United States General Accounting Office

GAO

Report to the Chairman, Subcommittee on Defense, Committee on Appropriations, House of Representatives

May 1991

COMPUTER TECHNOLOGY

Air Attack Warning System Cannot Process All Radar Track Data

GAO/IMTEC-91-15

GAO
United States
General Accounting Office
Washington, D.C. 20548

Information Management and
Technology Division

B-242249

May 13, 1991

The Honorable John P. Murtha
Chairman, Subcommittee on Defense
Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

In response to your request and subsequent discussions with your office, we assessed the capability of the computer system used to process Atmospheric Tactical Warning and Attack Assessment data for the North American Aerospace Defense Command, and Air Force plans to integrate upgraded and new radars into the system. We found that the system's computers do not have sufficient memory for processing and storing all the data from operational and planned radars. We also found that Defense's use of the computers to support the nation's counter-narcotics mission overburdens them and is unnecessary because it duplicates functions being performed by the United States Customs Service.

We are sending copies of this report to the Secretary of Defense; the Secretary of the Air Force; the Chairmen, House and Senate Committees on Armed Services; the Chairman, Senate Committee on Appropriations; the Director, Office of Management and Budget; and to other interested parties.

Sincerely yours,

for Ralph V. Carlone
Assistant Comptroller General

Executive Summary

Purpose

The Department of Defense is spending almost $3 billion to upgrade and expand radar coverage to provide accurate and timely warning information to the Atmospheric Tactical Warning and Attack Assessment (Atmospheric TW/AA) System. The North American Aerospace Defense Command (NORAD) uses this system to warn United States and Canadian leaders if North America is under aircraft attack, and to assess its nature and extent. The system, which consists of a diverse network of radars, communication links, and command centers, is also being used to support this country's counter-narcotics efforts.

At the request of the Chairman, Subcommittee on Defense, House Committee on Appropriations, GAO assessed Air Force efforts to integrate the network of radars with the computer systems at NORAD. Specifically, GAO assessed (1) the capability of the computer system used to process Atmospheric TW/AA radar data and (2) plans to integrate upgraded and new radars into the Atmospheric TW/AA System.

Background

The Atmospheric TW/AA System is a vast network of radars, located primarily in North America, that transmit data through various communication links to nine regional or sector operations control centers (regional or sector centers) in Hawaii, Alaska, Canada, Iceland, the continental United States, and ultimately to NORAD in Colorado Springs, Colorado. The regional and sector centers receive, process, and correlate the radar data using an AN/FYQ-93 (Q-93) computer.

Introduced in 1983, but based on 1960s and 1970s technology, the Q-93 was designed to receive data from four then-existing radar systems. Since 1983, the Air Force has begun to replace or add seven other radar systems into the Atmospheric TW/AA system, which will send the Q-93 more data.

In the Fiscal Year 1989 National Defense Authorization Act, the Congress designated Defense as the lead Federal agency for the detection and monitoring of air and maritime illegal drug traffic into the United States. Under the act, the Secretary of Defense is also authorized to make military assets available to support federal, state, or local law enforcement agencies in their efforts. Defense chose to use the Q-93 to support its counter-narcotics efforts. According to Defense officials they are to avoid duplicating the activities of other federal, state, and local agencies.

Results in Brief

Defense has not managed the components of the Atmospheric TW/AA system from a systems perspective; Defense continues to acquire and upgrade radars without resolving the impact the additional work loads would have on the Q-93. Because the architecture of the Q-93 limits the memory that can be used to process radar data, the Q-93 cannot process all the track data that the radars can generate.

Even before installing the Q-93 computers, the Air Force knew the computer did not have sufficient memory for processing and storing all the data from planned radar systems, yet it continues to add radars to support the Atmospheric TW/AA system. Recognizing the Q-93's limited memory for storing aircraft track information, the Air Force restricts the amount of data sent from some of these radars, thereby reducing the potential benefits envisioned by adding these expensive systems. The Air Force does not know the Q-93's capabilities because it has not established a comprehensive capacity management and performance monitoring program to determine current system performance and plan for future needs. Moreover, using the Q-93 to process radar data to support Defense's anti-drug mission further exacerbates this situation and is unnecessary because the Q-93 merely duplicates functions being performed by Customs Service systems.

Principal Findings

No Capacity Management Program Exists for the Q-93

The Department of Defense is spending billions of dollars building new and upgrading existing radars, knowing that all aircraft information that can be generated by them cannot be processed by the Q-93. The Air Force cannot accurately determine the Q-93's current or future processing and performance capabilities because it lacks a comprehensive system capacity and performance management program. Had such a program been in use by the Air Force, information on the computer capacity that current operations are using and the additional capacity needed to support future operations would be known.

The Q-93 Has Inadequate Memory to Process All Data Generated by Atmospheric TW/AA Radars

The Q-93's architecture prevents adding memory that is needed to process all radar track data. The Q-93 was delivered in 1983 with 192,000 bytes of memory, 128,000 of which could be used to process information on aircraft entering United States airspace. Since then the memory has been expanded twice. However, due to the way the Q-93 is designed, the memory available for processing radar data cannot be expanded beyond 128,000 bytes. Because of this memory limitation, the Q-93 cannot process and store all the track data that some radars are capable of sending to it. To avoid overloading the Q-93, the Air Force has had to limit the amount of data sent by the various radars. For example, the Over-the-Horizon-Backscatter radar can track up to 150 aircraft, but only 50 tracks are sent to the Q-93.

