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

July 1991

WEATHER SATELLITES

Action Needed to Resolve Status of the U.S. Geostationary Satellite Program

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National Security and
International Affairs Division

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The Honorable George E. Brown, Jr.
Chairman, Committee on Science,
Space, and Technology
House of Representatives

Dear Mr. Chairman:

This report responds to the September 27, 1990, request from the former Chairman, Robert A. Roe, that we review the National Oceanic and Atmospheric Administration's (NOAA) and the National Aeronautics and Space Administration's (NASA) joint efforts to develop and acquire the next generation of geostationary weather satellites—GOES-Next. Specifically, the report discusses the current cost, schedule, and technical status of the GOES-Next program; reasons for program problems that led to cost increases and schedule delays; and options available for precluding a gap in geostationary weather satellite coverage of the United States.

Unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after its issue date. At that time, we will send copies of the report to the Administrator, NASA; the Secretary, Department of Commerce; the Under Secretary for Oceans and Atmosphere, Department of Commerce; the Director, Office of Management and Budget; appropriate congressional committees; and other interested parties.

The work on this report was done under the direction of Mark E. Gebicke, Director, NASA Issues (202) 275-5140. Major contributors are listed in appendix I.

Sincerely yours,

Frank C. Conahan

Frank C. Conahan
Assistant Comptroller General

Executive Summary

Purpose

The National Weather Service faces the potential loss of geostationary satellite coverage of the United States. The Service currently has only one operational geostationary satellite, GOES-7, in orbit to provide data on severe storm conditions, and no replacement satellite is currently available. GOES-7 will begin to drift out of orbit in June 1992, and its capabilities will be significantly reduced after 1 year. Although the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) have been working together on a program to develop and build five new satellites (GOES-Next), numerous problems in the program have delayed the launch date of the first satellite until October 1992, and further delays are possible.

The Chairman of the House Committee on Science, Space, and Technology requested that GAO examine the current cost, schedule, and technical status of the GOES-Next program; the reasons for problems that have led to cost increases and schedule delays; and options for precluding a gap in geostationary satellite coverage.

Background

NOAA's National Weather Service uses geostationary satellites to provide observations of the earth used in weather forecasting. These satellites are used to identify emerging severe storm conditions, such as hurricanes and tornadoes, and to track the movement and intensity of these storms once they develop.

In the early 1980s, the National Weather Service embarked on a broad modernization program to reduce staffing and costs and to improve weather forecasts. Design and production of GOES-Next was a part of this modernization. NASA, as NOAA's agent, awarded a cost-plus-award-fee contract in 1985 to Space Systems/Loral, Inc. (formerly the Ford Aerospace Corporation), for GOES-Next. The subcontractor for the satellite instruments is a division of the ITT Corporation.

Results in Brief

The GOES-Next program is over 3 years behind schedule, has experienced a 134 percent contract cost overrun, and has been plagued by severe technical problems. In fiscal year 1991 alone, total estimated funding requirements for the program (including launch services) increased about $400 million, from $1.3 billion to over $1.7 billion, and the scheduled launch date of the first GOES-Next satellite slipped from June 1991 to October 1992. Further delays are possible.

GAO believes that design complexity, inadequate management of the program by NASA and NOAA, and poor contractor performance contributed to the cost, schedule, and technical problems experienced by the program.

GAO and NOAA identified several options to minimize the risk of a complete loss of geostationary satellite coverage or degraded weather forecast operations. These options range from making an emergency purchase of or using a foreign-owned satellite to doing nothing and assuming the risk that GOES-7 will not fail before the launch of an operational GOES-Next. The option or options that would be preferable depend whether NOAA delays the GOES-Next program.

Principal Findings

Program Costs Have Increased and Schedule Delays Have Occurred

Since the GOES-Next program began in 1985, the total estimated cost of the program (including launch costs, ground support system costs, and other government expenses) has increased from a low of $640 million in 1986 to over $1.7 billion in 1990. Space Systems/Loral's estimates for developing and building five satellites increased from $276 million to about $834 million during this period.

Over 3 years of schedule delays have occurred due to technical problems in the program. The first GOES-Next satellite could be launched in October 1992 at the earliest, about 4 months after GOES-7 will begin to drift out of its orbit. Continuing technical problems could further delay this scheduled launch.

Severe Technical Problems Plague GOES-Next

In May 1991, NASA and NOAA planned to launch the first GOES-Next with known problems in its instruments. NOAA agreed to waive some of the instruments' specified performance requirements in order to launch the first satellite by October 1992. In June 1991, discovery of a new problem involving wiring of the instruments threatened to delay the launch an additional 6 to 9 months unless NOAA was willing to grant additional performance waivers. This situation is currently under review. Concerns about the reliability of the instruments and satellite control systems will have to be resolved before a launch. NOAA is considering whether to delay the program for a significant period because of continuing technical problems.

Start of work on the last three GOES-Next satellites was delayed until 1993 so technical problems could be defined and resolved. Even if NOAA does continue with the current GOES-Next schedule, continued delay in resolving these problems could threaten National Weather Service needs for satellite data later in the 1990s.

Reasons for GOES-Next Problems Are Diverse

Design complexity, inadequate government management of the program, and poor contractor performance have contributed to past and current GOES-Next problems. NASA, NOAA, and the contractors underestimated the challenge of meeting NOAA's objectives in the program.

NOAA did not authorize and NASA did not require that engineering analyses be done prior to GOES-Next development work, although NASA usually conducts such studies. There is also evidence of inadequate NASA direction of GOES-Next work, a lack of proper direction of the contract by Space Systems/Loral, and poor quality of workmanship at ITT.

Necessary collaboration between NASA and ITT in developing the sophisticated GOES-Next weather instruments was restricted because ITT was performing on a subcontract to Space Systems/Loral rather than directly under contract to NASA. The program suffered as a result, since ITT was required to produce instruments that exceeded its previous experience.

Forecast Operations Could Be Interrupted

The United States will experience a loss in geostationary satellite coverage should GOES-7 unexpectedly fail before the first GOES-Next satellite or a replacement satellite can be placed in orbit. Further delay in the GOES-Next program or in the decision to procure a replacement satellite could lengthen the period of dependency on GOES-7 coverage, eventually leading to a degraded level of coverage. The loss of geostationary weather satellite data would disrupt National Weather Service forecast operations.

NOAA's plan to respond to a complete loss of geostationary satellite coverage was to use data from other types of satellites. NOAA indicated, however, that this would result in inadequate forecasting of severe storms.

Options Available to Address a Potential Gap

GAO and NOAA identified a number of alternatives that would resolve the risk of a loss or degradation of U.S. weather satellite coverage in 1993, but none of them will resolve the risk of a loss of coverage for the remainder of 1991 and most of 1992. These alternatives include purchasing a foreign-owned satellite, securing the option to procure a foreign-owned satellite, or doing nothing and assuming that GOES-7 will not fail before an operational GOES-Next has been launched. NOAA is also considering reprocuring a GOES-7 type satellite from the original manufacturer, but this option does not resolve the near-term risk of a gap in coverage and also poses long-term consequences for the National Weather Service.

NOAA has not reached a decision on which alternative it will adopt and has not developed a detailed plan to respond to the potential loss of satellite coverage.

Matters for Congressional Consideration

The Congress may wish to withhold fiscal year 1992 funds for the GOES-Next satellites until NOAA and NASA report on their resolution of current technical problems and the cost of and time frame for proceeding with this program. This report should be submitted to Congress before the end of fiscal year 1991.

To assist in its deliberations, the Congress may also want to direct NOAA to report on how it intends to resolve the current risk of a gap in U.S. geostationary weather satellite coverage, including identifying the benefits, risks, and long-term consequences of its proposed actions.

Agency Comments

As requested, GAO did not ask NASA or NOAA for written comments on a draft of this report. However, the views of responsible officials were sought during the course of GAO's work and are included in the report where appropriate.

Contents

Figures

Abbreviations

EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
GAO	General Accounting Office
GMS	Geostationary Meteorological Satellite
GOES	Geostationary Operational Environmental Satellite
ITT	International Telephone and Telegraph, Inc.
METEOSAT	Meteorological Satellite
NASA	National Aeronautics and Space Administration
NESDIS	National Environmental Satellite Data Information Service
NOAA	National Oceanic and Atmospheric Administration
SS/L	Space Systems/Loral, Inc.

Introduction

Since the 1960s, geostationary and polar satellites[1] have been used by the United States and other nations of the world to provide meteorological data for research and forecasting of the earth's weather. In 1974, a prototype of the first U.S. geostationary weather satellite was launched. In 1975, NASA placed the first Geostationary Operational Environmental Satellite (GOES) in orbit.

