corps studies are known. If division TOS meets the needs of that automation architecture, you should direct the Secretary of the Army to make a technical and cost trade-off analysis of continuing with the current division TOS effort.

We also recommend that you direct the Secretary of the Army to delay further experimentation with hardware and software for the corps-level TOS until the results of ongoing studies are known.

As you know, section 236 of the Legislative Reorganization Act of 1970 requires the head of a Federal agency to submit a written statement on actions taken on our recommendations to the House Committee on Government Operations and the Senate Committee on Governmental Affairs not later than 60 days after the date of the report and to the House and Senate Committees on Appropriations with the agency's first request for appropriations made more than 60 days after the date of the report. We would appreciate being informed of the actions you plan to take in response to our recommendations.

We are sending copies of this letter to the Director, Office of Management and Budget; the Chairmen, Senate and House Committees on Appropriations and Armed Services; the Chairman, House Committee on Government Operations; the Chairman, Senate Committee on Governmental Affairs; and the Secretary of the Army.

Sincerely yours,

R. W. Gutmann
Director

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APPENDIX I

TOS DEVELOPMENT PROGRAM

SHOULD NOT CONTINUE AS PLANNED

STATUS AND HISTORY OF TOS DEVELOPMENT EFFORTS

The Army has been attempting to develop automated systems to support tactical command and control operations since 1958. These developments have collectively been referred to as the TOS program. Complete cost data from these developments are apparently not available. However, Army records indicated the Army had spent at least $93.4 million for the entire program through 1978.

The current development, called division TOS, was started in 1971 as a test bed to prove the concept of applying automation to assist command and control operations at the division level. According to the Army, $63.4 million had been spent through fiscal year 1978 on this program's development portion, and another $154.5 million is required to complete development. For fiscal year 1979, the Army received $36.8 million to continue the program. The fiscal year 1980 request is $51.5 million, while total life-cycle costs for division TOS are presently estimated to be $4 billion.

At an Army Systems Acquisition Review Council meeting in January 1978, the Army directed that the program be continued and approved to proceed from the advanced development phase to the full-scale engineering development phase of the material acquisition process. The Army then asked the Defense Systems Acquisition Review Council to approve this action. In reviewing the program's status, staff members of the Office of the Secretary of Defense (OSD) objected to the Army's statement that division TOS development was ready to progress to full-scale engineering development.

In view of these objections, the Principal Deputy Under Secretary of Defense (Research and Engineering), in October 1978, postponed the pending Defense Systems Acquisition Review Council meeting and directed the Army to complete several actions, the foremost was to demonstrate, with test results, the military use of automation to assist division tactical command and control operations. At the time of the postponement, the Principal Deputy Under Secretary had withheld $20 million of the fiscal year 1979 division TOS funds from the Army. These funds were released in March 1979 when the Army was notified that revisions in division TOS were found to be generally responsive to the October 1978 directive from the Principal Deputy Under Secretary.

APPENDIX I

The Army's revisions provide for development and test of three configurations of division TOS, leading to a production decision for Defense Systems Acquisition Review Council consideration in 1982.

Historical development efforts

As originally conceived, the TOS program was intended to provide Army field commanders the essential information needed for command and control purposes. These information requirements were categorized originally into the following 32 functional areas:

Intelligence:

--Enemy situation
--Order of battle
--Terrain intelligence
--Strategic intelligence
--Counter intelligence
--Target intelligence
--Hostile air defense
--Intelligence collection management
--Weather data

Operations:

--Friendly unit situation
--Tactical troop movement
--Airfield/heliport location
--Barrier and denial operations
--Tactical gap crossing status
--Chemical contamination
--Engineering construction status
--Electronic warfare
--Biological contamination
--Tactical air support
--Communication planning
--Air space coordination
--Nuclear fire support
--Nuclear strike effects
--Air defense information
--Psychological operations
--Army air operations

Fire support:

--Preliminary target analysis
--Nuclear target analysis
--Nuclear fire planning

--Chemical target analysis
--Fallout prediction

Other

--Civil affairs

The Army has made five attempts to automate all or some of these functional areas at various command and control levels. A sixth attempt, to automate corps-level command and control, is being planned. A description of the attempts follows.

