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Y2K IN ORBIT: THE IMPACT ON SATELLITES AND THE GLOBAL POSITIONING SYSTEM

JOINT HEARING

BEFORE THE

COMMITTEE ON SCIENCE

SUBCOMMITTEE ON TECHNOLOGY

AND THE

COMMITTEE ON GOVERNMENT REFORM

SUBCOMMITTEE ON GOVERNMENT MANAGEMENT, INFORMATION, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED SIXTH CONGRESS

FIRST SESSION

May 12, 1999

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WEDNESDAY, MAY 12, 1999

HOUSE OF REPRESENTATIVES, SUBCOMMITTEE ON TECHNOLOGY, COMMITTEE ON SCIENCE, AND SUBCOMMITTEE ON GOVERNMENT MANAGEMENT, INFORMATION, AND TECHNOLOGY SUBCOMMITTEE, COMMITTEE ON GOVERNMENT REFORM, WASHINGTON, DC.

The Subcommittees met, pursuant to notice, at 10:08 a.m., in Room 2318, Rayburn House Office Building, Hon. Constance Morella [Chairwoman of the Subcommittee on Technology] presiding.

Mr. OSE [presiding]. The hearing will come to order.

Good morning, everyone. We are going to commence here with the hearing. It is scheduled for 10:00 today.

I would like to enter into the record Chairman Horn's statement.

[The statement of Mr. Horn follows:]

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"Y2K in Orbit: The Impact on Satellites and the Global Positioning System"
Opening Statement of Chairman Stephen Horn
Subcommittee on Government Management, Information and Technology
May 12, 1998

Thank you Madam Chairman.

Throughout history, sailors used the stars to set their course. For nearly two decades, however, the Global Positioning System, with its constellation of 27 satellites orbiting the Earth has been a network of "man-made stars," guiding weapons systems to their targets and fishermen to their catch.

I look forward today to examining the Year 2000 preparedness of the Global Positioning System as well as other satellite systems used for weather prediction and transportation.

Only 233 days remain in 1999, and we need to know whether these systems are vulnerable to the unstoppable date change.

I welcome our witnesses and look forward to their testimony.

Mr. OSE. Mr. Gutknecht, do you have a statement you would care to offer?

Mr. GUTKNECHT. No, Mr. Chairman. I would just simply say that we're delighted once again to have a distinguished group of panelists here. And I might just say for their benefit, there are other meetings going on here on Capitol Hill, and we will have more of the membership coming in and out drifting between meetings, so please don't take that as any kind of a slight on behalf of the Congress. We are delighted to have you here with us today, and we look forward to your testimony.

Mr. OSE. I am pleased to welcome Mr. Rohrabacher. This, as you know, is a joint hearing between Mr. Horn's Subcommittee and Mrs. Morella's Subcommittee. Congressman Rohrabacher, if you would care to—do you have an opening statement you would like to offer?

Mr. ROHRABACHER. All I can say is I'm, as you know, the Chairman of the Space and Aeronautics Subcommittee, and I want to learn from the experts whether we got some problems that we need to look at or whether those problems have already been looked at and whether we can sit back and figure out that the experts have been doing what we're paying them to do.

So, I'm here to hear your testimony, and I appreciate that. And I am not an expert on this problem whatsoever, so I'm very grateful that we've got this, and that is why I'm here is to learn, so thank you very much.

Mr. OSE. Thank you, Congressman.

The statements of Mr. Turner, Mr. Barcia, and Ms. Stabenow follow:]

OPENING STATEMENT OF THE HONORABLE JIM TURNER
GMIT: "Y2K IN ORBIT"

May 12, 1999

I am pleased to be here today to discuss the Year 2000 compliance status of the important satellite systems on which American businesses and the military rely. Generally speaking, satellite systems maintain our global communication and navigation systems—affecting the functional capabilities of instruments and equipment ranging from cellular phones to weapons systems and aircraft navigation.

One of our most important satellite systems, the Global Positioning System (or "GPS"), is designed and operated by the Department of Defense. The military relies on this system worldwide for navigation of its ground, sea, and air forces. The GPS also has many civilian applications, including corporate fleet tracking, geographic and surveying services, and atmospheric and astronomical studies. It is used by scientific and engineering laboratories, the telecommunications industry, and even individuals who engage in recreational activities such as boating, flying, and hiking.

Because so many important military and civilian activities rely on the accuracy of this system, it is crucial that the GPS not be disrupted with the date change. The vast array of uses for the GPS grow in number every year, as does the number of GPS receivers used commercially. These commercial receivers may not be Y2K compliant and must be checked by each user before the end of this year.

Additionally, while the satellites themselves are compliant, the computer systems that run them are not. The Department of Defense is replacing several of these operating systems for the satellites. Clearly, this is an area where we do not have much time to replace and test the new systems; therefore, it is essential to stay on the schedule intended for the replacement of these systems.

On August 22, 1999, it is expected that the GPS will experience problems similar to those anticipated by the Y2K concerns of January 1, 2000. While the August 22nd date only applies to the GPS, there is great concern for the consequences which will result when all the internal clocks in the satellites roll over as they do once every 1,024 weeks (or every 20 years).

In light of this quickly approaching date, I am pleased to have the opportunity to receive the testimony of our witnesses today on this important topic, and would like to thank Chairwoman Morella and Chairman Horn for their leadership on the Year 2000 issue.

OPENING STATEMENT

THE HONORABLE JAMES A. BARCIA

SUBCOMMITTEE ON TECHNOLOGY
HEARING
YEAR 2000 IN ORBIT: IMPACT ON SATELLITES AND THE GLOBAL POSITIONING SYSTEM

May 12, 1999

Good morning and I want to join my colleagues in welcoming everyone to this morning's hearing.

Although the hearing title suggests the Y2K readiness of satellites and GPS, it really about services that we all rely upon every day. Satellites are an integral element of the national and global telecommunications network – as we all found out first-hand last year when a satellite malfunction cause people to lose pager, beeper, and cell phone capabilities. In addition, satellites play an important role in weather prediction and disaster mitigation. And although GPS was originally designed to support military missions, it is now used in numerous civilian applications and industries. Airlines use GPS to develop flight plans; cargo companies use GPS systems to track ships, trains and trucks; farmers use GPS systems to improve the efficiency of fertilizer and herbicide applications; and GPS receivers are even an option in the family car.

In order for these services to be available, they rely upon an integrated and seamless network of satellites, receivers and ground-segment equipment. What I'm most interested in learning about today is what is the overall impact if one of the components in this "system" fails? Is adequate end-to-end testing occurring, are contingency plans being developed and is there enough time left to ensure that all the required steps are taken? In addition, ground-based control systems are located around the world. It's my understanding that any Y2K patches for foreign-based control systems are subject to export regulation overseen by the Department of State. I hope our witnesses can address whether this review and approval process is slowing down the abilities of US companies to fix their global ground systems.

I want to thank our witnesses for appearing before our two Committees and I look forward to their statements.

SUBCOMMITTEE ON TECHNOLOGY

HEARING ON Y2K IN ORBIT: THE IMPACT ON SATELLITES AND THE GLOBAL POSITIONING SYSTEM

Opening Statement of Congresswoman Debbie Stabenow
of the 8th District, State of Michigan

May 12, 1999

I would like to thank the leadership of all the subcommittees represented here for their hard work on the various Y2K preparedness issues. Eight months from now we will have answers to many of the questions we are currently addressing, and I hope our preparation proves to be worthwhile. Today's issue is especially intriguing because this August the Global Positioning System (GPS) rollover will give us a glimpse of what problems we may encounter next January. While the GPS has been deemed Y2K compliant, its support systems are another story. This is a scenario that the federal government must be prepared for next year, as many federal agencies that are expecting to be ready for Y2K will be dealing with state agencies and contractors that may not be. Contingency plans must be in place to deliver services in these cases.

I will be interested to learn today what the overall impact Y2K is expected to have on our satellite network and if any special preparations are being undertaken for the GPS rollover. Given that many of the problems associated with the GPS are expected to be in the private sector, representatives from some of these companies would certainly augment the analysis of our panel of government experts. Perhaps this will be forthcoming at a later date. I would also like to hear if there are liability issues to be concerned about in regard to any GPS problems. Again, I thank my colleagues for their efforts on these important topics, and I look forward to the presentations of our witnesses.

Mr. OSE. Gentlemen, we're going to go ahead and recognize and commence the testimony.

Today we have joining us Mr. Lee Holcomb, the Chief Information Officer of the National Aeronautics and Space Administration Office, and Dr. Marvin Langston, who is the Deputy Chief Information Officer for the Department of Defense. We have Mr. Neil Helm, who is a Member of the Communications Systems Technical Committee of the American Institute of Aeronautics and Astronautics. And we also have Mr. Keith Rhodes, who is the Technical Director for Computers and Telecommunications in the Office of the Chief Scientists from the GAO.

Gentlemen, as we do in this committee, we swear all our witnesses in. So if you would please rise, I'll give you the oath.

Do you solemnly swear that the testimony you will give before this Subcommittee will be the truth, the whole truth, and nothing but the truth?

Mr. HOLCOMB. I do.

Mr. LANGSTON. I do.

Mr. HELM. I do.

Mr. RHODES. I do.

Mr. OSE. Let the record note that they all answered in the affirmative.

Mr. Holcomb, you may commence.

TESTIMONY OF LEE B. HOLCOMB, CHIEF INFORMATION OFFICER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, WASHINGTON, DC., ACCOMPANIED BY MARVIN LANGSTON, DEPUTY CHIEF INFORMATION OFFICE, U.S. DEPARTMENT OF DEFENSE, WASHINGTON, DC.; NEIL R. HELM, MEMBER, COMMUNICATIONS SYSTEMS TECHNICAL COMMITTEE, AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, AND DEPUTY DIRECTOR, INSTITUTE FOR APPLIED SPACE RESEARCH, THE GEORGE WASHINGTON UNIVERSITY, WASHINGTON, DC.; AND KEITH RHODES, TECHNICAL DIRECTOR FOR COMPUTER AND TELECOMMUNICATIONS, U.S. GENERAL ACCOUNTING OFFICE, WASHINGTON, DC.

TESTIMONY OF LEE B. HOLCOMB

Mr. HOLCOMB. Thank you, Mr. Chairman, and members of the Subcommittee.

I appreciate this opportunity to discuss with you NASA's experience in addressing the Year 2000 challenge and how it affects satellites.

As the Chief Information Officer, I have overall responsibility to ensure that NASA takes corrective actions required to meet the Y2K challenge. This includes all work required to assure satellites and ground systems are Y2K compliant. Y2K remains the Agency's number one technology priority. While Y2K has represented a significant technical challenge, our success has resulted from the personal commitment of the Administrator and the entire NASA management team.

Before I discuss the specifics of Y2K and satellites, I'd like to summarize NASA's current Y2K status, as of March 30, 1999.

NASA has essentially completed Y2K repairs on mission-and non-mission-critical systems. We have only one remaining non-mission-critical systems. That is the SOHO Spacecraft, which was just recovered several months ago, and we are now implementing that, and we'll be finished by the end of June.

This extensive Agency-wide effort is evidenced by the following:

We have repaired, replaced, or retired 158 mission-critical systems and 350 non-mission-critical systems. We validated over 6,000 commercial off-the-shelf products, tested over 52,000 workstations and servers.

Throughout 1999, we'll be conducting end-to-end tests to demonstrate Y2K readiness, including the Space Shuttle, International Space Station, and a dozen tests to demonstrate the readiness of Y2K's satellite and ground systems.

We've also prepared Y2K contingency plans for our missions, programs, and systems. These plans build on existing proven flight rules, and operation disaster recovery, and contingency procedures.

Now to address the specific interest in satellites and how they may be affected by Y2K.

First, satellite timers do not keep track of calendar dates. There are no date-dependent elements on most satellite or spacecraft hardware. Onboard satellite timers basically keep time by a counter. It accrues since the start of an epic or a particular event—such as a launch—and, thus, they are unaware of specific calendar perturbations. As the satellite data is received on the ground, the ground station puts the relationship between the onboard time and the wall clock time. This is established in the ground system, itself.

Ground systems and commercial infrastructure are potentially affected by Y2K. Let me just address briefly what we have done to mitigate the Y2K risks associated with each of these elements that are so crucial to maintaining the health and safety of NASA's spacecraft.

NASA established a comprehensive Y2K program in August of 1996. It was modeled after the General Accounting Office Y2K framework of awareness, assessment, renovation, validation, and implementation.

In the assessment phase, we inspected software code and conducted testing to determinate Y2K remediation requirements. We then renovated necessary code and/or replaced necessary COTS upgrades. As part of our validation phase, systems have been tested against specific Agency-wide test requirements, and they must be formally certified by a NASA employee as being Y2K compliant. Validated systems were then run in a parallel with operational non-Y2K compliant systems to ensure operational functions were not impacted by Y2K upgrades. These operations take between 1 and 3 months, oftentimes. Only after satisfactory operational and independent tests, were the systems then transitioned to operations.

As I stated earlier, all but SOHO of our mission-critical systems are now Y2K compliant and implemented.

The NASA satellite missions have also executed, or will execute, end-to-end Y2K test plans that include testing or simulation of critical mission functions supported by instruments on board the spacecraft, itself, and the grounds systems.

As stated earlier, NASA has prepared Y2K contingency plans for each satellite program and supporting ground infrastructure.

As an added precaution, NASA missions are implementing additional measures during important Y2K dates. Prior to the rollover, we will back up all critical data and ensure that adequate storage exists to save data during this period. For the most part, missions will be put in a quiescent state just prior to the rollover date. New orbital parameters may be uploaded just prior to the rollover date to allow the mission to proceed with minimal ground contact during the first few days or potentially only hours of the Year 2000.

In summary, NASA believes it has taken aggressive steps to assure the safety and integrity of our spacecraft, satellites, and ground systems. In addition, we have in place plans to address operational anomalies that we will continue to validate and to refine throughout the remainder of 1999. NASA is committed to ensuring that our missions and programs move smoothly into the new millennium.

And I would welcome any questions the Committee or the Chairman would wish to offer.