Counter-Narcotics Role Places Unnecessary Burden on the Q-93

NORAD is now using the Q-93 to process significant amounts of radar data to detect and monitor aerial and maritime transit of drugs into the United States. In performing this function, the Q-93 now processes data on as many as 500 more aircraft a day, and plans for installing more Aerostat radars may increase the work load by another 5,400 aircraft per day. However, the radar data processed by the Q-93 is also sent to, and processed by, a Customs Service command, control, communications, and intelligence center. Consequently, NORAD's processing of this data is duplicative and places an unnecessary burden on the Q-93.

Recommendations

GAO recommends that the Secretary of Defense review the radar and data processing capabilities and requirements for its Atmospheric TW/AA System and implement a comprehensive computer capacity and performance management program. Using the results of this program, Defense should establish an appropriate radar and data processing architecture that can effectively accomplish its current mission and be expanded to meet future needs. GAO further recommends that Defense discontinue using the Q-93 to receive, process, and display counter-narcotics radar data.

Agency Comments

GAO requested written comments from the Department of Defense, but none were provided. However, GAO discussed its findings with responsible agency officials and have included their comments as appropriate. Defense partially agreed with the report's findings, it did not agree with two of the report's recommendations and partially agreed with the report's other recommendation. Defense stated that the Air Force has a Q-93 capacity management and performance monitoring program in

place and that the counter-narcotics mission does not overburden the Q-93. Defense did not provide convincing evidence or supporting documentation to support its claims. In addition, Defense said that the Q-93 can accomplish NORAD's missions, even though it is now considering replacing it. GAO did not question whether the Q-93 is meeting NORAD's mission, only Defense can make that determination. GAO's concern is whether Defense's approach to managing the system is prudent.

GAO's recommendations are designed to ensure that NORAD can carry out its required missions effectively and economically, both now and in the future. In this regard, GAO believes that the Air Force's efforts to manage Q-93 capacity and assess resource utilization have been incomplete and inadequate, and that accurate information concerning current and future work loads and the capability needed to process those work loads must be well-defined and analyzed. This is not the case. When asked to provide capacity and performance data, Defense was only able to provide sporadic, incomplete data. Finally, Defense did not explain why it is compelled to duplicate the processing done by the Customs Service. See chapter 4 for a detailed evaluation of Defense's comments.

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Abbreviations

AWACS	Airborne Warning and Control System
GAO	General Accounting Office
IMTEC	Information Management and Technology Division
NORAD	North American Aerospace Defense Command
TW/AA	Tactical Warning and Attack Assessment

Introduction

The Integrated Tactical Warning and Attack Assessment System is used by the North American Aerospace Defense Command (NORAD)—a binational United States and Canadian military command—and the United States Space Command to warn United States and Canadian leaders of an attack on North America or United States space systems in a timely, accurate, and unambiguous manner. Included in this system is the Atmospheric Tactical Warning and Attack Assessment (Atmospheric TW/AA) System, which is designed to warn of an atmospheric (aircraft) attack on North America. The system provides atmospheric surveillance, data correlation and assessment, and warning information. A counter-narcotics role was recently added to detect and monitor aircraft transporting illegal drugs into the United States. The radars that detect aircraft entering North American airspace and the control centers that process and correlate data and notify NORAD of unknown aircraft are the subject of this report.

What Is the Atmospheric Tactical Warning and Attack Assessment System?

The Atmospheric TW/AA System is a complex network of radars, communications systems, and control centers. The radar systems detect aircraft entering the North American air space and transmit either radar plot or track data[1] to regional or sector operations control centers (regional or sector centers) through various communication systems. The existing atmospheric radars include the Distant Early Warning Line, the Greenland-Iceland-Norway Barrier, the Alaskan Radar System Network, and the Joint Surveillance System. Additionally, the system receives data from existing Over-the-Horizon-Backscatter, Airborne Warning and Control System (AWACS), and Aerostat radars and is to receive data from additional radars when they become operational. The North Warning System, the Federal Aviation Administration/Air Force Radar Replacement Program, and the North Atlantic Defense System are upgraded radar systems that will replace some existing atmospheric radars (the Distant Early Warning System, Joint Surveillance System, and Greenland-Iceland-Norway Barrier radars) when completed. Future plans include adding still other radars, such as the Relocatable-Over-the-Horizon Radar, the Canadian Coastal Radar System, and the Caribbean Basin Radar Network. (See app. I for a description of each radar system.)

[1] A radar plot indicates the aircraft's position in terms of latitude, longitude, and azimuth (elevation angle in degrees from the radar). A radar track is a series of plots that, when processed, indicate an aircraft's altitude, speed, direction,and position.

Nine regional and sector centers located in Iceland, Canada, Alaska, Hawaii, and the continental United States receive, process, and correlate data from the radars. Each center uses an AN/FYQ-93 (Q-93) mainframe computer that was built by the Hughes Corporation using 1960s and 1970s technology. The Q-93 was originally procured to meet the needs of only four radar systems. By adding planned replacements and new systems, eventually the number of radar systems sending data to the Q-93 will increase to 11. Each Q-93 will generally manage and process radar data from the radar systems in its vicinity.

