

GAO

Report to the Subcommittee on the
Census, Committee on Government
Reform, House of Representatives

February 2000

2000 CENSUS

New Data Capture System Progress and Risks



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Contents

Letter		3
Appendixes	Appendix I: Briefing on the Decennial Census	18
	Appendix II: Comments From the Department of Commerce	99
Figures	Figure 1: Remaining DCS 2000 Activities	9
	Figure 2: Results of Cluster Accuracy Tests for Optical Mark Recognition	10
	Figure 3: Results of Cluster Accuracy Tests for Optical Character Recognition	10
	Figure 4: Trends in Defects—All Unresolved PTRs by Week	12
	Figure 5: Trends in Defects—Unresolved Severe PTRs by Week	13

Abbreviations

DCS	Data Capture System
PTR	program trouble report
SEI	Software Engineering Institute



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

Accounting and Information
Management Division

B-284367

February 4, 2000

The Honorable Dan Miller
Chairman
The Honorable Carolyn B. Maloney
Ranking Minority Member
Subcommittee on the Census
Committee on Government Reform
House of Representatives

The U.S. Census Bureau is preparing to conduct the 2000 decennial census—an event that will significantly influence the lives of every U.S. resident and constitutes the largest peacetime mobilization event in our nation's history. In particular, Census will be staffing 1.35 million temporary field positions to capture 1.5 billion pages of data from about 119 million households. To meet this important and massive challenge, the bureau plans to rely extensively on information technology, including its new Data Capture System (DCS) 2000. DCS 2000 is to be operated at four bureau data capture centers¹ to check in, digitally image, and optically read the data handwritten onto census forms and convert these data into files that will be transmitted to bureau headquarters for tabulation and analysis.

At your request, we determined the status and quality of DCS 2000 as well as the risks the bureau faces in successfully completing the system. This report summarizes the information presented at our December 14, 1999, briefing to your office. A copy of our briefing is provided in appendix I.

Results in Brief

The bureau has made considerable progress on DCS 2000. For example, as of January 7, 2000, DCS 2000 hardware has been installed at all four data capture centers, and 21 of the system's 23 planned application software releases have been completed. Despite this progress, however, the bureau faces a formidable challenge in delivering promised DCS 2000 capabilities on time because much remains to be accomplished and little time remains to accomplish it. In particular, the bureau has extended the system's

¹The data capture centers are located in Baltimore, Maryland; Jeffersonville, Indiana; Pomona, California; and Phoenix, Arizona.

schedule by 4 months due largely to requirements changes. And, before its revised completion date of February 25, 2000, the bureau must complete many important system development and testing activities, including the completion of the final two software releases as well as system acceptance, site acceptance, and operational tests. Furthermore, the numbers of yet-to-be-resolved defects for DCS 2000 have yet to show a clear and sustained downward trend that is expected as a system begins to mature.

To expedite the completion of DCS 2000, the bureau and its development contractor are following an incremental development and deployment strategy. Such a strategy can save time because it can get a system into the hands of users faster so that problems can be identified sooner rather than later. While the bureau's implementation of this strategy has introduced considerable development and test concurrency, which increases the risk of defects being found and corrected independently and thus inconsistent system baselines being produced, this risk is being mitigated by the development contractor through effective management controls, such as project risk management and configuration management.

The bureau and its development contractor have taken other steps to ensure the successful delivery of DCS 2000. For example, they have implemented a formal risk management program to address risks proactively, and they have defined and are following requirements management processes to ensure that only those changes that are justified on the basis of costs, benefits, and risks are approved and made. Also, they have added a test event just prior to the system's operational date to evaluate the system's capabilities in a true operational setting. Another factor strongly in Census' favor is that its development contractor has been independently assessed as having highly effective software development capabilities in such important areas as software project planning, tracking and oversight, configuration management, software quality management, and defect prevention.

Nevertheless, delivering promised DCS 2000 capabilities remains at risk because less than 2 months remain before data capture operations are to begin, leaving very little room for error. Moreover, many important development and test activities remain that will likely reveal more system defects and thus compound an already uncertain system maturation picture. In discussing this risk with DCS 2000 program officials, they agreed that delivering promised system capabilities on time is a risk, and they subsequently provided evidence that they have (1) designated this as a high risk under the DCS 2000 risk management program and (2) defined and

initiated proactive steps to mitigate the risk and its potential impact on the program.

In commenting on a draft of this report the bureau generally agreed with our observations and conclusions and stated that it appreciated our insights and contributions.

Background

The Constitution requires a decennial census of the population in order to reapportion seats in the House of Representatives. Public and private decisionmakers also use census data on population counts and social and economic characteristics for a variety of purposes. For example, state and local redistricting; allocations of government funding; and many planning and evaluation activities, such as site selection for new schools, market research, and evaluations of local labor markets, rely on decennial census data. In addition, the census is the only national source of detailed population statistics for small geographic areas, such as towns and school districts, and for population groups, such as Native Americans.

Since 1970, the bureau has used essentially the same methodology to conduct the census. It develops an address list of the nation's housing units and delivers census forms to those housing units, requesting that occupants mail back the completed forms. Most households are sent a short form to complete; however, some are asked to complete a long form.² The bureau then hires temporary census-takers, known as enumerators, by the hundreds of thousands to gather the requested information for each nonresponding housing unit. For the 2000 census, some households will have the option of completing questionnaires via a bureau-operated toll-free telephone number or a bureau-operated Internet site.

To conduct the 2000 census, the bureau will rely on 10 key systems. These systems will enable the bureau to develop and maintain address lists, maps, and geographic reference files; collect census data via the Internet; scan and process household-completed paper forms; analyze census data;

²The Census short form—three pages with eight questions—will be delivered to approximately 83 percent of all housing units. It will ask the respondent to provide information for up to six household members including information regarding name, age, sex, relationship, and race. The long form—40 pages with 53 questions—will be delivered to approximately 17 percent of all housing units. For up to six household members, it will ask the same questions as the short form as well as questions on social, economic, financial, and physical characteristics.

recruit and support temporary workers; facilitate follow-up surveys; and track costs and performance related to taking the census. A simplified diagram of the census 2000 systems architecture as well as descriptions of each system are provided in appendix I.

An important system for this census will be DCS 2000. The bureau will use this system to check in forms and digitally image and optically read the data handwritten onto census forms and convert these data into files that will be transmitted to bureau headquarters for tabulation and analysis. Specific DCS 2000 subsystems include:

- The *data verification and receipt subsystem*, which, among other things, (1) receives the paper census forms and prepares them for imaging and (2) identifies respondents so the bureau can identify and follow up with nonrespondents.
- The *scanning and imaging subsystem*, which creates an electronic image of the paper form.
- The *optical recognition subsystem*, which captures census data from the electronic form images.
- The *keying subsystem*, which is used to manually input data that cannot be satisfactorily read from the paper form.
- The *data preparation function*, which formats data from the optical recognition and keying subsystems and then sends the data to Census Bureau headquarters.

The bureau has contracted with Lockheed Martin-Mission Systems to develop, deploy, and maintain DCS 2000. As of November 5, 1999, the bureau had obligated \$127 million for this contract. The total contract value as of September 30, 1999, was \$153 million. The bureau has also contracted with TRW for space and facility management and for DCS 2000 operation at three of the four data capture centers.³

Objectives, Scope, and Methodology

Our first objective was to determine DCS 2000's status and quality, i.e., whether the system performs in a way that meets specified requirements and satisfies user needs. Our second objective was to assess the risks the bureau faces in successfully completing the system.

³The fourth data capture center, located at Census' National Processing Center in Jeffersonville, Indiana, will be operated by the bureau.

To determine the status and quality of DCS 2000, we first reviewed system development plans, project management plans, activity plans (test, deployment, etc.), project status reports, program management briefings, and system functional requirements and specifications. We then compared original to revised plans and current plans to status and test reports. We also identified how the bureau measured the maturity and quality of DCS 2000 throughout its development life cycle and analyzed these and other measures for indicators of progress and system health, including trends in defects and the results of testing activities. We observed the DCS 2000 operational test at the Baltimore data capture center and attended periodic DCS 2000 project review meetings between the bureau and the development contractor.

To determine DCS 2000 risks and risk mitigators, we determined bureau and development contractor key management processes (e.g., requirements management, configuration management, project planning, and project tracking and oversight). We analyzed the results of status and quality determinations vis-à-vis DCS 2000 expectations and remaining steps to complete the system. We also analyzed plans for completing DCS 2000 and compared these plans to generally accepted system engineering principles.

We interviewed bureau and contractor officials throughout our review, briefed them on the results of our work, and incorporated updated information they provided into our briefing. We performed our work at the Census Bureau's headquarters in Suitland, Maryland; the DCS 2000 program office in Lanham, Maryland; bureau and development contractor facilities in Bowie, Maryland; and the Census Bureau's data capture center in Baltimore, Maryland, from June 1999 through January 2000, in accordance with generally accepted government auditing standards. We requested comments on a draft of this report from the Department of Commerce. The Secretary of Commerce provided us with written comments, which are presented in appendix II, and are discussed in the "Agency Comments and Our Evaluation" section of this letter.

Considerable Progress Made on DCS 2000 But Much Remains to Be Done in Little Time

The Census Bureau has made considerable progress on DCS 2000. For example, as of January 7, 2000, 21 of 23 planned software releases had been completed and 6 of 10 major test events had been completed. Further, according to the bureau, all DCS 2000 hardware has been installed at all sites. As of January 7, 2000, the bureau was reporting that remaining DCS 2000 tasks were on target with revised expectations.

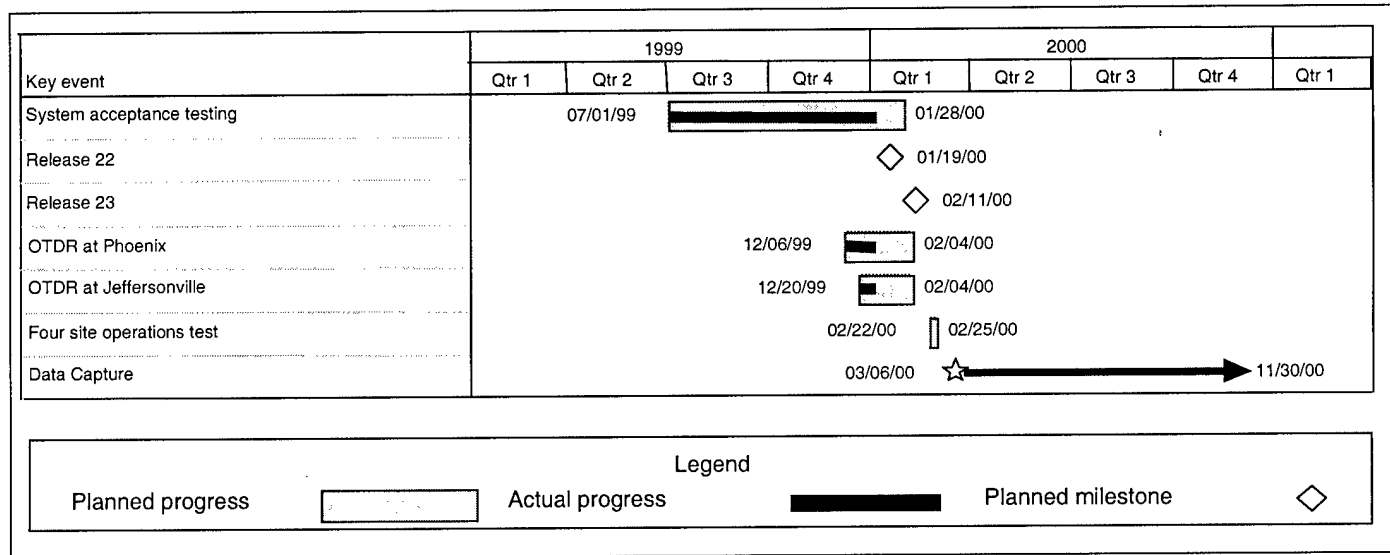
Nevertheless, DCS 2000's expected completion is much later than earlier planned and, in fact, perilously close to the date when census 2000 is to begin. In February 1999, the bureau expected to complete DCS 2000 by October 15, 1999. However, the scheduled completion date has since changed to February 25, 2000, which is an extension of over 4 months and is less than 2 weeks before data capture operations are to begin on March 6, 2000. Under normal circumstances, completion deadlines can be changed and some schedule slippage can be tolerated. However, the demands of the decennial census necessitate that remaining development, testing, and deployment activities be completed in less than 2 months.