[The statement of Mr. Holcomb follows:]

National Aeronautics and
Space Administration

Hold for Release Until
Presented by Witness

May 12, 1999

Subcommittee on Technology

Committee on Science
&
Subcommittee on Government Management,
Information and Technology

Committee on Government Reform and Oversight

House of Representatives

Statement by:
Lee B. Holcomb
Chief Information Officer

106th Congress

Statement of
Mr. Lee B. Holcomb
Chief Information Officer
National Aeronautics and Space Administration
Before the
Subcommittee on Technology
Committee on Science
and
Subcommittee on Government Management, Information and Technology
Committee on Government Reform and Oversight
United States House of Representatives

Mr. Chairman, Madam Chairman and Members of the Subcommittees:

Thank you for this opportunity to discuss NASA's experience in addressing the Year 2000 (Y2K) challenge and how it affects spacecraft and satellites. As Chief Information Officer (CIO), I have overall responsibility for ensuring that NASA takes all corrective actions required to meet the challenges imposed by the Y2K on our information technology systems, assets, and supporting infrastructure. This includes all work required to assure our satellites and supporting ground systems are Y2K compliant. NASA fully appreciates the seriousness of the Y2K challenge and its potential impacts on spacecraft flight operations, science productivity and the scientific user community, and the public image of NASA and the Federal Government. Y2K remains the Agency's number one information technology priority. While Y2K has represented a significant technical challenge, our success has resulted from the personal commitment of the NASA Administrator and the entire management team to ensure missions and programs move smoothly into the new millennium.

Before discussing specifics regarding Y2K and satellites, I would like to summarize NASA's current Y2K status. As of April 30, 1999, NASA has essentially completed all Y2K repairs on mission-critical and nonmission-critical systems. We have one remaining mission-critical system that will complete implementation in June (we deferred SOHO Y2K repairs until the spacecraft was recovered) and one mission-critical system left to retire in August 1999. We have a modest amount of work that we will complete this summer for nonmission-critical systems, primarily in ensuring our desktop environments are Y2K compliant.

Meeting the Governmentwide goals for Y2K work has required the most extensive "top down" and "bottom up" review of the Agency's information technology assets supporting missions, systems, and common infrastructure and facilities undertaken to date. No significant Agency asset has been untouched--we have tested and remediated (where necessary) our ground control systems, flight hardware and software supporting human and robotic programs, mission operations support systems, common infrastructure systems, and institutional systems. The results of this extensive Agencywide effort is evidenced by the following:

- Repaired, replaced or retired 158 mission-critical systems and 350 nonmission-critical systems, representing thousands of complex hardware and software modules and components (including ground control systems, flight hardware and software, mission operations support, institutional systems).

- Validated over 6000 commercial products used on the Agency's supercomputing, mainframe, midrange, desktop, and network assets.

- Tested over 52,000 workstations and servers.

- Tested in-flight system software and hardware for NASA's wide range of spacecraft, satellites, instruments, and aircraft.

- Tested NASA's unique research and development infrastructure--hundreds of simulators including wind tunnels, testbeds, computational facilities, and propulsion and flight-test facilities.

While these accomplishments are significant, NASA is going beyond stated requirements to ensure we are ready for the new millennium. Throughout 1999, we will be conducting mission-specific end-to-end tests to demonstrate Y2K readiness. End-to-end tests will be conducted for the Space Shuttle Program; the International Space Station; and NASA's command, tracking, telemetry, and data services supporting all satellites and spacecraft. Major missions supporting the Space and Earth Science Enterprises are also conducting end-to-end tests throughout the summer to demonstrate Y2K readiness. We have also prepared plans that address operating contingencies for our missions, programs, and systems to ensure we are prepared for a Y2K-related failure of internal assets or national infrastructure. Our plans build on existing and proven flight rules, operations, disaster recovery, and contingency procedures.

Now, to address your specific interest in satellites and how they may be affected by Y2K. Satellite timers do not keep track of calendar dates, so there are no date dependent elements provided in most satellite or spacecraft hardware. However, NASA satellites do have many time-related functions in onboard flight software. These time related functions are necessary for many operational activities and include ephemeris processing, processing of stored commands, and other scheduled processes. The format of time used by flight software is not stored or processed as a calendar date, with days or years. Instead, onboard satellite times are kept via counters that begin to accrue time starting with a given event or epoch and are thus unaware of calendar perturbations. As the satellite data is received at the ground station via telemetry and processed by the ground systems, the relation between the onboard time and the "wall-clock" time is established. I would like to emphasize, however, that NASA has assessed and tested or validated that all flight software and hardware is Y2K compliant. As expected, no changes to flight software or hardware have been required.

I would like to use NASA's Hubble Space Telescope (Hubble) as an example to highlight actions we have taken to assure the health and safety of NASA spacecraft relative to Y2K. As you know, Hubble was launched in April 1990, and is one of NASA's great observatories of astronomical observations in space. Hubble provides an excellent illustration of how time is processed for spacecraft. All of the computers on board the observatory depend only on the Hubble onboard clock for time information. The Hubble onboard clock is a free running 125 millisecond counter that has been incrementing since launch. This clock does not contain any date information but expresses time using 32 bits. Rollover to zero occurs after 17.024 years (from launch) and will occur in the year 2007. Rollovers of stored command time occur approximately every 24 days and are routine. Embedded systems planned for installation during servicing missions are designed to be Y2K compliant. Time correlation to calendar date for all Hubble commands and telemetry (engineering and science data) is performed in the ground systems. As we have validated on all NASA spacecraft, the Y2K is not an issue for the Hubble onboard computers and embedded microprocessors.

Ground systems, the commercial utility infrastructure, the commercial telecommunications infrastructure, and NASA's data distribution systems on the ground do, however, use calendar dates and are potentially affected by Y2K. Let me address briefly how we have mitigated Y2K risks associated with each of these elements that are so critical to maintaining the health and safety of NASA spacecraft.

As part of NASA's ongoing Y2K assessment, we have identified Y2K problems for ground systems primarily in the areas of ground system operating systems, Commercial-off-the-Shelf (COTS) components, and mission-unique custom software. Ground systems do rely on calendar dates, for example, to include date and time labeling of received data and to make various operational events occur at specific dates and times. If the applications, computer operating systems, or computers do not recognize or interpret certain dates correctly, the systems may produce erroneous data, malfunction, or simply stop working.

NASA established a very aggressive Y2K program in August 1996. Our program is modeled on the General Accounting Office framework for Y2K awareness, assessment, renovation, validation, and implementation. We have established specific Agencywide requirements and guidelines that have been consistently followed by all NASA Centers. As part of our initial assessment, we inspected software code and/or conducted preliminary testing for NASA systems to determine Y2K remediation requirements. We have renovated custom-developed code and made necessary COTS upgrades or replacements for supporting ground systems. As part of our validation phase, systems have been tested against specific Agencywide test requirements and must be formally certified as Y2K compliant by a NASA employee. Consistent with our rigorous systems management practices, validated ground systems were run in parallel with operational non-Y2K compliant systems using "current time" operational data to ensure operational functions were not impacted by Y2K upgrades. Only after satisfactory operational and independent test team checkout were systems transitioned to operations.

In addition to these requirements, NASA missions have executed or will execute end-to-end Y2K test plans that include testing or simulation of critical mission functions supported by the instruments on board, the spacecraft itself, and the ground systems. While the testing details vary from mission to mission, testing involves setting the clock forward and rolling through the millennium roll-over and other key Y2K dates. For those missions to be launched in the latter part of 2000, Y2K compliance tests will be incorporated as a natural part of routine integration and acceptance testing. An example of an end-to-end test recently completed was the Space Science/Deep Space Network test. For this test, we advanced the clocks to February 25, 2000, and tested the data flows from the Cassini spacecraft (a mission to explore Saturn) to the Deep Space Network-Goldstone Deep Space tracking station, through the Cassini test bed, and finally to two participating Cassini Principal Investigators. The Principal Investigators were at remote sites in Baltimore, Maryland, and the United Kingdom. The test accomplished all of its objectives and instilled confidence that NASA will not experience Y2K anomalies in tracking planetary spacecraft in the year 2000 and beyond.

Let me again use the Hubble Space Telescope as an example. The Hubble ground system actually consists of 36 mission-critical and 20 nonmission-critical computer systems, comprised mainly of COTS computer hardware and software, some government off-the-shelf software, and several million lines of applications software unique to Hubble. Each of these computer systems contains an internal clock with calendar date information. Correct time and calendar date capability is vitally important to Hubble mission-critical operations activities such as the execution of commands by the observatory; proper and accurate telescope pointing; communications between the observatory and the Space Telescope Operations Control Center; and time tagging of science data.

In early 1997, Hubble initiated a comprehensive and thorough effort spanning the operations, ground systems, and flight software to ensure operability in the year 2000 and beyond. All systems were assessed, remediated (where required), and rigorously tested. In addition, Hubble end-to-end tests were executed to independently verify Y2K compliance for all mission-critical systems. To conduct this test, we used a facility that replicates the Hubble electrical and electronics systems that is comprised of the actual flight spare components used for on-orbit servicing of the observatory. All final testing of any changes to flight hardware and software is conducted using this facility because it is the most faithful and highest fidelity replica of Hubble flight systems. During the end-to-end testing, all mission-critical ground system components and Y2K critical dates were exercised using a set of observation proposals, planned observations, and stored command loads to accurately simulate the full range of mission operations with the observatory. Based on these successful tests, Hubble was certified Y2K compliant in March 1999.

Another example I would like to share relates to NASA's Tracking and Data Relay Satellite System (TDRSS). TDRSS is a communication signal relay system that provides tracking and data acquisition services between low earth orbiting spacecraft and NASA/customer control center and data processing facilities. Customers which rely on TDRSS to deliver command and telemetry data include the Hubble Space Telescope, the

Space Shuttle, the Compton Gamma Ray Observatory, Landsat, the International Space Station as well as other current and planned low earth orbiting satellites.

The TDRSS is comprised of a space and ground segment. The existing space segment was developed by TRW, and consists of six on-orbit satellites located in geosynchronous orbit. These spacecraft are vintage 1970's design that has a very primitive 8-bit processing capability that does not maintain or use a clock on-board the spacecraft. Instead, the ground station sends real-time commands to configure the spacecraft to support user services and to step the antennas to track both user spacecraft and the Ground Station at White Sands, NM.

Currently under development are three replenishment satellites that are being designed and built by Hughes Space and Communications. These satellites are based upon their standard HS601 series of satellites. The first of this series, TDRS-H, is presently undergoing factory test and integration. Although the launch is planned for the fall of 1999, the satellite will not be placed into operational service until after the century transition. Hughes has performed specific testing of the flight software on the three replenishment satellites to ensure that no problems exist with respect to Y2K.

The TDRSS ground segment is located in New Mexico and consists of two functionally identical ground terminals known collectively as the White Sands Complex. The communications traffic between low-earth orbiting satellites being supported by the TDRSS --uplink and downlink -- pass through the White Sands facility. Work to remediate TDRSS ground systems is complete and verified to be Y2K compliant. In summary, the entire TDRSS – existing satellites, replenishment satellites, and ground systems - has been successfully verified to be Y2K compliant.

A technical problem similar to but not directly related to Y2K involves the US Space Command Global Positioning System (GPS). As I am sure you are aware, GPS is based on about two dozen satellites that orbit the Earth and send navigational signals. Two upcoming events may affect civil GPS users and government users of commercially procured receivers – GPS End of Week rollover and Y2K issues. GPS End of Week rollover happens every 20 years because GPS system time, counted in weeks, started counting on January 6, 1980. At midnight between August 21 and 22, 1999 the GPS week will rollover from week 1023 to 0000. This could be interpreted as an invalid date in GPS receivers that were not designed to meet GPS specification. The Department of Defense is the service provider for GPS and has verified that all generations of GPS satellites and ground support systems are Y2K and End of Week rollover compliant. NASA has assessed the impact of this known problem with GPS receivers, and has replaced or upgraded a small number of GPS receivers where required, either for this GPS-unique problem, or due to Y2K reasons. We do not anticipate problems with GPS receivers on August 21, 1999 or on January 1, 2000.

NASA remains confident that the probability of a Y2K-related failure of NASA-controlled assets and systems is very low. We are, however, reliant on national and local infrastructure such as telecommunications and electrical power for spacecraft operations.

All NASA missions routinely develop contingency plans to deal with the unexpected, including on-orbit anomalies. Each NASA Center has developed Y2K business continuity plans for NASA operating missions and supporting infrastructure that are based on these existing and proven plans. NASA's critical ground systems currently include provisions to mitigate the impact of short-term failures of the commercial power and telecommunications infrastructure which occur during day-to-day operations. Independent power sources such as batteries and generators exist to support continuing operations in the event of a commercial power failure. Diverse routing of communications traffic within our primary commercial telecommunications service provider and the capability to route data across other commercial telecommunications service providers exists to support continuing operations in the event of a commercial telecommunications failure. NASA plans have been used in actual utility outage conditions, systems failures, and recoveries. We know these plans work and believe that these contingencies will work during the Y2K rollover.

As an added precaution, NASA missions are implementing additional measures during important Y2K dates. Prior to the rollover, we will backup critical data and ensure that adequate storage exists to save data that may not be able to be processed in the event a Y2K problem is encountered. For the most part, missions will be put in a quiescent state, and we are evaluating strategies to minimize data gathering or scheduled operations activities. New orbital parameters may be uploaded just prior to the rollover to allow the mission to proceed with minimal ground contact during the first few days or hours of 2000. During the rollover weekend, we will have key operations staff at each NASA Center to monitor and support critical operations, and resolve and report any anomaly, Y2K or otherwise, through established operational procedures and management processes. In addition, we will have extra staff at each NASA Center to communicate frequent Y2K status of all NASA assets and systems to my Office at NASA Headquarters, both affirmation of positive status and problem reporting. To ensure a coordinated, well-planned, and appropriate response to any Y2K anomaly, priorities for problem resolution across missions are:

1. Health and safety of the spacecraft
2. Health and safety of the onboard instruments
3. Real-time mission operations (command uplink and telemetry downlink)
4. Non-real time mission operations including spacecraft system analysis, sequence generation, and navigation
5. Science data capture
6. Science data product generation and archiving.

The impact on NASA if there is a Y2K-related failure depends, of course, on the nature of the failure and the duration of the failure. Many of the possible failures would be inconvenient, but would not necessarily result in permanent loss of data. All NASA operating missions have standard operational procedures in place to handle ground contingencies, and would be placed in "safehold" status until the contingency was resolved. The likelihood of a Y2K failure causing damage to spacecraft or causing an extended period of downtime is considered to be very remote.

In summary, NASA believes it has taken aggressive steps to assure the safety and integrity of our spacecraft, satellites, and supporting ground systems and infrastructure. In addition, we have adequate plans in place to address operational anomalies due to Y2K problems, and we will continue to validate and refine these plans throughout the remainder of 1999. NASA is committed to ensuring that NASA's missions and programs move smoothly into the new millennium.

I welcome any questions you may have.

BIOGRAPHICAL SKETCH

Lee B. Holcomb

Lee B. Holcomb has been named Chief Information Officer (CIO) at NASA Headquarters, Washington, DC effective October 22, 1997.

The CIO reports directly to the NASA Administrator and is responsible as an integrated Agency focus for the development of information resource management strategies, policies, and practices. These encompass strategic planning; standards in computing, networking, and security; establishment of system and information architectures; and incorporation of life-cycle management concepts into information technology acquisitions and management. In addition, the CIO serves as the NASA-designated senior official for information resource management. Holcomb also will continue to represent NASA on the Committee on Technology of the National Science & Technology Council.