Atmospheric TW/AA Data Is Routed Through Regional and Sector Operations Control Centers to NORAD

Radar data is collected at the sensors, processed at the sensors or at the regional and sector centers, and sent to NORAD's Air Defense Operations Center in Cheyenne Mountain, Colorado. Upon receiving the radar data, the regional or sector center computer processes the radar plots to create an aircraft track for display on center display consoles. Aircraft tracks that cannot be correlated within two minutes, with an approved flight plan filed with the Federal Aviation Administration, or by other means, are classified as unknown and forwarded to NORAD's Air Defense Operations Center.

Organizations Responsible for Acquiring, Operating, and Maintaining Atmospheric TW/AA Components

As the system's primary user, NORAD is responsible for establishing requirements and providing overall direction to numerous major commands supporting the system. The United States Tactical Air Command and Alaskan Air Command, and the Canadian Department of National Defence manage and operate the radar systems located in their respective geographic areas. Air Force Logistics Command maintains all computer hardware and NORAD's Regional Operations Control Center Software Support Facility (Software Support Facility) maintains the software for computers at the regional and sector centers.

Objectives, Scope, and Methodology

In September 1989, the Chairman, Subcommittee on Defense, House Committee on Appropriations, asked us to assess Air Force plans to integrate Atmospheric TW/AA System radars with the computer system in Cheyenne Mountain. Specifically, we agreed to assess the capability of the computer system (the Q-93) used to process Atmospheric TW/AA data for NORAD and to assess Air Force plans to integrate upgraded and new radars into the system.

To assess the Q-93's capabilities we interviewed Air Force officials responsible for hardware and software acquisition and maintenance. We

reviewed documents that describe and prescribe the system's configuration control process and that assessed the capability of the Q-93 (performance and capacity) to meet current and future Atmospheric TW/AA requirements.

To assess Defense's plans to integrate upgraded and new radars into the system, we interviewed Air Force and NORAD officials to obtain a thorough understanding of the upgraded and new radar systems planned for future integration. We reviewed system architecture plans, requirements' documents, Air Force and contractor studies and analyses, and other technical documents. We also reviewed documentation delineating the responsibilities of NORAD for the recently implemented counternarcotics role, and NORAD's approach for discharging these responsibilities.

We conducted our work from December 1989 through March 1991 at the Joint Chiefs of Staff and Air Force Headquarters in Washington, D.C.; NORAD Headquarters, United States Space Command, and Air Force Space Command at Peterson Air Force Base, Colorado; Air Force Systems Command's Electronic Systems Division at Hanscom Air Force Base, Massachusetts; the Over-the-Horizon Backscatter radar site at Bangor, Maine; Air Force Logistics Command's Sacramento Air Logistics Center, Sacramento, California; the Northeast Sector Operations Control Center at Griffiss Air Force Base, New York; the Southeast Sector Operations Control Center and the Regional Operations Control Center Software Support Facility at Tyndall Air Force Base, Florida; Alaskan Air Command, Elmendorf Air Force Base, Alaska; and Tactical Air Command and 1st Air Force in Langley, Virginia. Our audit work was conducted in accordance with generally accepted government auditing standards. We requested written comments from the Department of Defense on a draft of this report but none were provided. However, we discussed its findings with responsible agency officials and have included their comments as appropriate.

The Q-93's Data Processing Capability Is Limited

The Q-93 is crucial to accomplishing NORAD's Atmospheric TW/AA mission. The Q-93 collects, processes, and displays radar surveillance data used to identify and intercept potentially hostile aircraft. Although sufficient to process its original work load, the Q-93 computer architecture has limited expansion capabilities to accommodate changing processing work load and requirements. Several Air Force studies completed since 1982 identified serious problems with the Q-93's memory available to process and store aircraft tracks generated from planned radar sources.

The Air Force has not adequately determined the Q-93's capacity and performance capabilities, nor established a continuous and comprehensive capacity management and performance monitoring program to assess the capacity and performance needed to support current and future data processing needs. The Q-93's memory has been expanded twice (to its maximum capability) since installation to accommodate new system requirements; however, the current system cannot process and store all aircraft tracks that could be generated from data sent by current and future radars. While the Air Force is aware of this problem, officials at Air Force Space Command, NORAD, and the Software Support Facility could not adequately explain why it has not been fully resolved.

Q-93's Architecture Provides Limited Memory Capacity and Software Flexibility

The Q-93 is limited by the memory available to store, process, and display track data and by an inflexible, limited software architecture that does not easily support its expanding and evolving work load. Because its memory is severely limited, the system can process only a specific number of tracks (the exact number is classified), regardless of the data generated by the sensors, and needed system enhancements cannot be made in a timely fashion. Further, the software is structured such that needed changes are difficult, labor-intensive, and time-consuming.

Q-93 Memory Constraints Severely Limit System Capabilities

The Q-93, which is no longer manufactured, was delivered in 1983 with 192,000 bytes (characters) of memory. In 1986, the memory was increased by 64,000 bytes to 256,000, and in 1989, by 256,000 bytes to a system maximum of 512,000. However, the Air Force has not been able to integrate the final 256,000 byte memory expansion with the existing system memory. The memory used to process radar data cannot be expanded even if the additional 256,000 bytes of memory can be made to work, since the system design limits the memory that can be used to process radar data to 128,000 bytes. To overcome this problem, the Air Force limits the number of tracks the Q-93 can receive from some radar

systems. As a result, all tracks cannot be displayed on radar screens at the control centers.