DCS 2000 program officials told us that this extension is due largely to system requirement changes. Specifically, from May 15, 1999, through October 30, 1999, 63 requirements changes were initiated for DCS 2000. And, in October and November 1999, two new software releases were added to DCS 2000—one slated for January 19, 2000, and one for February 11, 2000. The bureau has no plans for additional requirements changes. However, if the results of ongoing and planned operational tests show that DCS 2000 does not adequately support production environment data capture operations, then more changes are possible.

In addition to the development and deployment of final software releases, significant testing activities—including system, site, and operational tests⁴—remain to be completed before February 25, 2000. These activities are illustrated in figure 1.

⁴DCS 2000 is currently undergoing three types of major test activities: (1) *system acceptance testing*, which assesses whether the system performs according to specifications, (2) *site acceptance testing*, which assesses whether the system performs correctly at its deployment site, and (3) *operational testing*, which assesses whether the system performs as intended when operated on-site by those expected to use it.

Figure 1: Remaining DCS 2000 Activities



Results from early site acceptance tests showed that not all performance targets were achieved; however, the tests were reported as being successful either because the problems were corrected and retested or because they were scheduled for correcting and retesting as part of a future test event. More recent results show that key performance measures are being met. For example, as shown in figures 2 and 3, results from “cluster” accuracy tests—which were performed to demonstrate the ability of each individual configuration (known as “clusters”) of scanners, workstations, and servers to scan census forms and recognize data on those forms—were within expected tolerances for errors.

Similarly, results from the operational test conducted at the Baltimore, Maryland, data capture center identified problems that have since been reported as fixed and scheduled to be retested as part of a future operational test. An additional operational test was conducted at the Baltimore data capture center by an independent research organization to assess DCS 2000's accuracy. Results from this test showed that DCS 2000 exceeded accuracy goals for both short and long Census forms.

Despite these reported successes, DCS 2000's readiness is still uncertain due to the fact that (1) the numbers of yet-to-be-resolved system defects have yet to show a clear and sustained downward trend expected as a system begins to mature and (2) the time left between the conclusion of test events and the day that DCS 2000 must be operational is less than the average time it has been taking to resolve defects. Defects are system problems (both hardware and software) that require a resolution (referred to by Lockheed Martin as Program Trouble Reports, or PTRs). They can be attributed to a failure to meet system specifications or to a requirement that was not previously anticipated. As figures 4 and 5 further illustrate, we found that the number of *unresolved* PTRs each week during the last 12 months does not show a maturing trend, including those defects categorized as severe.⁵ In addition, as mentioned earlier, many key test events, which are major producers of PTRs, have yet to be conducted for DCS 2000. Lastly, the time left between conclusion of the last test event, scheduled for February 25, 2000, and the day that DCS 2000 must be operational is 9 days, whereas it has been taking an average of 16 days to resolve all PTRs over the last 6 months and 10 days for severe PTRs.

⁵Two categories of severe defects include *emergency*—a problem with no deliverable/procedural workaround available, which blocks operational use of the product or completion of all or some test cases or test phases—and *critical*—a problem with no deliverable/procedural workaround available, which significantly degrades operational use or which blocks a top-level test case or test phase from completion.

Figure 4: Trends in Defects—All Unresolved PTRs by Week

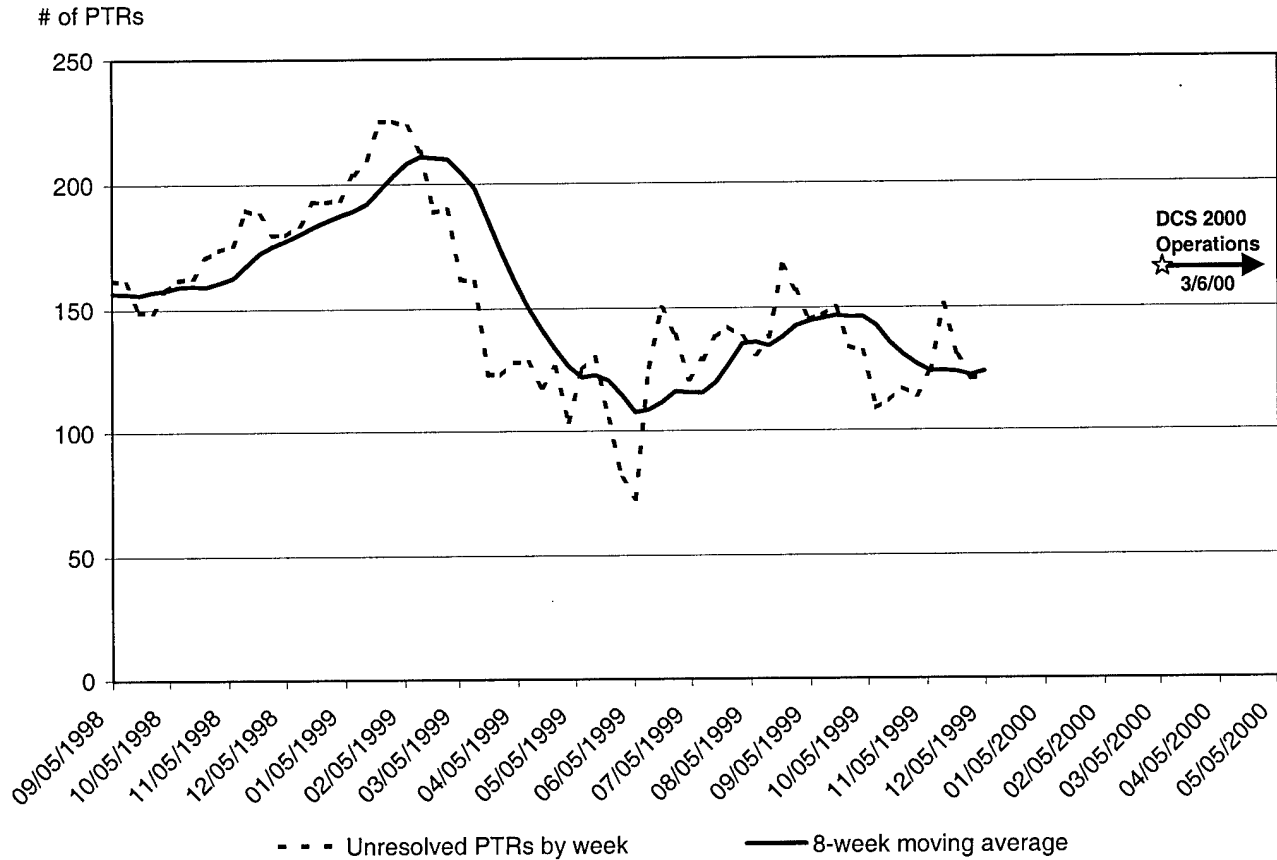
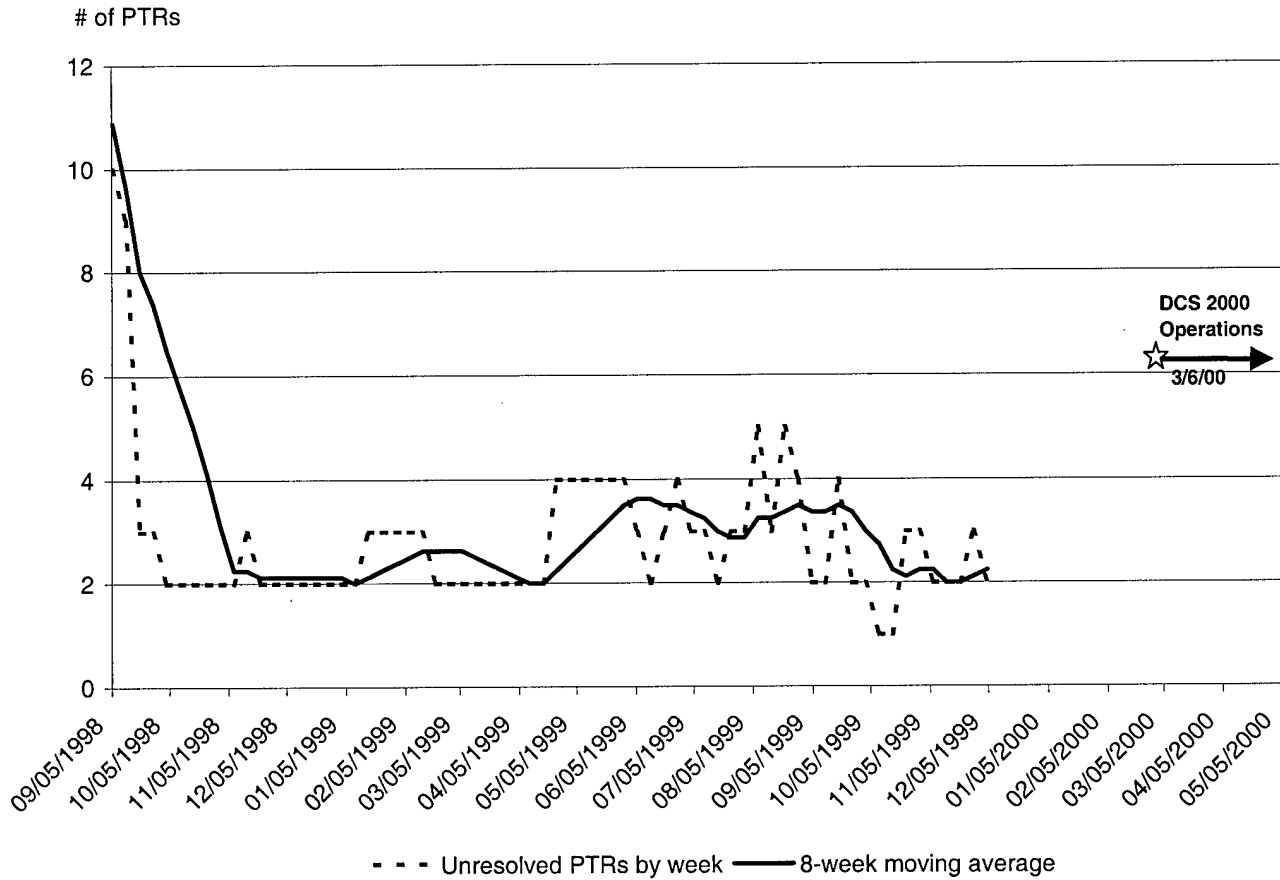


Figure 5: Trends in Defects—Unresolved Severe PTRs by Week



Risk Mitigation Steps Are Being Taken to Address DCS 2000 Risks

The bureau and its contractors are employing measures to expedite the completion of DCS 2000 and to minimize risks related to its tight schedule and other aspects of development and deployment. The bureau and Lockheed Martin are following an incremental development and deployment strategy. Such a strategy is recognized as a best practice for large, complex systems by leading public and private organizations because it can get a system into the hands of users faster so that problems can be identified sooner rather than later.