From 1995 to 1997, Holcomb was the Director of the Aviation Systems Technology Division; from 1991-1995, Director of the High Performance Computing & Communications Office; and from 1984 to 1991, Director of the Information Sciences and Human Factors Division, all in the Headquarters Office of Aeronautics. Holcomb began his NASA career in Aeronautics at NASA Headquarters in 1975.

Significant programmatic accomplishments for which he has been directly involved include the development and operation of the world's first massively parallel processing computer; the development of a real-time synthetic aperture radar processor for the Magellan spacecraft; the development and application of information technology tools for support of the operational commanding of planetary spacecraft (Voyager), the Space Shuttle, and air traffic control systems; and Internet-based sites for access to aeronautics and space data and K-12 education products.

Prior to joining NASA, Holcomb served as a senior engineer with the Jet Propulsion Laboratory, Pasadena, CA, where he was responsible for directing Voyager spacecraft hardware development and numerous systems analysis tasks.

Holcomb holds a B.S. from the University of California at Los Angeles and an M.S. from the California Institute of Technology.

Mr. OSE. The Chair thanks the witness.

We have a ringing in the microphones on the testimony. Is there any chance of getting that adjusted, please?

With the consent of the other members, perhaps all four witnesses will testify and then we will take questions.

Dr. Langston.

TESTIMONY OF MARVIN LANGSTON

Mr. LANGSTON. Thank you, Mr. Chairman; and we certainly thank the Committee for your interest and your help in this critical, technical area. It has been a significant benefit to the Department for the help you have given us.

I would just like to state up front what Dr. Hamre, the Deputy Secretary, has stated to the Committee several times. The Department of Defense is fully committed to repairing these systems and bringing them along and is fully confident that we will be completely Y2K ready to carry out all missions throughout the Y2K period of time.

As you know, the Department has more than 2,000 mission-critical systems—over one-third of the mission-critical systems within the Federal Government—and we have an additional 4,600 non-mission-critical systems that we have been working to remediate over the past several years. Of those mission-critical systems, we are pleased to report that, as of the end of April, we have completed over 97 percent of them, and all but 8 percent of that 97 percent have been fully installed throughout the Department of Defense.

In addition, we have over 600 installations that we are working to make completely Y2K compliant, and that includes the interactions with the associated communities that provide critical services to those bases and installations.

We have also, as a result of Dr. Hamre's challenge or tasking to the unified commanders of the operational forces and to the under secretaries of all the functional organizations—that is personnel and logistics and intelligence, et cetera—we have the largest testing activity ongoing in the Department that the Department has ever engaged us in. We have over 42 what we call "operational evaluations" being conducted through the operational forces to test the tie-together of all these mission-critical systems and what we call "thin line of systems" that represent mission functions. Of those 42, 18 of the mission-critical threads have been tested. To date, we have only discovered a few of what we call "soft failures," which are non-mission disabling failures such as improper information in a window on a screen. And we have discovered a couple of mission-critical failures where we have had messages fail to process. Those systems have been put back into remediation and are going back into the testing process through those operational evaluations.

We are confident that, as we complete most of these operational evaluations through the spring and early summer months that the Department will be well on the step towards having completed all of its Y2K remediation and mission-critical testing.

And we also have in that process tested contingency plans, or contingency operations, for what we are doing. And in fact, to take contingency planning beyond the system level and into the operational, functional level, the Chairman of the Joint Chiefs is conducting a series of what they call "Chairman's Contingency Assessments." They take significant numbers of mission-critical systems offline; they challenge the operational commanders to conduct those missions, such as the mobility mission for mobilizing Armed Forces, to determine their ability to conduct those operations without those systems should we, for some reason, have a failure on those systems. To date, those contingency operations have been very successful, and we are going through a sequence of three more contingency assessment major exercises. These are 2-week exercises that will occur throughout the next several months.

To the point, specifically on satellite systems, we have four major groupings of satellite systems within the Department. We have weather systems; we have communications systems; we have early warning systems, and we have navigation systems. As you know, the Global Positioning System is one of the critical elements of our modern warfare and is also critical to all of our civilian users throughout the United States and the world. This Global Positioning Satellite System has a constellation of 27 satellites operationally in orbit to date; 24 of them are required for full operations.

In the Global Positioning System, there are three major component pieces: the control segment, a space segment, and a ground segment. Of those segments, the control segment is fully Y2K compliant as it sits. Of the space segment, the satellites, themselves, have no Y2K dependencies and are fully Y2K compliant. We have non-mission-critical data analysis components of the space segment which are being repaired, will not be completed until the December timeframe, but these—I remind you again—are non-mission-critical data analysis pieces which have many ways to work around for the support of the satellite systems. In addition, the ground segment components of the Global Positioning System has—that deals with all the receivers that basically provide the information as to what the location is on the Earth. In the Department of Defense, we have several receiver systems that were procured by our Joint Program Office for GPS receivers. Each of those systems are fully Y2K compliant and have been validated.

We also have several embedded global positioning satellite receivers in weapon systems such as Tomahawk or in aircraft and other vehicles. Those systems are being tested in these operational evaluations and remediated as a part of our mission-critical systems and will be fully compliant by August of this year.

We also have a concern for the non-DOD commercial receivers that many people are using to receive the GPS signals. We are not in the responsible position of certifying any of the commercial receivers. We are, however, working with the Department of Transportation and applying everything we know about which receivers—which manufacturers' receivers are compliant. We support a web page that advertises those receivers, and there are several hundred of them that have already been validated and are up on that website.

As I said, we are conducting these operational evaluations and large end-to-end tests to test everything the DOD inventoried. That includes the Global Positioning System and the receivers that are supporting them. We have completed one test that does include the Global Positioning System as of 30 April. We had no Y2K problems during that event. My understanding is that there is a Coast Guard differential GPS system that was used, that they have discovered a system design error in a relatively new system, which is a non-Y2K problem, but it is an example of positive outcome that's occurred as a result of this testing and where people are able to go back and repair those systems.

Of the other space segments that I mentioned that are non-navigational segments, we have Y2K compliance in all of our satellites, themselves, and we have some user segment pieces that are going through the operational process or the repair process for our mission-critical systems. And we will complete all of those "op evals" in May and August of this year.

So in conclusion, the Department of Defense feels that we have turned the corner; we are in excellent shape, with respect to moving our large number of systems through the Y2K remediation process. We have an enormous testing process ongoing and a contingency plan validation ongoing, and we feel completely confident that we will be there to support the Nation in all national security needs as we go into this period.

And that concludes my remarks.

[The statement of Mr. Langston follows:]

Statement

of

Dr. Marvin Langston

Deputy Assistant Secretary of Defense

(Deputy Chief Information Officer and Year 2000)

Before the

Joint Hearing of the

Subcommittee on Technology

Committee on Science

and the

Subcommittee on Government Management, Information, and Technology

Committee on Government Reform

United States House of Representatives

YEAR 2000 PREPAREDNESS

Satellites and the Global Positioning System (GPS)

May 12, 1999

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Introduction

Thank you Mr. Chairman and members of the Committee. I am honored to be here and pleased to have the opportunity to discuss the status of the Department of Defense in preparing for the Year 2000. I am also pleased to report that DoD will continue operations and maintain military readiness before, during, and after January 1, 2000. Today I would like to briefly review the overall DoD effort on the Year 2000 problem and then discuss the Global Positioning System and other satellite systems.

DoD's Leadership Focus for 1999 – Ensuring Mission Capability

In early January of this year, senior DoD leaders held a daylong meeting to review the results of our efforts to fix systems in 1998. Another meeting was held on April 13, 1999, to review DoD progress toward meeting the OMB deadline of March 31, 1999, for mission critical systems. There are still important efforts necessary to achieve Year 2000 compliance for all DoD systems. DoD management efforts in 1999, however, are shifting to end-to-end evaluations of functional capabilities, contingency plan preparation and testing, and preparing for Year 2000 operations in the period surrounding the millennium change as shown below.

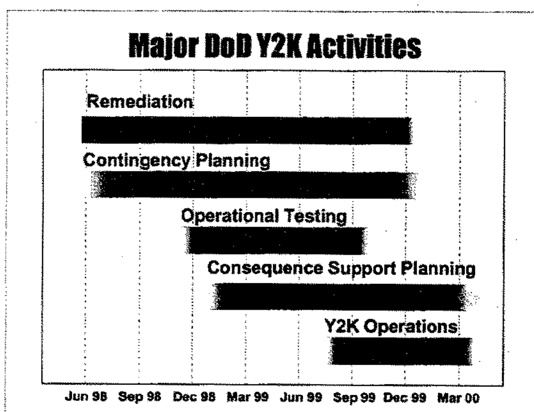

Figure 1 – Major DoD Year 2000 Activities in 1999

Evaluation and Testing of Capabilities

DoD efforts this year are principally focused on improving confidence in the Department's ability to continue to execute the National Military Strategy. DoD has already completed initial testing of most individual systems and their immediate interfaces. In 1999, DoD will concentrate on complex, real-world end-to-end testing of DoD "business functions" and Warfighter missions – the things that DoD does in carrying out the national military strategy.

During 1999, DoD will test everything from paying service members to exercising vital command and control capabilities from "sensor to shooter." This will involve a "thin line thread" of systems that operate in concert in order to perform a function. Testing in this manner is as complex as going to war and, therefore, involves all areas of the Department of Defense: the Services, the functional areas overseen by the Principal Staff Assistants of the Office of the Secretary of Defense (OSD), and the Commanders in Chief (CINCs) of Unified Commands.

DoD evaluation and testing efforts are extremely complex with many events occurring nearly simultaneously. The Services will be conducting integration testing of functional or mission threads. Principal Staff Assistants on the OSD staff will organize and conduct end-to-end evaluations of functional capabilities. Finally, the CINCs, the Warfighters, have each selected among their own unique missions to devise real-world operational evaluations to exercise various warfighting missions. The number of activities, finite amount of key resources (particularly testing experts and time), and demands of real world day-to-day operations have forced an iterative and highly centralized synchronization of the entire evaluation plan.

The number and complexity of testing and evaluation efforts is managed in synchronization sessions co-chaired by members of OSD and the Joint Staff. The DoD Inspector General provides oversight and another review to search for holes in the evaluation program. Finally, the GAO and the OMB provide a review by external auditors.

The key events in the DoD evaluation plan are CINC Operational Evaluations, PSA functional end-to-end evaluations, and Service end-to-end and integration testing.

Operational Readiness Evaluations

DoD is using the Department's Warfighters, the CINCs, to evaluate operational readiness to conduct operations unaffected by the Year 2000 problem. The Fiscal Year 1999 Defense Authorization and Appropriations Acts require us to conduct at least 25 operational evaluations with each Unified Command conducting at least 2 exercises. DoD will exceed those requirements and, as shown in the figure below.

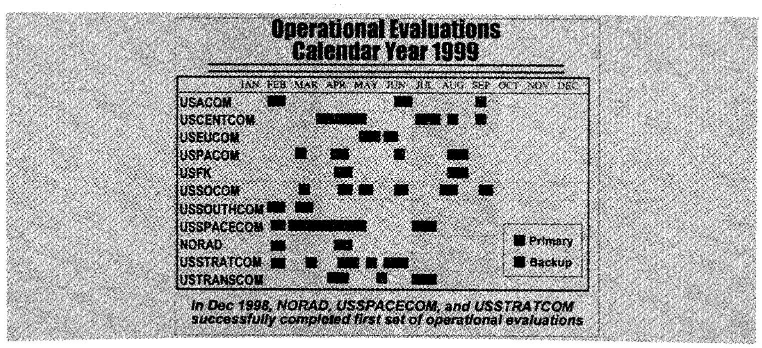

Figure 2 – DoD Combatant Command Operational Evaluation Activities in 1999

The DoD approach has been to validate the complete warfighting process, from "sensor-to-shooter" using the significant dates specified by the GAO Testing Guide. Initial results from the three already conducted confirm that this kind of evaluation is essential to providing the additional assurance that systems will remain operational over the millennium date change.

In addition to the CINC Operational Evaluations, CJCS is holding a series of Contingency Assessments of DoD ability to execute warfighting operations.

Functional End-to-End Evaluations

DoD is using the Department's Business Process Managers – the Functional Proponents -- to evaluate its ability to continue core support functions despite Year 2000. Each functional process owner: logistics, finance, communications, intelligence, personnel, medical and others will conduct end-to-end evaluations of core business functions as shown in the figure below.

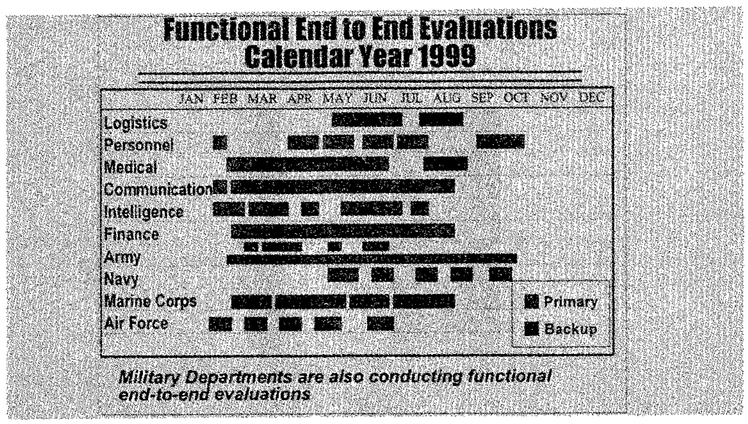

Figure 3 – DoD Functional End-to-End Evaluations in 1999

In some functional areas, particularly logistics, the Services are conducting end-to-end evaluations of their internal functional systems prior to a DoD-wide functional evaluation. These tests are in addition to the CINC operational evaluations and include, in many cases, organizations and systems outside of DoD.

Integration Testing

Service integration testing will fix responsibility with the Department's system owners – the Military Departments – to ensure continued functioning of other key processes that allow for Title 10 functions of organizing, training, and equipping forces. This testing is over and above the five-phase OMB process each individual system must complete to be certified as Year 2000 compliant.

Service testing is critical to the ability of the CINC Service Components to carry out their parts of the CINC warfighting plans. Service testing provides a useful foundation prior to more complex, real-world CINC operational evaluations. The successful testing of several weapons systems (Kiowa, Apache, Hellfire, and Multiple Launch Rocket System) at White Sands, New Mexico, for example, provided an excellent basis for future CINC operational evaluations. The testing conducted by the Military Departments is in addition to CINC operational evaluations and functional proponent end-to-end testing. These tests are the third method DoD are using to ensure departmental compliance with the evaluation requirements contained in the Fiscal Year 1999 Defense Authorization and Appropriations Acts. Those Acts require that "all mission critical systems that are expected to be used if the Armed Forces are involved in a conflict in a major theater of war are tested in at least two exercises."