Several independent technical reviews commissioned by the Air Force since 1982 have highlighted the Q-93's memory as a limiting factor in current and future system performance. The Software Support Facility, as well as the Mitre Corporation[1] and Lawrence Livermore National Laboratory, have analyzed the Q-93's ability to process all the data generated by all operational and planned radar systems. They concluded that the Q-93 cannot process and store all this data because of its limited memory.

In July 1982, before Q-93 development was complete, the Software Support Facility studied the feasibility of modifying the Q-93 design so that it could accept and process radar tracks from the Over-the-Horizon-Backscatter radar. Seven different alternatives were considered. The study concluded that a "serious problem exists" with the Q-93's memory available for processing radar data and that the problem must be addressed and resolved before data from additional radars (such as the Over-the-Horizon Backscatter Radar and the North Warning System radars) could be successfully integrated.

In April 1983, the Mitre Corporation completed a study, at the Air Force's request, to identify changes needed to integrate radar data from Over-the-Horizon Backscatter, North Warning System, and AWACS radars into the Q-93. The Mitre report stated that several previous studies addressed the addition of individual radar data sources, but none had addressed the effect of adding all sources combined on the Q-93's processing capability. Mitre considered several alternatives to integrate the new data sources into the existing Q-93 design, including expanding the Q-93's memory beyond the 192,000 bytes available in 1983. However, Mitre rejected memory expansion because its analysis showed that even with the expanded memory, the Q-93 could not process the increased work load.

In 1985, the Software Support Facility completed a study that addressed adding data from the same new radar systems as the Mitre study had addressed 2 years earlier. This study concluded that the Q-93 had insufficient memory to perform all software maintenance and to implement new functions when radar systems are added throughout the system's life cycle.

[1]The Mitre Corporation provides engineering support to Air Force Systems Command.

In 1987, the Software Support Facility again studied the Q-93's software limitations. The Software Support Facility cited memory limitations as a major reason that additional aircraft tracks could not be processed by the system.

And finally, in 1989, the Lawrence Livermore National Laboratory completed a system-level analysis of all communications and data processing requirements, from the radars through the regional or sector centers to the continental United States regional center (at Langley Air Force Base, Virginia) and NORAD (at Cheyenne Mountain). The study examined the Q-93 with its maximum memory capacity (512,000 bytes) and concluded, among other things, that data input from new and existing radars would exceed the Q-93's capability to process and store all the aircraft tracks that could be generated. The Lawrence Livermore National Laboratory proposed acquiring a computer that would augment and expand the capabilities of the Q-93 in the near-term, and that could be expanded into a network of computers to replace the Q-93 in the far-term. According to the Laboratory, this approach would solve the Q-93's problems in the near-term, and would be a first step toward achieving a more flexible system architecture to meet future needs.

Poorly Structured Software Makes Maintenance Difficult and Expensive

Software maintenance on the Q-93 is difficult, labor-intensive, and time-consuming. It takes nine programmers to maintain the Q-93's operating system software, whereas it takes only two to maintain another, more modern operating system also maintained by the Software Support Facility.

Well-designed software is structured into modules with carefully defined interfaces so that changes made (e.g., functional enhancements or system corrections) to one module will not generally require changes throughout the system. In particular, applications modules are well isolated from operating system modules. The Q-93 software, however, is structured as a monolith of interdependent modules rather than as well-defined, independent modules. Applications modules are not well isolated from operating system modules. As a result, changes made to applications programs often require that the operating system be changed as well.

Further, modern software is written in standard higher order languages for which development and maintenance tools and training programs are readily available. Contrary to this practice, Q-93 software is written in a combination of assembler language and HOVIAL (a rarely used

Hughes Corporation proprietary version of the JOVIAL language), and has a very small pool of trained programmers and only limited programing and maintenance tools.

A Formal Q-93 Capacity Management and Performance Monitoring Program Does Not Exist

Although the Q-93 has been operational since 1983 and several radar systems have been added since that time, and more are planned, the Air Force has not adequately analyzed the Q-93's capacity and performance, nor established a formal program to manage capacity and monitor performance. Consequently, the Air Force cannot accurately determine the Q-93's current processing and performance capabilities nor address the impact of future work loads on the Q-93, despite the fact that numerous studies have concluded that the Q-93 cannot meet planned data processing requirements.

The Air Force has put itself in the position of not knowing the capabilities of the Q-93 because it lacks a capacity and performance management program for the system. Capacity management is the process by which the components of the computerized system are configured, utilized, and maintained to assure that the work load is processed effectively, efficiently, and economically. The components of the system are the central processor, the memory hierarchy, the peripheral equipment and their controllers, communications processors, and the associated software and data files. Because the components have different operating characteristics, e.g., size and speed, and because the demands upon these components vary with the work load, poor capacity management can result in bottlenecks that degrade overall system performance.

To manage capacity effectively, system performance and behavior must be monitored regularly; the acceptability of current service levels to users must be determined; reasoned predictions about work load changes in the future must be made; the effect of proposed and actual changes to the system must be determined and evaluated; and recommendations must be made for assuring good service to users both currently and in the future. Performance data gathered by system facilities, hardware monitors, and software monitors and use of effective analytic modelling tools and techniques are essential in managing capacity effectively.

Federal government regulations prescribe policies and procedures for the management of automated data processing resources. The Federal Information Resources Management Regulation requires government agencies to conduct capacity management activities in planning for,

acquiring, and using computer resources. Such activities are important because they provide agencies with information about the computer capacity the current operations are using and the additional computer capacity needed to support future mission work load requirements.