This approach needs to be carefully managed because it has introduced considerable development and test concurrency in the DCS 2000 schedule. Such concurrency can increase demands for test resources as well as the possibility of defects being found and corrected independently, resulting in more than one baseline test configuration. Moreover, if defects surface during concurrent testing that are severe enough to require all affected test activities to be stopped until the baseline is fixed, the deployment schedule could be delayed. We found that these risks are being managed by Lockheed Martin through the use of multiple test labs and effective configuration management processes.

The bureau and Lockheed Martin are also jointly managing DCS 2000 risks through a formal risk management program that includes proactive identification of risks and analyses of their impacts and probabilities, definition of risk mitigation plans, and tracking and reporting of the plans' implementation and effectiveness. Such programs are also recognized as a key practice in government and the private sector. In following the risk mitigation program, the bureau and Lockheed Martin have already acted to resolve several risks related to DCS 2000 site staffing, daily system maintenance, and technical support. For example, they have strengthened training programs for on-site DCS 2000 personnel, defined technical support roles and responsibilities, and increased central technical support.

More important, the bureau and Lockheed Martin have also identified the tight development schedule as a risk and taken measures to reduce the risk. For example, they have

- added staff to manage PTR progress;
- begun holding regular PTR status meetings with sites and other support areas to review resolution progress;
- developed a rapid response process that requires a fix or workaround within 24 hours;
- established an Engineering Review Board to review all change requests to ensure that only changes that are justified on the basis of costs, benefits, and risks are approved and made; and
- implemented processes to ensure that all releases with new functionality are tested during an operational evaluation.

Furthermore, Census and Lockheed Martin have added another test to the DCS 2000 schedule to demonstrate simultaneous operation of all four data capture centers. The test, planned for February 22 through February 25, will include assessments of DCS 2000's ability to process workload

equivalent to that expected during actual data capture operations, and it will include operational testing of the final DCS 2000 software releases.

Another important risk mitigating factor is that Lockheed Martin-Mission Systems has been independently assessed as having highly effective software development capabilities in important areas such as software project planning, tracking and oversight, and configuration management. This assessment was performed using models and methods developed by Carnegie Mellon University's Software Engineering Institute (SEI), which is recognized for its expertise in software processes. With DCS 2000 as one of three systems included in the evaluation, Lockheed Martin-Mission Systems was rated as a "Level 5" (on a scale of 1 to 5), meaning that all projects use standard processes for developing and maintaining software and that such processes are continually improved through quantitative feedback and from piloting innovative ideas and technologies. Having such capability should help to reduce risks related not only to developmental activities such as project planning and oversight, but all remaining DCS 2000 development, testing, and deployment activities.

Conclusions

The Census Bureau has made considerable progress in acquiring and deploying DCS 2000; however, its prospects for completing this system on time are still mixed. In particular, significant system functionality remains to be developed, acceptance tested, deployed, and site tested. Further, a key measure of system quality—trends in unfixed severe defects—is not yet moving in a direction consistent with that of a maturing system. Given that a number of significant test events have yet to occur and these are likely to uncover more defects, the chances of the defect trend moving in a favorable direction soon are uncertain. Moreover, given that the average time to fix severe defects (about 10 days) over the last 6 months would consume the time between the conclusion of later test events and the day that DCS 2000 must be operational, the chances of all specified capabilities being ready on time are reduced.

At the same time, results from system-level tests performed so far are showing that key DCS 2000 performance targets are being met. Additionally, to meet the challenge of a very demanding and fault-intolerant schedule, the bureau has been following a plan that provides for development and testing of DCS 2000 in a series of increments. This strategy could save time by allowing early system capability to get into the hands of end users faster. Lastly, the development contractor has been following effective processes for risk management, project planning,

tracking and oversight, configuration management, software quality management, and defect prevention—all critical to the successful completion of DCS 2000.

Nevertheless, the schedule challenge facing the bureau on DCS 2000, particularly in light of where the system currently stands and what remains to be accomplished, is formidable. Both the bureau and development contractor agree and, accordingly, have initiated proactive and appropriate risk management steps, such as strengthening oversight over PTR progress and requirements changes. While these steps do not guarantee success, they should mitigate the risk and its potential impact on the program.

Agency Comments and Our Evaluation

In commenting on a draft of this report, the bureau stated that it generally agreed with our observations and conclusions. Additionally, the bureau stated that it shared our awareness of the challenges the bureau faces in delivering promised DCS 2000 capabilities on time, and that it appreciated our insights and contributions.

The bureau also offered two additional comments. First, it stated that one sentence in the draft report implies that *all* of the DCS 2000 system must be developed, tested, and deployed in 2 months while, in fact, the system is in the final stages of testing, and only a small portion of development remains to be completed before becoming fully operational. It was not our intent to imply this and we have accordingly modified the sentence.

Second, the bureau stated that the 16 days that the bureau has averaged over the last 6 months to resolve *all* PTRs that we cite in the draft report is not a true representation of the time it has been recently taking to resolve *emergency* PTRs, which according to the bureau was 2 days for 7 recent emergency PTRs. We did not modify our report in response to this comment. The report does not state that the 16-day average time needed over the last 6 months (which covered June through November 1999) to resolve *all* PTRs is the operative indicator of the time to resolve emergency PTRs, which is the most severe category of PTRs. Rather, it cites the time necessary to resolve severe PTRs—which was 10 days—as the operative indicator. This category represents the average time that the bureau's own data show it has taken over the last 6 months to resolve both *emergency* and *critical* PTRs. We focused on both emergency and critical because both types of PTRs, according to the Bureau's own definition of them, will have to be resolved before March 6, 2000, if DCS 2000 is to operate as intended.

We are sending copies of this report to the Honorable William M. Daley, Secretary of Commerce; the Honorable Kenneth Prewitt, Director of the U.S. Census Bureau; the Honorable Jacob J. Lew, Director of the Office of Management and Budget; and other interested parties. Copies will be made available to others upon request.

If you have any questions on matters discussed in this letter, please contact me at (202) 512-6240. Other key contributors to this report include Mark Bird, Cristina Chaplain, Garry Durfey, Richard Hung, and Aaron Thorne.

A handwritten signature in black ink that reads "Randolph C. Hite". The signature is written in a cursive, flowing style.

Randolph C. Hite
Associate Director
Governmentwide and Defense Information Systems

Briefing on the Decennial Census

GAO Accounting and Information Management
Division

**Briefing to the
Subcommittee on the Census, Committee on
Government Reform, House of Representatives**

**Decennial Census: Data Capture System
2000 Progress and Risks**

December 14, 1999



GAO Briefing Overview

- Introduction
- Objectives
- Results in Brief
- Background
- Audit Results: DCS 2000 Status and Quality
- Audit Results: DCS 2000 Risks/Risk Mitigators
- Conclusions
- Appendixes
 - Scope and Methodology
 - Description of Other Decennial Census Systems

GAO Introduction

- Required by the Constitution, our nation's decennial census is a landmark event whose results are instrumental in decisions affecting the lives of every U.S. citizen.
- The 2000 decennial census is the largest peacetime mobilization event in our nation's history, entailing the staffing of about 1.35 million temporary positions to collect and capture 1.5 billion pages of data from about 119 million households.
- Information technology is the critical enabler for successfully accomplishing this mammoth and historical event.

GAO Objectives

- Because the Data Capture System (DCS) 2000 is viewed as an important system in accomplishing the 2000 census, the Chairman and Ranking Minority Member of the Subcommittee asked GAO to determine the following.
 - What is the status and quality of DCS 2000?
 - What risks does the bureau face in successfully completing DCS 2000?
- The scope and methodology of our review is described in appendix I.

GAO Results in Brief

Status and Quality

- Since February 1999 and largely because of system requirements changes, the DCS 2000 completion date has been extended by over 4 months (meaning that the last system release is now scheduled for deployment less than 4 weeks before the system's immovable March 6, 2000, deadline).
- Changes to system requirements continue to occur, with more activities being added to an already challenging schedule, but change management controls are in place and functioning.

GAO Results in Brief (cont.)

-
- The bureau reports that DCS 2000 is meeting the revised schedule and that it is meeting cost expectations.
 - Trends in yet-to-be resolved system defects are not consistent with those of a maturing system.
 - Five of the 10 scheduled system-level test events have been completed, and, while early test event results show that not all performance measures were satisfied, more recent test event results show that key performance measures are being met.

GAO Results in Brief (cont.)

Risks

- Important system development, test, and deployment activities remain that will likely generate more system defects, and the current schedule will not accommodate slippage.
- Concurrent system-level test activities increase contention for test resources and complicate control of test baseline system configurations.

Risk Mitigators

- Incremental development and deployment gets system into hands of users faster.

GAO Results in Brief (cont.)

-
- Formal risk management program is in place to address risks proactively, including steps to mitigate the possibility of not completing remaining system development activities on time.
 - An additional test event to exercise all planned system capabilities in an operational environment is to occur just prior to the March 6, 2000, deadline.
 - Development contractor's software process capabilities are effective, including processes for configuration management.

GAO Results in Brief (cont.)

Bottom Line on DCS 2000 Status, Quality, and Risks

- Considerable progress has been made on DCS 2000 and important risk mitigators exist.
- Nevertheless, delivering promised system capabilities on time is a high risk because:
 - very little time remains (3 months), and the deadline is immutable;
 - many important development and test activities remain;
 - new requirements continue to be added;
 - trends in system defects do not yet demonstrate system maturity; and

GAO Results in Brief (cont.)

- more defects are likely to surface during later test events.
- On December 7, 1999, we briefed DCS 2000 program officials on the results of our work and they provided updated information that has been incorporated into this briefing as appropriate. The officials agreed that delivering promised system capabilities on time is a high risk, and they subsequently provided evidence that (1) they have designated this as a high risk under the DCS 2000 risk management program and (2) they have defined and initiated proactive steps to minimize the probability of the risk occurring and the impact on the program if it does.

10

GAO Background

Decennial Census Serves Many Purposes

- Public and private decisionmakers use census population and socioeconomic data for various purposes. For example,
 - the bureau will deliver to the President the population counts needed to determine each state's number of seats in the House of Representatives;
 - each state will use tabulations in its individual redistricting plan;
 - federal agencies can use census data to evaluate the effectiveness of established programs and identify geographic areas needing attention;

GAO Background

Decennial Census Serves Many Purposes (cont.)

- local governments will use census data to target delivery of services, such as schools and public transportation; and
- businesses will use census data to target new services and products and tailor existing ones to demographic changes.

GAO Background

Overview of How 2000 Census Data Will Be Captured

- The primary method for gathering census data is through paper questionnaires mailed to households that the occupants are to complete and mail back. Paper questionnaires will also be available in public locations for people to fill out and mail back.
- Some households will also have the option of responding via a toll-free telephone number or the Internet, rather than completing and mailing back paper forms.
- Bureau procedure calls for nonresponding households to be visited by an enumerator, who will fill out a paper form for each household.

