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Report to the Chairman, Committee on Science, Space, and Technology, House of Representatives

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SPACE COMMUNICATIONS

Performance of NASA's White Sands Ground Terminal

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GAO

United States
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Information Management and
Technology Division

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The Honorable Robert A. Roe
Chairman, Committee on Science,
Space, and Technology
House of Representatives

Dear Mr. Chairman:

This report responds to your request for information about the performance and reliability of the National Aeronautics and Space Administration's (NASA) White Sands ground terminal in White Sands, New Mexico. The White Sands terminal is the main ground component of NASA's Tracking and Data Relay Satellite System (TDRSS), which also includes three space-based satellites and the network control center at the Goddard Space Flight Center in Greenbelt, Maryland.

Various satellites and the space shuttle use TDRSS to relay tracking and scientific data to users. This relay through the White Sands terminal is essential to the safety of NASA astronauts and the receipt of scientific data from space experiments. In our April 1989 report[1] to you on NASA's communications support for earth orbiting spacecraft, we noted problems with the reliability of the automated equipment and software at the White Sands terminal. As agreed by your office, our current objective was to determine how NASA evaluates and assesses the performance and reliability of this terminal. Details on our objective, scope, and methodology are in appendix I.

Results in Brief

NASA does not evaluate the reliability of the White Sands terminal. Instead, it assesses performance in terms of how the terminal met the user's data transmission needs, which it calls user support proficiency. Given this criterion, NASA has exceeded its goal of 95 percent user support proficiency since 1986 and is, on average, delivering telecommunications services to users about 99 percent of the time when scheduled to do so. Moreover, TDRSS users expressed general satisfaction about the services they received.

NASA's user support proficiency measure does not address the terminal's reliability or availability, which are standard engineering measures of

[1] Space Operations: NASA's Communications Support for Earth Orbiting Spacecraft (GAO/IMTEC-89-41, Apr. 7, 1989)

TDRSS Usage Is Increasing

Although TDRSS capacity exceeds present use, NASA anticipates demand for services will significantly increase in the 1990s. Since TDRSS began initial operations in 1983, NASA has provided services to various spacecraft including the space shuttle, the Solar Mesosphere Explorer, the Earth Radiation Budget Satellite, Solar Maximum Mission, and LANDSAT 4 and 5. In addition, a new generation of spacecraft are now using TDRSS, including the Hubble Space Telescope and the Cosmic Background Explorer. NASA statistics indicate that since 1983, actual use of TDRSS' high data rate telecommunications services reached a high of about 13 percent of capacity in mid-1989 and is projected to increase to about 42 percent of capacity in 1993.

According to NASA officials, the maximum operating capacity for high data rate services is estimated at 70 to 75 percent of total time available. Operating continuously above this level would result in a rapid decline in service. Under normal circumstances, about 25 to 30 percent is required for handling peak work loads, as well as for factors such as establishing communications visibility—the time needed to line up a user satellite with a TDRSS satellite so communications can be relayed to the ground terminal.

Terminal Problems Are Being Addressed

The White Sands terminal is contractor owned and operated at a cost of about $25 million annually, according to a NASA budget manager. The terminal has two principal functions: (1) to safely operate and maintain the three TDRSS relay satellites, and (2) to provide uninterrupted communication between earth orbiting spacecraft and their users. The terminal was designed to support spacecraft users from 1983 through 1993. Between 1983 and 1985, NASA recognized various problems with TDRSS, including the terminal, and began a comprehensive study to identify problems needing resolution.

Having identified problems in system design, tracking, operations, and testing, NASA sponsored a 5-year terminal enhancement project, costing about $34 million, scheduled to be completed in July 1990. The project seeks to improve the reliability, maintainability, and availability of the terminal through the end of its operational life in 1993. For example, NASA upgraded, added, and replaced various equipment components of its testing, automated data processing, radio frequency, command, and monitoring systems to reduce failure rates and to improve reliability and availability.