GOES-7, the current geostationary satellite in orbit, was launched in 1987. The satellite provides both visible and infrared images of the earth's clouds. GOES-7 also performs "sounding," or measurement, of the temperature and humidity throughout the atmosphere.

GOES-7 is the only geostationary satellite in orbit over the Western Hemisphere today, and this type of satellite is not currently in production. Typically, two GOES have been used to provide continuous observation of the eastern and western portions of North and South America. However, after GOES-G was destroyed during launch in 1986 and GOES-6 failed in orbit in 1989,[2] the National Weather Service was left with only a single operational satellite in geostationary orbit.

Uses of Geostationary Satellite Data

Geostationary satellite data is critical to the operations of the National Weather Service, since it provides unique information daily about the emerging conditions of severe weather.[3] GOES imagery is used to detect specific patterns that indicate the type of a developing weather condition and the geographic boundaries of the condition. Once severe weather has been identified, the satellite data is used in combination with radar and other types of data to track the movement and intensity of the storm.

GOES data is a primary source of information for the National Severe Storm Forecast Center and the National Hurricane Center. The Severe Storm Center has primary responsibility for forecasting severe thunderstorms and tornadoes that can develop and dissipate in minutes over

[1]Geostationary satellites maintain a constant view of a single location on the earth from about 22,300 miles in space. Polar satellites, which are only about 500 miles from the earth, orbit about the earth's poles as the earth rotates beneath them. As a result, polar satellites provide observations of the weather over the United States infrequently.

[2]Weather satellites are given an alphabetic designation until they are launched; they are then assigned a number in the series.

[3]Severe weather is defined by the National Weather Service as those storms resulting in major losses of property and human life: specifically, hurricanes, severe thunderstorms, hailstorms, tornadoes, and snow and ice storms.

small geographic areas of 100 kilometers or less. Forecasting these small-scale events requires observation of the larger scale weather patterns in the surrounding area. The geostationary satellite is the only observing system that can observe these large- and small-scale weather events concurrently.

The Hurricane Center relies on GOES imagery to detect the onset of hurricanes and tropical cyclones. These develop over tropical oceans where data is sparse because of limitations on the number of reconnaissance aircraft and other systems available to the National Weather Service.

National Weather Service Modernization Program

In the 1980s, the National Weather Service began to plan a modernization program to reduce operational staff and costs and to improve forecast lead time and accuracy. This was to be done by streamlining forecast operations and acquiring new technologies. New computing capabilities and displays would be used in local forecast offices to integrate forecast guidance from national centers with data from a new ground radar, new satellites, and other new sources of weather data. This modernization is to be implemented beginning in 1994.

In 1982, the National Weather Service sponsored a review of what new technologies were available and what new missions could be performed by the future generation of geostationary weather satellites, GOES-Next. This review was supported by the National Environmental Satellite, Data, and Information Service (NESDIS), by science staff from NASA's Goddard Space Flight Center, and by industry representatives.[4] NASA was influential in setting the level of imaging capabilities of GOES-Next, the National Weather Service specified that it required a greater level of sounding capability for its future needs in forecasting, and NESDIS prescribed the desired quality of sounding data.

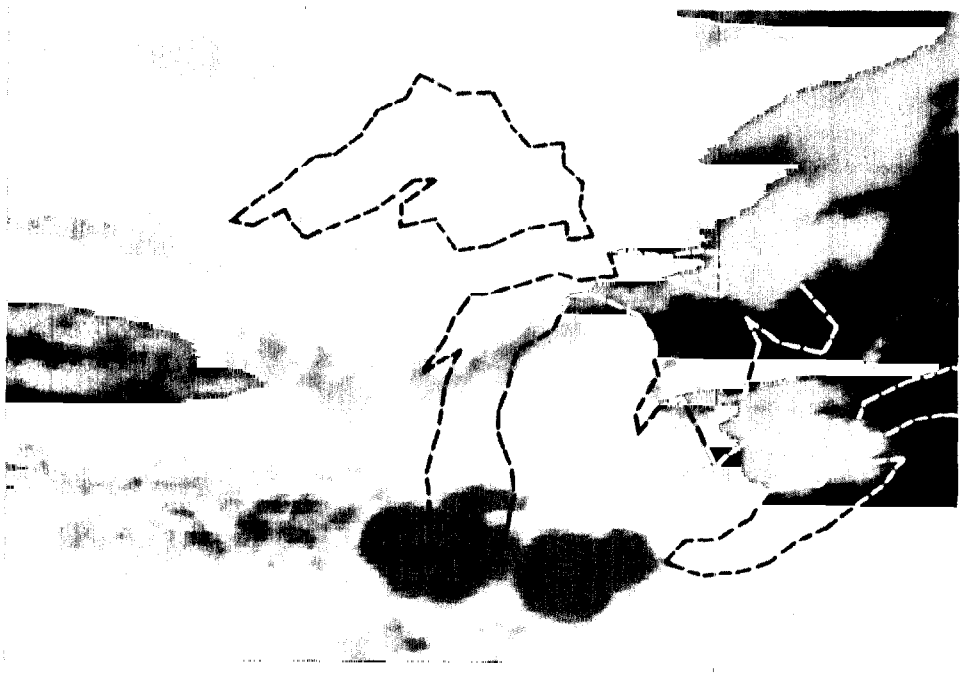
The Weather Service indicated that a new geostationary satellite should sustain existing forecast capabilities, enhance severe weather forecasting, and advance the state-of-the-art in numerical weather prediction.[5] This would be accomplished by enhancing existing satellite imaging and "earth location" capabilities and by adding a sounder that operated continuously.

[4]NESDIS and the National Weather Service are activities within the National Oceanic and Atmospheric Administration (NOAA).

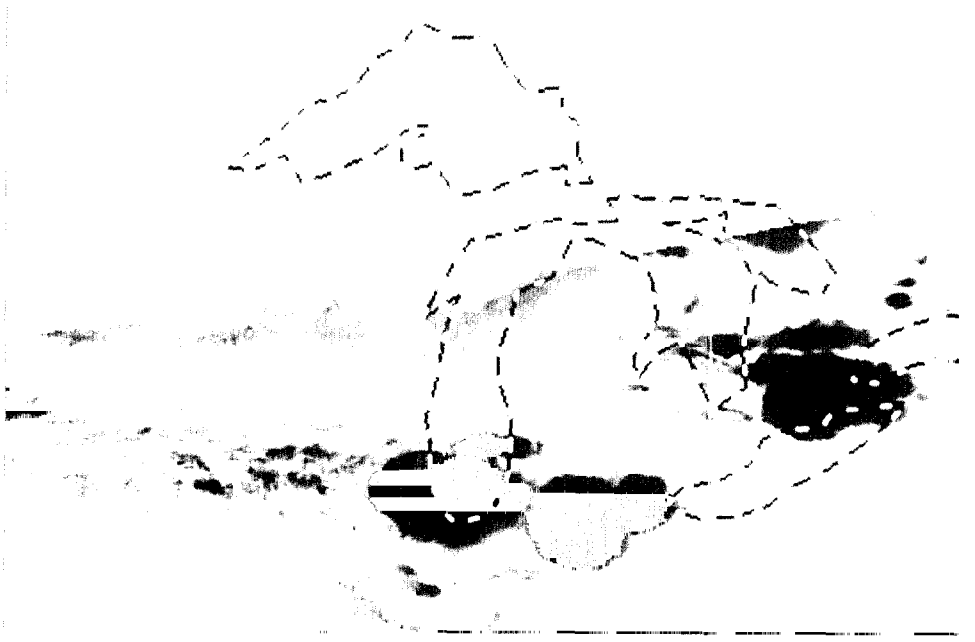
[5]Numerical weather prediction models are used to supplement the activities of weather forecasters.

NESDIS and NASA translated these needs into the desired features of the new satellite. GOES-Next was to retain existing visible imaging but provide higher resolution infrared imagery, which would be useful in predicting and monitoring severe thunderstorms. Figure 1.1 compares the differences in the quality of infrared imagery available from GOES-7 with that expected from GOES-Next. These two displays are of a tornado in northern Illinois in 1990. Note the greater amount of cloud detail in the simulated GOES-Next image.