GAO Background

Overview of Systems Supporting 2000 Census

- The bureau relies on 10 key systems to execute the 2000 decennial census, including DCS 2000. The other nine systems are listed below and described in appendix II.
 - Geographic Support System (GSS)
 - Pre-Appointment Management System/Automated Decennial Administrative Management System (PAMS/ADAMS)
 - Operations Control System (OCS 2000)
 - Management Information System (MIS 2000)
 - Telephone Questionnaire Assistance and Coverage Edit Follow-Up (TQA/CEFU)
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14

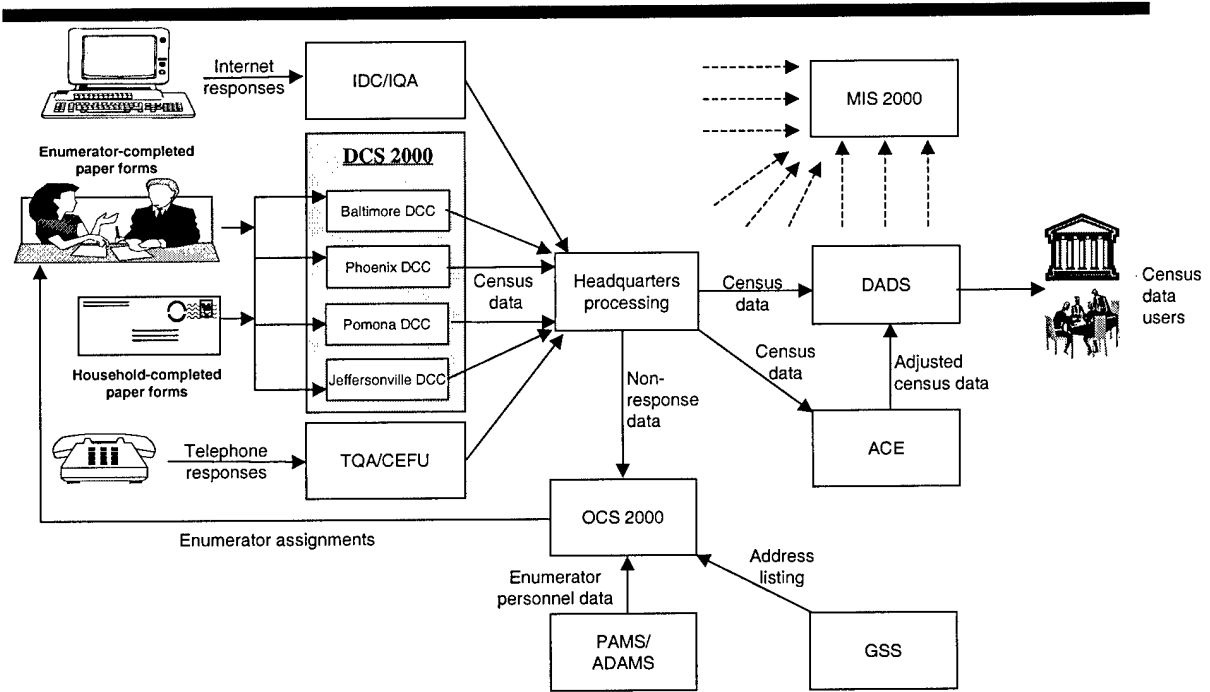
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Overview of Systems Supporting 2000 Census (cont.)

- Internet Data Collection/Internet Questionnaire Assistance (IDC/IQA)
- Accuracy and Coverage Evaluation System (ACE)
- Headquarters (HQ) Processing
- Data Access and Dissemination System (DADS)

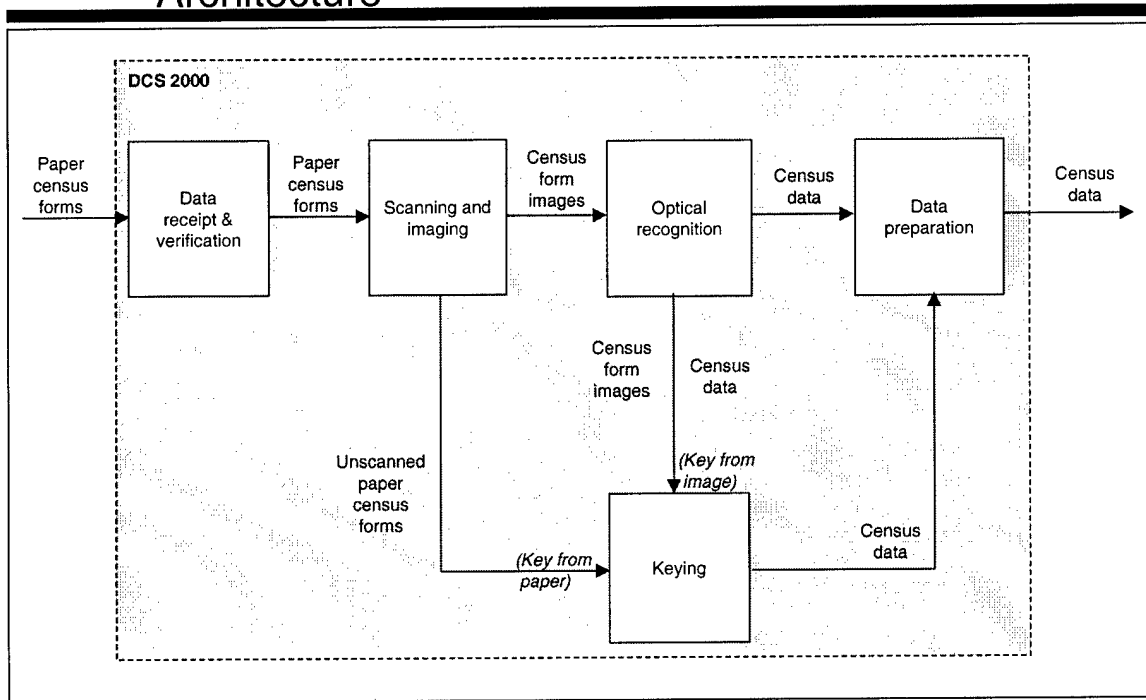
GAO Background

Simplified Diagram of Decennial Census Systems Architecture



GAO Background

Simplified Diagram of DCS 2000 Functional Architecture



GAO Background

DCS 2000 Technical Architecture Overview

- DCS 2000 consists primarily of mail sorters, document scanners, workstations, and servers running in a Windows NT-based environment.
- DCS 2000 software is commercial off-the-shelf (COTS); new software development amounts to about 85,000 lines of code written in C, C++, and Perl.
- New system development is for modifying COTS, creating new applications, and integrating components.
- DCS 2000 software is being developed in 23 incremental releases.
- Scanners, workstations, and servers are configured into clusters.

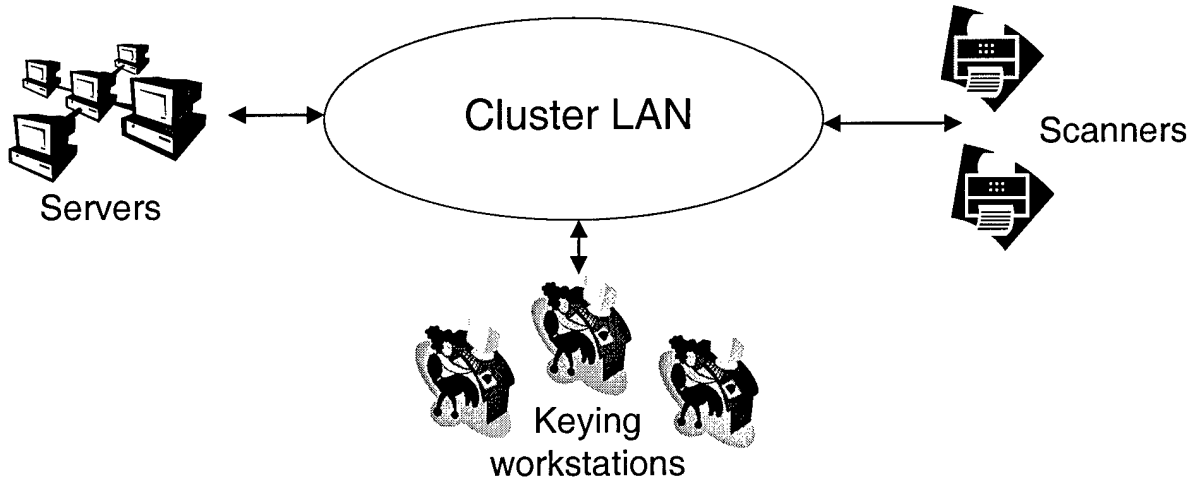
18

GAO Background

DCS 2000 Technical Architecture Overview (cont.)

- Each data capture center (DCC) is configured with the number of clusters needed to support expected workload.
 - Baltimore: 15 clusters
 - Jeffersonville: 10 clusters
 - Pomona: 14 clusters
 - Phoenix: 15 clusters

GAO Background DCS 2000 Technical Architecture Overview (cont.)



GAO Background DCS 2000 Project Structure

- The bureau has contracted with Lockheed Martin-Mission Systems for DCS 2000 development, deployment, and maintenance.
- For three of four DCCs, the bureau has contracted with TRW for space and facility management and for DCS 2000 operation. The bureau plans to operate DCS 2000 at the fourth DCC (the bureau's National Processing Center).

GAO Audit Results: DCS 2000 Status and Quality (cont.)

1. Since February 1999 and largely because of system requirements changes, the DCS 2000 completion date has been extended by over 4 months (meaning that the last system release is now scheduled for deployment just 4 weeks before the system's immovable March 6, 2000, deadline).
2. Changes to system requirements continue to occur, with more activities being added to an already challenging schedule, but change management controls are in place and functioning.

GAO Audit Results: DCS 2000 Status and Quality

3. The bureau reports that DCS 2000 is meeting the revised schedule and that it is meeting cost expectations.
4. Trends in yet-to-be resolved system defects are not consistent with those of a maturing system.
5. Five of the 10 scheduled system-level test events have been completed and while early test event results show that not all performance measures were satisfied, more recent test event results show that key performance measures are being met.

GAO Audit Results: DCS 2000 Status and Quality

1. Scheduled Completion Has Changed

- In February 1999, the scheduled date for completing DCS 2000 was October 15, 1999. The scheduled date has since changed to February 25, 2000, an extension of over 4 months and less than 2 weeks before data capture operations are to begin.
- Program officials told us that this extension is largely due to system requirements changes.
- In October/November 1999, major activities were added to the end of the schedule.
 - Two new software releases were added, one on January 19, 2000, and one on February 11, 2000.

GAO Audit Results: DCS 2000 Status and Quality
1. Scheduled Completion Has Changed (cont.)

- A new operational test at the four DCCs was added for February 22-25, 2000. This additional event is planned to demonstrate simultaneous operation of all four DCCs, including DCS 2000's capability to process the workload expected during data capture operation.

GAO Audit Results: DCS 2000 Status and Quality

2. System Requirements Changing But Controlled

- Changes to system requirements, particularly those made late in the development cycle, can impact the delivery of promised system capabilities on time and within budget. Accordingly, changes to requirements must be controlled to ensure that only changes that are justified on the basis of costs, benefits, and risks are approved and made.
 - For DCS 2000, 63 requirements changes were initiated between May 15, 1999 and October 30, 1999.
 - We reviewed the bureau's management process for controlling requirements changes and analyzed selected DCS 2000 requirements changes to ensure they were managed in accordance with this management process.
-

GAO Audit Results: DCS 2000 Status and Quality

2. System Requirements Changing But Controlled (cont.)

- We reviewed five requirements change requests.