--The Army Tactical Operations Center effort (1958-64), directed at the field level, was a display oriented system and provided storage and retrieval of selected information. The hardware assemblage was called MOBIDIC.

--European TOS development (1964-70), directed at field and corps levels, was undertaken to evaluate the feasibility of TOS. The objective was to develop an operational system for the 7th Army's use, costing about $30 million. The primary hardware supplier was Control Data Corporation and the software contractor was Bunker-Ramo Corporation. The system was incorporated into the tactical operations centers of the 7th Army for testing in a command post exercise. The Army planned to automate 18 functional areas, but only 5 were actually automated.

--Development TOS (1969-73) used the European TOS hardware and software to apply automation at the division level. Bunker-Ramo Corporation continued as the software contractor. Seven functional areas were to be addressed, however, software for only six functions was modified or developed for use on this division-level system. The seventh functional area was delivered to the Army, but it was not tested due to scheduling conflicts.

--The TOS Operable Segment (1971-77) effort originally addressed corps and division levels, but was redirected to division level only. Three functional areas selected for automation were later reduced to two. This development effort also redirected the Army from commercial hardware to militarized hardware. This test bed effort evolved into division TOS.

--Division TOS is the current effort. The two functional areas (enemy situation and friendly situation) developed for the prior division effort are to be improved

with software enhancements. These two functional areas, according to the Army, have been expanded and now include all or parts of 15 of the original 32 functional areas. Also, additional militarized hardware is to be added and the Army would like to extend automation to the battalion level.

--TOS corps and subordinate echelons' development is the planned effort. The Army has performed studies and tests to begin defining the functional requirements for this system. A contractually supported study to complete the functional requirements definition and to develop system alternatives is underway and is scheduled for completion in April 1980.

SYSTEM DEVELOPMENT PRACTICES MUST BE EFFECTIVELY CONDUCTED

The ultimate objective of Army research and development is the timely development of systems, with minimum total costs and with adequate performance to meet the required needs and capabilities. Basic system development practices, which all systems should follow, are specified in the Office of Management and Budget, Department of Defense, and Army acquisition policy guidance. Successfully performing and documenting the results of these practices provide higher level decisionmakers the basis for program direction decisions.

These practices are interrelated and should progress in an orderly fashion. The successful completion of one practice provides data for the next practice. To date, the Army has not completed some basic practices for a successful system development of division TOS. However, Army headquarters approved the system for advancement to the next stage of development.

Defects in the Army's management of the division TOS development were:

--Alternative system design concepts were not explored and analyzed.

--Test objectives were not met, and proposed solutions were accepted without testing.

--A cost and effectiveness analysis, used to examine different alternatives based on performance from testing, did not provide meaningful data.

Because of these deficiencies, we believe the TOS program development efforts have not been effectively

conducted. Unless these basic development practices are properly completed, it is likely that the TOS program will continue with costly delays and incomplete, inconclusive, and inadequate results.

Alternate system design concepts were not explored

Research and development should emphasize early competitive exploration of alternative system design concepts; i.e., system needs should be expressed in general performance capabilities and characteristics.

Alternative system design concepts should be explored within the context of mission needs and program objectives, with emphasis on generating innovative and conceptual competition from industry. Benefits from this approach could be optimized by the competitive exploration of alternative system design concepts and by tradeoffs of capability, schedule, and cost.