Figure 1.1: Comparison of GOES-7 Infrared Image With Simulation of GOES-Next Image



GOES-7 image



GOES-Next simulated image

NESDIS also prescribed the desired features of an operational geostationary sounder. The National Weather Service needed uninterrupted data about the atmosphere for numerical modeling of the weather and predicting the onset of storms well ahead of their occurrence. NESDIS and the National Weather Service specified that GOES-Next soundings should also be of a higher quality than GOES-7 soundings and address future research as well as operational requirements.

In addition to new instrument capabilities, GOES-Next imagery and soundings were to be very precisely controlled as its instruments scan the earth. These "earth location" features would allow weather forecasters to track wind and storm speed and direction more easily and to locate storms on the earth's surface more accurately. While the resulting GOES-Next capabilities were not intended to be that different from existing earth location capabilities, GOES-Next was designed to make satellite data easier to use throughout the forecast system, down to the level of local forecast offices.

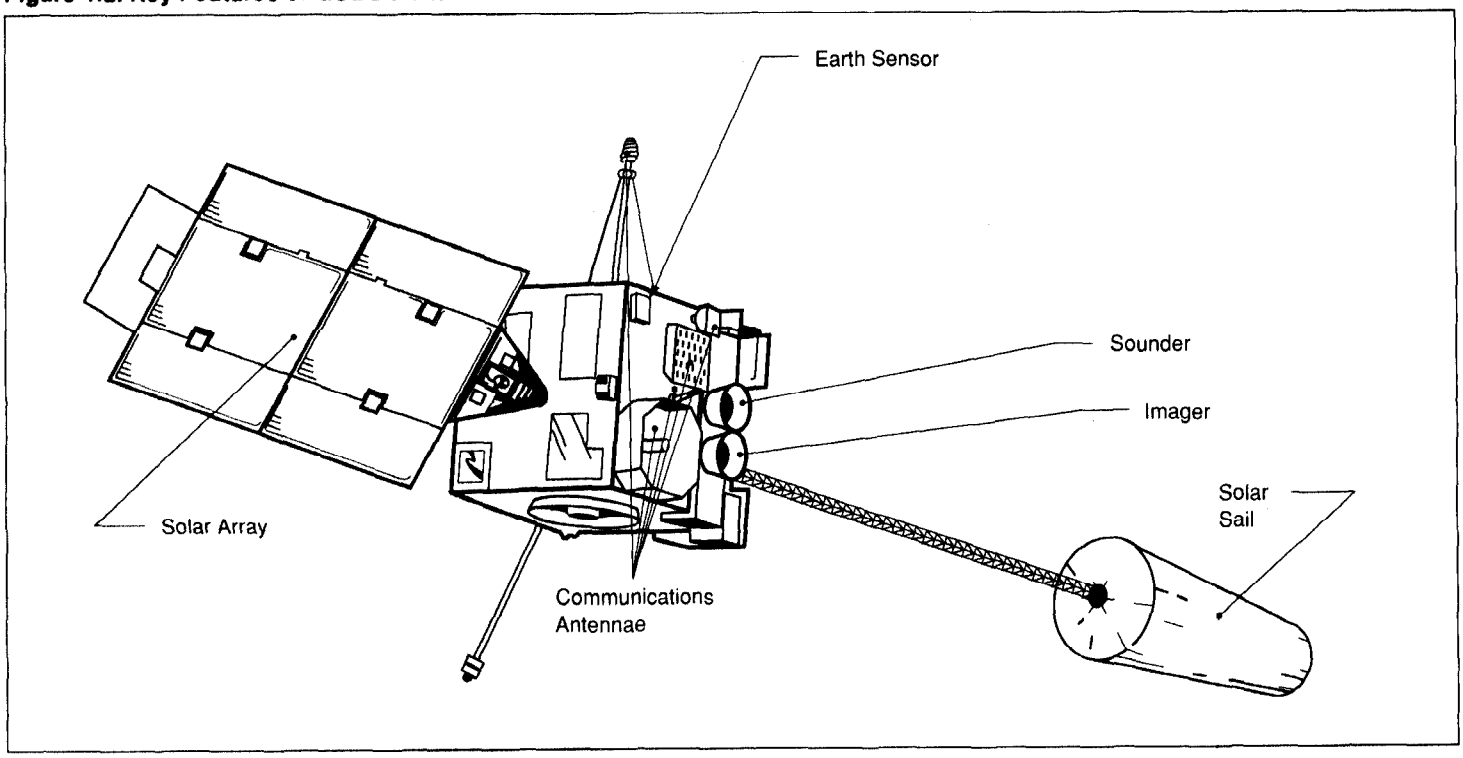
GOES-Next Program History

In 1985, NASA and NOAA selected a contractor to develop GOES-Next, and a cost-plus-award-fee contract was issued to the Ford Aerospace Corporation.[6] Five satellites, GOES-I through M, were to be manufactured and prepared for launch in July 1989 through May 1997. The two instruments to be used for weather forecasting, an imager and a sounder, were to be developed by the Aerospace/Communications Division of the International Telephone and Telegraph (ITT) Defense Corporation under a subcontract to Ford. The five satellites were originally estimated to cost $276 million, and the total cost of the program (including launch, ground systems support, and other government expense) was estimated in 1986 to be $640 million.

Figure 1.2 displays some of the key features of the GOES-Next satellite discussed in this report. Note the cube-like structure of the satellite and the viewing ports of the imager and sounder instruments, which always face the earth. GOES-7, in comparison, is a rounded, spinning satellite. GOES-Next will be about 96 feet long when fully deployed; the body itself is a 7-foot cube.

[6]In 1990, the Ford Aerospace Corporation was purchased by the Loral Corporation and renamed Space Systems/Loral (SS/L).

Figure 1.2: Key Features of GOES-Next



NASA required NOAA to fund GOES-Next. This arrangement was a departure from arrangements made prior to 1982 in that NASA had previously funded all developmental satellites that would later become operational systems for NOAA. NASA altered this funding arrangement in 1982 when it decided not to fund acquisition programs, developmental or otherwise, targeted to fulfill NOAAoperational requirements.

The Meteorological Satellite Project Office of NASA's Goddard Space Flight Center was assigned official contract and engineering management responsibilities. These included oversight of contractor performance assurance, quality assurance, and testing. On behalf of NOAA, NESDIS had the responsibility of monitoring the activities of NASA and the contractor. NESDIS representatives participated in the GOES-Next source evaluation board, for example. The National Weather Service was not a participant in the source selection.

Objectives, Scope, and Methodology

The Chairman, House Committee on Science, Space, and Technology, requested that we examine the current cost, schedule, and technical status of the GOES-Next program; reasons for problems that have led to cost increases and schedule delays; and potential options for precluding a gap in geostationary satellite coverage of the United States.

To assess our first two objectives, we held discussions with NASA officials and technical staff and reviewed project technical analyses, status reports, and financial summaries. We also met with contractor officials and technical staff and reviewed materials at those locations. We solicited the views of the Directors and staffs of NESDIS and the National Weather Service and met with the Deputy Undersecretary of Commerce for Oceans and Atmosphere. We observed several program reviews at the invitation of NASA. We also examined historic project materials, including project requirements, contract specifications, and agency correspondence to identify the causes for the problems in the GOES-Next program.

For our third objective, we met with various NOAA officials and staff and reviewed NOAA's assessments of the likelihood and implications of a gap in satellite coverage. We also solicited information from the Hughes Aircraft Corporation and the European Organization for the Exploitation of Meteorological Satellites to determine the availability of a replacement satellite.

We performed our work at NASA Headquarters and the Department of Commerce, Washington, D.C.; the Goddard Space Flight Center, Greenbelt, Maryland; the headquarters of the National Weather Service, Silver Spring, Maryland, and of NESDIS, Suitland, Maryland; the National Meteorological Center, Camp Springs, Maryland; the National Severe Storm Forecast Center, Kansas City, Missouri; the Forecast Systems Laboratory of the Office of Atmospheric Research, Boulder, Colorado; and the Denver Weather Forecast Office, Denver, Colorado. We also performed work at Space Systems/Loral, Palo Alto, California, and the Aerospace/Communications Division of the International Telephone and Telegraph Defense Corporation, Ft. Wayne, Indiana. We conducted our review from August 1990 through June 1991 in accordance with generally accepted government auditing standards.

As requested, we did not obtain written comments on a draft of this report; however, we discussed its contents with agency and contractor officials and have incorporated their comments where appropriate.

Cost, Schedule, and Technical Problems Result in Program Uncertainty

Technical problems in the GOES-Next program continue to cause significant cost increases and schedule delays. Waiver of key performance capabilities is necessary to launch the first GOES-Next satellite by October 1992. However, the inability to resolve at least one technical problem involving degraded performance of detectors used in the imager and sounder instruments threatens the reliability of the satellite's instruments. This and another more recent problem involving wiring of the instruments could result in further launch delays.