Change control #006	Submitted 12/15/98	After data have been captured, review all forms to ensure that headquarters has received the information.	Reviewed 2/10/99	Approved
Change control #028	Submitted 3/1/99	Modify the audit resolution process so that the system better handles images that fail the audit process.	Reviewed 12/10/98	Approved
Change control #047	Submitted 4/29/99	Create three sets of CD-ROMs of questionnaire images on a daily basis at each site for the ACE system.	Reviewed 7/23/99	Approved
Change control #070	Submitted 8/2/99	Use remote copy protocol (RCP) to transfer the Title 13 acknowledgement files from Census headquarters to the data capture centers.	Reviewed 8/31/99	Approved
Change control #75	Submitted 8/12/99	Add additional checkout reporting data, as requested by TRW.	Reviewed 9/17/99	Disapproved

GAO Audit Results: DCS 2000 Status and Quality

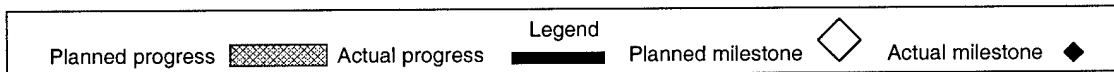
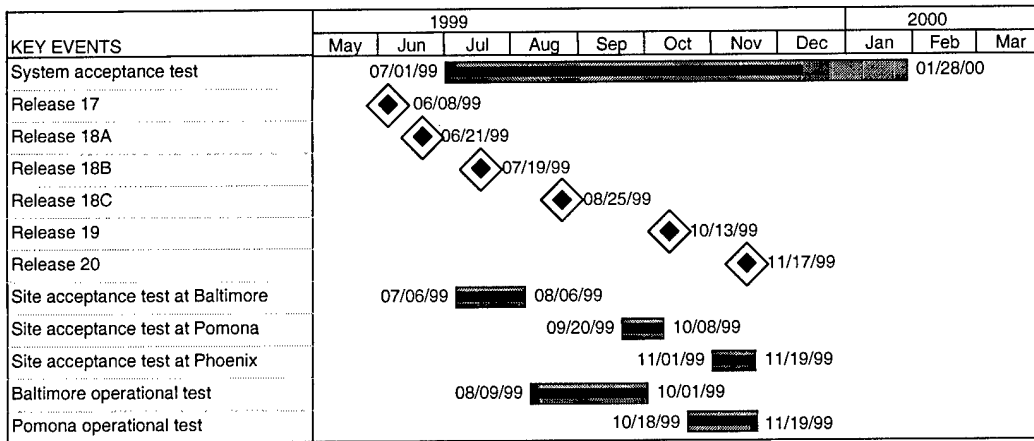
2. System Requirements Changing But Controlled (cont.)

- We selected these five change requests using the following criteria: (1) significant in terms of cost or impact, (2) representative of other change requests, and (3) demonstrated request approval and disapproval. Bureau officials agreed that these requests met these criteria.
- We found that the bureau's change control management process provided for reviews of costs, benefits, alternative solutions, and risks.
- We also found that the five requirements changes that we reviewed were assessed and approved/disapproved in accordance with the bureau's management process.

28

GAO Audit Results: Status and Quality

3. Progress Against Current Schedule and Cost Baselines



GAO Audit Results: DCS 2000 Status and Quality
3. Progress Against Current Schedule and Cost Baselines
(cont.)

- All DCS 2000 hardware reported as installed at all sites.
- Reported DCS 2000 contract costs are as follows:
 - Obligated: \$127 million reported (as of November 5, 1999) and
 - Contract value: \$153 million (as of September 30, 1999).

GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects Raise Questions About System Maturity

- One measure of system maturation and quality is trends in defects.
- Defects are system problems (hardware and software) that require a resolution. A defect can be due to a failure to meet the system specifications, or it can occur because a requirement is identified that was not in the system specification.
- Effective system engineering requires that defects be formally managed (identified, documented, and resolved). To facilitate defect management, defects are categorized by severity (impact) and age (time unresolved).

GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects Raise Questions About Maturity (cont.)

- Lockheed Martin manages DCS 2000 defects, called program/trouble reports (PTRs), according to five severity categories.

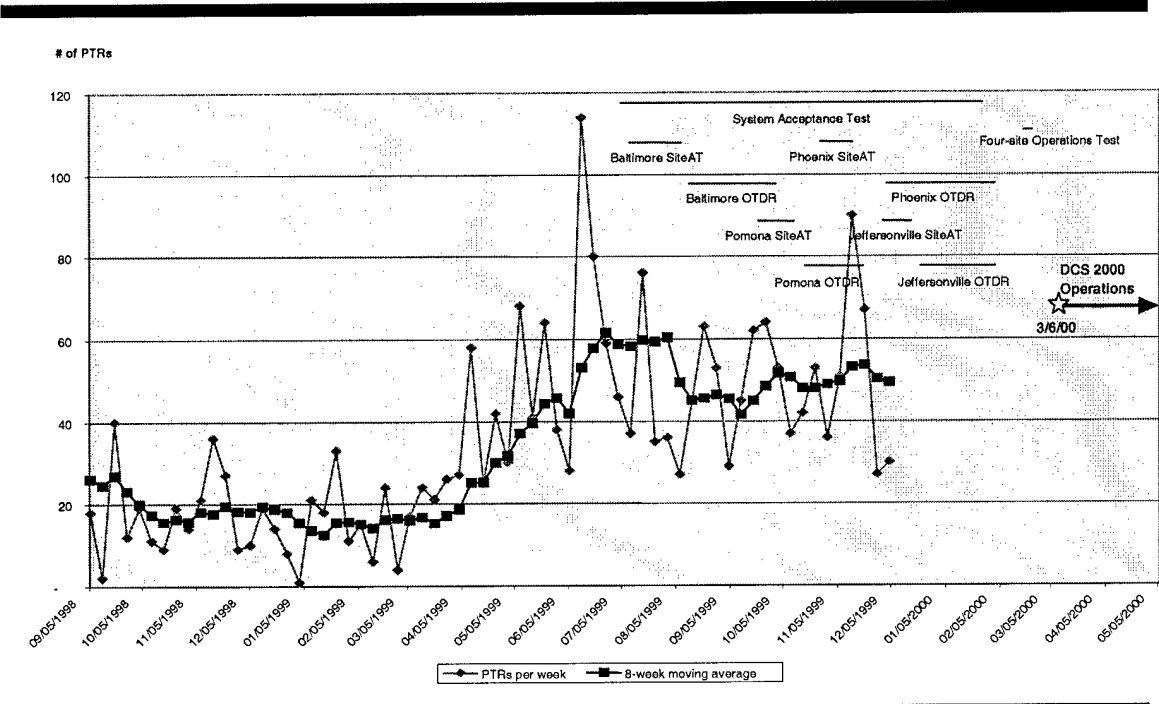
Emergency	A problem with no deliverable/procedural workaround available, which blocks operational use of the product or completion of all or some test cases or test phases.
Critical	A problem with no deliverable/procedural workaround available which significantly degrades operational use or which blocks a top-level test case or test phase from completion.
Important	A problem with a deliverable/procedural workaround available (noncritical failed steps in a test case or test phase would fall here).
Medium	A problem discovered through normal use, which is not covered directly by a test case or test phase.
Low	A problem that needs to be fixed but otherwise does not block development or testing activities.

GAO Audit Results: DCS 2000 Status and Quality
4. Trends in Defects Raise Questions About Maturity
(cont.)

- PTRs are *open* during the time the software development organization is designing and implementing a fix or change. After the development organization has implemented and tested the fix or change and submitted it for system integration testing, the PTR is designated *fixed*. PTRs are *closed* after the fix or change has successfully completed system integration testing.
- We analyzed trends in DCS 2000 PTRs during the last 12 months.

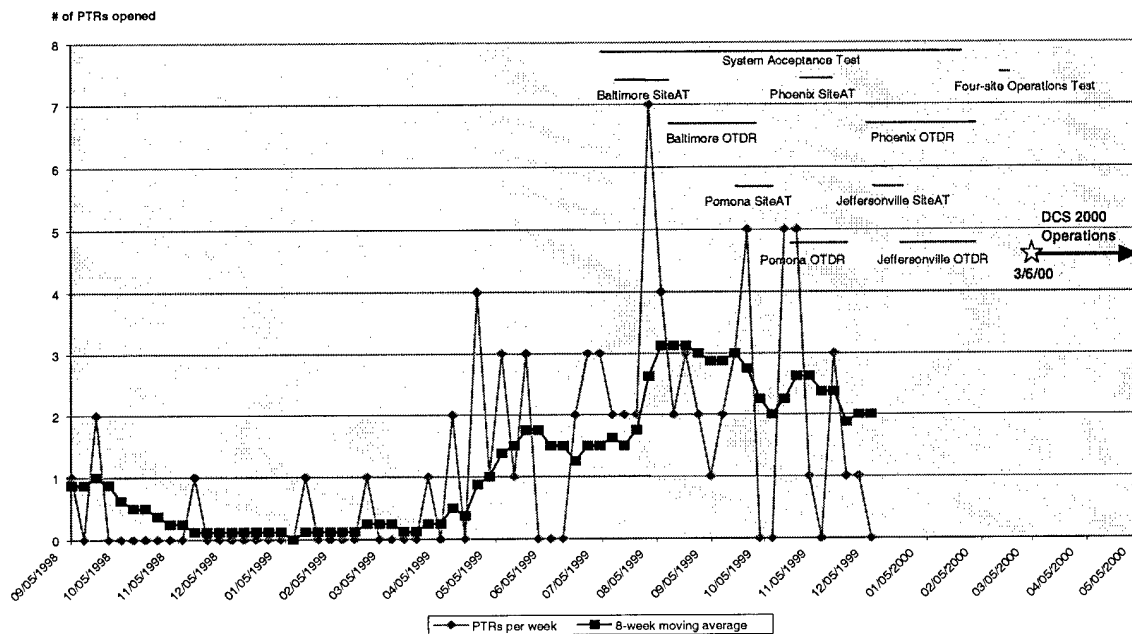
GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects--All PTRs Opened by Week



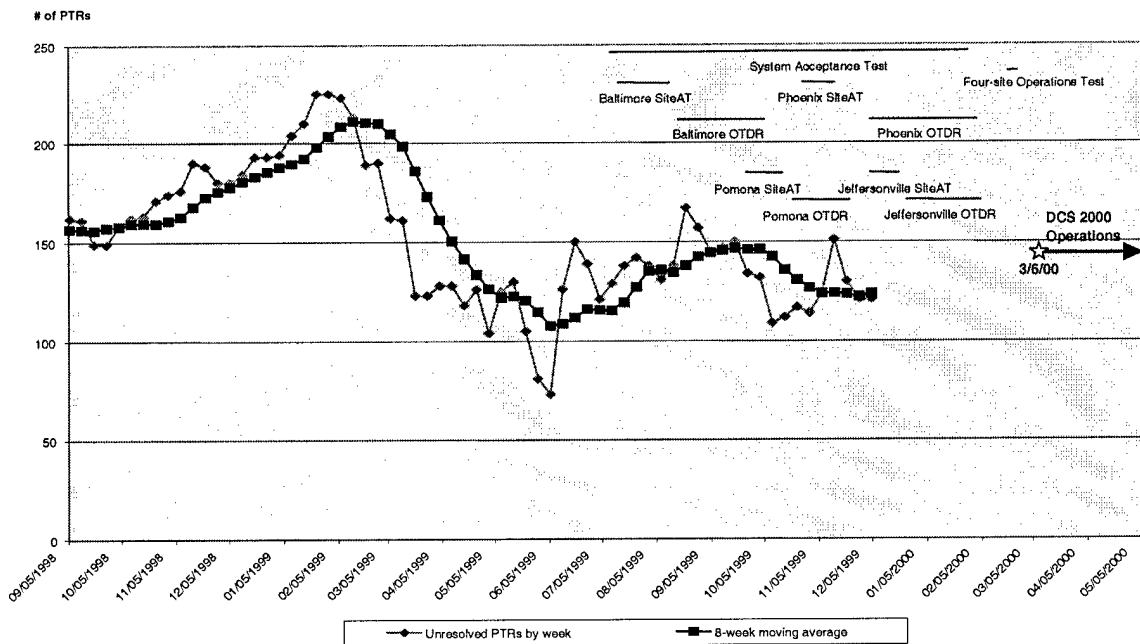
GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects--Emergency/Critical PTRs Opened by Week