Alternative system design concepts were not explored for division TOS. The general performance capabilities and characteristics of hardware and software were never offered to industry to solicit their ideas for the total system design. At the start of the program, the hardware was preselected as the TACFIRE processor and peripherals, all to be supplied by Litton Industries. As it became evident that the division TOS design had to be changed to make the system more useful, a revised assemblage of hardware, built around the Litton processor, was decided on and software is being rewritten. These revisions, in our opinion, constitute a new system. The Army has little basis in fact, analysis, or evaluation for the configuration and design it wants to now develop. Is it the best design? Can other qualified firms in industry provide better designs? These questions are unanswered.

With the changes needed in the division TOS test bed, in our opinion, the Army was at the point where alternative system design concepts could be explored. However, the Army believes that such exploration will delay the TOS program and that any further delay in the program will not be tolerated by decisionmakers. Some Army officials believe that such delays will result in the termination of the TOS program. We have not attempted to measure any such delay. We believe, however, that if there is a delay, the Army should obtain a conceptual design for the TOS program based on a sound analysis, rather than a reaction to design deficiencies.

System approved by the Army for advancement in development was not tested

Test and evaluation should begin as early as possible and be conducted throughout the system acquisition process to assist in progressively reducing acquisition risks and in assessing military worth and use. Each phase of testing should provide a level of assurance that the (1) hardware operates and meets minimum levels of reliability, (2) software functions and can be run on the hardware to accomplish the mission, (3) system is suitable for the intended operational environment, and (4) military use has been proven.

The Army began division TOS as a test bed effort. Using the test bed hardware and software, the Army's test objectives were to evaluate, refine, and validate a division TOS concept. Despite the many years and dollars that the Army has put into testing, these objectives have not been met. The initial test of division TOS, in early 1976, was characterized as a complete operational failure and was prematurely terminated because the computer operating system software was not usable. The next major test, in mid-1977, produced more favorable results, but software problems were still present and the hardware did not function properly.

Based on the test results, the Army made significant changes. These changes involved (1) replacing much of the hardware, (2) retaining only the central processor, and (3) rewriting much of the software. These changes greatly revised the system. The Army also reconfigured the system, adding both another computer as a front-end message processor and input/output devices at the battalion echelon. This additional hardware had not been fully developed by the Army nor had the system configuration been tested.

More importantly, testing did not demonstrate the operational effectiveness of a useful division TOS concept. It did not provide data to measure effectiveness of a useful division TOS concept nor did it provide data to measure effectiveness needed for making cost and effectiveness comparisons.

The Army expects to correct major deficiencies observed in the division TOS test bed through extensive hardware and software changes. These changes were determined as necessary to increase the effectiveness of division TOS. However, in the absence of adequate testing, the issues of the military use of division TOS and its effectiveness remain unresolved. Thus, although the Army had not complied with basic principles in system development, Army decisionmakers approved the continuation of the effort in an Army Systems Acquisition Review Council meeting by recommending, in January 1978, full-scale engineering development of division TOS.

Cost and operational effectiveness is unknown

A cost and operational effectiveness analysis is a study which develops a recommended rank ordering of candidate systems based on meaningful relationships between costs and operational effectiveness. Such a study should be used at each decision point in the material acquisition process to assure that, before additional resources are committed to development, a candidate system is cost effective.

Such a study for the TOS program was completed in early 1978. The study recommended the most cost-effective system--a configuration with equipment at the division level alone--for full-scale development. The Army did not support this choice and maintained that results of the cost-effectiveness study were inconclusive. It decided to continue developing a different system configuration--a configuration with equipment at division and subordinate levels down to the battalion. Because of inadequacies in the data provided for the study, we doubt whether the study should have been used as the basis for making any choice.

The data used in the study had the following inadequacies.

--Five automated alternatives were examined in the study. These five alternatives were variations of the same hardware used at differing field levels, comprising different configurations. In effect, all the automated alternatives analyzed were a variation of one system. Thus, it would seem, no alternative system design concepts were analyzed.

--The functional capabilities of the automated alternative configurations were not treated alike. Operational enhancements to represent improved intelligence processing of sensor and corps-level data were postulated for the Army's "chosen" configuration. These same operational enhancements were not ascribed to the other automated configurations for comparison and evaluation purposes.