User satisfaction is another indicator of terminal performance. Users submit their original requests for telecommunications services to the network control center at Goddard at least 3 weeks before the services are needed. The control center aggregates these requests and during the ensuing 3 weeks negotiates a final telecommunications schedule with all spacecraft users based on priority ranking, planned hardware and software upgrades, and maintenance schedules. Although the control center sets and maintains user schedules, the contractor who operates the terminal is responsible for keeping the equipment functioning to support the user schedules.

Users we interviewed were generally satisfied with the telecommunications services they had received. For example, a representative from the shuttle program, a high priority user, said he was satisfied with the services provided, and added that shuttle data transmissions can only be preempted by an emergency on board another spacecraft. Should this occur, scientific experiments can generally still be performed because the data from these experiments are recorded on tape. Should transmissions be interrupted, spacecraft tape recorders can be rewound and the data retransmitted at a later time. The shuttle representative was confident that the terminal will be able to provide adequate service to meet the shuttle's needs until 1993, when the terminal is scheduled to be replaced.

LANDSAT users were also generally satisfied with the services received. LANDSAT sells earth images to the private sector, with about 20 percent of the images ordered in advance. LANDSAT users pointed out, however, that LANDSAT spacecraft lacked on-board tape recorders. As such, interruptions in telecommunications resulted in lost images. For example, during the first 5 months of 1989, LANDSAT spacecraft lost 502 minutes of data, representing about 20 percent of the total TDRSS data losses for the period. LANDSAT representatives told us they could not readily determine the financial impact of this loss.

Some users had concerns about the administrative process of using TDRSS. Several mentioned having to negotiate changes in their initial schedule request with NASA due to conflicts with other users or other NASA activities. Despite the additional work and frustrations, users said they generally received adequate transmission time to accomplish their mission objectives. Even when NASA changed a schedule just before transmission time, or when transmissions were interrupted, they said mission impact was usually minimal.

Contractor officials said they cannot measure the mean time between equipment failures, or system reliability, because the terminal's electronic system lacks the comprehensive diagnostic capability necessary to precisely capture real-time data on all equipment failures. As a result, in some cases maintenance personnel become aware of an equipment failure only if it is being used to transmit data at the time of failure. In other words, a component failure in a spare chain of equipment or any unused equipment could go unnoticed until put to use.

In 1988 NASA awarded a contract for the design and development of a new terminal at White Sands by 1993. The terminal manager told us that in contrast to the old one, NASA will own the new terminal and therefore, has developed specifications emphasizing its reliability, availability, and maintainability. These specifications address reliability requirements and call for (1) developing a fault isolation system to identify equipment subcomponent failures, and (2) measuring mean time between failures to determine the terminal's reliability.

System Availability

System availability, another performance indicator focusing on equipment, measures the mean time between component failure and mean time to repair. Availability is computed by dividing the time the system was actually available for use by time it should have been available had it functioned according to specifications.

Although NASA officials said they routinely gathered information on the availability of some terminal equipment, they could not supply detailed data on when it was unavailable. The contractor staff said that they were enhancing the maintenance program during the remaining contract period by developing a management information system to supply this data. Because NASA could not provide comprehensive data on equipment availability or summary information on total system downtime, we could not assess the terminal's overall availability.

As in the case of reliability, NASA's contract specifications for the new terminal require that (1) the system be available 99.9 percent of the time, and (2) actual availability be measured against this performance criteria.

Conclusion

The current performance of the White Sands terminal—using NASA's measurement of support proficiency—is high. However, because the terminal is only processing a small percentage of the estimated future

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Objective, Scope, and Methodology

In June 1989, the House Committee on Science, Space, and Technology asked for information on how NASA evaluates and assesses the performance and reliability of its White Sands ground terminal. To evaluate the terminal's performance, we reviewed three indicators of a system's performance: NASA's user support proficiency, which measures how well the terminal is meeting user schedules for telecommunications services; user satisfaction; and equipment reliability and availability. We obtained monthly statistics on user support proficiency from NASA and CONTEL, Inc., the contractor. We then compared these performance data to the 95-percent support proficiency requirement established in NASA's performance evaluation plan with CONTEL. We also interviewed NASA officials at the Goddard Space Flight Center in Greenbelt, Maryland, and the White Sands Ground Terminal in White Sands, New Mexico, to determine how they collect, analyze, and report data on user support proficiency. We did not independently test the accuracy of this data.