Finally, OSD and the Joint Staff are working together to develop a configuration management plan to ensure DoD maintains the hard won confidence in systems that will result from this comprehensive series of evaluations. While still under development, the underlying tenet is a coordinated approach to configuration control involving the CINCs, PSAs, Services, and the OSD and Joint Staff.

In summary, DoD has the largest and most comprehensive evaluation plan in the Department's history, and is continuing to work on refining plans to improve the overall evaluation of core DoD functions. This plan will significantly improve the level of confidence in DoD's ability to carry on operations despite Year 2000. While these extensive efforts will mitigate risk, the interconnectedness of everything guarantees that Year 2000 will have an impact on DoD. To deal with this reality, DoD must focus on realistic contingency planning.

Contingency Planning

The Department of Defense promulgated guidance for contingency planning efforts in the DoD Year 2000 Management Plan in December 1998. As mentioned, senior management focus in January of 1999 was on the status of systems compliance. On March 23, 1999, the Deputy Secretary of Defense hosted a Year 2000 Steering Committee meeting focused exclusively on the status of contingency plans. Each major component of the Department of Defense reviewed the status of system contingency plans in detail as well as progress towards developing operational contingency plans, including the Services; the Principal Staff Assistants responsible for the business functions of the department; the Unified Commands (represented by the Joint Staff); and key defense agencies. As with all DoD Year 2000 Steering Committee meetings, Senate and House staff, the GAO, OMB, and DODIG representatives attended and personally observed the presentations concerning contingency planning.

System/Operational Contingency Planning

Contingency planning is a normal aspect of DoD operations and DoD is applying its experience to the special case generated by the Year 2000 problem. The key elements of the contingency planning effort involve common guidance, focusing on core missions and functions, an adequate management oversight structure, and DoD engagement with other agencies and activities.

Common Guidance

Using the GAO guidelines, DoD has published policy and guidance that requires every system, mission, and function owner to develop and validate system and operational contingency plans. The essential elements and status are contained in the figure below.

Contingency Plans: Definition & Status

- System Contingency Plans
  - Restore Disrupted Systems
  - IT/CIO Centric
  - Required: Date-aware Mission-critical Systems
  - Complete
  - 1,996 Plans on Hand / 2,038 Plans Required (97.9%)
- Operational Contingency Plans
  - Ensure Successful Mission Execution
  - Operator / Commander Centric
  - Identify Alternative Procedures, Workarounds, Gap-fillers
  - Required As Directed by Each DoD Component
  - USMC, DLA, and DFAS - Excellent models forDoD

Figure 4 - Contingency Plans Definitions and Status

DoD efforts at managing the individual component contingency planning activities are designed to ensure the Department as a whole can accomplish the myriad missions assigned. To ensure that these plans are adequate, oversight responsibility for these plans is delegated to the Joint Staff for their subordinate commands and to the Services and the PSAs for all other plans. The overall DoD status for system contingency plans is shown in the figure below.

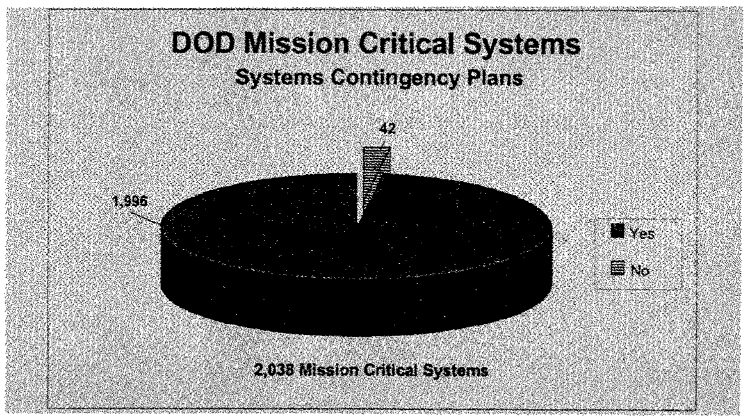

Figure 5 - DoD Mission Critical System Contingency Plans

Focus on Core Missions and Functions

DoD planning focus is on core missions and functions. The Department is using the CINCs to manage its core warfighting missions and the PSAs and Military Departments to manage the core support functions.

Warfighting capability is the domain of the Chairman of the Joint Chiefs of Staff (CJCS) and the CINCs and their Service components. The CJCS and CINCs use the Universal Joint Task List (UJTL) to hierarchically group critical activities involved in execution of CINC Operational Plans. UJTL tasks are apportioned across the CINCs for evaluation during operational evaluations of "Thin-Line Threads" or core missions and functions. If systems on the "thin line thread" have not yet completed the Year 2000 compliance process, the system contingency plan is used.

Enterprise-wide support is the domain of the PSAs. Each core business function has internally derived "mission critical" capabilities that must be executed to accomplish the DoD mission. Logistics, transportation, medical services, finance, procurement, supply, and other proponents are charged with assessing vulnerabilities and interdependencies and developing contingency plans to quickly restore services or otherwise accomplish the mission. An example that shows the complexity of business function operations in an organization as complex as DoD surveillance and reconnaissance, weather, and navigation. DoD operates one government-wide space based system – the Global Positioning System (GPS).

Global Positioning System

Overview

The Global Positioning System is a satellite-based radionavigation system developed and operated by DoD. GPS consists of a space segment (satellites), a ground control segment, and a user equipment (receiver) segment. GPS uses 24 satellites (28 are in orbit) to continuously broadcast coded signals that can be processed in a GPS receiver. These signals enable the receiver to computer position, velocity, and time 24 hours a day in all weather anywhere in the world. Receivers must process signals from at least four satellites in order to compute a position in three dimensions and time. The basic structure of GPS is shown in the figures below.

The Global Positioning System

- GPS is a satellite-based radionavigation system developed and operated by the DOD
- GPS consists of a space segment (satellites), ground control segment, and a user equipment (receiver) segment
- The 24 satellites (28 currently in orbit) continuously broadcast coded signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time 24 hours a day in all weather, anywhere in the world
- A receiver must process signals from at least four satellites in order to compute a position in three dimensions and GPS time

Figure 7 - Global Positioning System Overview

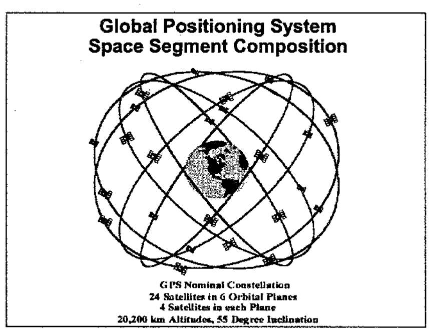

Figure 8 - GPS Space Segment Composition

There are 2 major issues concerning GPS: the End-of-Week (EOW) roll over and Year 2000 compliance. The EOW problem stems from a known design decision which receiver manufacturers are responsible for ensuring their designs can handle. The Year 2000 problem may affect software or firmware that processes date information as shown in the figure below.

Y2K Related Dates Important to GPS

- GPS End of Week (EOW) Rollover
  - Beginning on 5-6 Jan, 1980, GPS system counts weeks from 0000 to 1023
  - GPS week rolls over from week 1023 to week 0000 at 23:59:47 UTC 21 Aug 99 and approximately every 20 years thereafter
  - GPS receiver manufacturers are responsible for conforming to this rollover
    - Non-compliance could cause satellite positions to be miscalculated, resulting in gross position fix errors
    - Receivers that process and display calendar dates based on weeks since 1980 may generate date calculation errors
- Year 2000 (Y2K) Rollover
  - Transition from Dec 31, 1999 to Jan, 1, 2000
  - 2000 becomes "00"
    - Could be interpreted as 1900 for calculations or could be treated as invalid date
    - Receiver software (and firmware) could malfunction or cause data corruption
  - Other leap year related transition dates are 28 to 29 Feb, 2000 and 29 Feb to 01 Mar, 2000

Figure 9 - GPS End of Week and Year 2000 Rollover

GPS Year 2000 Compliance Status

The Department continues to make great progress on Year 2000 preparations to ensure the GPS operates reliably before, during, and after the Year 2000 event. The GPS Joint Program Office (JPO) is working the issue from ***three*** perspectives - the control segment, the space segment, and the user segment.

GPS Control Segment

The Control Segment has been certified complete as of February 22, 1999. The Master Control System (MCS) has been fully upgraded with Y2K compliant software/hardware and all remote GPS sites are Y2K and EOW compliant as shown in the figure below.

Control Segment Status

GREEN

- Certification complete 2/22/99, #2240
- Master Control Station (MCS)
  - Y2K Software fixes developed, tested and delivered
  - COTS software components integrated and checked out
  - Implemented in the operational system
- Remote Sites
  - Legacy system is Y2K and EOW compliant
  - Ground Antennas/Monitor Station compliant
  - Deployment to all sites completed

Figure 10 - Status of GPS Control Segment

GPS Space Segment

The mission critical GPS satellites (Block II/IIA/IIR) are Y2K and EOW compliant. Some mission essential support systems that provide real-time telemetry monitoring are still in the process of achieving Y2K compliance. The ground-based, off-line satellite data analysis tools used for trending and anomaly resolution are behind schedule to achieve Y2K and EOW compliance. The GPS Block II/IIA analysis tool, however, has an acceptable Y2K workaround as shown in the figures below.

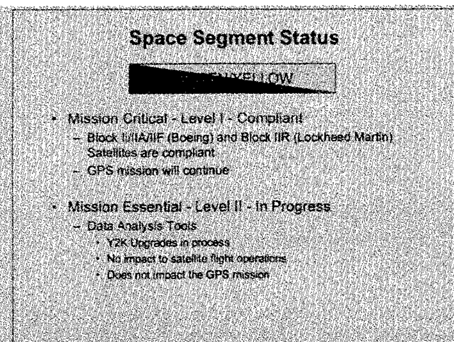

Figure 11 - GPS Space Segment Status

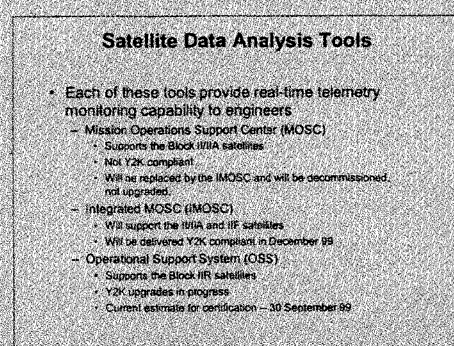

Figure 12 - Space Segment Mission Essential Monitoring Tools

GPS User Segment

The overall plan of action for achieving Y2K compliance for the GPS User Segment is to follow the 5 phase process outlined by the DoD Y2K Management Plan as shown in the figure below.

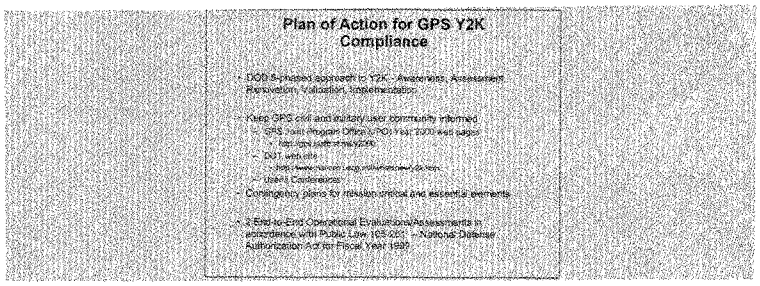

Figure 13 - GPS Y2K Compliance Plan of Action

The User Segment consists of two major groups. The first group is GPS receivers procured by the JPO. This group was certified on December 11, 1998, and is Y2K compliant. The second group consists of GPS receivers not procured by the JPO. This group includes GPS systems in other DoD systems. Responsibility for Y2K and EOW compliance of these systems lies with the overall system program and project managers. A small number of certain models of GPS receiver, particularly timing receivers, are not compliant and need to be upgraded or replaced. This effort is expected to be completed by the end of August 1999.

The JPO has made Y2K compliance information available to the general public via their Internet web site at **http://gps.laafb.af.mil/y2000/index.html**. The overall status of Y2K compliance for the GPS user segment is shown in the figure below.

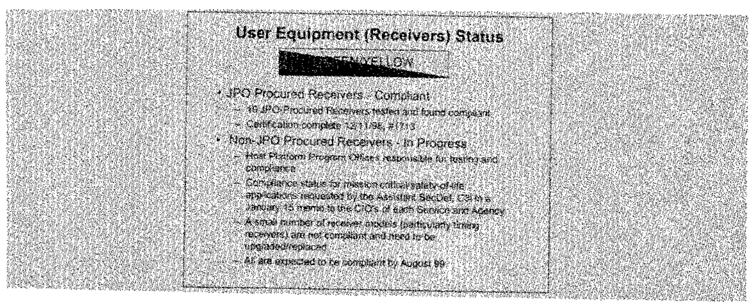

Figure 14 - GPS User Segment Status

Overall Evaluation/Test Plan

As required by the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 and the Fiscal Year 1999 Defense Appropriations Act, the Department of Defense is conduction two evaluations of all systems "expected to be used if the Armed Forces were to become involved in a conflict in a major theater of war." The plan for evaluating GPS is shown in the figure below.

GPS End-to-End Testing

- 1) US Space Command (USSPACECOM) - US Central Command (CENTCOM) Operational Evaluation of GPS
  - Tests conducted from 23 April to 1 May using one Block II/IIA satellite (SV 27), one of three computers at the master control station (CPU-C), one remote monitoring site (MS), and one ground antenna (GA)
  - Simultaneous testing of 4 satellites not possible due to real-time operational impacts to global users
    - Therefore, a receiver's ability to determine position and/or time before, during, and after a date crossover cannot be observed during the evaluation
- 2) Air Force Space Command Operational Assessment
  - Tests will be conducted beginning in late May
  - Tentative plan is to test a Block IIR satellite

Figure 15 - GPS End-to-End Testing

The plan for the operational evaluation at USSPACECOM and USCENTCOM requires exercising a "thin line" of critical systems required to ensure GPS can operate. A graphical depiction of the GPS thin line is shown in the figure below.

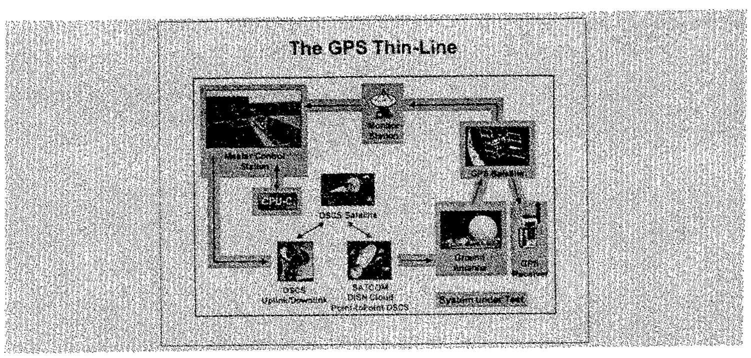

Figure 16 - GPS Operational Evaluation Thin Line

The initial official results of the first operational evaluation, conducted from April 23 to May 1, 1999, are expected to be available in mid-May.