--A way to measure the performance and effectiveness of a system is through proper testing. The Army wanted maximum utilization of the division TOS test bed to verify the performance of automated command and control. Because a major portion of the division TOS test bed projected capability was inoperative during testing, needed performance data was never obtained, and a direct comparison of the system alternatives on an equal basis through field tests or simulations was not done. Specifically, only

the manual system and the division TOS test bed were compared through testing; approximations and results of sensitivity studies were used as inputs to the analysis for the other automation configurations. Lack of consistent and valid test data reduces the confidence in the selection of a preferred alternative for the TOS program, and, therefore, it is unknown whether the preferred alternative is the best alternative.

--Cost and resource data in cost and effectiveness studies are used for evaluating alternatives. Each alternative analyzed in such studies should have a comparable and validated cost associated with it. The cost data used in the TOS program study were not validated by the Comptroller of the Army, and according to the Defense Department's Cost Analysis Improvement Group, the Army's estimated costs had been understated. Costs for the TOS program should be updated, verified, and validated. For example, costs used in the TOS study did not include an estimate for providing continuity of operations.

Measures of effectiveness

A measure of effectiveness is a criterion for expressing quantitatively the extent to which a system or force performs an assigned task or mission under a specified set of conditions. Without good ways to measure effectiveness, the cost and effectiveness study is a meaningless exercise. This may have been the case with the TOS program study. Although the study has been completed, much debate still exists regarding how to measure the effectiveness of automation on command and control.

For years, the Army has been struggling with a means to express the benefits of employing automation in support of command and control. The study organization determined that the effectiveness of each system alternative should be measured on the basis of its contribution to the accomplishment of a tactical mission. The primary measurements used were the enemy rate of advance and the status of enemy forces, measurements designed to accurately assess the outcome of a tactical engagement. Used properly, the data provided by a TOS-like system can influence the outcome of a tactical engagement. However, the objectives of the TOS program are to provide the commander with timely, accurate, and reliable data. It would appear, then, that the benefits of the program would be expressed more appropriately in terms of measures related to satisfying the objectives of the functional operations supported by the system. Whether these

types of measurements could be easily made and whether they would be any more meaningful are still the subjects of debate.

Thus, there is still a lack of agreement of the precise way to measure the effectiveness for the TOS program and for command and control systems in general. The subject of measures of effectiveness for command and control systems is being studied within the corps and subordinate echelons' effort now underway. The study may provide useful input in future TOS cost effectiveness analyses.

REQUIREMENTS IDENTIFICATION PROCESS NEEDS TO BE COMPLETED

Despite more than 20 years of study and development effort to define how automation should be used to support the battlefield command and control decision process, the Army intends to field division TOS without fully identifying the system's functional requirements. In our opinion, the Army needs a complete statement of functional requirements in order to identify and substantiate the information needs of the system's primary user--the battlefield commander.

The Army, however, claims that functional requirements and information processing for command and control are difficult to define for automation purposes. The Army cites the lack of common manual procedures for doing the command and control functions. While there are uniform "fighting" policies and Army doctrinal and tactical statements, the Army allows each commander to use his military judgment, experience, and battlefield management perogatives. In our opinion, this logic confuses the need for information with the process of how the information will be used. Instead of identifying all the functional requirements, the Army intends to field a division TOS in Europe, in fiscal year 1982, to further define requirements and system use. Even here, fielding one system may not be beneficial. One division set operating alone will not address a larger problem--to define automation needs from the corps level to subordinate levels.

In this regard, two ongoing Army studies--the command and control master plan and the corps and subordinate echelons' requirements--should result in a complete definition of functional requirements for a division command and control system. In general, both studies take a "top down" look. In particular, the former study ties together, for the first time, both strategic and tactical needs. The latter study will tie together detailed requirements for automated tactical command and control at the corps level and below. The results of these studies will provide a basis for using a systematic approach in developing systems that support the command and

control arena. The master plan study is scheduled to be completed in late 1979, and the corps study in mid-1980.