Without a computer capacity and performance management program, assessments of Q-93 computer capacity have been limited. Assessments of the Q-93 have focused primarily on computer storage and track capacity. While such assessments provide some useful information, they do not give a complete picture of computer performance, primarily because computer utilization has not been adequately measured. Without utilization statistics, Defense cannot determine the system's ability to process its current work load in a timely manner, or its planned future work load.

Up to this time, sector personnel have not been able to accurately describe the Q-93's capabilities. Measuring Q-93 performance is difficult because the Q-93 is based on obsolete technology and no commercial tools are available to measure its performance. Software Support Facility personnel have begun to design software to assist them in gathering and analyzing system performance information. As of December 1990, this software development effort had not been completed.

The Department of Defense Has Not Approached Atmospheric TW/AA System Integration From a System Perspective

Defense has not managed the components of the Atmospheric TW/AA system from a system level perspective. While it is spending almost $3 billion to acquire planned radar upgrades and additions for NORAD's Atmospheric TW/AA and counter-narcotics missions, Defense has not resolved the fundamental question of how the work load generated by these radars will be effectively processed and forwarded to decision makers.

Approach to Integrating New Radar Data Into the Atmospheric TW/AA System Has Been Costly and Ineffective

Defense continues to spend billions of dollars building new and upgrading existing radar systems that generate additional data. However, Defense has not taken action to ensure that all the additional data can be received and processed by the Q-93. For example, the Over-the-Horizon-Backscatter radar is capable of simultaneously tracking up to 150 aircraft as far away as 1,800 miles and sending these tracks to sector centers. However, the Air Force has limited the number of tracks sent to each Q-93 at any one time to 50 because of the Q-93's limited memory to store track data.

As another example, AWACS is capable of simultaneously tracking up to 300 aircraft and sending these tracks to the Q-93. As was the case with the Over-the-Horizon-Backscatter radar, the Air Force has restricted the number of tracks sent by AWACS to the Q-93 to 30 because of the computer system's limited memory to store track data. Consequently, the Air Force is unable to derive full benefits from the data generated by both of these radar systems.

Defense's Counter-Narcotics Mission Generates Unnecessary Work Load for the Q-93

Counter-narcotics activity could involve detecting, identifying, and monitoring as many as 6,000 flights a day at the southeast sector center. NORAD's decision to use the Q-93 for this purpose is ill-advised for two reasons. First, NORAD's efforts to identify potential drug smugglers duplicates the efforts of the Customs Service; and second, the Q-93, already unable to handle its current and future Atmospheric TW/AA work load, is a poor choice to handle the additional drug work load.

Defense's Counter-Narcotics Role

The Fiscal Year 1989 National Defense Authorization Act designated Defense as the lead federal agency for the detection and monitoring of air and maritime transit of illegal drugs into the United States. Under the act the Secretary of Defense is also authorized to make military assets available to federal, state, or local law enforcement agencies to

support their efforts. The act also stated that Defense's counter-narcotics support to civilian law enforcement officials must not adversely affect military preparedness. The Secretary of Defense asked the Commander-in-Chief of each command to evaluate the priority of drug-fighting actions within their commands. NORAD's Commander-in-Chief cited the counter-narcotics role as second only to NORAD's Integrated Tactical Warning and Attack Assessment mission. NORAD officials also said that an important element of carrying out their counter-narcotics role is to avoid duplicating the activities of other federal, state, or local authorities.

NORAD Duplicates Customs Processing of Counter-Narcotics Data

Not only does NORAD's use of the Q-93 to process radar data, related to counter-narcotics activities, place an unrealistic burden on the Q-93, it also duplicates Customs Service activities. The Customs Service detects and tracks aircraft suspected of being used to smuggle drugs and apprehends persons engaged in drug smuggling. The Customs Service uses two command, control, communication, and intelligence centers (one in Florida and one in California) to direct its counter-narcotics efforts. Data from the Joint Surveillance System and Aerostat radars are transmitted simultaneously to the Customs Service's centers and to the Q-93 computers at NORAD's sector centers. Under NORAD's current procedures, sector centers receive and process the same radar data on potential drug smugglers as the Customs Service. Such duplication is unnecessary.

NORAD does not use aircraft tracks from the Q-93 to allocate aircraft resources (AWACS and fighters) to assist the Customs Service in drug interdiction efforts. The Customs Service, based on its intelligence sources, often predicts that a drug-smuggling aircraft will be taking a certain route at a certain time. If a Customs Service-owned aircraft is not available to track and monitor the suspected drug smuggler, the Customs Service may request that a military AWACS aircraft perform this function.

Similarly, when a military fighter may be needed to assist the Customs Service in providing airborne surveillance of a potential drug smuggler, the Customs Service notifies the military of that need. Although a radar track is available to the sector center when a fighter is needed to monitor such aircraft, the mechanism used to initiate such military actions is the Customs Service's request for assistance.

Implementation of the Counter-Narcotics Role Increased the Processing Burden on the Q-93

NORAD uses the Q-93 to process information on all aircraft entering United States airspace. However, using the Q-93 to process and display tracks on potential drug-smuggler aircraft places an additional burden on the already stressed Q-93 and reduces the memory available to store Atmospheric TW/AA track data.