Work on the last three satellites under contract has been halted, and the future of the program is being reviewed. NASA is now considering how to proceed should NOAA decide to continue with the current program.

Delays and Cost Increases Have Occurred

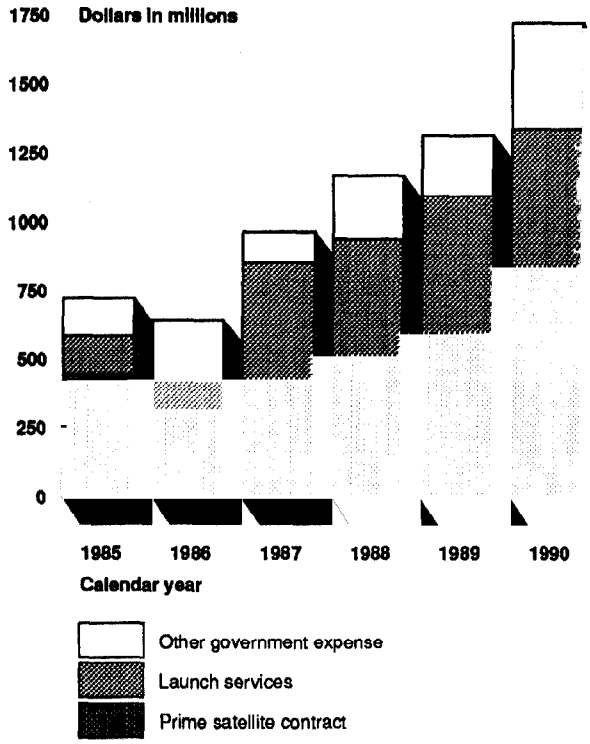
In our June 1989 report entitled Weather Satellites: Cost Growth and Development Delays Jeopardize U.S. Forecasting Ability (GAO/NSIAD-89-169), we reported that contract costs had grown from the original estimate of $276 million to over $359 million and that launch of the first GOES-Next would be delayed from July 1989 to the late fall of 1990. Since then, the program has experienced additional technical difficulties that have resulted in additional cost increases and program delays.

The first GOES-Next is currently scheduled to be launched in October 1992. This is over a 3-year delay to the original program plans. The total program cost has increased by over 250 percent since contract initiation, and there has been a 134-percent cost overrun in the prime satellite contract.

GOES-Next Program Cost Has Increased Sharply

Since the GOES-Next program was begun in 1985, the estimated contract cost of designing and building the five GOES-Next satellites has increased from $276 million to $834 million, and the total estimated cost of the program (including launch, ground system support, and other government expense) has increased from a low of $640 million in 1986 to $1.7 billion in 1990. Figure 2.1 documents the increase in contract cost estimates and in the total funding requirement for the GOES-Next program from 1985 through 1990.

Figure 2.1: Cost Estimates for GOES-Next



Notes: Contract values are based on NASA estimates except for 1990, which is an SS/L estimate. The low estimate in 1986 reflects an adjustment to the 1985 estimate as a result of contract negotiation.

Annual NOAA fundings requests were derived from these figures.

Forty-eight percent of the program's cost increase of $1.1 billion has been due to increases in the cost of the SS/L contract, 37 percent due to the increased cost to launch GOES-Next, and 15 percent due to changes in NASA's reserves and other NOAA and NASA costs.[1] Of the $558 million increase in contract cost, $80 million was for contract changes for which an additional contract fee or profit was awarded to SS/L. The remaining $478 million was due to the contractors' inability to complete the scope of work of the GOES-Next contract within the negotiated contract value.

As of early 1991, SS/L's estimate of the total cost of the GOES-Next contract was $834 million; NASA's estimate was higher. NOAA's fiscal year 1992 estimate of the total funding needs for the GOES-Next program was

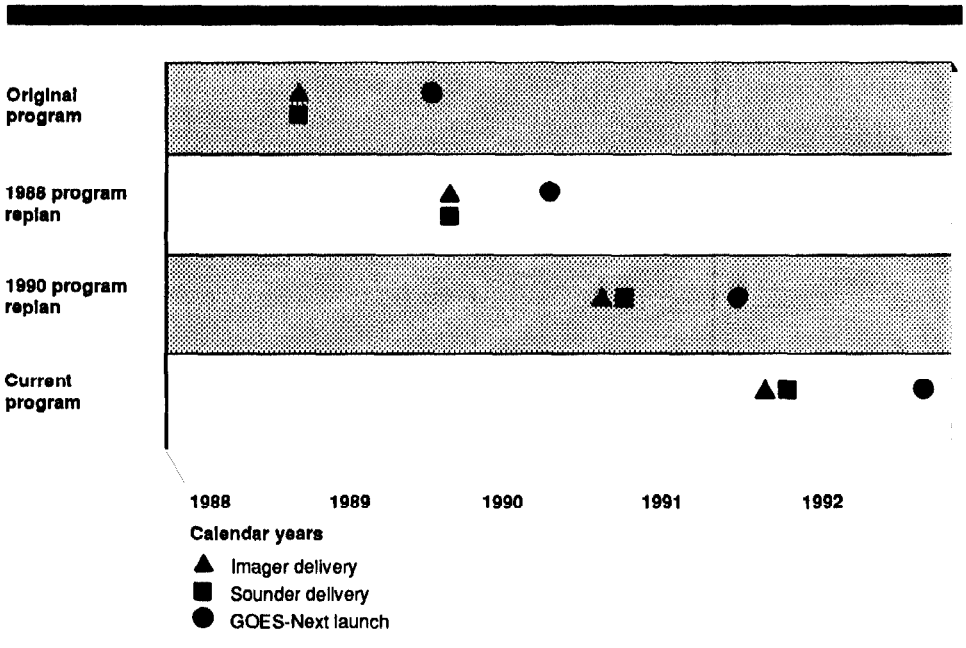
[1]Prior to 1986, NASA planned to launch GOES-Next on its shuttle orbiter system. Due to changes in the shuttle's payload launch policy, GOES-Next will now be launched by a commercial vendor under contract to NASA.

$1.7 billion, a 24-percent increase over its $1.3 billion estimate for fiscal year 1991.

Numerous Problems Caused Delays in Launch of GOES-I

Since its inception, the GOES-Next program has experienced slippages in the schedule for delivery and launch of the first GOES-Next satellite, GOES-I, and its principal weather instruments. In 1985, NASA estimated that GOES-I would be launched in July 1989. By 1988, however, this launch date had slipped to March 1990. Further slippage occurred and in February 1990 the launch date was estimated to be June 1991. The current launch, tentatively scheduled for October 1992, is now over 3 years later than the original launch date of July 1989. (See fig. 2.2.)

Figure 2.2: Slippages in the Key Dates Leading to the Launch of GOES-I



The reason for the initial delay was an inadequate design of the satellite's instruments. Because the design was inadequate, program officials converted the GOES-I instruments to prototype articles to test other elements of the satellite. The instruments for the second satellite, GOES-J, were modified and used as flight articles for GOES-I.

SS/L officials said there were many causes for the additional delays in the program, as many items required rework, retest, or new analysis. These causes are discussed in chapter 3. According to NASA officials,

until recently, there has never been a realistic schedule for the program, and many delays occurred as a more realistic schedule was established for the required level of effort.

First GOES-Next's Capability and Launch Date Are Uncertain

As of May 1991, NASA and NOAA planned to launch the first GOES-Next satellite, GOES-I, in October 1992 with degraded instrument performance. There are also outstanding concerns about the satellite's and the instruments' reliability that must be resolved before the satellite is launched. The reasons for some technical problems are unknown.

In June 1991, NASA discovered an additional problem with the instruments. This problem as well as the prior problems may necessitate launch delays beyond October 1992.

Faulty Instruments May Need to Be Repaired

Instrument performance has been of continuing concern to NASA and NOAA. During the past year, a team of specialists provided guidance to ITT during its instrument testing. By February 1991, project officials had determined that the imager's performance was falling short of several specifications, and they were also concerned about the performance of the sounder. Later sounder test results confirmed that the instrument fell far short of meeting its specifications. If GOES-I were to be launched in October 1992, some contract specifications for the instruments needed to be relaxed.

A joint NOAA, NASA, and SS/L review was convened to determine whether less than full contractual performance was acceptable to NOAA. NOAA officials believed that GOES-I should be launched with less than full contractual performance to preclude the risk of a gap in geostationary satellite coverage. They noted that they would continue to seek full contractual performance for the later GOES-Next satellites, provided the costs were acceptable.