Within both studies, the functional requirements of an automated system for division-level application will be identified. An analysis to define a single system within a larger system (e.g., division TOS versus TOS for corps and subordinate echelons), without looking at the functional areas and information needs of the larger system, can produce an inefficient product when viewed in the larger context. The current division system, for example, does not identify the corps level information exchange needs, and the Army does not know the total number of functional areas that will be or need to be automated.

User input must be timely

The current attempt to define functional requirements, which began in 1971, was not built on timely input from the system user. While there was contact with the European Command as early as 1975, this did not constitute useful user input. As evidenced by the division TOS development, it was not until the European Command representatives fully understood the system that useful input was provided. Thus, it was not until 1977, just prior to the second major test, that the European Command--the prime system user--became actively involved. Based on that test and the user's input, the system being developed was found to be functionally and mechanically unfit for fielding.

User input to the requirements definition processed up to that point had been very limited. Subsequent direct input to system design by the European Command should result in a more useful system, but the applicability of the functional aspects to the user--the military--is still questionable. Early and more involvement by the user in the requirements definition process for tactical automated systems is needed to develop a useful product.

OSD QUESTIONS THE VALIDITY OF DIVISION TOS DEVELOPMENT

In fulfilling its review obligation, OSD raised many issues about the readiness of division TOS to transition from advanced to full-scale engineering development and directed the Army to demonstrate and document that program development was sound. The issues were summarized in several letters from the Office of the Under Secretary of Defense (Research and Engineering). In a June 1978 letter, the Army was asked to:

--Demonstrate the military use of division TOS through an analysis of existing configuration alternatives without considering design alternatives.

--Demonstrate the system's ability to provide communications needed to support division TOS in the field, including an assessment of the status of digital communications requirements.

--Present its plans for providing competition for the central processor, the AN/GYK-12, including (1) a cost-benefit analysis of retaining it, (2) going to emulation, or (3) going to a derivative of a standard computer being developed under the military computer family program.

--Complete its testing of the new input/output devices and validate that they, also, were ready to enter full-scale development.

Army representatives and the Principal Deputy Under Secretary met and agreed to keep the program in advanced development while the Army worked out solutions to the above issues. The Army presented a revised development program plan to Defense in January 1979. The plan provides for (1) retaining division TOS in advanced development, (2) developing and testing three hardware configurations all based on the use of existing hardware, and (3) devising a plan that could lead to a production decision for division TOS in 1982. The Army was notified, in March 1979, to proceed according to its revised program plan.

The Department's direction of division TOS, however, has not corrected other deficiencies in the development program. The Army has not been directed to explore alternative system design concepts nor to complete the requirements identification process, two important aspects that affect the military use and cost effectiveness of any Army program.

MILITARY USE OF SYSTEM WAS NOT DEMONSTRATED

Battlefield commanders place heavy reliance on properly functioning military equipment to accomplish their assigned missions. This equipment must be available and reliable when needed, easy to maintain and operate, and mobile and transportable. Also, the equipment must not make the commander's location easily susceptible to enemy detection and attack. In addition, for the command and control function, this equipment must be capable of exchanging information readily with other command and control systems, regardless of any technological or functional differences. These equipment

characteristics are essential to maintain the battlefield commander's continuity of operations. The proof of accomplishment during the development of military equipment is successful testing to demonstrate its military worth. Testing has shown division TOS to be lacking in this important requirement.

The system developed and tested was difficult to operate, and was cumbersome for the operating environment, while not providing continuity of operations. In addition, interoperability between division TOS and other systems has not been defined.

User operating issues

The Army did not do a very good job in defining the usability of the division TOS test bed. At the time this effort went into the mid-1977 test, the Army was aware that changes had to be made. For example, the Army knew that improved message input/output devices would be required prior to the test.