GPS Summary

The Department of Defense is making excellent progress on all fronts related to GPS and Year 2000 compliance. The bottom line is the GPS mission will continue through EOW and Y2K. We do not anticipate any "show stoppers" to occur resulting in disruption of this crucial navigation and time-keeping capability.

Conclusion

The Department of Defense will be prepared to execute its national security responsibilities before, on, and after January 1, 2000. The Department's comprehensive systems compliance efforts, operational evaluations and end-to-end testing, and systems and operational contingency plans are being developed and executed within a solid management structure. All Year 2000 efforts are receiving the personal attention of the Department's senior leadership. Finally, these efforts are being rigorously scrutinized by independent auditors, including the Department's Inspectors General and the General Accounting Office.

The Year 2000 problem is one of enormous scope and complexity for the Department of Defense, which has over 1/3 of the Federal Government's mission critical systems. Despite this challenge, the high percentage of systems compliance already achieved, combined with the results of end-to-end and operational evaluations already conducted and system contingency plans already tested, provides a high degree of confidence the Department will be able to execute the national military strategy unimpeded by Year 2000-related problems.

Office of the Assistant Secretary of Defense **OASD C3I** Command, Control, Communications, & Intelligence ASD C3I

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Marvin Langston

Deputy Assistant Secretary of Defense (DASD) for CIO Policy & Implementation, Deputy CIO

Dr. Marvin J. Langston was appointed the Deputy Chief Information Officer of the Department of Defense on 2 June 1998. In this capacity, he serves the DoD CIO, Mr. Arthur Money, in all functions related to the 1996 Information Technology Management Reform Act. His primary role is facilitating information technology enabled process change throughout the Department.

Prior to this assignment, Dr. Langston served as the Director of the DARPA Information Systems Office from October 1997 to June 1998. As the Director of the ISO, he managed projects to include sensor exploitation, advanced simulation, networked infrastructure, automated command support, and related core technology developments.

From 1994 to 1997, Dr. Langston served as the acquisition Deputy Assistant Secretary Navy for C4I (command, control, communications, computers and intelligence), DASN (C4I), and as the first Chief Information Officer (CIO) for the Department of Navy (DON). This position involved acquisition oversight of space systems, ballistic and cruise missile defense, communications, information assurance, electronic warfare, information technology, network systems, and the stand-up of the DON CIO organization.

Dr. Langston, a native of Salt Lake City, Utah, began his career with the Navy in 1966 as a Seaman Recruit. Through Navy education programs he received a bachelor's degree in Electrical Engineering from Purdue University and was commissioned an Ensign in 1973. After serving aboard U.S.S. America (CV 66) and converting to Engineering Duty, he attended the Naval Postgraduate School, receiving a master's degree in Electrical Engineering in 1976. His career as a naval engineering duty officer spanned assignments associated with surface ship combat direction, weapons, command and control, and space systems.

Following his naval career, Dr. Langston joined the staff of the Johns Hopkins University Applied Physics Laboratory in 1988, where he worked on space-based surveillance and communications, tactical datalinks, advanced cruise missiles, sea-based ballistic missile defense, and strategic planning.

He also holds a doctorate in Public Administration from the University of Southern

California, where he teaches part time.

(Current as of November 1998)

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Chairwoman MORELLA [presiding]. Thank you, Dr. Langston. It is very encouraging.

I wanted to take this moment just to thank Congressman Ose who took the Chair before I got here and, also, to point out that we have with us Congressman Rohrabacher, who is the Chair of the Space Subcommittee; Mr. Turner, who is the Ranking Member on the Government Reform Subcommittee, that is doing this hearing with us jointly, Government Management, Information, and Technology; Mr. Gutknecht, who is the Vice Chair of this Technology Subcommittee; Mr. Ehlers was here and will be returning; and Mr. Miller.

And we will now proceed with you, Mr. Helm, and then Mr. Rhodes, and then I will have a statement I'd like to make.

So, Mr. Helm, you're up.

TESTIMONY OF NEIL R. HELM

Mr. HELM. Thank you.

Chairpersons, subcommittee members, I am Neil Helm; I'm Chair of the Satellite Communications Standards Committee of the American Institute of Aeronautics and Astronautics. I am also Senior Research Scientist at the Institute of Applied Space Research, at the George Washington University, but I'm here today testifying before the joint Committees as a representative of the AIAA.

We are a nonprofit society of over 35,000 aerospace professionals. Because the AIAA represents such a broad spectrum of the aerospace community, it does not reflect the single viewpoint of a single company or constituency, but provides a balanced spectrum of the profession as a whole.

We commend the members of these Committees for holding this hearing as the Y2K problem is creating fears and indecisions in our commerce and society.

Many people don't realize how this all started. Some 30 years ago, computer programmers were working with very limited memories and capacities, and they were really pushed to eliminate a lot of redundancies in especially the headers in satellite programs. And so they eliminated the 1900 first two numbers, the dates, as a redundancy, as a lot of us sign our memos or notes with just the last two letters of the year, and that is how this started. Possibly we should have picked up this programming shortcut earlier for its ramifications to the calendars, the 2000 one, these last two digits, perhaps may give ambiguous directions, and the operating systems, in fact, may stop. But the Y2K problem is now understood in the developed world. Unfortunately, the cost of reviewing and correcting all this code is staggering.

As a university scientist who has followed the Y2K problem since pretty much its beginning, I bring up a positive statement to you today. I believe the U.S. commercial space community is diligent, responsible, and doing an outstanding job to ensure that the systems will be fully 2000 compliant.

I believe there will be some minor outages outside of the space community. These outages will be more disturbing in the developing world where much of the system software was pirated from mixed and largely unknown sources. Therefore, the work of your committees on evaluating the level of commitment and compliance is extremely important. I also hope that you can provide a level of assurance to our society that the Y2K problem should not greatly affect our everyday activities.

One of my major research activities in 1997 and 1998 was as a panelist in a very large study for NASA and the National Science Foundation. We were panelists in this study from industry, academia, and Government. We went to some 61 satellite manufacturers, service providers, R&D laboratories in 14 countries in the United States, Europe, and Asia. One of the inquiries of our study was on this Y2K compliance. And I will quote from our report.

"The Year 2000, or as it is typically called, the Y2K problem, has not gone unnoticed in the satellite community. Several transponder service providers have studied this and stated that there will not be an affect. Satellite manufacturers also believe that there are no known problems since the dates are not included in any of the onboard software or firmware. The Global Positioning System satellites are Y2K compliant and the support systems will be complaint before the Year 2000. If there is a satellite Y2K problem, it will probably originate in the Earth stations. Of concern is the software that controls the satellites, and this is being studied in great details. Another area of concern is the end-user network software; however"—and I put in that "however"—"all public announcements by these service providers indicate that they will be Y2K compliant."

I have added in my statement letters from Lockheed Martin. After my research, I followed up with these major companies to see what their status is today. I have major letters from Lockheed Martin and from Loral that are part of the record which say that they are on top of the Y2K compliance. They feel that all of their systems under their control will be compliant within the time. Most of them will issue it—a compliance letter by perhaps the third quarter of this year.

In summary, the problem is real, and I would be misleading if I were to say that the problem is not real. There was one manufacturer, TRAK Microwave, in Tampa, Florida, that makes GPS receivers. And I believe that TRAK is a very good and responsible company, but a number of those receivers are not Y2K compliant. And I have tracked down their web page where they now go into quite some detail on what models are not compliant and what models are and how their customers can bring about working with the manufacturer to make their equipment compliant.

So in summary, the Y2K problem has been examined by the commercial satellite community. The results of the examination indicate that spacecraft onboard timing clocks will not be a problem. There may be some Earth-to-ground problems, but they're being very diligently looked at. If there are minor problems, they will be outside of the space community. They probably will be in the developing world, and I think that is the worst that we can look at.

I would again like to thank the Committee for holding these important hearings and look forward to answering any questions you may have.

[The statement of Mr. Helm follows:]

Statement to
Subcommittees of
House Committee on Science and
House Committee on Government Reform

On

Y2K in Orbit: Impact on Satellites and the Global Positioning System

By Neil Helm
Chair, Satellite Communications Standards Committee
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Ste 500
Reston VA 22091

May 12, 1999

INTRODUCTION

Chairpersons, subcommittee members, I am Neil Helm, member of the American Institute for Aeronautics and Astronautics's Technical Committee on Communications Systems. I am also a senior research scientist at the Institue for Applied Space Research at the George Washington University. Today, however, I am testifying before this joint-committee as a representative of the AIAA. The AIAA is a nonprofit professional society of over 35,000 aerospace professionals whose mission is to advance the arts, sciences, and technologies of aerospace. Our viewpoint is based primarily on the technical considerations that underlie policy decisions concerning the U.S. civil aeronautics and space programs. Because the AIAA represents such a broad spectrum of the aerospace community, it does not reflect the viewpoint of a single constituency, but provides a balanced perspective of the profession as a whole. We commend the members of these three House subcommittees for holding this hearing, as the Y2K problem is creating fears and indecision for our commerce and society.

BACKGROUND

Nearly thirty years ago, computer programmers were working with limited memories and capacities, and were instructed to eliminate as many redundancies as possible. Thus, the first two letters of calendar clocks were deemed to be redundant, and were shortened to only the last two numbers of the year, as is commonly done in our correspondence, memos and notes today. Possibly this programming shortcut should have been recognized earlier for its ramifications to calendars for the year 2000 when the two 00 letters may give ambiguous directions or even cause the operating system to shut down for lack of an acceptable time stamp. This can basically be attributed to the traditional lack of communications between software programmers and hardware systems and equipment engineers. Certainly, the Y2K problem is now understood in the developed world; but unfortunately, the costs of reviewing and correcting all the software and firmware codes are staggering. As a university scientist who has followed the Y2K problem since it was first announced, I bring a positive statement to this hearing. I believe that the US commercial space community is diligent, responsible, and doing an outstanding job to ensure that its systems will be fully year 2000 compliant. However, I believe that there may be some minor system outages outside of the space community. These outages may be more disturbing in the developing world, where much of their systems software was pirated from mixed, largely unknown sources. Therefore, the work of your committees on evaluating the level of commitment and compliance is extremely important. In addition, I hope you can provide a level of assurance to our society that the Y2K problem should not greatly affect the activities of everyday life.

Y2K RESEARCH

One of my major research activities in 1997 and early 1998 was as an active panelist in the conduct of a major study for NASA and the NSF entitled "Global Satellite Communications Technology and Systems." Our panel, composed of experts from industry, academia and government, conducted interviews with 61 satellite manufacturers, service providers and R&D laboratories, in 14 countries in North America, Asia and Europe. One of the inquiries we made in our visits concerned compliance with the Y2K problem. I will provide a quotation on our Y2K inquiries from our report dated December 1998, and ask that this report be added to the record.

"The year 2000, or as it is typically called, the Y2K problem, has not gone unnoticed in the satellite community. Several transponder service providers have studied this and stated that they will not be affected. Satellite manufacturers also believe that there are no known problems since the dates are not included in any of the onboard software or firmware. The Global Positioning System satellites are Y2K compliant and the support systems will be compliant before 2000. If there is a satellite Y2K problem, it will probably originate in the earth stations. Of concern is the software that controls the satellites, but this is being studied in great detail. Another area of concern is the end user networking software. All public announcements by the service providers indicate that they are Y2K compliant."

When I was asked to provide this testimony, I contacted officials from many of the US satellite manufacturers. The results of these inquiries, which I will detail to some extent in this testimony, are that the US satellite manufacturers are completely knowledgeable about the Y2K problem, and that they are all conducting rigorous compliance programs comprising the following areas: awareness, assessment, renovation, validation, implementation and post-implementation and testing if required.

First, the companies have confirmed that all spacecraft onboard clocks are "timing" clocks, usually in parts of one second. These clocks may have an epoch or reference date, but the clocks do not normally reference calendar dates. Further, all the spacecraft clocks can be tested and changed. Therefore, I am happy to report to the subcommittees that there is a high level of industry confidence and assurance that there will be no spacecraft failures due to the Y2K problem.

LOCKHEED MARTIN LETTER

This assurance can be seen in the following example, taken in part from a letter from the Manager of Contracts of the Lockheed Martin Commercial Space Systems company dated February 9, 1999, to the Contract Manager of one of its customers, Societe Europeenne des Satellites, Grand Duchy of Luxembourg.

"The following satellite systems have been identified as having been delivered to your Organization and/or are being operated by your Organization:

SES ASTRA-1A
SES ASTRA-1B

Our evaluations indicate that the flight software for our Series 3000, 4000, 5000, 7000 and A2100 Satellites are not subject to Y2K problems since the various on-board clock systems do not use a representation of a calendar date for operation.

· *The flight software for our Series 3000, 4000 (Astra-1A) and 5000 (Astra-1B) satellites uses assorted software-maintained clocks and timers (e.g. for time dependent roll and pitch offsets), all of which use times in some multiple or fraction of seconds, counted down from the single 1024Hz interrupt in the RCA 1802-based flight computers. As such none of these clocks contain any representation of a date.*

· *Flight software of Series 7000 and INMARSAT 3 Series of Satellites (not a S7000, but has the same processor and software/interface architecture as a S7000) also have software-maintained clocks. A clock-calendar package is in the run-time software, but only the clock time in seconds is used in the flight software, i.e. the date is not set or used by the flight code. There is a day number within the flight software for INTELSAT VIII, but it is a count of days derived from the spacecraft clock, not a date.*

· *The spacecraft clock in the A2100 flight software is a count of seconds before the Julian 2000 epoch (noon on 1/1/2000). The standard Y2K issue of representing the current year as two digits only does not apply to the A2100 flight software. Since the on-board computer OBC clock is seconds before J2000, the time is currently a negative number and will roll over to a positive number on 1/1/2000. Flight software testing has been performed with the OBC clock set to both negative and positive times and is being actively used on-orbit on the four operational A2100 spacecraft with the current (negative time).*

· *While the flight software of our satellites is not subject to the classic Y2K two-digit year problem you should be advised that ground-based flight software development tools that may have been delivered under your contract might be susceptible. Series 7000, INMARSAT and A2100 satellite systems have re-programmable flight computers and as such their flight software compilers and test beds may, or may not, have Y2K issues."*

This letter demonstrates that Lockheed Martin has taken the responsibility to inform its customers, US and non-US, of its analysis of the Y2K problem. It provides assurance to its customer that there are no problems in the space segment. The letter continues to inform its customer of potential ground segment problems and promises to work with the customer to assure compliance.

is seen in the figure below, which displays the contingency planning efforts of the Defense Finance and Accounting Service.