NASA officials expressed concern about the general quality of the satellite's instruments. Specialists indicated to NASA that the instruments should be able to meet some of the performance specifications they had been unable to meet. However, no one could determine the reasons that the instruments have not met these specifications, even though they have been under detailed examination for over a year. More recent analyses have clarified some, but not all, of the reasons for this lack of performance. However, according to the NASA Project Manager, GOES-I

may be launched before this problem is resolved or the reasons for it are understood.

In June 1991, project officials determined that there was a new problem with the instruments. An improper design change made by ITT several years ago led to the installation of a set of wires that resulted in flawed instrument performance. NASA and the contractors are currently assessing how to resolve the problem, which could lead to an additional 6- to 9-month delay in the launch of GOES-I. If not resolved, some loss of GOES-I's imaging capability, which may be unacceptable to NOAA, could result.

Testing of the GOES-I imager has been interrupted until this new problem is understood and a plan to resolve it is identified. NOAA officials indicated that they may decide to significantly delay the launch of GOES-I and J and focus on the acquisition of replacement satellites because of continuing technical problems with the program.

Some Technical Problems Affect GOES-Next Reliability

NASA and NOAA officials are also concerned about the reliability of the GOES-Next instruments and satellite control systems. Reliability problems are different from performance issues in that the satellite can perform with some of the known faults, but a flaw in reliability can result in loss of instrument functions or total satellite failure.

According to the NASA Project Manager, any problems that affect the design life of GOES-Next will be corrected before a satellite is launched. NASA officials stated that they would not launch GOES-I until these reliability problems are resolved or they have clearly determined that the problems do not threaten the life of the satellite.

Yet detectors made of Mercury Cadmium Telluride, an electro-optical material critical to the instruments' ability to record observations of the earth, have been degrading to a level where the life of the instruments is threatened. The sample of detectors tested is manufactured from the same batch of material that is currently used in the GOES-I flight instruments, although no evidence of detector decay has been found in the tests of the GOES-I imager and sounder thus far.

Although the problem was recognized in the spring of 1990, NASA has been unable to determine the cause of the problem. SS/L recently contracted with alternative sources to obtain new detectors that it hopes

will not display the same problems. NASA anticipates that the new detectors will be available by late summer 1991. Prior to June 1991, NOAA and NASA officials said that they would use the detectors already installed in GOES-I to preclude further delays of its launch and install new detectors in GOES-J and later satellites. They made this decision based on the assumption that the detectors installed in the GOES-I flight instruments would not degrade. NASA is now considering whether to install new detectors in GOES-I as well.

NOAA and NASA officials also expressed concern about the reliability of the satellite itself. SS/L has built several satellites that suffered catastrophic losses; the last failure occurred as recently as December 1990. Of five satellites the company has launched similar to GOES-Next in design, three have failed before achieving their design lifetime.

According to NASA officials, the kinds of catastrophic failures that have occurred on other SS/L satellites reflect a poor design. When control of the SS/L satellite is threatened, errors in restoring control can lead to loss of the satellite. NASA officials claim that there is a better approach to restoring control than that used by SS/L. NASA has authorized a series of changes to GOES-I's automated satellite control procedures to preclude the same type of problem.

Work on the Last Three GOES-Next Satellites Has Been Halted

Work on GOES-K, L, and M, the last three of the GOES-Next satellites under contract with SS/L, has been halted until 1993. According to NASA project officials, this delay was necessary because the manufacture of these satellites is not desirable until the instrument performance of the initial satellites is better understood. The NASA Project Manager said that the added cost to redesign the instruments for the remaining three GOES-Next satellites could range from $45 million to $75 million.

In May 1991, NOAA officials indicated that if the cost to correct the design of GOES-Next was unacceptable, they might not continue to purchase the system after the purchase of GOES-I and J. The officials stated that NOAA might have little choice but to continue to manufacture GOES-I and J because of the lack of any other reasonable alternative to preclude a near-term gap in geostationary coverage. As of June 1991, NOAA officials were reconsidering their position.

NASA officials stated that if NOAA proceeds with GOES-K, L, and M, as well as GOES-I and J, a full review of NOAA's requirements for its weather satellite system should complement NASA's attempts to understand and correct GOES-Next performance. NASA wishes to verify the operational utility of the GOES-Next requirements before proceeding with an expensive and time-consuming effort to redesign portions of the system. For example, GOES-I will not fully meet the level of precisely organized images and soundings of the earth specified by NESDIS.[2] However, NASA technical staff questioned the wisdom of attempting to provide the fully specified level of this capability, since it does not appear to be critical to the way satellite data is to be used in weather forecasting. NASA officials indicated that NOAA has already decided not to require this attribute for GOES-Next soundings.

NASA has requested that SS/L submit a new program plan for completion of all of the GOES-Next satellites. This plan is due by late summer 1991. Such a plan is important to exercising control and establishing the cost of the program. There has been no formal plan since the summer 1990 due to the number and severity of technical problems in the program.

Conclusions

The GOES-Next program has experienced significant cost increases, schedule delays, and technical problems. Total program costs are now likely to exceed $1.7 billion, and the first GOES-Next satellite will not be launched before October 1992.

As of June 1991, continuing technical problems led NOAA to reconsider the future of the program. Work on the last three satellites, GOES-K, L, and M, has been halted until NOAA and NASA decide how to proceed.

It is not clear when or if GOES-I will be placed in orbit and what capability the satellite will have. It is also not clear what the eventual cost of the GOES-Next program will be. We believe that these issues must be clarified before the program is allowed to proceed.

[2]To ease its operations, NOAA desired not only that data be more accurately located on earth but also that each image or sounding of the earth be precisely organized. Currently, this can be accomplished only by intensively reprocessing GOES-7 data. Precisely organized observations improve the quality and utility of the data.

Matter for Congressional Consideration

In view of the continuing technical problems in the GOES-Next program, the Congress may want to direct NASA and NOAA to report by the end of fiscal year 1991 on their progress in resolving existing problems and the time frame and cost for achieving proposed solutions. Fiscal year 1992 funds for the production and testing of GOES-Next satellites should be withheld until a favorable solution is identified and reported to the Congress.

Problems in the GOES-Next Program Have Diverse Causes

Past and current program problems have arisen for many reasons, all of which are intertwined. Design complexity, inadequate management of the program by NASA and NOAA, and poor contractor performance all contributed to the cost, schedule, and technical difficulties. However, each cause's precise contribution to these problems cannot be readily determined.

NASA, NOAA, and contractor officials acknowledged that they did not appreciate the complexity of GOES-Next when the program began. Government officials acknowledged that they have not managed the program properly. These officials also noted, however, that poor SS/L direction of subcontractor efforts on this contract and problems in the workmanship of ITT occurred.

In spite of the problems and complexity of the GOES-Next satellite system, NASA believes that GOES-Next will meet the "earth location" requirements, which have been a major contributor to the program's historical problems, even though this capability will not be verified until the satellite is in orbit.

GOES-Next Requirements Led to a Sophisticated Design

NASA and NOAA selected a "body-stabilized" satellite[1] because they believed this type of satellite was the best approach to meeting NOAA's requirements. But SS/L's approach to accomplishing accurate satellite "pointing" led to a quantum increase in the complexity of the satellite's instruments and the on-board control and ground control systems. Government and contractor officials acknowledged that the complexity of the requirements and the design approach was not fully recognized when the specifications were written and the contractors' proposals were reviewed. This unanticipated complexity led to additional analyses, redesigns, and remanufacture of parts, which resulted in increased costs and delays.

[1] A "body-stabilized" satellite maintains a stable position by fixing its position in space relative to the stars. In contrast, a spinning satellite like GOES-7 continuously rotates in order to maintain stability. As a result, a body-stabilized satellite "stares" at the earth, whereas a spinning satellite's instruments view the earth only for a portion of each spin cycle.

NASA and NOAA Underestimated the Complexity of GOES-Next

According to NASA and NOAA officials, GOES-Next's earth location requirements could have been met by either a body-stabilized or a conventional spinning satellite.[2] NESDIS officials indicated that their earth location requirements for GOES-Next were not dissimilar to the way GOES-7 is capable of performing, but they had not anticipated the difficulty of meeting the requirements with a body-stabilized satellite.