We also interviewed the principal users of TDRSS on their degree of satisfaction with the terminal's performance. These included project staff from the program offices of Space Shuttle, Solar Mesosphere Explorer, Earth Radiation Budget Satellite, Solar Maximum Mission, and LANDSAT 4 and 5.

We also determined the extent to which NASA and CONTEL use standard engineering measurements of equipment reliability and availability to evaluate the performance of the ground terminal system. We reviewed contract documents to verify whether NASA had required the contractor to perform such measurements and if NASA had also established reliability and availability performance criteria. We also interviewed NASA and contractor officials at the terminal to find out if the system was designed with the diagnostic capability necessary to precisely capture reliability and availability data and, if so, what data were collected.

We obtained comments on this report from officials at NASA headquarters, the Goddard Space Flight Center, and White Sands terminal. Their comments have been incorporated into the report where appropriate. We performed our work from June 1989 to March 1990 in accordance with generally accepted government auditing standards.

work load, it is not being stressed. In the absence of comprehensive reliability and availability data which is important for assessing system performance under increasing work loads, NASA officials cannot accurately predict how well or how long the terminal will perform in the future.

Responsible officials from NASA provided comments on this report. These comments are included where appropriate. As arranged with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the date of this letter. We will then provide copies to appropriate congressional committees, the Administrator of NASA, and other interested parties upon request.

This work was performed under the direction of Samuel W. Bowlin, Director for Defense and Security Information Systems, who can be reached at (202) 275-4649. Other major contributors are listed in appendix II.

Sincerely yours,

Ralph V. Carlone
Assistant Comptroller General

Two users wondered whether TDRSS could meet higher future demand for services. Similar concerns were expressed in a December 1989 NASA report[2] that said

> the practical problems of scheduling and conducting an operation with TDRSS are substantial, even considering the recent redesigns within the network control center. In other words, the current design and implementation for scheduling and operationally utilizing TDRSS is fragile. There is considerable uneasiness that the TDRSS, when confronted by increasing high priority loading, is likely to become grossly inefficient and that low priority users will therefore be left without support.

System Reliability and Availability Are Uncertain

Besides user support proficiency and satisfaction, determining a system's reliability and availability are important. These measures are standard engineering concepts for assessing a terminal's current performance and predicting its future performance. However, NASA and contractor officials at White Sands do not measure system reliability, nor do they maintain sufficient data to determine the total time the system equipment was unavailable for use. As a result, NASA cannot predict how reliably the terminal will perform in the future.

System Reliability

Reliability, a standard engineering indicator of a system's technical performance, measures the actual mean time between component failures and, when compiled over a number of years, can be used to predict the likelihood of system failures under future operating conditions. Thus, data on the failure rates of the terminal equipment could be used to model and predict how reliably it will perform in the 1990s when usage is expected to grow significantly.

But according to NASA's ground terminal manager, the 1976 contract for the design and development of TDRSS did not require the contractor to develop built-in diagnostic capability to monitor the technical reliability of the terminal's equipment. Although such diagnostic capability was available at the time of contract award, NASA wanted to buy telecommunications services, not equipment. Hence, NASA's contract and performance criteria focused on the ultimate delivery of telecommunications services to users, not on equipment reliability. NASA saw the operation, maintenance, performance, and reliability of the equipment as the responsibility of its owner, the contractor.