Testing showed that other changes were needed and user participation during testing identified a host of improvements needed to make the system more useful and to simplify its use on the battlefield. The nature of the changes, in our opinion, shows that user and military use needs were not the prime considerations when the system was being designed. The changes being made include:

Change	Reasons
Simplified formats and added prompting feature to assist message composition.	System had 55 formats; they were complex and took too long to compose while requiring a full knowledge of complicated structures and codes.
Standardized data element dictionary.	Different symbols were being used for the same data element in different files, and nonstandard military symbols were being used.
Revised data base management system.	Separate data bases were established for the various system files. The arrangement was not flexible or easy to access.

Change	Reasons
Correlation of data between messages and filtering of similar data in separate messages.	Messages containing similar or confirmation type data need to be acted on or eliminated. Also reduces data base storage requirements.

The system designed as the division TOS operable segment (the test bed) worked, but could not be easily used. Army officials characterized it as a "programmer's dream, but a user's nightmare."

Operational environment needs not met by division TOS

The operational environment for tactical automation is the antithesis of normal computer operational environments. Division TOS testing demonstrated that it was feasible to operate a computer system in the field. However, it also demonstrated the necessity of extensive continuity of operations and consideration of the equipment's sensitivity and vulnerability. Unfortunately, susceptibility to enemy direction finding and traffic analysis, reliability, availability, maintainability, and logistics supportability have not been tested for division TOS. Also, high stress environmental conditions require a straightforward and uncomplicated man-machine interface. This interface has yet to be demonstrated for division TOS.

In the battlefield environment, automated systems, such as division TOS, rely on communications. Yet, tactical communications represent a major constraint on the system. The requirement to transmit large volumes of data characters via frequency modulation links with multiple relays and secure devices imposes a severe burden on communications that tends to limit the capabilities of automation. During testing, extraordinary measures were employed to ensure proper alinement of equipment, equipment availability, and communications coordination. These measures were not sufficient to achieve desired operational capability. Also, secure, digital, frequency modulation communications were not tested. Some testers believe that dedicated networks and improved maintenance and equipment will be required to achieve full benefits from automation. In 1976 the Army completed a study which projected communications requirements to the year 1985. Army officials advised us that the study did not fully consider the requirements for digital data transmissions, but a more recent update, to be completed later in 1979, would contain a greater provision for such transmission needs.

The size of the division TOS hardware may also be a matter of concern. At division headquarters, a 12-foot shelter mounted on a 2-1/2 ton truck will be used to house the hardware. Division TOS adds another van to the division main command post which the Army considers too large already. Adding large pieces of equipment decreases mobility, increases vulnerability, and in general, could have a detrimental effect on the effectiveness of division command and control.

In order for the TOS program to be effective in an operational environment, the Army must have properly trained personnel. The observed high-error rate during testing indicated that overall the training program conducted for division TOS testing did not produce well-trained personnel. Lack of an adequate training program will continue to hamper testing and would be unacceptable in a fielded system. Because of the complexity of division TOS, extensive training will be required for the introduction of TOS into a division. Specific military occupational specialty training will be required for computer center operations, and training methods will need to be developed.

The Army testers concluded that the division TOS test bed did not provide significant benefits to commanders and staff, and it provided little functional assistance to the battalion. Tests showed, in fact, that battalion input to brigade information needs could be accomplished manually. Thus, testing did not show at what field level the system could be used effectively.

Continuity of operations

Continuity of operations addresses the question of how to keep the commands operating when the automated system cannot be used. In the battlefield environment, continuity of operations may be the most important single factor that decides the kind of automation to be provided. Numerous factors cause automated systems to fail or become degraded--hardware failure, loss of communications, destruction by the enemy, relocation of the computer center, and jamming. The need for a plan to provide continuity of operations is critical. It becomes even more critical once user reliance on the automated system has been established.