Y2K CONTINGENCY PLANNING

Defense Finance & Accounting Service

Mission Critical (MC) Systems

- **41 of 41 MC systems contingency plans prepared**

Operational Contingency Plans

- **Over 1700 plans (24 locations, 18 core/core support processes, 13 types of contingency/continuity of operations plans)**
- **Tests/exercises**
  - **CJCS Positive Response exercises**
  - **DoD table-top Y2K "War Game" exercises**
  - **Conducting paper tests**
  - **Tabletop tests--April 30, 1999**
  - **Live tests--May - Dec 1999**

Figure 6 - Contingency Planning at Defense Finance and Accounting Service

Core missions and capabilities not addressed by the CINCs or PSAs are bridged by Year 2000 contingency plans developed by the various activities charged with those missions. For example, each Military Department is responsible for "training, organizing, and equipping" its Department. Each Military Department has a series of business activities to perform these core missions and functions.

In summary, through a designed overlap of individual system contingency plans, CINC warfighting contingency plans, PSA functional contingency plans, and Military Department mission and functional contingency plans DoD achieves an overall collective organizational contingency plan.

Satellites and the Global Positioning System

Categories of space based systems

The Department of Defense operates a variety of space based (satellite) systems for many different functions. The functions using satellite systems include communication, intelligence

LORAL LETTER

I would now like to share with the Committee members a letter from Loral Space & Communications Ltd. This letter addressed to me, dated April 30, 1999 is from Mr. Barry Goldfeder, Loral's Corporate Director of Information Technology and Telecommunications. I quote in part:

"... Loral and its operating divisions are committed to ensuring that our customers suffer no interruption or degradation of service from Loral as a result of the critical millennium change period.

To this end, Loral has established a Year 2000 Task Force reporting to the President of the corporation, consisting of program managers from each operating division. It is the responsibility of this Task Force to implement Loral's formal Year 2000 Compliance Plan.

Loral has established a seven-phase strategy to become Year 2000 compliant. In short, it consists of the following:

- *Awareness of the importance of achieving Year 2000 compliance;*
- *Inventory of hardware, software, and firmware services;*
- *Assessment of the potential impact due to Year 2000-induced failures;*
- *Remediation as necessary of affected software and hardware;*
- *Implementation of corrected systems;*
- *Validation of replaced or corrected systems; and*
- *Continued vigilance and vendor compliance.*

At this point in time, Loral's Year 2000 program goals have been outlined and are being incorporated into our Year 2000 program Compliance Program Plan. Currently, we have target dates for each major step in the process of assessing Loral's Year 2000 Compliance.

Divisional inventories (both ground and space segment inventories) were substantially completed by February 28, 1999. Testing, modifying and replacing (if necessary) equipment are scheduled to be completed by the third quarter of 1999. Divisional audits commenced in January of 1999.

Upon completion of the Year 2000 compliance program, Loral will publish a Year 2000 Compliance Statement."

Again, the Committee members can see that a substantial level of commitment has been made by this US space vendor. Loral is providing a statement of compliance that will give full confidence to the users of its communications and information systems.

THE Y2K PROBLEM IS REAL

I would be misleading the members of the subcommittees if, in providing this positive information on behalf of the AIAA and the commercial satellite communications community, that I gave the impression that the Y2K problem is not a real problem. The ground terminal manufacturers and systems and software providers are finding software and timing products that need to be changed or replaced. I believe the US industrial community is working responsibly to resolve these problem areas.

I will provide the members with an example of a US company, TRAK Microwave, located in Tampa, Florida that makes timing mechanisms and systems for GPS receivers and other ground equipment. I believe that TRAK is a responsible company, but its early-designed and manufactured equipment has shown itself to be non-GPS Week Rollover and Year 2000 compliant. The DOD statement provided today goes into the GPS Week Rollover in much more detail, but suffice it to say that when the GPS system clocks were started on January 6, 1980, they were set for 1,024 weeks or 7,168 days. Therefore on midnight August 21 to August 22, 1999, the GPS message rolls over from 1023 to 0000. A number of receivers, including some models built by TRAK, will not be able to function properly after this rollover.

SOLVING THE PROBLEM

TRAK has made an analysis of all its equipment and has made a responsible effort to inform its customers regarding equipment that is not compliant to the GPS Rollover and the Year 2000 problem. I reference the TRAK web page policy announcement http://www.trak.com/traktime.htm that specifies what equipment will need modifications and how TRAK will accommodate these modifications. This is just one example of where the problem has been identified, assessment of the problem has been made, corrective methods have been recommended and information on these corrections has been provided to the customer.

CONCLUSIONS

The Y2K problem has been examined by the US commercial satellite communications vendors and service providers. The results of the examination indicate that because spacecraft onboard timing clocks are not referenced to calendar dates, there will be no space segment anomalies with the Year 2000 rollover. However, problems will be found in early designs of ground-segment equipment, both in the hardware and software. The major companies are currently addressing these problems with a rigorous compliance program, and are informing their customers if and when modifications need to be made.

The major satellite communications equipment and service providers have issued or are in the final preparations for issuing, compliance statements that provide a high level of confidence that the communications systems, including all hardware and software under their corporate control, will be year 2000 compliant. Some problems may exist outside the control of the major US companies, and the developing world may experience the worst of these problems. However, I do not believe that these problems will greatly affect our commerce or society. To that end, again, I would like to thank the committees for holding these important hearings and look forward to answering any questions you all may have.

BIO

Neil R. Helm
8000 Riverside Drive
Cabin John, Maryland 20818

Mr. Helm is the Deputy Director of the Institute for Applied Space Research of the School of Engineering and Applied Science, and Senior Research Staff Scientist in the Department of Electrical Engineering and Computer Science of the George Washington University. Prior to joining GWU in 1990, Mr. Helm was for six years the President of a Washington, D.C. consulting firm which provided technical systems and services, primarily in the satellite communications field. One 18-month project included being the Principal Investigator for the final integration, testing, launch, and in orbit demonstration of a DOD experimental satellite. From 1967 to 1984, Mr. Helm was employed at Comsat and Comsat Laboratories where he held technical and management positions including the Director of Marketing for the Systems Technology Services division. Mr. Helm is a Member of the International Academy of Astronautics, an Associate Fellow of American Institute of Aeronautics & Astronautics and Chair of its Satellite Communications Standards Committee. He is a Senior Member of the Institute of Electrical and Electronics Engineers and Chair, 1997-98 of Aerospace R&D Policy Committee. Mr. Helm is a Charter Member of the Society of Satellite Professional International and President of its Mid-Atlantic Chapter, 1989. He is on the editorial board of Satellite Communications, an international journal. Mr. Helm received a BSFS degree from Georgetown University, Washington, D.C. in 1966.

The George Washington University
WASHINGTON DC

INSTITUTE FOR APPLIED SPACE RESEARCH

May 12, 1999

Congressman Sensenbrenner
Chairman, Committee on Science
US House of Representatives
Washington, DC 20515

Dear Congressman Sensenbrenner:

I am asked to provide expert testimony on the impact of the Year 2000 problem on satellites and the Global Positioning System to the Science Committee's Subcommittee on Technology and the Committee on Government Reform's Subcommittee on Government Management, Information, and Technology.

As requested under the rules governing testimony, I need to inform you of any government contracts that may have financed my testimony. I acknowledge that I have a NASA contract at the Goddard Space Flight Center through the Center for Earth Science Data Information Systems (CESDIS) that is approximately $70k for FY99. However, all the research in that contract is in the area of communications satellite systems and no task or reference in the statement of work of that contract addresses the Y2K problem. I will not charge this NASA contract with any research that I have conducted in preparing for this testimony.

Sincerely,

Neil Helm
Deputy Director

SCHOOL OF ENGINEERING AND APPLIED SCIENCE
2033 K STREET, N.W. • WASHINGTON, DC 20052 • (202) 994-5509 • FAX (202) 994-5505

Chairwoman MORELLA. Thank you, Mr. Helm.

We now look forward to hearing from Mr. Keith Rhodes of GAO.

TESTIMONY OF KEITH RHODES

Mr. RHODES. Thank you, Chairwoman Morella, members of the Subcommittees. Thank you for inviting me to participate in today's hearing on the Year 2000 problem and its impact on the Global Positioning System.

In addition to being the Department of Defense's primary radio navigation system, GPS has become an integral asset in numerous civilian applications and industries. It also plays a critical role in communications networks and, hence, the Internet. The system is affected by both the Year 2000 computing problem and a problem associated with the way the system keeps track of time, commonly referred to as the "end-of-week rollover."

Today I will discuss these two important issues, their potential impact, and the status of remedial efforts.

As you've heard, GPS was designed to support military missions such as missile guidance and search and rescue and consists of 24 operational satellites which Defense began launching in 1978 and started using in 1980. The system became fully operational in 1995. However, since anyone using a GPS receiver can determine his or her location with great precision, GPS is now used in numerous civilian applications and industries. Additionally, telecommunication companies are increasingly relying on GPS receivers to synchronize their own networks.

GPS is affected by both the Year 2000 computing problem and an upcoming end-of-week rollover. The upcoming end-of-week rollover is a problem that will occur for the first time on August 21, 1999. It is actually Greenwich Mean Time changed midnight between August 21 and August 22. Instead of using calendar dates, GPS counts weeks and seconds within weeks from precise clocks on the satellites. This is based on how the signal codes transmitted to the satellite are generated. GPS started at week 0 on January 6, 1980. Because of its design, the GPS time counter starts over after counting 1,024 weeks. They can't count 1,025, so it goes back to 0. The end of the 1,024th week will occur for the first time on August 21, 1999.

There are three components to GPS, as Dr. Langston pointed out: The space component, ground component, and user component.

The space component of GPS includes the satellites, themselves, which, according to the Air Force Materiel Command, the executive agent for the Department of Defense in acquiring GPS satellites, are both Year 2000 compliant as well as end-of-week rollover compliant. The space component also includes satellite support systems which are physically located on the ground.

Chairwoman MORELLA. Mr. Rhodes, excuse me, but evidently we are having technical difficulties with the sound system. While we are resolving that problem, if you don't mind, I will just give my opening statement, and then we will ask you to continue when we have the sound system back.

MS. MORELLA'S OPENING STATEMENT

Today our House Y2K Working Group, made up of the Technology Subcommittee and the Government Management, Information, and Technology Subcommittee, is holding the first House hearing on the impact of the Year 2000 computer on the satellites that orbit above us in space.

I am pleased to once again, join with my distinguished colleague, Mr. Horn of California, in our series of ongoing Y2K hearings.

Since this Y2K issue is one of natural interest to the Science Committee's Space Subcommittee, chaired by Congressman Rohrabacher of California, their members have also been invited to attend this hearing, and I welcome their participation.

Currently, we rely on satellites to do so much in these modern, technologically advanced times. And as we prepare to enter the 21st century, satellites will be playing an ever-increasing role in the new millennium.

Satellites enhance our quality of life, provide for our national security, and allow us to learn about distant galaxies and, in so doing, learn more about ourselves and our own universe. They provide us with capabilities for navigation, military applications, intelligence gathering, telecommunications, television, and space exploration, among many others.

For example, some of the most important satellites include Marine 4, which showed us what the surface of Mars really looked like; the Venus Magellan satellite, which mapped out the surface of Venus; the Hubble Space Telescope, which has revolutionized astronomy and our understanding of the most distant universes and black holes; the Voyager spacecraft which gave us our first good looks at the outer planets and many of their moons; and the soon-to-be 28 fully operationally orbiting satellites of the Global Positioning System constellation that has allowed for pinpoint navigational accuracy for both military and commercial applications.

All we need to fully understand the importance of satellites in our modern lives is to recall the disruptions and frustrations resulting from a recent satellite failure this past year that rendered cellular phones inoperable, shut down paging systems, and created a telecommunications chaos that caused business interruptions estimated to be in the millions of dollars.

While the satellite failure was not Y2K related; the example gives us a glimpse into a possible catastrophic scenario should Y2K disable our Nation's satellite system. We are getting a little mini example of something that is not catastrophic but poses a problem.

Today's testimony indicates that a majority of our Y2K concerns affecting satellites are not about the satellites, themselves, either its physical hardware or that any satellite is going to fall out of the sky on January 1, 2000, and come crashing down to Earth, but rather that the ground stations that operate our network of satellite systems may be affected by the millennium bug.

Since, apparently, timers on board the satellites do not keep track of calendar dates, there are no date-dependent elements provided in most satellite and spacecraft hardware. The computers running those satellite networks, however, could be Y2K vulnerable, since those networks rely on computers that are controlled by thousands of software programs and millions of lines of programming code.

Of all satellite systems, it is believed that the GPS system may be the most vulnerable to malfunction because GPS satellites will endure double difficulties in the last 14 weeks of the year, as a result of Y2K and, as has been mentioned, the August 23, 1999, rollover and reset to zero of the GPS timing mechanism.

I am pleased that the United States Space Command has taken the lead in addressing these concerns and conducted a recent series of successful tests on the GPS system, of which, you know, Dr. Langston has given us good information.

The panel is very distinguished, helping us to address the GPS system, as well as our other satellite concerns.

So I thank you all by way of thanking this distinguished panel for sharing with us.

Chairwoman MORELLA. I think now we might be able to continue now. If you want to start a little bit ahead of where you ended——

Mr. RHODES. Okay.

Chairwoman MORELLA [continuing].—That would be splendid.

Mr. RHODES. All right.

While the satellite support systems——

Chairwoman MORELLA. So you are going to get the full 5 minutes.

Mr. RHODES. I get the full 5 minutes?

Chairwoman MORELLA. Right.

Mr. RHODES. While the satellite support systems are end-of-week rollover compliant, as Dr. Langston pointed out, some of the non-mission-critical tracking software are not yet Year 2000 compliant. Air Force Materiel Command reports that these systems are in process of being either replaced or renovated and tested. The work is expected to be done by December of this year, and workarounds have also been developed for systems being replaced.

The GPS control, or ground component, consists of a master control station, five monitoring stations, and three ground antennas located throughout the world which, according to Air Force Materiel Command, are now both Year 2000 and end-of-week rollover compliant. Contingency plans are also in place for these systems.

The user component consists of receivers, processors, and antennas that allow land, sea, or airborne operators to receive GPS satellite broadcasts and compute their precise position, velocity, and time. According to Air Force Materiel Command, many newer GPS receivers, including all designed procured for the Department of Defense by the GPS Joint Program Office, have been tested and have demonstrated that they are Year 2000 compliant and end-of-week rollover compliant. According to the U.S. Coast Guard Navigation Center, however, the accuracy of navigation on some older receivers may be severely affected by the end-of-week rollover.