As discussed previously, Atmospheric TW/AA radars can generate more information than the Q-93 can receive and store given its limited memory. Prior to implementing the counter-narcotics role, the sector centers did not create tracks for aircraft flying slower than 180 knots because Soviet bomber aircraft cannot fly below that speed. Drug smugglers' aircraft generally fly slower than military aircraft; therefore, NORAD eliminated the 180-knot exclusion rule, requiring the centers to identify all aircraft. Although Air Force officials could not precisely quantify the additional demands that carrying out the counter-narcotics role in this manner has placed on the Q-93, they estimated that over 500 more aircraft a day now meet their criteria for identification. According to sector center operators, however, they do not attempt to track and identify all aircraft flying slower than 180 knots because it would overload the Q-93's track capacity.

NORAD officials stated that increased demands created by the counter-narcotics role have exceeded the Q-93's capabilities. NORAD recognizes that the additional Aerostats intended to provide more counter-narcotics radar coverage along the southern United States border, including the area between Gulf of Mexico oil rigs and the Gulf coast, will further compound the problem. These Aerostats will detect the estimated 5,400 helicopter flights per day to these oil rigs, which currently are not detected by existing radar systems.

In May 1990, NORAD notified the Joint Chiefs of Staff that the Q-93's capabilities to meet changing operational requirements are becoming impossible and that the increased demands of the counter-narcotics mission have exceeded system capabilities. As a result, NORAD requested Joint Chiefs of Staff support for funding an immediate hardware and software upgrade to meet NORAD requirements. Costs for these upgrades have not yet been determined.

Conclusions and Recommendations

Defense has not managed the components (e.g., radars and Q-93 processors) of the Atmospheric TW/AA system from a system level perspective. It has acquired expensive radars without addressing the impact the additional work loads would have on the Q-93. When the Q-93 could not process all the data generated, the Air Force simply reduced the data sent to it, sending to the Q-93 only the quantity it could handle. Nonetheless, Defense continues to plan and acquire new and upgraded radars, costing billions of dollars.

To keep the system operational, the Air Force expanded the memory capacity twice and continues to make cumbersome, labor-intensive, and time-consuming changes to the system's software. While these actions keep the system running, the system's archaic and inflexible architecture prevents any increase in the number of aircraft that can be tracked.

The Q-93's problems are not new. Even before the Q-93 became operational in late 1983, the Air Force knew that simply expanding the memory would not enable it to process and store the volume of tracks from planned radars. Several studies completed since 1983 have sounded a similar theme, but their warnings have gone unheeded by the Air Force as well.

NORAD compounded this data overload situation by directing the regional and sector centers to process radar data for counter-narcotics activities. However, decisions to allocate fighter and AWACS resources for the counter narcotics role are based on requests from the Customs Service, rather than on information generated by the Q-93. It is, therefore, unclear what purpose is served by using the Q-93 to process counter-narcotics data. What is clear, however, is that such use adds work load to an already heavily burdened system that has insufficient memory to store all the tracks that could be generated using data from existing radars.

Although the Air Force is aware of the Q-93's shortcomings, it has not implemented a comprehensive capacity management and performance monitoring program. Air Force has sponsored several individual assessments of the Q-93 that focused on limitations in storage and track capacity. While these assessments are useful, they do not provide the kind of comprehensive information on Q-93 resource utilization as called for by the Federal Information Resources Management Regulation. As a result, the Air Force cannot accurately determine the Q-93's current processing and performance capabilities nor address the impact of future work loads.

At a time when Defense is expanding the Atmospheric TW/AA system by spending billions of dollars to acquire and upgrade radar systems that will send even more data to the Q-93, the Air Force knows it does not have the memory necessary to process and store much of this vital information. The approach Defense has taken to integrate radars into the Atmospheric TW/AA system has not considered the Atmospheric TW/AA system's needs as a whole, nor has it provided any assurance that the Atmospheric TW/AA mission is being accomplished in the most economical, effective, or efficient manner.

Recommendations to the Secretary of Defense

We recommend that the Secretary of Defense review the radar and data processing capabilities and requirements for its Atmospheric TW/AA system and implement a comprehensive computer capacity and performance management program. Using the results of this program, Defense should establish an appropriate radar and data processing architecture that can effectively accomplish its current mission and be expanded to meet future needs. In developing this architecture, Defense should

- validate current and planned radar data processing requirements;
- identify a range of alternatives for processing the current and planned work loads, including alternatives based on a modern, flexible, and expandable architecture;
- select the most advantageous alternative, using criteria including flexibility, to meet expanding requirements and life cycle costs;
- ensure that, in the future, the impact of upgrading or adding radars to the Atmospheric TW/AA system, including the impact on the processing component, is fully evaluated and approved.

We also recommend that the Secretary of Defense discontinue using the Q-93 to receive, process, and display counter-narcotics radar data, which duplicates that processed by the Customs Service.

Agency Comments and Our Evaluation

We requested written comments from the Department of Defense, but none were provided. However, we discussed our findings with responsible agency officials and have included their comments as appropriate. While Defense partially agreed with our findings, it did not agree with two of our recommendations and partially agreed with our other recommendation. Specifically, Defense stated that

- the Q-93, with on-going memory upgrades, can accomplish NORAD's missions;
- the Air Force has a Q-93 capacity management and performance monitoring program in place;
- NORAD has taken action to ensure that all necessary radar data can be received and processed by the Q-93; and
- carrying out the counter-narcotics mission does not overburden the Q-93; but
- the Air Force has decided to replace the Q-93.