NESDIS desired that GOES-Next be designed to eliminate the current inaccuracies of satellite data in an automated fashion. Currently, many ground-based data processing systems are required to convert satellite imagery into useful information for analyzing winds and tracking storm systems. By designing this capability into GOES-Next, NOAA expected to simplify its reprocessing of satellite data and to deliver higher quality satellite data to National Weather Service forecast offices in a more timely manner.

NASA officials agreed that GOES-Next's performance in the earth location of data would be similar to that of GOES-7. Key NASA participants in the early phases of the program said they knew that, regardless of the similarities in performance, NOAA's requirements would be difficult to meet. They believed that NOAAhad underestimated how sophisticated the satellite control systems would have to be and that NOAA's earth location requirements for GOES-Next would have been difficult to meet using any of the designs proposed by contractors.

NASA, NESDIS, and contractor officials acknowledged that, when the contract was awarded, they did not anticipate the level of complexity of NOAA's requirements or SS/L's approach to meeting the requirements. NASA, with the concurrence of NOAA, selected SS/L's body-stabilized design because, overall, it was a more straightforward approach to achieving the quality of soundings specified by NOAA and could provide even higher quality soundings and images than specified. However, NASA recognized that the body-stabilized design would be inherently less stable. In fact, just after awarding the contract, NASA provided funds to SS/L for a special study because it recognized that SS/L had not adequately defined its approach to meeting the earth location requirements.

[2]The Hughes Aircraft Corporation proposed modifying the current GOES-7 spinning satellite by placing a sounder on a "despun," or staring, portion of the satellite. The sounder had to be despun to meet NOAA requirements for high quality soundings.

National Weather Service officials said that neither NESDIS nor NASA told them about any inherent complexities of its requirements or about the difficulty in producing a body-stabilized design that would meet them.

Pointing Accuracy Requirements Became Difficult to Meet

Since 1987, the program has focused on a large number of issues related to the problem of "aligning" satellite data taken throughout the day and determining its true location on the earth. Officials from NASA, SS/L, and ITT said that what SS/L had proposed to do and what the government accepted turned out to be more difficult than expected because of unknowns about how a precisely controlled satellite would perform. Because GOES-Next is body-stabilized, it is difficult to control for three reasons.

First, over the course of a day, heat from the sun can introduce variations in the satellite's position that must be measured, predicted, and compensated for in order to maintain control of the satellite's observations. To accomplish this, GOES-Next uses a complex mathematical model to determine how to adjust the angle of each viewing instrument throughout the day. This model became more complicated than originally intended. To illustrate, control of the GOES-7 satellite requires the use of 8 items of information about the satellite's position; GOES-Next could require up to 380 separate items of information.[3]

Second, GOES-Next's instruments and sensors would be directly exposed to the sun around midnight. Direct sunshine could disrupt GOES-Next's observations of the earth at that time of the day.

Third, internal movement of the satellite's components would affect the instruments' accuracy. For example, the satellite's momentum wheels, on-board mechanisms that are used to stabilize the satellite, and instrument mirrors would adjust their positions at different speeds and times, causing motions that would have to be minimized.

Overcoming these sources of error in satellite pointing accuracy became very difficult. For example, the GOES-Next earth sensor, used to maintain stable viewing of the earth, had to be upgraded because it alone could

[3]The analysis of thermal effects on the satellite's pointing accuracy submitted at the time of proposal was not adequate, according to project officials, because it assumed that thermal effects on the satellite and its instruments were independent and could be assessed separately. NASA officials said that a complex relationship existed between the structure of the satellite and its instruments in terms of how internal and external sources of heat would affect their performance. This problem was little understood when the program began.

introduce about 4 kilometers of pointing error. To meet the accuracy required, the earth sensor could not introduce an error of more than one-half kilometer.

As a result of analyses of thermal and motion effects on the satellite structure, the satellite's earth location requirements were relaxed. However, changes were still needed to satellite, instrument, and ground control systems. For example, SS/L added ground systems that could adjust the satellite's pointing hourly rather than daily, as is currently planned, if that became necessary to achieve specified levels of performance.

NASA officials pointed out that they now expect GOES-Next to meet its "true earth location" requirement, although this capability will not be verified until the satellite is in orbit due to the difficulty of simulating the conditions of space using ground tests. In discussions with SS/L staff, they indicated that GOES-Next will validate not only a satellite design but also a scientific method for understanding the control of satellite systems.

NASA and NOAA Inadequately Managed the GOES-Next Program

Inadequate management of the GOES-Next program has played a significant part in its cost increases and program delays. From the beginning, NASA and NOAA made misguided decisions; these were later compounded by poor direction and technical management of the program and the contractors.

First, NOAA did not authorize and NASA did not require that engineering analyses be done before GOES-Next development work began, even though NASA usually conducts detailed engineering studies and analyses before the award of a contract for a developmental system. NOAA officials did not authorize these analyses because of fiscal constraints and pressure to launch GOES-Next as quickly as possible.

Second, SS/L had little experience in directing the design of complex weather instruments and should not have subcontracted with ITT to produce the weather instruments. NASA's usual practice is to direct the work on sophisticated systems such as the GOES-Next instruments. The necessary technical collaboration between ITT and NASA was limited, however, because ITT was under a subcontract to SS/L. NASA officials said that NOAA had opposed NASA's desire to have separate contracts for the satellite and its instruments.

Third, NASA technical staff provided limited technical guidance to the project. Because of other demands, staff at Goddard Space Flight Center gave limited priority to NOAA-funded programs, and the staff assigned to GOES-Next were responsible for other efforts during critical stages of the project. As recently as last year, NASA provided limited technical support to GOES-Next in the areas of optics, satellite control systems, and thermal engineering. Also, NASA did not assign specialists in thermal dynamics to the program during its critical early stages.

NASA acknowledged that it had limited experience in developing body-stabilized satellites to be used to observe the earth from geostationary orbit. They discounted the relevance of other satellites' similar attributes (such as those of communications satellites) because of GOES-Next's precise earth location requirements and the greater difficulty of obtaining accurate data from geostationary orbit versus near-earth orbit.

NASA officials indicated that senior NASA technical support is now being provided to the GOES-Next program, and NASA is now directing the work of ITT.

Contractors Have Performed Poorly

SS/L's direction of this contract and ITT's work have been poor. SS/L provided little technical guidance to ITT because it had little experience in managing the design of an instrument required to achieve the accuracy of GOES-Next. According to NASA, the inexperience of ITT's staff led to significant problems and delays in the program.

The prior work of SS/L and ITT on another body-stabilized weather satellite did not prepare these contractors for the challenge of GOES-Next. GOES-Next contains many features similar to ITT's other designs and is the same spacecraft as other SS/L systems. However, the complexity of GOES-Next's optics, the precision of the instruments' mechanical subsystems, and the fact that GOES-Next's data must be located on the earth under all conditions and seasons of the year exceeded the demands of these prior efforts. SS/L's and ITT's previous work had only required them to meet limited earth location requirements under limited thermal test conditions.

ITT also had problems in design, manufacturing workmanship, test procedures, and quality control. Government and contractor officials, including officials at ITT, emphasized that ITT's problems have accounted for a large share of the problems in the GOES-Next program. The delay of

the program in 1988, for example, was due to a poor ITT design of the instrument telescope system, which caused the system to move unpredictably. Also, in several instances, designs had to be corrected due to poor wiring or other manufacturing problems and careless mistakes that led to damage of the instruments.

ITT was unprepared for GOES-Next; its staff has grown from about 40 to 50 individuals to over 300 staff due to GOES-Next. However, ITT officials noted that the instruments have had to meet manufacturing and testing standards that ITT had never experienced before. They also asserted, and NASA and SS/L agreed, that ITT bore the brunt of the challenge of having to design subsystems that would meet the GOES-Next earth location requirements.

Options for Addressing the Loss of Geostationary Coverage

The future of the United States geostationary weather satellite program involves a complex set of possible scenarios, each with its attendant risks and benefits. The United States will experience a loss of geostationary satellite coverage that cannot be avoided should GOES-7 unexpectedly fail before a replacement satellite can be placed in orbit. A replacement, be it GOES-I or a foreign satellite purchased by the United States, will not be available to NOAA until late 1992 at the earliest. The United States does not possess a GOES-7 type satellite and could not produce one until fall 1994 or later. The loss or degradation of GOES-7 satellite coverage would disrupt National Weather Service forecast operations.

NOAA developed a contingency plan in the fall of 1990 to respond to a possible gap in coverage but found its plan to operate without geostationary satellite data to be inadequate for effective forecasting of severe storm conditions. Complicating NOAA's situation is the fact that it has not developed a detailed plan to respond to the significant periods of loss or degradation of satellite coverage that could be faced.