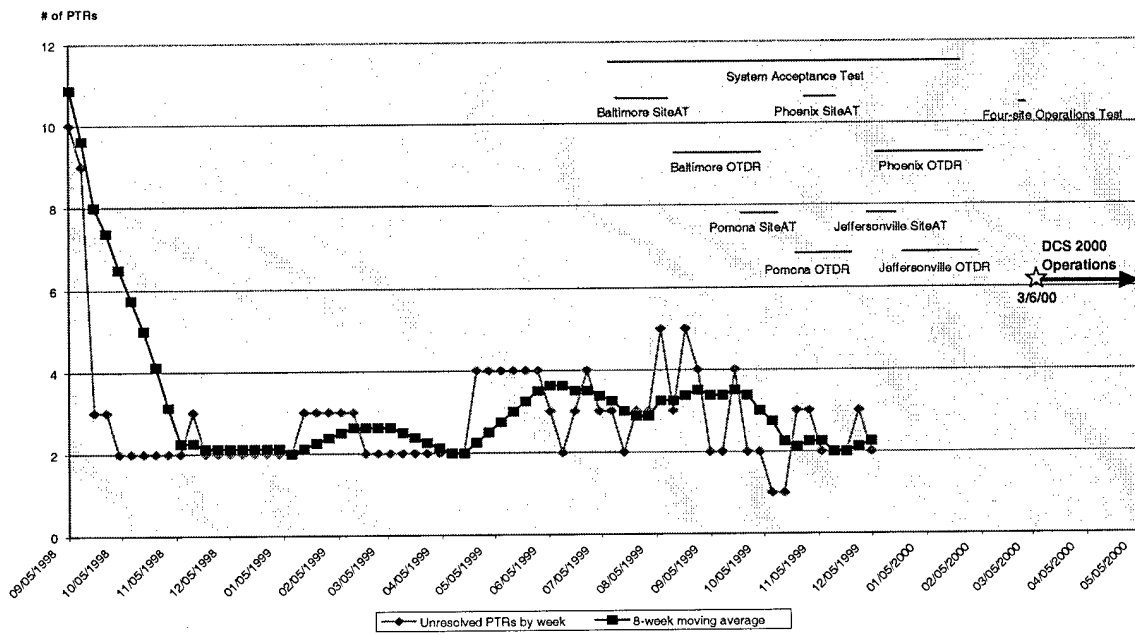
GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects--All Unresolved PTRs by Week



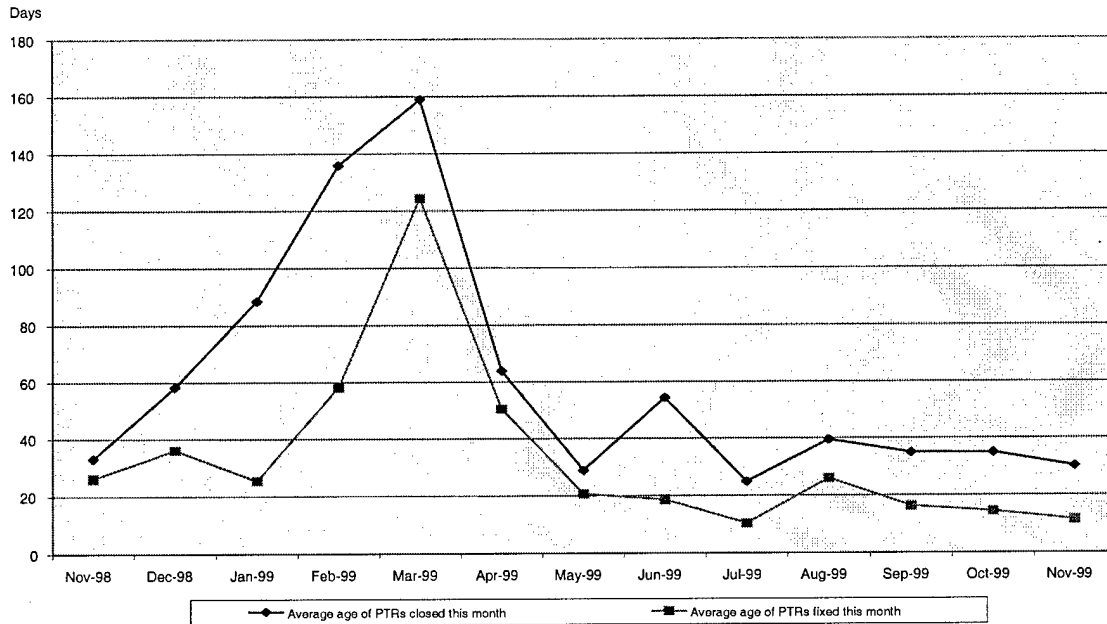
GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects--Unresolved Critical/Emergency PTRs by Week



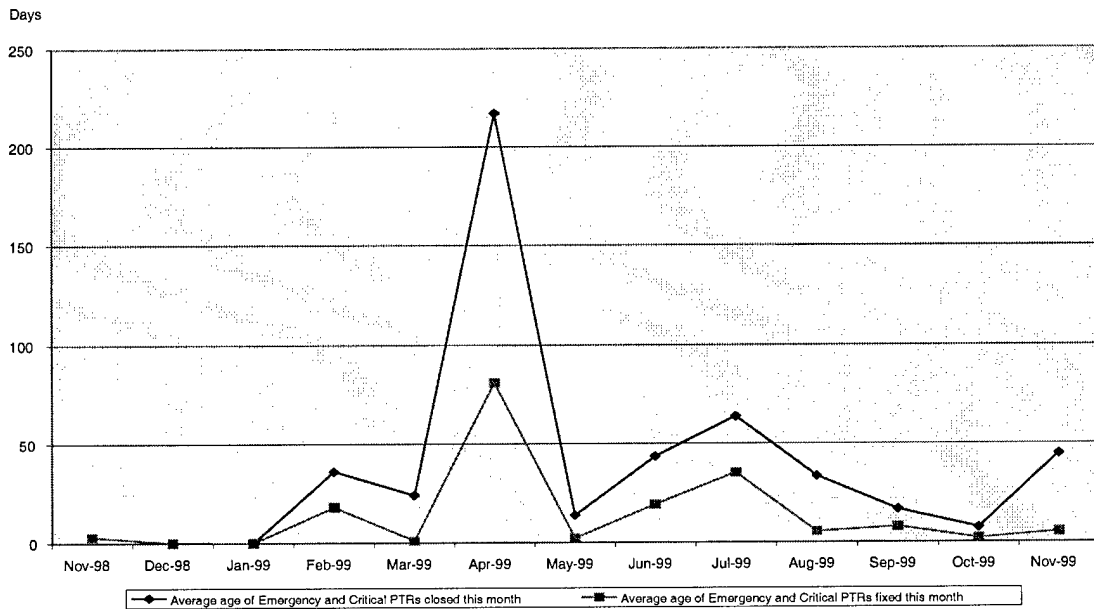
GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects--Average Age of All PTRs



GAO Audit Results: DCS 2000 Status and Quality

4. Trends in Defects--Average Age of Emergency/Critical PTRs



GAO Audit Results: DCS 2000 Status and Quality
4. Trends in Defects--Composite View

- Data on the number of PTRs opened and unresolved each week do not show a maturing trend.
- Test events are major producers of PTRs and many key test events have yet to occur.
- Average time in the last 6 months to resolve (fix) all PTRs was about 16 days; emergency and critical PTRs was about 10 days. A key test event will conclude less than 2 weeks before the system must be operational.

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful

- Acceptance testing is intended to show that a system correctly performs according to the system specification, i.e., performs specified functions within defined performance parameters. Acceptance testing is generally conducted by the developing organization, with the acquiring organization's participation.
- Operational testing is intended to demonstrate that a system performs as intended when operated on-site by those expected to use it.
- DCS 2000 is undergoing three types of major test activities.

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

- System Acceptance Testing (SAT) is to be performed on the incremental releases of DCS 2000. As of November 3, 1999, 309 of DCS 2000's 405 top-level requirements had been tested (about 76 percent).
- Site Acceptance Testing (SiteAT) is to be performed by Lockheed Martin, with government witnesses, at each of the four DCCs on the system functionality released as of the date of the scheduled SiteAT.
- Baltimore, Pomona, and Phoenix SiteAT are completed.

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

- According to Lockheed Martin’s test results report for Baltimore’s SiteAT, the test disclosed various system problems; however, the test was reported successful because the problems were either (1) corrected and retested or (2) scheduled for correction and retesting as part of a future test event. The following are examples of tests and results from Baltimore’s SiteAT.

GAO Audit Results: DCS 2000 Status and Quality

5. Test Events Remain; Completed Events Reported Successful (cont.)

Test Name and Description	Test Results
Cluster Accuracy : This test's purpose was to demonstrate each individual cluster's ability to scan a small number of census forms and recognize data on those forms within specified tolerances. The expected tolerance for optical mark recognition (OMR) errors was 0% to 1.5% and the expected range for optical character recognition (OCR) errors was 0% to 2.0%.	The test was reported successful. For short forms the OMR error rate ranged from .06% to .66% and the OCR error rate ranged from .07% to .14%.
Site Accuracy : This test's purpose was to demonstrate the accuracy of OMR and OCR for about 25,000 census form images on four clusters and create "high confidence" data files in the format used for transmission to Census headquarters. The expected tolerance for OMR errors was 0% to 1.5% and the expected range for OCR errors was 0% to 2.0%.	The test was reported successful although output data files were not prepared for three of four form types. OMR and OCR error rates were captured for all four form types and ranged from .35% to .94% and between .81% and 1.45%, respectively. Output data files for the other 3 form types were to be part of the next SiteAT.

GAO Audit Results: DCS 2000 Status and Quality

5. Test Events Remain; Completed Events Reported Successful (cont.)

Test Name and Description	Test Results
<p>Load Stability: This test's purpose was to exercise all clusters' ability to <i>sort</i> and <i>scan</i> census forms over three 8 hour shifts. During each shift, 13 clusters' operations are simulated while one cluster is operated by test personnel using paper forms. Simulations are run at 110 percent of planned (i.e., normal) operating capacity.</p>	<p>The test was reported successful with noted exceptions. First, while simulated <i>sorting</i> of long forms (419,424) exceeded the goal (360,000), simulated <i>sorting</i> of short forms failed to meet the expected goal due to an error in the sorter simulator. Simulated <i>scanning</i> of both short (1,205,218) and long (120,787) forms exceeded the goals of 1,033,116 and 69,888, respectively.</p> <p>Second, while actual <i>scanning</i> of short forms exceeded the form per shift goal (24,596) in two of the three shifts (29,151 and 26,884), it did not in the third (22,743). Third, <i>scanning</i> of long forms did not meet the form per shift goal in any of the three shifts (952, 681, and 1,221 versus a goal of 1,658).</p>

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

- According to Lockheed Martin’s test results report for Pomona’s SiteAT, the test was reported successful.
- The Pomona SiteAT results were consistent with the Baltimore SiteAT results for the cluster accuracy and site accuracy tests and demonstrated improvement for the load stability test.
- The following are examples of tests and results from Pomona’s SiteAT.

GAO Audit Results: DCS 2000 Status and Quality

5. Test Events Remain; Completed Events Reported Successful (cont.)

Test Name and Description	Test Results
Cluster Accuracy: This test's purpose was to demonstrate each individual cluster's ability to scan a small number of census forms and recognize data on those forms within specified tolerances. The expected tolerance for optical mark recognition (OMR) errors was 0% to 1.5% and the expected range for optical character recognition (OCR) errors was 0% to 2.0%.	The test was reported successful. For short forms the OMR error rate ranged from .0% to .21% and the OCR error rate ranged from .08% to .28%.
Site Accuracy: This test's purpose was to demonstrate the accuracy of OMR and OCR for 6,000 long census forms on all clusters. The expected tolerance for OMR errors was 0% to 1.5% and the expected range for OCR errors was 0% to 2.0%.	The test was reported successful. OMR and OCR error rates were .69% and 1.16% respectively.