Memory Limitations of the Q-93 Computer

In commenting on a draft of this report, Defense stated that the Q-93's computer memory constraints hinder meeting future requirements, but that an additional 256,000 bytes of memory, delayed because of hardware flaws, which have been corrected, should be installed during 1991. Defense believes that this addition, along with some other improvements, will allow the Q-93 to process all radar data required to perform NORAD's missions.

Defense fails to point out, however, that the additional 256,000 bytes of memory will not increase the amount of memory that can be used to actually process radar data. The system design limits this memory to the 128,000 bytes that were available when the system was delivered, as we point out in the report. Consequently, the additional 256,000 bytes of memory will not provide any additional data processing capability beyond that which is currently available.

Need for Capacity Management and Performance Monitoring

Defense contends that we erroneously report that the Air Force cannot accurately determine the Q-93's current processing and performance capabilities. Defense states it has a formal capacity management and performance monitoring program with procedures and tools, and has continuously assessed the Q-93's capacity and capabilities.

Information obtained during our review indicates that the Air Force's program consists of using software management tools obtained from the Q-93 development contractor. The Air Force told us that these tools are inadequate to accurately measure system performance and Defense characterized them as marginal for this purpose. Our analysis of test methodology and results provided by the Air Force reveals that the tools have limited capabilities and are used only infrequently in a controlled environment—they do not provide assessments of current and

potential computer performance or capacity under realistic and varying operational conditions.

Our point is that Air Force efforts to manage system capacity and assess resource utilization are infrequent, incomplete, and therefore, inadequate. A formal program includes having in place a set of detailed procedures describing how hardware and software monitors and analytic modelling tools should be employed, and for continuously monitoring system performance under varying work load conditions. In this case, Defense and Air Force have been unable to provide us with copies of the capacity management and performance monitoring program procedures that are used to guide the planning, acquisition, and use of computer resources, nor with detailed data that would be collected under a formal program. To call the Air Force's efforts a formal capacity management and performance monitoring program is misleading.

Inability of the Q-93 to Receive and Process All Radar Track Data

Defense states it has taken action to ensure that all necessary radar data can be received and processed by the Q-93, but that additional track capacity will be sought to reduce operations work load and provide for future requirements. Defense expressed concern that our report implied that the Air Force was not receiving or acting upon all needed radar data.

We did not intend to imply that the Q-93's processing limitations were adversely affecting NORAD's mission, but to point toward a more prudent approach to managing the Atmospheric TW/AA system. Defense does not dispute that the Q-93 cannot receive and process all the track data generated by existing radars. As a result, Defense has had to limit the amount of data sent to the Q-93 from Over-the-Horizon-Backscatter and AWACS radars, and to manually filter this information to manage the amount of data the Q-93 stores and processes. These actions are required because of Defense's piecemeal approach to Atmospheric TW/AA system integration and the lack of a comprehensive radar and data processing architecture.

Counter-Narcotics Mission Burdens the Q-93 Work Load

Defense stated that the counter-narcotics mission enhances NORAD's ability to carry out its other roles by providing additional surveillance data and more "real-world" missions. According to Defense, the counter-narcotics effort is an integral part of NORAD's air sovereignty mission, which it has been performing for 34 years.

Defense's treatment of the importance of its recently assumed counter-narcotics mission has changed dramatically. For 32 of the last 34 years NORAD did not attempt to track slow flying aircraft (slower than 180 knots). Such aircraft, now classified as potential drug runners, were automatically classified as friendly prior to NORAD assuming a counter-narcotics role. Because Defense (1) can only estimate the number of tracks generated by counter-narcotics activities, (2) does not have a comprehensive capacity management and performance monitoring program, and (3) has already limited the amount of radar tracks other operational radars send to the Q-93, Defense cannot support its claim that the increased radar data burden is well within the Q-93's capabilities.

Further, Defense's comments do not address the fact that its processing of counter-narcotics data duplicates the efforts of the Customs Service's Command, Control, Communications, and Intelligence centers in Florida and California. Congress did not specify how Defense was to carry out its lead role in the detection and monitoring of aerial drug smugglers, nor did Defense evaluate alternatives concerning how it should accomplish its role or the impact of processing the additional data on the Q-93. Such evaluations would have been a normal outgrowth of a formal capacity management and performance monitoring program, had Defense implemented one.

Although Defense Claims the Q-93 Can Perform All NORAD's Missions, the Air Force Plans to Replace or Upgrade It

Throughout our review, the Air Force maintained that it intended to keep the Q-93 operational throughout its "full life-cycle," which the Air Force set at 20 years. Consistent with this position, the Air Force constrained its various studies, which are cited in our report, to consider only alternatives that retained the Q-93. In March 1991, when we obtained oral comments on a draft of this report, Defense stated that it is aware of the limitations of the Q-93 and is developing plans for its replacement or upgrade. Such plans are inconsistent with Defense positions taken throughout our review—namely that the Q-93 will be retained and upgraded but not replaced. Further, Defense could not provide us with evidence of such a plan. It is therefore, unclear to us what Defense's intentions are regarding the Q-93.

Defense Views on GAO's Recommendations

Defense did not concur with our recommendations to implement a comprehensive capacity management and performance monitoring program and to discontinue using the Q-93 to process counter-narcotics data. Defense partially concurred with our recommendation to establish an appropriate radar and data processing architecture.