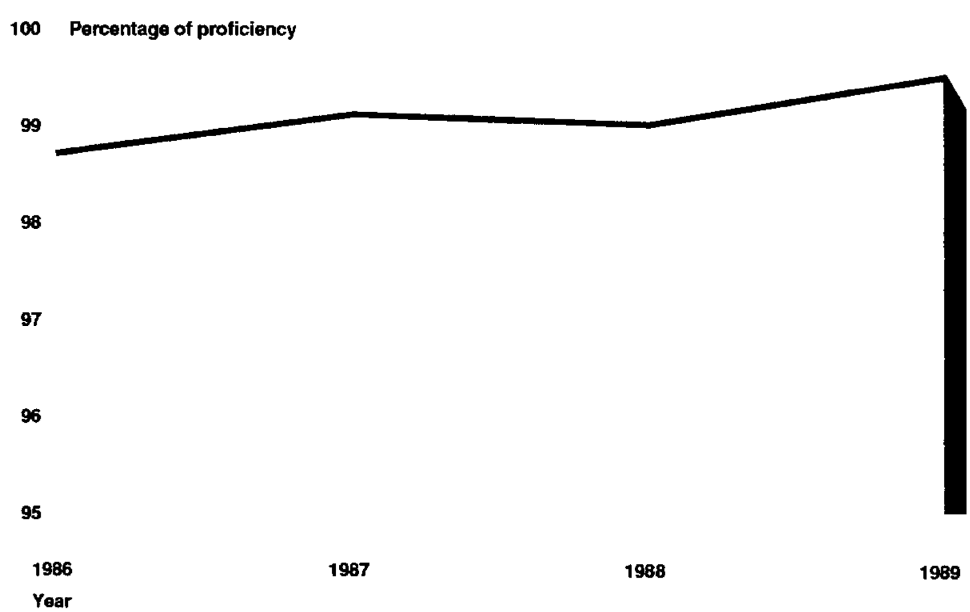
[2]Information System Scenarios for Space Science and Applications, Section 2.4.2: Data Relay Satellites and Ground Stations, System Diversity and Dependability, December 1989.

NASA plans to replace the White Sands terminal in 1993. NASA then plans to completely upgrade the old terminal, making it identical to the new one, in order to provide additional capacity and backup capability to support TDRSS demand in the 1990s. Given an overall investment of about $427 million for building the new terminal and upgrading the old one, NASA plans no major interim upgrades of the old terminal. However, NASA officials said they would continue to make minor enhancements until shortly before the new one becomes operational.

Terminal Is Generally Meeting User Needs

Statistics from 1986 to 1989, confirmed by discussions with TDRSS users, indicate the terminal exceeds NASA's performance expectations. NASA officials told us their primary indicator of overall terminal performance was user support proficiency—a measure which compares the actual amount of communications relay time provided to users with the amount of time scheduled for them. As shown in the figure below, NASA's annual support proficiency statistics from 1986 to 1989 show that the terminal exceeded NASA's goal of 95 percent user support proficiency and was, on average, providing communications services to users about 99 percent of the time when scheduled to do so.

Figure 1: User Support Proficiency



equipment failure rates and repair times, and of the total time the equipment is available for use so that predictions can be made about future performance. NASA cannot use these measures because the terminal lacks the necessary diagnostic capability to capture information on the incidence and duration of equipment failures.

Use of the White Sands terminal is expected to increase significantly during the next several years. In June 1989, demand for high data rate telecommunications services—one of several types provided to users—was about 13 percent of available TDRSS capacity. However, demand is projected to increase to about 42 percent in 1993. Without reliability and availability data, NASA officials cannot predict how well the terminal will perform or how long it will be available for use in the future.

NASA plans to replace the White Sands terminal in 1993. Recognizing that increased demand for services in the 1990s will require greater assurance that the new terminal be reliable and available, NASA's design and development contract for the new terminal requires a diagnostic capability as well as specifications for the standard measurements of reliability and availability to determine system performance. NASA also plans to upgrade the old terminal after the new one becomes operational. The estimated cost of these projects is $427 million.

Background

In 1983, NASA launched and began operating its first TDRSS satellite. TDRSS became fully operational in June 1989 with its set of two active satellites and one spare. The active satellites are located over the Atlantic Ocean, off the coast of Brazil; and over the Pacific Ocean, southwest of the Hawaiian Islands. The spare is located between the two and can be used if a major problem occurs with one of the active satellites. TDRSS allows an earth orbiting spacecraft, like the space shuttle, to relay its communications through the active TDRSS satellites to the White Sands terminal and on to its users.

The types of communications relayed through TDRSS include (1) data from spacecraft on their orbital positions, (2) scientific information collected by on-board instruments, (3) commands from users to operate the spacecraft, and (4) engineering data on the health and safety of user spacecraft. Communications through TDRSS are available 24 hours a day, 7 days a week.