GAO Audit Results: DCS 2000 Status and Quality

5. Test Events Remain; Completed Events Reported Successful (cont.)

Test Name and Description	Test Results
<p>Load Stability: This test's purpose was to exercise all clusters' ability to <i>sort</i> and <i>scan</i> census forms over three 8 hour shifts. During each shift, 14 clusters' operations are simulated while one cluster is operated by test personnel using paper forms. Simulations are run at 110 percent of planned (i.e., normal) operating capacity.</p>	<p>The test was reported successful. Simulated <i>sorting</i> of long forms (585,000) met the goal (585,000) and simulated <i>sorting</i> of short forms (2,843,400) met the goal (2,242,500). Simulated <i>scanning</i> of both short (1,227,240) and long (84,870) forms exceeded the goals of 1,033,116 and 69,888, respectively.</p> <p>While actual <i>scanning</i> of short forms exceeded the form per shift goal (24,598) in two of the three shifts (28,638 and 28,785), it did not in the third (24,190). Also, <i>scanning</i> of long forms exceeded the 1,664 form per shift goal in each of the three shifts (1,983; 1,922; and 2,145).</p>

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

- Lockheed Martin’s test results report for Phoenix’s SiteAT was being reviewed and analyzed by the bureau.
- DCS 2000 program officials told us the Phoenix SiteAT was successful and preliminary results demonstrated improvement over the results from Pomona SiteAT.
- The following are examples of tests and results from Phoenix’s SiteAT as provided by bureau officials.

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

Test Name and Description	Test Results
<p>Cluster Accuracy: This test's purpose was to demonstrate each individual cluster's ability to scan a small number of census forms and recognize data on those forms within specified tolerances. The expected tolerance for optical mark recognition (OMR) errors was 0% to 1.5% and the expected range for optical character recognition (OCR) errors was 0% to 2.0%.</p>	<p>For short forms the OMR error rate ranged from .0% to .11% and the OCR error rate ranged from .15% to .28%.</p>
<p>Site Accuracy: This test's purpose was to demonstrate the accuracy of OMR and OCR for 6,000 long census forms on all clusters. The expected tolerance for OMR errors was 0% to 1.5% and the expected range for OCR errors was 0% to 2.0%.</p>	<p>OMR and OCR error rates were .61% and 1.04% respectively.</p>

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

Test Name and Description	Test Results
<p>Load Stability: This test's purpose was to exercise all clusters' ability to <i>sort</i> and <i>scan</i> census forms over three 8 hour shifts. During each shift, 14 clusters' operations are simulated while one cluster is operated by test personnel using paper forms. Simulations are run at 110 percent of planned (i.e., normal) operating capacity.</p>	<p>The results for simulated <i>sorting</i> and simulated <i>scanning</i> are still being analyzed.</p> <p>Actual <i>scanning</i> of short forms exceeded the form per shift goal (24,598) in each of the three shifts (32,795; 30,772; and 34,412). Also, <i>scanning</i> of long forms exceeded the 1,664 form per shift goal in each of the three shifts (2,389; 2,546; and 2,609).</p>

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

- Operations test and dry runs (OTDRs) are to be conducted by TRW, and witnessed by the bureau, at each of the three contractor-operated DCCs. The bureau is to conduct the OTDR at the Jeffersonville center.
- TRW’s Baltimore test results report identified the following problems.
 - › The workload for performing the “key from image” function was unevenly distributed.
 - › The “key from paper” interface was not configured efficiently, thus limiting productivity.

GAO Audit Results: DCS 2000 Status and Quality
5. Test Events Remain; Completed Events Reported Successful (cont.)

- › The “check-out” bar code scanner often misread the form identification number.
- Each of these problems is reported as fixed and is to be retested as part of a future OTDR.
- An additional operational test was conducted at the Baltimore DCC by an independent research organization to assess DCS 2000’s accuracy. The test results showed DCS 2000’s short and long census form OCR accuracy was 99.4% and 99.3%, respectively, exceeding the 98% accuracy goal. Further, DCS 2000’s 99.6% OMR accuracy for short and long forms exceeded the 99% accuracy goal.

GAO Audit Results: DCS 2000 Risks/Risk Mitigators

- Risks

1. Important system development, test, and deployment activities remain that will likely generate more system defects, and the current schedule will not accommodate slippage.
2. Concurrent system-level test activities increase contention for test resources and complicate control of test baseline system configurations.

- Risk Mitigators

1. Incremental development and deployment gets system into hands of users faster.

GAO Audit Results: DCS 2000 Risks/Risk Mitigators (cont.)

2. Formal risk management program is in place to address risks proactively, including steps to mitigate the possibility of not completing remaining system development activities on time.
3. An additional test event to exercise all planned system capabilities in an operational environment is to occur just prior to the March 6, 2000 deadline.
4. Development contractor's software process capabilities are effective, including processes for configuration management.

GAO Audit Results: DCS 2000 Risks

1. Activities Remain/Delays Cannot Be Accommodated

- The bureau must be ready to process census forms by March 6, 2000, thus leaving only 3 months to complete DCS 2000.
 - The following significant DCS 2000 system development steps remain:
 - development and deployment of three releases, including fixing known defects;
 - completion of system acceptance testing;
 - completion of one site acceptance test;
 - completion of two operational tests; and
 - completion of one operational test at all four sites.
-

56

GAO Audit Results: DCS 2000 Risks

**1. Activities Remain/Delays Cannot Be Accommodated
(cont.)**

- The available time between the last system release and the DCS 2000 operational date is less than 4 weeks; thus the current schedule cannot tolerate any delays.

GAO Audit Results: DCS 2000 Risks

1. Activities Remain/Delays Cannot Be Accommodated (cont.)

Key Event	1999				2000				Qtr 1
	Qtr 1	Qtr 2	Qtr 3	Qtr 4	Qtr 1	Qtr 2	Qtr 3	Qtr 4	
System acceptance testing	07/01/99		[Actual progress bar]		01/28/00				
Release 21					◇ 12/17/99				
Release 22					◇ 01/19/00				
Release 23					◇ 02/11/00				
Site acceptance test at Jeffersonville			11/29/99		[Actual progress bar]		12/17/99		
OTDR at Phoenix			12/06/99		[Actual progress bar]		02/04/00		
OTDR at Jeffersonville			12/20/99		[Actual progress bar]		02/04/00		
Four site operations test			02/22/00		[Actual progress bar]		02/25/00		
Data capture			03/06/00		☆		→ 11/30/00		

Legend				
Planned progress	[Cross-hatched box]	Actual progress	[Solid black bar]	
Planned milestone	◇	Actual milestone	◆	

GAO Audit Results: DCS 2000 Risks

2. Multiple Test Activities Occurring Concurrently

-
- Under normal system-level test progression, system acceptance testing occurs first, followed by site acceptance testing, and then site operational testing. While some overlap in the conduct of these test events is normal, the greater the level of concurrency among the events, the greater the risk.
 - Introducing concurrency of test events is one way of saving time and thus delivering systems sooner. This practice has proven successful on systems where no significant problems are expected during the test events (e.g., FAA Display Channel Complex-Rehost).
 - The DCS 2000 schedule provides for as many as three system-level test events to occur concurrently.
-

59

GAO Audit Results: DCS 2000 Risks
2. Multiple Test Activities Occurring Concurrently
(cont.)

- Test concurrency introduces risks that must be formally and carefully managed. For example:
 - Concurrency will increase contention for test resources, particularly key staff.
 - Concurrency introduces the possibility of defects being found and corrected independently during the different test activities, resulting in more than one baseline test configuration.
 - Concurrency can require additional time if severe defects are found that necessitate stopping all affected test activities, fixing the baseline, and then restarting the tests.

60

GAO Audit Results: DCS 2000 Risk Mitigators

1. Incremental Development and Deployment

- Incremental system development and deployment is a recognized “best practice” used by leading public and private organizations to mitigate risks on large, complex systems.
- As previously described, DCS 2000 is being built, deployed, and operationally tested incrementally. By doing so, the bureau is able to learn sooner rather than later about system problems so that it can better manage their resolution and better ensure that needed system capabilities will be ready on time.

GAO Audit Results: DCS 2000 Risk Mitigators

2. Formal Risk Management Program in Place

- Carnegie Mellon University's Software Engineering Institute (SEI) recommends a formal risk management program that includes activities to continually identify, assess, track, control, and report risks for acquisitions like DCS 2000.
- The bureau and Lockheed Martin are jointly managing DCS 2000 risk through a formal DCS 2000 risk management program that includes proactive identification of risks and analysis of their impacts and probabilities, definition of mitigation plans, and tracking and reporting of the plans' implementation and effectiveness.

GAO Audit Results: DCS 2000 Risk Mitigators

2. Formal Risk Management Program in Place (cont.)

- Risk severity is categorized as high, medium, or low.
- As of December 13, 1999, five risks were categorized as high, meaning that they have a high probability of occurrence and a high program impact.

Risk	Mitigation Steps	Status
On-site support personnel are not adequately trained.	Lockheed Martin is developing training materials, scheduling and conducting training, and will rotate development staff to the DCCs to augment site personnel.	Training materials have been developed and on-site support personnel are to receive training as they are brought onto the program. Development staff have been identified to go to the sites.
Daily maintenance of system administration software cannot be performed at night if a third shift is added.	Census and Lockheed Martin will assess alternative ways of increasing system performance other than adding a third shift.	Alternatives are being analyzed. A recommended solution is expected by January 7, 2000.

63

GAO Audit Results: DCS 2000 Risk Mitigators 2. Formal Risk Management Program in Place (cont.)

Risk	Mitigation Steps	Status
Undefined technical support roles and responsibilities may affect site operations.	Lockheed Martin is defining the roles and responsibilities for the site operations team and developing procedures and guides for use during operations. The procedures and guides are to be used during the final 2 OTDRs and the 4-site operations test.	Roles and responsibilities are defined in the on-site support procedures and guides, which were completed on December 10, 1999.
Central technical support staffing levels are currently insufficient to provide technical support coverage during all processing shifts at the DCCs.	Lockheed Martin is seeking a contract modification to increase central technical support staffing.	Lockheed Martin is developing a proposal and associated cost estimate for increased central technical support. The proposal and cost estimate is expected to be provided to the Bureau in January 2000.

GAO Audit Results: DCS 2000 Risk Mitigators 2. Formal Risk Management Program in Place (cont.)

Risk	Mitigation Steps	Status
Tight development schedules poses risk to successful data capture.	1) Extend release management function. 2) Increase focus on PTRs to ensure proper priority and planning for the remaining schedule. Review PTR status regularly and establish contingency plans for all PTRs, which may miss committed schedules. 3) Continue to review all new change requests to ensure they are high priority and that they can be delivered with manageable risk. 4) Make sure that all releases with new functionality are tested during an OTDR. 5) Continue to develop and refine the Rapid Response process, which requires a fix or a workaround within 24 hours.	1) Proposal submitted and additional release management support authorized. 2) Added staff to manage PTR progress. Regular PTR status meetings held to review PTRs with sites and other support areas. 3) Established Engineering Review Board to review all change requests. 4) Current release plan reflects all new functionality as part of Release 22 and will be tested during the Phoenix and Jeffersonville OTDRs. Release 23 will be part of 4-site test and will contain PTRs only. 5) Rapid response process developed.

65

GAO Audit Results: DCS 2000 Risk Mitigators
3. Additional Test of All System Capabilities Planned

- A test to demonstrate simultaneous operation of all four DCC's, including DCS 2000's capability to process workload equivalent to that expected during actual data capture operation, is planned for February 22-25, 2000.
- The test will include operational testing of all DCS 2000 software releases.
- The test will use the same system operations and support personnel that will be on board for actual data capture operations.