In this chapter, we will discuss alternatives for addressing the potential loss of geostationary coverage and the implications of these alternatives. The option or options selected are dependent on whether NOAA decides to continue the current plan for the GOES-Next program and must take into account near-term and long-term consequences for National Weather Service operations.

The Risk of a Loss of Coverage Is Real

The United States and the Western Hemisphere could be exposed to a loss of geostationary satellite coverage under the following circumstances:

- GOES-7 fails before the first GOES-Next satellite or a replacement satellite is ready for launch.
- GOES-Next or a replacement satellite is placed in orbit but does not perform adequately, and GOES-7 fails in the meantime.

NOAA believes GOES-7 is "healthy." The satellite, however, will exceed its factory design life in February 1992. NOAA expressed concern that because of an earlier mishap in a GOES-7 backup control system, the satellite could be lost if the primary system should fail.

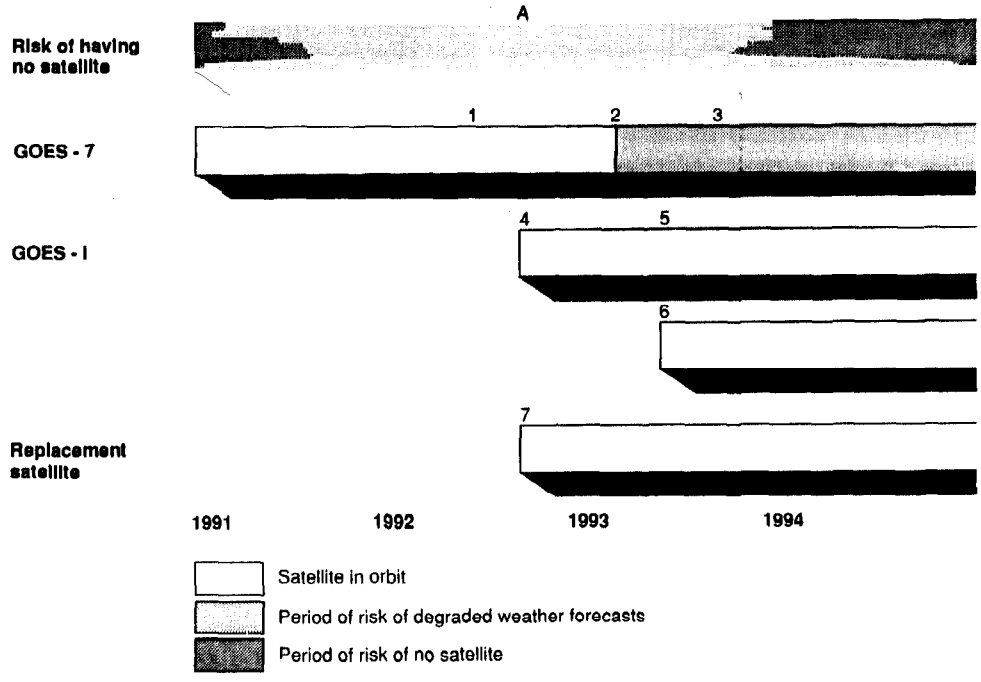
Even if no catastrophic failure occurs, GOES-7 will begin to drift from its position over the equator in June 1992. Useful imagery could still be

obtained for a few years, but critical functions such as hurricane tracking could be affected after about 8 months, and the data would be useless for some analyses within 14 months.

NOAA's decision on what to do with the GOES-Next program will affect the extent and quality of available geostationary satellite coverage. GOES-I could be fully operational 6 months after its current launch date of October 1992, although, as stated in chapter 2, current technical problems could cause this launch date to slip. NOAA could assume the risk that GOES-7 will not fail before GOES-I is launched, although some degradation in forecast coverage could occur for a period of time. However, if GOES-I is successfully launched by early 1993, this degradation would be minimized. If NOAA chooses to significantly delay the GOES-Next program, the United States will have to purchase a foreign-owned satellite to preclude a gap or severe degradation of its weather satellite coverage.

The United States does not possess a replacement satellite for GOES-7 and has not initiated any action to acquire one to date. Figure 4.1 summarizes the critical events and the significant periods of risk to the National Weather Service.

Figure 4.1: Key Dates in Assessing the Risk to NOAA Operations



A Point in time when a replacement for GOES-7 may be available. There is no replacement available before this date.

1 Start of drift of GOES-7
2 Decay in forecasting begins
3 Some forecast uses lost
4 Earliest launch of GOES-I
5 End of on-orbit verification period
6 Estimated 6-month delay of GOES-I launch
7 First available launch of a replacement satellite

Impact of a Loss of Geostationary Satellite Data

According to staff of the National Weather Service's Severe Storm Forecast Center, a loss of geostationary satellite data would severely cripple the Center's operations and degrade the public watch and warning program. Similarly, the Weather Service's National Hurricane Center indicated that the absence of GOES data could lead to a serious degradation of forecasts and warnings, particularly for the high seas marine community and across the tropics.

However, the National Weather Service indicated that GOES-7's imaging capability is sufficient for the continuation of its modernization program. The Weather Service is able to proceed with its modernization program with the equivalent of GOES-7 performance because other

sources of weather observation and analysis will allow forecast offices to be consolidated and weather forecasts to improve.

NOAA Does Not Have an Adequate Solution to a Loss of GOES Data

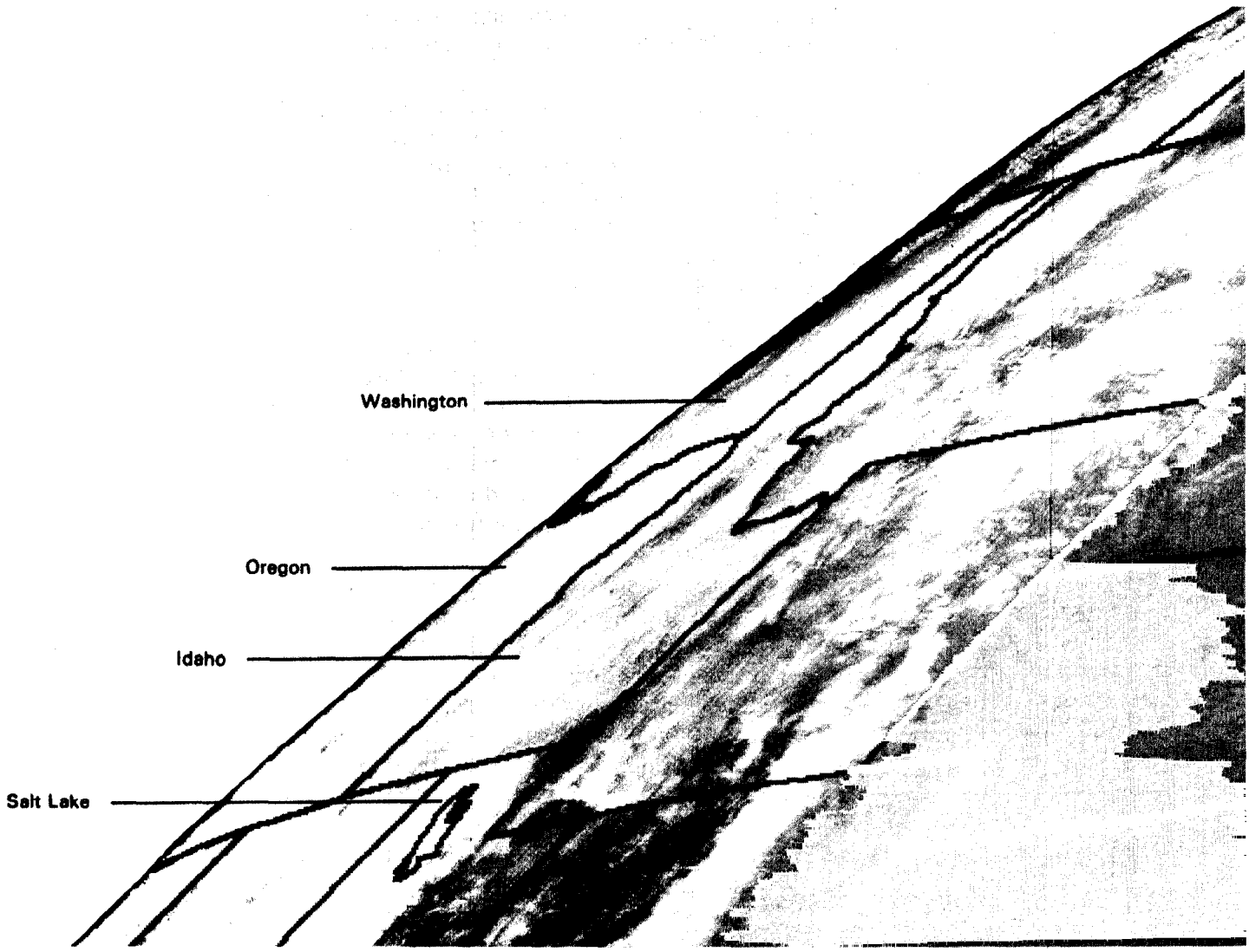
Since the summer of 1990, NOAA has been developing and testing a contingency plan that outlines how it would respond to a complete loss of geostationary satellite coverage. NOAA officials indicated that these contingency procedures do not provide adequate coverage, however, and pose an unacceptable risk to National Weather Service forecast operations.