Several activities are ongoing to raise awareness among owners of older GPS receivers of the upcoming end-of-week rollover problem. The U.S. Coast Guard Navigation Center has been assigned with responsibility of being the Government liaison to the civil sector for GPS. Its Internet website explains the potential rollover problem on older receivers and provides an extensive list of manufacturers and points of contact. The Air Force has provided a list, also available on the Internet, of specific receivers that have been tested and found to be compliant by the Department of Defense. Furthermore, the President's Council on Year 2000 Conversion's Internet site provides links to sources of GPS Year 2000 compliant—Year 2000 and end-of-week rollover information. These activities are important and should be useful to GPS users seeking to determine whether their receivers will operate correctly at the end-of-the-week rollover.

However, even with these awareness efforts, it is conceivable that some organizations and users may not even be aware that their GPS receiver could be vulnerable to the end-of-week rollover problem. Moreover, some may not be aware that they rely on a GPS receiver as a communications network tool. Because they contain precise clocks, GPS receivers are sometimes used to synchronize time in communications networks. Synchronization is critical to the transmission of compressed or packetized voice, data, and video transmissions. Timing errors due to the lack of synchronization, in fact, can lead to data loss and degradation, and eventually to network disruption or even complete failures. Because of the interconnective and interdependent nature of networks, these problems, in turn, could impact other networks and even the Internet.

As a result, it is vital that organizations make an effort to, one, determine whether the networks they operate rely on GPS equipment as a time source and, two, determine the potential GPS-related risks. Once the problem and its potential impact are known, organizations and individual users can modify the receivers, replace them with newer models, or contact their service providers to ensure that GPS receivers supporting their telecommunications networks are not susceptible to the upcoming end-of-week rollover. Because the rollover is less than 4 months away, however, organizations must take these measures as quickly as possible.

Chairwoman Morella, and, members of the subcommittee, that concludes my testimony. I would be happy to answer any questions you or the Subcommittee members have.

[The statement of Mr. Rhodes follows:]

United States General Accounting Office

GAO

Testimony

Before the Subcommittee on Government Management, Information, and Technology, Committee on Government Reform and the Subcommittee on Technology, Committee on Science, House of Representatives

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YEAR 2000 COMPUTING CHALLENGE

Time Issues Affecting the Global Positioning System

Statement of Keith A. Rhodes
Technical Director, Office of Computers and Telecommunications
Accounting and Information Management Division

Mr. Chairman, Madam Chairwoman and Members of the Subcommittees:

Thank you for inviting me to participate in today's hearing on the Year 2000 problem and its impact on the Global Positioning System (GPS). In addition to being the Department of Defense's primary radionavigation system, GPS has become an integral asset in numerous civilian applications and industries, including emergency services, airlines services, commercial fishing and shipping, corporate vehicle fleet tracking, and surveying. It also plays a critical role in communications networks and, hence, the Internet. The system is affected by both the Year 2000 computing problem and a problem associated with the way the system keeps track of time.[1] Today, I will discuss these two important issues, their potential impact, and the status of remedial efforts.

GPS, THE YEAR 2000 PROBLEM, AND THE END-OF-WEEK ROLLOVER PROBLEM

GPS was designed to support military missions, such as missile guidance and search and rescue. The system consists of a constellation of 24 operational satellites which are positioned so that system users can receive signals from at least 6 satellites nearly 100 percent of the time at any point on earth. The satellites are constantly monitored by ground stations located throughout the

[1] Instead of using calendar dates, GPS counts weeks, and seconds within a week, from precise clocks on the satellites. GPS started at week zero on January 6, 1980. Because of its design, the GPS time counter starts over after counting 1024 weeks. The end of the 1024th week will occur, for the first time, on August 21, 1999. This is known as the end-of-week rollover problem in the GPS community.

world. Anyone using a GPS receiver can determine their location with great precision. Defense began launching GPS satellites in 1978 and started using the system in 1980. The system became fully operational in 1995.

GPS is now used in numerous civilian applications and industries. For example, emergency vehicles use GPS to pinpoint destinations and map routes; shipping companies use the system to track movement of their vessels; truck and transportation services use the system to track their fleets and to speed deliveries; and airlines use GPS to develop flight plans and to land planes. GPS is also being used to map roads, track forest fires, assist in construction projects, and even monitor earthquakes. Additionally, telecommunications companies are increasingly relying on GPS receivers to synchronize their own networks, comparing their reference clocks directly with a GPS receiver.

GPS is affected by both the Year 2000 computing problem and an upcoming end-of-week rollover. The Year 2000 computing problem is rooted in the way dates are recorded and computed in many computer systems. For the past several decades, systems have typically used two digits to represent the year, such as "97" representing 1997, in order to conserve on electronic data storage and reduce operating costs. With this two-digit format, however, the Year 2000 is indistinguishable from 1900, 2001 from 1901, and so on. As a result of this ambiguity, system or application programs that use dates to perform calculations, comparisons, or sorting may generate incorrect results when working with the years after 1999.

The upcoming end-of-week rollover is a problem that will occur for the first time on August 21, 1999. Instead of using calendar dates, GPS counts weeks, and seconds within a week, from precise clocks on the satellites. This is based on how the signal codes transmitted by the satellite are generated. GPS started at week zero on January 6, 1980. Because of its design, the GPS time counter starts over after counting 1024 weeks. The end of the 1024th week will occur, for the first time, on August 21, 1999. This is known as the end-of-week rollover problem in the GPS community.

I will now discuss the potential impact of the Year 2000 problem and the upcoming end-of-week rollover on each of the three GPS components—space, control, and user—as well as the status of remedial efforts.

Space Component

The space component of GPS consists of 24 operational satellites in 6 orbits at approximately 11,000 miles above the earth. The satellites transmit radio signals that permit adequately equipped users to calculate position, velocity, and time anywhere on or above the earth's surface and in any weather condition. They are equipped with very precise clocks that keep accurate time to within three nanoseconds. According to the Air Force Materiel Command (AFMC), the executive agent for the Department of Defense in acquiring GPS satellites, all GPS satellites are Year 2000 compliant as well as end-of-week rollover compliant.

The space component also includes satellite support systems, which are physically located on the ground. These systems are responsible for maintaining the satellites and their proper functioning. This includes keeping the satellites in proper orbits (called station keeping) and monitoring satellite subsystem health and status—e.g., monitoring solar arrays, battery power levels, and propellant levels, and activating spare satellites, if possible. While the satellite support systems are end-of-week rollover compliant, they are ***not*** yet Year 2000 compliant, according to AFMC. AFMC reports that these systems are in the process of being either replaced or renovated and tested. This work is expected to be done by December 1999. Workarounds have also been reportedly developed for systems being replaced.

Ground Component

The GPS control, or ground, component consists of a master control station, five monitoring stations, and three ground antennas located throughout the world. The monitoring stations track all GPS satellites in view and collect ranging[2] information from the satellite broadcasts. The stations send this data to the master control station, which computes precise satellite orbits. This information is then formatted into updated navigation messages for each satellite and transmitted to each satellite through the ground antennas, which also transmit and receive satellite control and monitoring signals. These systems are interconnected through networks and also have their own information systems and equipment which must be renovated for Year 2000 compliance. According to AFMC, the ground support systems are now both Year 2000 and end-of-week rollover compliant. Contingency plans are also in place for these systems.

User Component

The user component consists of receivers, processors, and antennas that allow land, sea, or airborne operators to receive the GPS satellite broadcasts and compute their precise position, velocity, and time. According to AFMC, many newer GPS receivers, including all designs procured for the Department of Defense by the GPS Joint Program Office, have been tested and have demonstrated that they are Year 2000 compliant and end-of-week rollover compliant. According to the U.S. Coast Guard Navigation Center, however, the accuracy of navigation on some older receivers may be severely affected by the end-of-week rollover.

[2] Distance from a receiver to the satellites.

ACTIVITIES ONGOING TO RAISE AWARENESS OF PROBLEM WITH OLDER RECEIVERS

Several activities are ongoing to raise awareness among owners of older GPS receivers of the upcoming end-of-week rollover problem. The U.S. Coast Guard Navigation Center has been assigned with responsibility of being the government liaison to the civil sector for GPS. Its Internet website explains the potential rollover problem on older receivers and provides an extensive list of manufacturers and points-of-contact. The Air Force has provided a list, also available on the Internet, of specific receivers that have been tested and found to be compliant by the Department of Defense. Furthermore, the President's Council on Year 2000 Conversion's Internet site provides links to sources of GPS Year 2000 and end-of-week rollover information. These activities are important and should be useful to GPS users seeking to determine whether their receivers will operate correctly at the end-of-week rollover.

However, even with these awareness efforts, it is conceivable that some organizations and users may not even be aware that their GPS receiver could be vulnerable to the end-of-week rollover problem. Moreover, some may not even be aware that they rely on a GPS receiver as a communications network tool. Because they contain precise clocks, GPS receivers are sometimes used to synchronize time in communications networks. Synchronization is critical to the transmission of compressed or packetized[3] voice, data, and video transmissions. Timing errors due to the lack of synchronization, in fact, can lead to data loss and degradation and eventually to network disruption or even complete failures. Because of the interconnective and interdependent nature of networks, these problems, in turn, could impact other networks and even the Internet.

As a result, it is vital that organizations make an effort to determine (1) whether the networks they operate rely on GPS equipment as a time source and (2) the potential GPS-related risks. Once the problem and its potential impact are known, organizations and individual users can (1) modify receivers, (2) replace them with newer models, or (3) contact their service providers to ensure that GPS receivers supporting their telecommunications networks are not susceptible to the upcoming end-of-week rollover. Because the rollover is less than 4 months away, however, organizations must take these measures as quickly as possible.

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Mr. Chairman, Madam Chairwoman and Members of the Subcommittees, this concludes my testimony. I will be happy to answer questions you or Members of the Subcommittees may have.

(511155)

[3] Digital voice, data, and video transmissions are sent in packets or cells.

Keith A. Rhodes

BIOGRAPHICAL SKETCH

Mr. Rhodes has been Technical Director in AIMD's Office of the Chief Scientist for Computers and Telecommunications since January 1997, providing assistance throughout GAO on computer and telecommunications technology issues, and participating in reviews requiring significant technical expertise. Prior to assuming his current position, he served as Technical Assistant Director in the Chief Scientist's office, providing technical advice on a range of GAO assignments such as the year 2000 computer crisis, computer security, tax systems modernization, air traffic control system, and various weapon systems. Immediately before joining GAO in 1991, he was a supervisory computer scientist at Lawrence Livermore National Laboratory. His other work experience includes computer and telecommunications projects at Northrop Corporation and Ohio State.

Mr. Rhodes holds graduate degrees in computer engineering and engineering physics from Ohio State University and the University of California (Los Angeles), respectively. Throughout his career, he has garnered numerous awards and citations, and is a voting member of the Internet Engineering Task Force, a certified Professional Engineer, and Certified Computing Professional. He holds two patents and has authored articles on performance modelling of communication networks and computer architecture for several technical journals.

Chairwoman MORELLA. I thank you very much, and thank you for weathering that little glitch that we had.

I thank you all for being here; let me start off with Mr. Holcomb.

I read your testimony—didn't hear you state it actually—but I wonder if you might tell us how many satellites does NASA manage? And how much has NASA spent on Y2K-related computer issues?

Mr. HOLCOMB. We currently have approximately 38 satellites that we manage that are active at the moment, and of course we have International Space Station and Shuttle included in that.

Our expenditures, to date, for Y2K in total have been around $46–47 million. I can provide you an exact number. That is to date up until this point in time.

Chairwoman MORELLA. How much was that again? Forty-six to——

Mr. HOLCOMB. Forty-six to forty-seven million——

Chairwoman MORELLA. Million?

Mr. HOLCOMB [continuing]. Somewhere in that range.

Chairwoman MORELLA. That seems to be adequate?

Mr. HOLCOMB. It has been adequate. We've not included in that cost the replacement costs if we were going to upgrade hardware and so forth, so this is primarily the cost associated with remediating the code, correcting code that had to be fixed, and——

Chairwoman MORELLA. Did you redirect money?

Mr. HOLCOMB. We——

Chairwoman MORELLA. Or did you have a special allocation?

Mr. HOLCOMB. We, like I think all agencies, made priorities and made sure we put the funding into Y2K. We did not ask for any additional money for Y2K; this was all within the Agency's guidelines. We did not go after the supplemental funds that OMB had.

Chairwoman MORELLA. Okay.

How many contractors have you employed to work on Y2K? Do you have an idea?

Mr. HOLCOMB. I couldn't give you the exact number. It is quite a large number. Out of our about 150 mission-critical systems, I would say we may employ 40 or 50 separate contractors amongst those; some of them are sharing the same contractor.

Chairwoman MORELLA. And to what extent have your systems undergone independent validation and verification process?

Mr. HOLCOMB. We have—early on, we've had a lot of discussion, because we have an independent verification/validation facility in West Virginia that we—in fact, fairly uniquely have, as an Agency. We had it way before Y2K. We run all of our human-rated systems through that IV&V facility, so if we make a change to a very expensive piece of hardware—be it Shuttle, International Space Station, the EOS program, those systems—any change to that code is run through the independent verification/validation facility. So our Y2K tests were included in the independent tests that were run in that facility. So we've used that facility for our very expensive pieces of equipment, human-rated systems.

For systems, we do a risk-grade for systems that are not in that category. We don't necessarily go to an independent test group to do independent tests; we bring in auditors to validate that the tests were done.

Chairwoman MORELLA. You're doing end-to-end testing now?
Mr. HOLCOMB. Yes, we are.
Chairwoman MORELLA. When do you think you'll have those tests completed?
Mr. HOLCOMB. We expect all of our end-to-end tests to be completed by the end of June. We have already——
Chairwoman MORELLA [continuing]. By the end of June?
Mr. HOLCOMB [continuing]. By the end of June. We've conducted quite a number of significant ones. The Cassini program—we ran an end-to-end test basically from the satellite through the Deep Space Network, through our Control Center, and all the way to two PI's—one at Johns Hopkins in Maryland and one in England. We have already run several on the International Space Station, and we will be running more. And we've conducted several on the Shuttle.
We do have one—I will say we do have one end-to-end test in August that is planned. We have planned to put the Shuttle on the pad and run it down to 5 seconds with Y2K software in total in August.
Chairwoman MORELLA. Thank you.
I will get to the others later, but I'll just pick up on—Mr. Rhodes, you gave us that enumeration of things that needed to be done with the Global Positioning System, and I just wonder, do you see a role for the Federal Government in publicizing what needs to be done? You know, for consumers to have their GPS system-related receivers checked for, you know, end-of-week and Year 2000 compliance issues?
Mr. RHODES. Well, obviously, more information is better than no information. Currently, the Coast Guard has a web page set up, and they have a long list of receivers. The Department of Defense, through the United States Air Force, they have their web page set up, and, as I stated, the President's Council has pointers to both of those web pages.
The concern that I have is that, you know, with hearings like these, that the word will get out, but the more information that is available to people, just so they understand that GPS is not just for, you know, we are in our bass boat trying to find our nice fishing hole. It is not just a locator. A great deal of people are using it as a time source, because it is accurate to within 3 billionths of a second, so that is—a lot of networks, as they become faster and require greater precision, people are going out to there, because it is basically a very inexpensive source of timing.
So the more that the Government gets the information out, the better we will all be.
Chairwoman MORELLA. Of course you need technical, you know, publications and all to——
Mr. RHODES. Right.
Chairwoman MORELLA [continuing]. Also help out, in addition to the web pages, to refer people——
Mr. RHODES. Right.
Chairwoman MORELLA [continuing]. To the websites.
I thank you.
And I defer now with pleasure to the Chairman of the Space Subcommittee, Congressman Rohrabacher.