We believe that Defense efforts to manage Q-93 capacity and assess resource utilization are incomplete, inadequate, and ad hoc. If Defense had a comprehensive program in place, it would be able to accurately evaluate its current work load and project the system's capability to process future work loads. Further, Defense says that it is in the process of implementing our recommendation to establish an architecture to guide accomplishment of current and future missions. However, for these efforts to produce an effective and efficient Atmospheric TW/AA system now and in the future, Defense needs accurate information concerning current and future work loads, and the capability required to process those work loads.

Finally, Defense's comments were not responsive to our recommendation to discontinue using the Q-93 to process counter-narcotics data because it duplicates data processing performed by the Customs Service. Defense did not explain why it feels compelled to duplicate the processing done by Customs, but responded that the continued use of the Q-93 to receive, process, and display counter-narcotics radar data are considered valuable to all NORAD missions and to the multinational war on drugs. We agree that processed radar data are valuable to NORAD, however the Customs Service already processes this data.

Atmospheric TW/AA System Radars

Existing Radars

Distant Early Warning Line	The Distant Early Warning Line radar system, located primarily along the northern Canadian border, consists of a series of long-range radars and a supporting communications network that warn of a bomber attack on North America. Other Distant Early Warning radars, which are being replaced by the North Warning System, send aircraft tracks to the regional center in Alaska and the Canadian sector centers.
Greenland-Iceland-Norway Barrier	Five Greenland-Iceland-Norway Barrier radars detect and track aircraft operating in the North Atlantic. Of the 17 Distant Early Warning radars, three located in Greenland are included in this system. Two long-range radars located on Iceland forward radar plot data to the Iceland regional center, while the three long-range radars in Greenland forward track data.
Alaskan Radar System	The Alaskan Radar System network detects and tracks aircraft entering or operating within Alaska. Eight radar sites are positioned along the Alaskan coast, and six are located in the interior. These long-range radars transmit radar plot data to the Alaskan regional center.
Joint Surveillance System	Joint Surveillance System radars detect aircraft entering United States airspace. The system uses 44 Federal Aviation Administration and military long-range radars to provide air surveillance for the continental United States. These radars send radar plot data to the southeast, southwest, northeast, and northwest sector centers. The 14 Alaskan radars are also considered part of the Joint Surveillance System and forward radar plot data to the Alaskan regional center.
Airborne Warning and Control System (AWACS)	AWACS aircraft provide a long-range, low-level, air surveillance extension to NORAD ground-based sensors. AWACS aircraft can be deployed anywhere in the continental United States in a few hours. Track data from the AWACS aircraft are transmitted to the regional or sector centers via a secure data link known as the Regional Operations Control Center Airborne Warning and Control System Digital Information Link.

Radars Being Deployed

Aerostat Radars

An aerostat radar is mounted to an unmanned, helium-filled balloon, which is tethered by a 15,000 foot cable to provide low-altitude surveillance. Aerostat radars are used primarily to detect and monitor suspected drug-smuggling aircraft. Six aerostat radars currently operate along the southern border of the United States and send radar plot data to the continental United States southeast and southwest sector centers. Future plans include the addition of 12 more aerostat radars primarily along the United States southern border.

Over-the-Horizon-Backscatter Radar

The Over-the-Horizon-Backscatter radar system will provide long-range surveillance up to 1,800 nautical miles from the radar location. The Over-the-Horizon-Backscatter radar, located in Bangor, Maine, is presently undergoing system testing. Another such radar is to be located along the United States west coast. The Maine radar system transmits track data to the continental United States northeast and southeast sector centers, and the Canadian east sector center.

North Warning System

The North Warning System radars are replacing the Distant Early Warning radars in Alaska and Canada to improve detection capability at lower altitudes, and of smaller targets. The North Warning System radars will provide surveillance of the polar and northern approaches to North America. The completed system will consist of 15 minimally attended long-range radars and 39 unattended short-range radars. To date, 14 long-range radars have been installed. The new radars will transmit track data to the regional or sector centers in Canada and Alaska.

Relocatable Over-the-Horizon Radar

The Relocatable Over-the-Horizon Radar is a Navy system similar to the Air Force's Over-the-Horizon-Backscatter radar. The system will transmit aircraft track data to regional and sector centers on an as available basis. The Air Force plans to integrate data from Relocatable Over-the-Horizon Radars into the Atmospheric TW/AA system.

Caribbean Basin Radar Network

The Caribbean Basin Radar Network will provide air surveillance throughout the Caribbean Basin to assist in the interdiction of illicit drug traffic. The completed system will consist of 14 long-range radars located in selected Central American, South American, and Caribbean Basin nations that will transmit radar plot data to Caribbean regional centers.

Future Radar Systems

North Atlantic Defense System

The North Atlantic Defense System will upgrade the Iceland Air Defense System. It is to perform air surveillance of the North Atlantic; provide air defense to Iceland; and identify threats to North America and allied naval forces. Radar plot data will be transmitted from four long-range radars to the Iceland regional center.

Canadian Coastal Radar System

The Canadian Coastal Radar System is to provide long-range air surveillance of the east and west coasts of Canada using five radar sites. The radars will transmit radar plot data to the Canadian east and west sector centers.

Federal Aviation Administration/Air Force Radar Replacement

The Federal Aviation Administration/Air Force Radar Replacement Program will replace Joint Surveillance System radars. The new radars are three-dimensional, solid-state, unattended or minimally attended surveillance radars that will supply radar plot data to regional and sector centers. The Federal Aviation Administration will operate and maintain these radars, while the Air Force will provide technical guidance.

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