Division TOS does not have a plan to ensure continuity of operations. Several ideas have been postulated on how continuity of operations could be achieved, but a definitive statement on how it will be accomplished has not been proposed. The current proposed solution is to provide a second division computer center as a "redundant" backup. Key issues of cost, computer center location, and updating procedures have not been resolved. The system envisioned by the Army

should not be implemented in the field without a workable, cost-effective continuity of operations plan.

Interoperability

Automated systems must be capable of exchanging data in a timely manner without mutual interference. The systems must interoperate. Division TOS does not have its interoperability requirements defined. Those requirements are substantial since the system is generally recognized as the center around which all other automated systems will operate. The system, for example, must exchange data with intelligence, electronic warfare, field artillery, and air defense systems.

The Army has not given interoperability for the TOS program the attention it deserves because the immediate plan is to solve the issue for each automated system as the system is introduced into the field. The long-range plan for interoperability is being studied in a series of technical evaluations and appraisals.

Efforts to achieve interoperability are hampered by the lack of a standard data element dictionary and standard message formats. To achieve interoperability between TOS and TACFIRE, 1/ the project managers for the two systems have developed a scheme whereby TACFIRE data would be translated, within TOS, to data elements acceptable to it. In our opinion, unless there is standardization, the rapid exchange of data to take advantage of the capabilities of automation may be lost. The TOS/TACFIRE method of interoperability becomes more unacceptable when one considers the need to exchange data with other services' systems and with our allies' systems. Without this standardization, TOS would need a special translation program for each of the systems it would exchange data with.

DANGERS ASSOCIATED WITH PRESELECTION OF COMPUTER EQUIPMENT

At the start of the test bed development in 1971, the Army decided that, in continuing with the TOS program developments, readily available hardware would be used. In the case of division TOS, the hardware the Army considered to be readily available was the TACFIRE militarized hardware, and system design was tied to the AN/GYK-12 processor and TACPOL 2/ software.

1/Acronym for Tactical Fire Direction System, the Army's artillery control system recently approved for fielding.

2/Acronym for Tactical Procedure Oriented Language, the Army's high-order software language.

Thus, the hardware and software commitment was made and the Army had no technological choices to make that could influence system design. Now, because of later definitions of user needs, the Army has had to make major changes in hardware and software design to accommodate those needs.

Due, in part, to the preselection of computer equipment, the division TOS test bed development produced a system that was found to be mechanically and functionally unfit by the prime system user (the European Command) and by the testing community. The system developed and tested was difficult to operate and had understated storage and processing capacity. To make it usable in the field, the system requires a major software rewrite effort and vastly improved input devices. Also system software, because it is written in the Army's high-order language of TACPOL, has been expensive to write and maintain--more expensive than other languages.

As a result of user and tester evaluations, system design changes are being made to division TOS. The system, however, will continue to use the AN/GYK-12 processor and the TACPOL software. The Army is taking actions to upgrade these technologies. But the changes have not been completed and tested. Thus, we can not assess the degree to which the current design efforts will be better than the previous efforts. The changes are so significant, in our opinion, as to constitute a new system. However, the Army has, again, preselected the hardware to be used for division TOS. (See p. 3.) Also, the same conditions that impaired the division TOS design are coming to bear on the corps TOS design. The Army is planning to use division TOS hardware in a test bed for the corps system, without waiting for the results of the design study to decide the best technical approach to use.

System design efforts were constrained

Hardware

The division TOS test bed disclosed many inadequacies in design. For example, system storage and processing needs were understated and the system could not accept the volume of messages and queries being inputted. These are basic system design characteristics which should be known and provided for during design. Design problems and changes being made are:

--The test bed system, which provided for approximately 256,000 bytes of primary memory and about 4 million bytes of secondary memory, was inadequate. The addition of mass core memory units will provide approximately 2 million bytes of primary memory, and the use of disk storage for secondary memory will

provide 134 million bytes. The Army, however, still does not know capacity requirements for a full-division TOS, but it maintains that the system is expandable to provide for future capacity needs.