GAO Audit Results: DCS 2000 Risk Mitigators
4. Development Contractor Process Capabilities Are Effective

- SEI has developed criteria for determining organizations' capability to develop software effectively.
- SEI's criteria defines five levels of development capability, ranging from level 1 (ad hoc and chaotic) to level 5 (optimized).
- Lockheed Martin-Mission Systems has been independently evaluated as an SEI Level 5 development organization, and DCS 2000 was one of three systems included in the evaluation determination.

GAO Audit Results: DCS 2000 Risk Mitigators
4. Development Contractor Process Capabilities Are Effective (cont.)

- Among the effective software development key processes that Lockheed Martin-Mission Systems has are configuration management; project planning, tracking, and oversight; and quality assurance.

GAO Conclusions

The Census Bureau has made reasonable progress in acquiring and deploying DCS 2000, and under normal circumstances, where completion deadlines can be changed and some degree of schedule slippage is tolerable, delivering promised DCS 2000 capabilities would not represent a significant risk. However, the demands of the decennial census necessitate that DCS 2000 be developed, tested, deployed, and ready to operate in just 3 months, with no allowance for slippage.

Given DCS 2000's current status and quality, completing DCS 2000 by March 6, 2000, poses considerable risk. In particular, significant system functionality remains to be developed, acceptance tested (e.g., 24 percent of the total number of DCS 2000 high-level functional requirements have not yet been acceptance tested), deployed, and site tested. Further, a key measure of system quality (trends in unfixed severe defects) is not yet moving in a direction consistent with that of a maturing system. Given that (1) a number of significant test events have yet to occur and (2) these yet-to-occur events are likely to uncover more defects, the chances of the defect trend moving in a favorable direction soon are uncertain. Further, given that the average

69

GAO Conclusions (cont.)

time to fix severe DCS 2000 defects over the last 6 months (about 10 days) would consume the time between conclusion of the later test events and the day that DCS 2000 must be operational, the chances of all specified system capabilities being ready on time are reduced.

To meet the challenge of a very demanding and fault-intolerant schedule, the bureau has been following a plan that provides for (1) development and testing of DCS 2000 in a series of increments, called releases, and (2) deployment and site testing of the releases as they become ready. This concurrent development and testing approach, while introducing risk due to the concurrent activities, allows early system capability to get into the hands of the end users faster, which could save time. Further, while this concurrent approach does increase the risk of contention for test resources and uncontrolled changes to the system baseline configuration (because of the number of development and test baselines being used), these risks can be mitigated by effective system development capabilities, such as project risk management, configuration management, project planning, and oversight. In DCS 2000's case, these activities are being performed by the development

70

GAO Conclusions (cont.)

contractor, which has been independently certified as an SEI level 5 (on a 5 level scale) software developer. Such contractor capability is an important risk mitigator, not only with respect to each of these activities, but for all remaining DCS 2000 development, testing, and deployment activities.

Nevertheless, the schedule challenge facing the bureau on DCS 2000, particularly in light of where the system currently stands and what remains to be accomplished, are formidable. Both bureau and development contractor officials agree. Accordingly, they have initiated proactive and appropriate risk management steps. While these steps do not guarantee success, they should minimize the probability of the risk occurring and the impact on the program if it does.

GAO Appendixes

- Appendix I: Scope and Methodology
- Appendix II: Description of Other Decennial Census Systems

GAO Appendix I Scope and Methodology

- We determined DCS 2000 status and quality by:
 - Reviewing system development plans, project management plans, activity plans (test, deployment, etc.), project status reports, program management briefings, system functional requirements and specifications, and test results reports.
 - Comparing original to revised plans and current plans to status reports.
 - Observing DCS 2000 OTDR in Baltimore.
 - Attending periodic DCS 2000 project review meetings between the bureau and the development contractor.

GAO Appendix I Scope and Methodology (cont.)

- Interviewing bureau DCS 2000 project management and contractor officials.
- Identifying how the bureau measured maturity and quality of DCS 2000 throughout its development life cycle, and analyzing these and other measures for indicators of progress and system health (e.g., PTR trends and age and test results).
- Reviewing the scope and results of DCS 2000 testing activities, including test plans and results.

GAO Appendix I Scope and Methodology (cont.)

- We determined DCS 2000 risks and risk mitigators by:
 - Determining bureau and development contractor key management processes (e.g., requirements management, configuration management, project planning, and project tracking and oversight).
 - Analyzing the results of status and quality determinations vis-à-vis DCS 2000 expectations and remaining steps to complete.
 - Analyzing plans for completing DCS 2000 vis-à-vis generally accepted system engineering principles.
 - Interviewing bureau DCS 2000 project managers and contractor officials.
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75

GAO Appendix I Scope and Methodology (cont.)

- We briefed bureau and development contractor officials on the results of our work and incorporated updated information they provided, as appropriate.
- We performed our work at the bureau's headquarters in Suitland, MD; the DCS 2000 program office in Lanham, MD; bureau and development contractor facilities in Bowie, MD; and the bureau's DCC in Baltimore, MD from June 1999 through December 1999 in accordance with generally accepted government auditing standards.

GAO Appendix II Description of Decennial Census Systems

- Geographic Support System provides the basic census address list, maps, and geographic reference files for all census programs, including the 2000 decennial census.
- Pre-Appointment Management System/Automated Decennial Administrative Management System is the administrative management system that supports temporary bureau employee applicant tracking and processing, temporary employee selection records, recruiting reports, personnel and payroll processing, and archiving of historical employment data.

GAO Appendix II
Description of Decennial Census Systems (cont.)

- Operations Control System 2000 supports, manages, and controls all field operations for Census 2000.
- Management Information System 2000 is the official source of management information on Census 2000 and will provide information on scheduling, progress to date, cost to date compared to budget, and performance anomalies.

GAO Appendix II Description of Decennial Census Systems (cont.)

- Telephone Questionnaire Assistance and Coverage Edit Follow-Up
 - TQA is a telephone response system that uses both automated interactive voice response technology and live operator responses to ensure that the public's needs are addressed.
 - CEFU flags edit failures on census forms and sends them to a telephone follow-up operation where a generic follow-up interview will be conducted.

GAO Appendix II
Description of Decennial Census Systems (cont.)

- Internet Data Collection/Internet Questionnaire Assistance
 - IDC provides respondents, on a limited basis, the ability to complete their short form questionnaire on-line over the Internet.
 - IQA provides respondents with answers to questions via the Internet.
- Accuracy and Coverage Evaluation is a follow-up survey for a representative sample of 300,000 housing units across the nation.

GAO Appendix II Description of Decennial Census Systems (cont.)

- Headquarters processing is a group of systems, applications, and processes performed on the data collected by various Census 2000 systems during the census and during the ACE phases. Headquarters processing is also responsible for creating final census data files.
- Data Access and Dissemination System consists of two primary subsystems, American FactFinder and Data Products Production. These subsystems jointly provide access to census results through the Internet.

Comments From the Department of Commerce

Note: GAO comments supplementing those in the report text appear at the end of this appendix.



THE SECRETARY OF COMMERCE
Washington, D.C. 20230

JAN 27 2000

Mr. Jeffrey C. Steinhoff
Acting Assistant Comptroller General
U.S. General Accounting Office
Washington, D.C. 20548

Dear Mr. Steinhoff:

The Department of Commerce appreciates the opportunity to comment on the U.S. General Accounting Office draft document entitled, *2000 Census: New Data Capture System Progress and Risks*. The U.S. Census Bureau's comments on this report are enclosed.

Sincerely,

A handwritten signature in black ink, appearing to read "W. Daley".

William M. Daley

Enclosure

Enclosure

Comments from the U.S. Department of Commerce
Bureau of the Census

U.S. General Accounting Office Report Entitled "2000 Census: New Data Capture
System Progress and Risks"

The U.S. Census Bureau is in general agreement with the observations and conclusions outlined by the U.S. General Accounting Office (GAO) in this report. Census Bureau officials agree that the Census 2000 schedule is tight, and that the Data Capture System (DCS) 2000 must meet significant challenges associated with the successful completion of Census 2000. Appropriate risk management procedures have been initiated, therefore, to ensure that the continued implementation of the DCS 2000 is on schedule, and that the system fulfills all of its operational requirements.

See comment 1.

However, the Census Bureau does have some comments on the report. The GAO states that "the demands of the decennial census necessitate that DCS 2000 be developed, tested, deployed, and ready to operate in just 2 months." The Census Bureau is concerned that this sentence implies that *all* of the DCS 2000 system must be developed, tested and deployed in 2 months. As the GAO documents in its report, one of the strengths of the DCS 2000 system is that it has been incrementally developed and tested. In fact, the Census Bureau is in the final stages of testing, and only a small portion of development remains to be completed before the DCS 2000 system will be fully operational.

See comment 2.

In addition, the GAO states that "the time left between the conclusion of the last test event, scheduled for February 25, 2000, and the day that DCS 2000 must be operational is 9 days whereas it has been taking an average of 16 days to resolve all [Program Trouble Reports (PTRs)] over the last 6 months. . ." In fact, the PTR resolution rates identified in the report occurred during periods of significant software development, and not during periods of dedicated software maintenance. During the software development period, PTR resolution was not given the priority it now receives. Census Bureau officials believe, therefore, that the "average of 16 days" cited in the report is not a true representation of the time it takes to resolve emergency PTRs. Moreover, as noted by GAO, a "rapid response process" is in place to deal with emergencies. When this process was used for 7 emergency trouble reports that occurred during the operational testing dry run, the resolution rate was only 2 days. This constitutes a much more accurate indication of the time it will take to resolve any future problems that may arise.

Except for these concerns, the Census Bureau shares the GAO's awareness of the significant challenges associated with the unprecedented use of information technology in meeting Census 2000 data capture requirements. The GAO's insights and contributions in the development of this report are appreciated, and Census Bureau officials are confident that the implementation of DCS 2000 is on schedule.

The following are GAO's comments on the Department of Commerce's January 27, 2000, letter responding to a draft of this report.

GAO Comments

1. It was not our intent to imply this. As we discuss throughout the report, DCS 2000 development, testing, and deployment has been ongoing on an incremental basis and we clearly identify what activities have been accomplished to date. Further, we identify what development, test, and deployment activities remain to be accomplished, and we characterize these remaining activities as significant and formidable in light of the short time remaining before DCS 2000 must be operational. Nevertheless, we have modified the sentence that the bureau cited to eliminate the possibility of misinterpretation.
2. We agree that the 16-day average time for resolving *all* PTRs is not a good indicator of the time necessary to resolve *emergency* PTRs because *all* PTRs include five different categories of PTRs and each category receives a different priority, *emergency* being the most severe category and the highest priority for resolution. For this reason, we do not state anywhere in our report that the 16-day average time needed over the last 6 months (which covered June through November 1999) to resolve *all* PTRs is the operative indicator of the time to resolve the most severe category of PTRs (*emergency*). Rather, the operative indicator that we cite in the report for the time necessary to resolve severe PTRs is 10 days, which is the average time that the bureau's own data show it has taken over the last 6 months to resolve both *emergency* and *critical* PTRs. We focused on these two most severe categories of PTRs in our analysis because the bureau's own definition of *emergency* and *critical* PTRs (*emergency* PTRs are problems that prevent system operation and *critical* PTRs are problems that significantly degrade system operation) mean that both of these categories of PTRs will have to be resolved before March 6, 2000, if DCS 2000 is to operate as intended. Accordingly, we state in the report that "it has been taking an average of 16 days to resolve all PTRs over the last 6 months and 10 days for severe PTRs."

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