NOAA's plan includes using polar satellite data that is available infrequently throughout the day. Also, data from the European geostationary satellite, METEOSAT, could be used if that satellite were moved to a position over the Atlantic Ocean. At that position METEOSAT would provide additional coverage of the eastern coast of the United States.

The National Weather Service indicated that the infrequency of polar satellite data would severely limit its ability to monitor rapidly evolving weather phenomena. Since geostationary satellites continuously view the earth rather than orbit around it, geostationary data is available throughout the day. Thus, storms that develop over the United States in the mid-afternoon, for example, can be observed. Polar satellite data is only available every 6 hours for any single location of the earth, and over 6 hours of polar satellite data is required to construct a single composite image of the continental United States.

Also, staff of the National Severe Storm Forecast Center indicated that METEOSAT's limited coverage of the middle and western United States would degrade a forecaster's ability to issue public watches and warnings for those areas. Figure 4.2 portrays the view that METEOSAT would have of the northwest coast of the United States if it were moved to a position over the Atlantic Ocean (50 degrees west). Note that the states of Washington and Oregon and the northern portion of California would lie on the horizon of METEOSAT's view. Weather Service officials indicated that even when converted, a blurred view of cloud systems is the result of this poor viewing angle.

Figure 4.2: NOAA Simulation of METEOSAT Image of the West Coast of the United States



A Foreign-Owned Satellite Could Be Made Available to the United States

The potential sources of geostationary weather satellites are limited. Other than the United States, only Japan, India, and the European Economic Community operate geostationary weather satellites. Japan and the European Economic Community are currently producing satellites that the United States could use as replacements for GOES-7. According to NOAA officials, the United States could deploy one of these satellites sometime in late 1992. The exact date would depend on when formal discussions with the United States actually began, when the United

States could obtain launch services, and how long ground verification and testing of the satellite and its unique ground control system would take. Either satellite has a predicted on-orbit life of 5 years.

Outright purchase of one of these two foreign satellites would require an expenditure of about $160 million to $180 million, according to NOAA, depending upon which satellite was chosen. This figure includes the launch of the satellite. NOAA officials said that purchase of a foreign satellite would require a supplemental appropriation to its current fiscal year 1992 request if this purchase were added to NOAA's other obligations.

Alternatively, the United States could secure an option to procure one of these foreign satellites, perhaps avoiding needless expense while still protecting the operations of the National Weather Service. Under this alternative, the United States would be party to current negotiations between the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) and its satellite manufacturer to procure an option on a satellite that has not yet been produced.

Foreign representatives indicated that under terms of this negotiation, if the United States exercised its option to use a European satellite currently in production, the United States would provide funds to build a replacement for European coverage. The near-term obligation of funds would be limited, therefore, until the work was actually scheduled to begin on the replacement satellite. If no gap in geostationary coverage of the United States occurs, the expense of purchasing a replacement satellite could be avoided.

Securing an option to purchase a future satellite would ensure that a gap in geostationary coverage would be limited but would not ensure that some gap or degradation would not occur. Because a satellite would not be launched unless geostationary coverage was actually lost, there would be some delay between a loss of coverage and the launch of a replacement satellite. Also, this alternative assumes that a satellite will be available from EUMETSAT when needed.

Impact of a Foreign Satellite on Forecast Operations Would Be Minimal

Each of the foreign-owned satellites is of proven capability and would provide sufficient satellite coverage of the United States to allow the National Weather Service to proceed with its modernization and restructuring program. Both satellites could provide rapid images during severe weather, for example.

Although neither satellite can perform atmospheric soundings, both provide imaging capability. One satellite would provide reduced visible resolution of the earth compared to GOES-7, but both have slightly better resolution in their infrared measurements of the earth.

The National Weather Service cautioned that purchase of either satellite would have some effect on its forecast operations. The reduced visible resolution of the one satellite would hamper the ability of the forecaster to monitor detailed features of severe weather, for example.

Accept the Risk and Do Nothing

Congress and NOAA could assume the risk that GOES-7 will not fail before a GOES-Next satellite has been launched. This alternative would involve no additional costs to the government and could preclude unnecessary expense. The purchase of a foreign satellite or an option to purchase a foreign satellite could be a costly and unnecessary action should GOES-7 continue to operate in a satisfactory manner up to the time that GOES-Next is made operational.

If NOAA significantly delays the GOES-Next program and does not launch a replacement, a gap of satellite coverage could occur for a lengthy period, and a degradation of coverage is certain.

Options to Resolve Near-Term Risks Do Not Preclude Later Risks

Near-term decisions about GOES-Next have long-term consequences. Even if NOAA decides to proceed as planned with the GOES-Next program, redesign of GOES-K, L, and M may delay their availability until the late 1990s. SS/L officials stated that if the decision to redesign the instruments is not made soon, another gap in geostationary satellite coverage could occur late in the decade.

On the other hand, if GOES-Next is abandoned altogether (which is not currently under consideration), the United States would face the possibility of a near-term gap, and the National Weather Service's long-range objectives could be threatened. The National Weather Service considers geostationary sounding to be important to its future forecast system, and the GOES-Next type sounding system is not currently available on any other geostationary satellite in the world. NOAA is considering the additional purchase of one or more GOES-7 type satellites, but the satellite's experimental sounder would preclude expected advances in the use of geostationary sounding data in weather forecasting.

Agency Actions

In February 1991, NOAA began to explore the purchase of a foreign-owned satellite because of continuing problems in the GOES-Next program. Subsequently, NESDIS initiated a formal task force study designed to identify and evaluate options available to the government.

The task force identified and evaluated the schedule, capability, and cost implications of four options: purchasing a GMS-5 satellite currently being built by Hughes Aircraft Corporation for the Japanese government; purchasing a METEOSAT-6 currently under construction for EUMETSAT; procuring a GOES-7 duplicate from Hughes, which NESDIS believes could be available in 1994; or using an older Japanese geostationary satellite that has little remaining fuel and is in an orbit that provides degraded satellite imagery. The task force also identified a fifth option—using an innovative communications arrangement with a METEOSAT satellite—that NOAA is still evaluating.

The task force completed its study in late May 1991. The report offered no recommendations on how to proceed, although NESDIS has since contacted the international parties that would be involved in the purchase of one of the foreign-owned satellites. These discussions are ongoing.

Conclusions

GAO and NOAA identified a number of alternatives for addressing the near-term risk of a loss or degradation of geostationary coverage, ranging from the purchase of a foreign-owned satellite to doing nothing. The only alternative that addresses the current risk to U.S. weather forecast operations under all possible scenarios is the purchase of a foreign-owned satellite. Such a purchase would (1) resolve the risk of a loss or degradation of satellite coverage in 1993 or later if the GOES-Next program is further delayed or canceled and (2) allow time for further repairs to GOES-I if NOAA decides to proceed with the program. No alternative can preclude a possible loss of satellite coverage up to late 1992, however, since this is the earliest date that any replacement satellite could be placed in geostationary orbit above the United States.

NOAA could cancel the GOES-Next program and pursue an alternative acquisition strategy, including the purchase of additional GOES-7 type satellites. This course does not address the near-term risks to the National Weather Service, however, and may pose long-term risks as well.

Matter for Congressional Consideration

We believe that the budgetary implications and risks faced by the National Weather Service in its geostationary satellite program warrant the attention of Congress. To assist in its considerations, the Congress may want to direct NOAA to develop a plan identifying the actions NOAA intends to take should it lose satellite coverage during the period of transition from its GOES-7 to future satellite operations. The action plan should, at a minimum, consider the near-term and long-term benefits, risks, timing, and cost of each alternative identified by GAO and NOAA.

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