--The high volume of message and data requests during the test caused the system to overload and stop. The Army has added a "front-end processor" to handle the volumes, estimated to be 280 percent higher than the test bed planned volumes.

--The test bed message input/output device was cumbersome to use, had no graphics display capability, and limited memory. The replacement hardware, with its prompting feature and greater memory capability, streamlines the data entry and output capability and gives the user some stand-alone processing capability. However, at an estimated $400,000 each, it is an expensive device.

Software

From its infancy, division TOS software development has been a major drawback to the system's success. The Army was directed to develop the software in-house--a task it acknowledges it was ill-prepared to undertake. The initial evaluation of that effort disclosed major problems with the operating system software which affected successful testing of the system. As a result, an outside contractor was given more responsibility in writing software. A subsequent test still showed software deficiencies, but, for the most part, the software that was written worked.

Testing showed, however, that the software written for division TOS must be changed if the system is to be useful in the battlefield environment. Software changes being made are significant. One source estimates only 34 percent of the test bed software is transferable and, when rewritten, will again have to be tested. Hardware additions--the front-end processor and smart terminals--account for a large part of the change.

Software changes related to the AN/GYK-12 and TACPOL include the need to develop

--a unique data base management system and

--other software support tools which are not provided with the mainframe processor.

The effect of these changes is to add an extra cost to the division TOS development effort for features usually supplied by the hardware developer. An Army study 1/ defined a desirable software support base to include 28 software tools. This study determined that the AN/GYK-12 contained 12 of the 28 desirable software tools. It also estimated that it would cost millions of dollars to develop the remaining software tools. Without these tools, the development of software for TOS is costly when compared to software developed for other military computers. Another Army study 2/ listed the estimated cost per instruction of TACPOL as higher than language used for other military computers included in the study, more than double the cost per instruction of the language used for the AN/GYQ-21 computer.

The division TOS software contractor is designing a unique data base management system, and the Army is buying other software support tools to facilitate the development of the software. The February 1978 Army study estimated these additions to cost over $6 million. We do not have a firm statement of the cost to develop these tools for division TOS.

Preselection of hardware continues

Division TOS design was tied prematurely to the AN/GYK-12 processor, which is now technologically outdated. Better technology is and has been available for use in division TOS. However, the Army believes it is not needed at this time. The Army further believes any transition to better technology will cause a delay in the TOS program. Also, the Army believes the decisionmakers will not tolerate a further delay in the program, for the most part, because of the previous 15-year unsuccessful history in trying to automate the command and control function.

The Army, again, has the opportunity to study alternative designs for division TOS, not separately, but as part of the

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1/"A Comparison of the Existing Support Software Bases of the AN/GYQ-21 Architecture and the Current Military Architecture," February 1978.

2/"Final Report Life Cycle Cost Analysis of Instruction-Set Architecture Standardization for Military Computer-Based Systems," January 1978.

study of an automated system for application at corps and subordinate echelons. The selection of a system design for the corps and subordinate echelon application will have the benefit of reviewing state-of-the-art technology and defining requirements for the entire spectrum of command and control for tactical operations.

Since 1976 the Army has been conducting a requirements definition effort for a corps-level system. The effort has since been consolidated with the corps and subordinate echelons' study. In contrast to division-level efforts, the corps-level program more analytically defines requirements, probably due in part to profiting from the mistakes in the division-level development.

However, the Army is making the same types of decisions for the development of the corps system as were made for division TOS, which in retrospect were not good decisions. Division TOS hardware and software, including the technologically outdated central processor, are planned to be used in a fiscal year 1981 test bed environment (force development test and experimentation) for the corps' system, and testing is planned for a system configuration which may not be as good as the one the corps study will identify as being the best alternative design. The same conditions that affected the division TOS could apply to the corps development effort, where premature commitments to hardware will drive the design of the system.

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