Mr. ROHRABACHER. Let me see if I get this right, Mr. Rhodes. Are you saying that this rollover problem which will happen in August, which sort of mirrors the problem of the GPS system that will come about in the Year 2000, will this or will this not disrupt the time—the people who are relying on GPS's for their time sequences?

Mr. RHODES. If their receivers are not end-of-week rollover compliant, then it will disrupt their time.

Mr. ROHRABACHER. But only on a receiver end?

Mr. RHODES. Right.

Mr. ROHRABACHER. Not on——

Mr. RHODES. Right.

Mr. ROHRABACHER. Not on——

Mr. RHODES. No, the satellites are not going to fall out of the sky. They won't loose their position.

Mr. ROHRABACHER. Well, they won't—but more importantly, they will not loose their precision time sequence?

Mr. RHODES. No, they will not. The satellites, themselves, will not have the problem. It is on the receiving end; it is on the ground segment, the—what you hold in your hand or what you have connected to your network is where the problem is. If that receiver is——

Mr. ROHRABACHER . Okay.

Mr. RHODES [continuing]. Say, older than 5 years, then you're probably going to have a timing problem.

Mr. ROHRABACHER. Okay. And from what I've heard today—actually it makes me much more confident than what I was before I came into the room. Everything seems to be rosy. I mean everybody is giving us this—I mean, what could be rosier than hearing that NASA spent $47 million—is that it?—making sure that everything is going to be okay, and we didn't even have to allocate anymore money to get that $47 million? That is, you know, further proof of the existence of God, as far as I'm concerned, as a miracle.

[Laughter.]

But let's go back then. From what I'm hearing, our systems are okay, but the problems are going to be in what the public has to take advantage of those systems. For example, one of the witnesses mentioned that perhaps the people who have pirated software—especially in Asia—[Laughter.]— will suffer considerably, and that is their problem. People who have pirated "surfware," certainly, they are going to have to pay the price one way or the other.

But let's go back to this rollover. What—is there—because we will get a glimpse of that in August of the problems that will take place later on. Tell me what is going to happen. If any of you would like to jump in on this. What are we going to see in August and September that is going to be—make us aware of this problem?

Mr. RHODES. Well, since there really is, in terms of the Department of Defense, you won't see anything. I mean things will keep on going as they are going, because the satellites aren't going to fall out of the sky, and the people who have the rollover compliant receivers——

Mr. ROHRABACHER. There won't be—you know, missiles won't land on the wrong targets and things like that?

Mr. RHODES. No.

[Laughter.]

As long as the map is new.

[Laughter.]

The—but in the civilian sector is where the concern is that I have, because the civilian sector—you know, you are talking about trying to get information out to a mass public. You are trying to get information out to people who are using a system in myriad ways.

Some of the receivers will give you bad location information. Some of the receivers will give you bad time. Some of them will just fail outright; they won't give you any data at all. They won't receive the signal from the satellite at all. So there will be—there will be a range of problems that we can't really gauge right now, because all we can do is lay out the potential for it. There is a potential that the networks—the networks aren't necessarily going to crash, but you won't be able to get the data that somebody is sending you. If they can't—if their network—they are trying to send you e-mail, and their network is synchronized to GPS, and their receiver isn't up to date, well, then their e-mail probably won't get out. Or if it does get out, it won't make any sense on your receiving end. Those are the level of network problems we are talking about.

Mr. ROHRABACHER. So we could have people in businesses with their own personal computers and their corporate computers might start in August and September experiencing some sort of a jumble?

Mr. RHODES. Right. You would start to see—what will probably happen is that you will see a great deal of network activity because they're trying—they are requesting a retransmission of the data because they can't organize the data that has been sent to them.

Mr. ROHRABACHER. How would you compare—if you were going to "guesstimate" the impact of that, how would it compare to the Chernobyl Virus that we just went through?

Mr. RHODES. Well, since I—in a sense, it is——

Mr. ROHRABACHER. A much greater effect?

Mr. RHODES. In——

Mr. ROHRABACHER. Or about the same or——

Mr. RHODES. In a sense, it may—it will probably follow the same kind of pattern that there will be awareness up front, and people will, close to the day, know what is going to happen. But, as you can see, no economies failed across the globe because of the Chernobyl Virus, and I don't think——

Mr. ROHRABACHER. Right.

Mr. RHODES [continuing]. Eonomies are going to fail because of the networks.

Mr. ROHRABACHER. And will the—well, sometimes personal economies are also important——

Mr. RHODES. Yes.

Mr. ROHRABACHER [continuing]. To people, you know.

[Laughter.]

Mr. RHODES. Yes. Organizations are desperately tied to their e-mail and networks.

Mr. ROHRABACHER. Right, and if—how correctable will—if we start seeing this rollover problem come into personal computers or commercial systems, how correctable will it be, and how difficult will it be to correct it?

For example, with the Chernobyl Virus, people had to go out and get some work done and get some kind of program to take care of the situation.

Mr. RHODES. Right.

Mr. ROHRABACHER. How correctable will it be?

Mr. RHODES. It is actually very correctable and easily correctable, assuming the supply chain is there. You see you have a problem; you realize that you have a timing error. You replace your receiver; you're done, and then you re-initialize your network; the network comes up as its synchronization and goes on. It is not that you have to go through every line of code. This is a single-point solution, or it is a known-point solution. You go in, replace either the firmware or a module or a device.

Mr. ROHRABACHER. Well, I wasn't joking earlier on—although I was joking, but it wasn't really joking, about when the microphones went off here a few minutes ago. I mean we have become so dependent on technology that we can't even talk to one another at this close range—[Laughter.]—without the assistance of some sort of a prosthetic device to make our voice sound stronger than they are.

So, throughout our society, we actually are using these crutches, and we don't even know they are crutches anymore. But all of you seem to be suggesting that the computer crutches that we are using are not going to let us down to the point that we are going to have any type of catastrophic or—let's put it this way, nobody is going to die because of this problem. Is that what we are hearing?

Mr. LANGSTON. Sir, if I could comment?

Mr. ROHRABACHER. Please.

Mr. LANGSTON. The Department of Defense is very concerned about the international ramifications of Year 2000 potential events.

Just as you point out, we have become enormously dependent on electronic supplementation in one form or another, and also we have become very interdependent as a global society, and, therefore, we believe that the interaction of our economic and commercial commerce processes throughout the world could be affected through this. And, likewise, we could have national security issues associated with instability, so, therefore, we are very concerned and working very hard to support international outreach as a part of John Koskinen's President's Council on Y2K for the defense sector, and as well support energy or other sectors to the degree that we can.

So, I do not believe that we can rest on our laurels because we, in the United States, have worked hard on this. I think we do need to worry about the outreach.

Mr. HOLCOMB. I would just add to Marv's comments. I think that—also, I serve on John Koskinen's committee. Very early on, he shifted the focus of that committee away from, say, the core activities of the Government to, what is the country doing, in general? More broadly, what is the world doing?

Not only is it an international issue, but there are issues of state and local communities. Some communities have not stepped up to this, and so, even within this country, there are likely maybe pockets of communities. Senator Bennett recently issued his report on

Y2K, and they found that medical offices have a tremendous problem of bringing up.

So I think that commerce, in general, not just international, but also even within the United States, there are pockets of areas where we should be concerned. It is not a totally solved issue. We've got to reach out and engage other parts of the community that maybe haven't become aware of this—profusely aware of what this might mean.

Mr. LANGSTON. I would just add to that. It is not the DOD's job to track county and local government activity, but my understanding is there is still a significant portion of our local county governments that have not stepped up to the correction of Year 2000 problems.

We worry about it in the Department of Defense from the support of local bases where we sit in outside communities and worry about those vital services coming into the base. And we continue to work with those communities to ensure that we will have those services.

Mr. ROHRABACHER. So perhaps we are talking about people not getting their water bill?

Mr. LANGSTON. We're more concerned in the context of—I'd like to categorize it as flow systems. If you think about money flow, food flow, oil flow, water flow—we have many control systems that are controlled with embedded chips, some of which—a small percentage of which have Year 2000 compliancies in them. If those flow systems back up a flow in any particular area, that flow has significant ramifications. And an analogy would be, how much disruption on a freeway does it take to back up a freeway? We all know it only takes one or two cars to significantly slow one down. Likewise, if a controller in a flow system, in one form or another, causes a slowdown, that will have significant backups in one form or another, and, of course, that is what Mr. Koskinen is preparing to support throughout this period of time.

Mr. ROHRABACHER. Okay.

Mr. Rhodes, will these possible disruptions that we are looking at, these flow problems and such, will they begin to start—will they start appearing in August and September because of the rollover problem? Is that what you are saying?

Mr. RHODES. Well, there will be some amount of disruption, but the real trigger date for what Dr. Langston and Mr. Holcomb are talking about is January 1, Year 2000.

For example, on the power grid, itself, there will be a test that is run on September 9 exercising the power grid. There will be exchanges of power. They will make certain that the interconnections are up and can run. And they will actually run some of the systems in date-forward situations.

But when you get to January 1, 2000, that is when you find out that, you know, the grid is up; the Nation has power, but you, locally, have a brownout condition, or you, locally, have a blackout condition because your main power provider doesn't provide power directly to your home. You know, you have some intermediary, and they aren't up to date.

And if you find, as Dr. Langston pointed out, if you find that there are embedded systems in that power flow control environment, either a SCADA system, a supervisory control and data acquisition system, then you could end up saying, "Yes, we, as a Nation, have power, but these local communities do not. Yes, we, as a Nation, have water, but some local communities have water problems." But those are mainly triggered on January 1, 2000.

Mr. ROHRABACHER. One last question and that is, then, what we are talking about is a timing system and it is actually in the little chip, itself?

Mr. RHODES. Right.

Mr. ROHRABACHER. You know I never did understand those things anyway.

[Laughter.]

I'll have to admit that is just mind-boggling to think about having timing mechanisms that are electrical impulses and something that we have constructed out of sand. And my hat's off to all the scientists and the physicists and the people who understand these things, who are able to do this for us.

And I hope that the picture is as rosy as you, guys, have painted it today, because I'm not as apprehensive as I was when I came into the room. So, thank you very much.

Chairwoman MORELLA. We've been joined by Mr. Larson, from Connecticut, and on the Subcommittee Chair of Government Management, Information, and Technology, of the Government Oversight Committee.

Did you want to—I could defer to Mr. Horn?

Would you like to have unwinding time?

Mr. HORN. No; I'm thoroughly wound up from the hearing I just came from, so——

Chairwoman MORELLA. We mentioned you were at a markup.

Mr. HORN. Yes——

[Laughter.]

Let me just ask one question that—or two here—that concerns us all, and we are going to be holding some field hearings on it.

So I guess my question is, to what extent have you back-up power generation for your satellites and ground systems in the event of a power outage and potentially damaging power surge?

That is what worries me more than a lot of the things that can happen in microchips; that when they happen there, they can have a major impact on our economy and just wipe out the communications, power, all of that, in a particular area.

What reaction do you have to that?

Mr. Holcomb.

Mr. HOLCOMB. We have, since the inception of the space program, had to deal with the anomalies of that nature. Most all of our systems—ground systems—have current provisions for backup power in them. A typical facility has a capacity of 2 weeks, and beyond that, if we need more power, we bring more fuel to the generators. This is present at most of our major control facilities. It is not at all of our data capture facilities, and we are looking at the degree to which we need to extend that capability into other aspects of our ground systems.

But we do have backup power to assure that we will not lose any of our spacecraft in orbit.

We will be refining our contingency plans over the next 6 months. We've already developed one set of contingency plans, and we will be looking at where we extend that. I, in fact, will be having all of the NASA Y2K managers in town next week to go over all of our contingency plans and review them in depth.

I would also say that it has come up on several occasions, what are we doing about backup power for our Moscow Control Center? That is a key issue that we are concerned about, and we will be developing specific backup power capability for that facility.

Mr. HORN. Are you familiar with the Boeing Sea Launch operation?

Mr. HOLCOMB. I——

Mr. HORN. Launching satellites at the equator?

Mr. HOLCOMB. I'm very—I'm a little familiar with it, but not very.

Mr. HORN. I just wondered if you were looking at that because that's involved a four-country consortium—I believe Norway, Ukraine, Russia, and the United States—and I would think what you might find out in other foreign situations might also apply to that one which seems to be quite a success at this point.

Well, Mr. Rhodes, let me ask you how can the Federal Government better publicize the need for consumers to have their Global Positioning System and related receivers checked for end-of-the-week and the Year 2000 compliance issues?

Mr. RHODES. Well, first of all, there is a great deal that the Government does publish. I stated earlier that the Coast Guard is responsible as the liaison to the civil sector. The Department of Defense, in the Air Forces—United States Air Forces' web page has a great deal of information about the Defense Department procured receivers.

The concern that I have is that—as with all situations of public outreach—you are placed in a position—the Coast Guard is placed in the position of having list after list after list after list of receiver manufacturer, but they are also placed in the position of saying we haven't validated what the receiver manufacturer says—basically, caveat emptor, you know, use at your own risk. If there can be—I don't know; if you had a field hearing or hearings and had the receiver manufacturers come in and discuss it, that would be real-time information.

But there is a great deal of information available on Government websites; it is just, you know, we don't have the ability to do the validation and verification of what the manufacturer is actually holding up.

Mr. HORN. Yes, I notice in a lot of the journals that relate to specific segments of the space community and the defense community, that they are suddenly waking up now—[Laughter.]—and advising their clientele, if you will, how best to focus in on some of these questions.

Mr. RHODES. Right.

Mr. HORN. And I just wonder if both the General Accounting Office, the Defense Department, NASA might all want to focus in on some of these things and use those publications to reach the people that can do something about it—just to advise that as a 2-cent non-consultation view.

[Laughter.]

Dr. Langston, for the Department of Defense, as I looked at your written statement, you had a number of charts and illustrations. And on one, you showed several functionally end-to-end evaluations which will not be complete until October, I think the Army, the Navy personnel. And I guess, in your opinion, does this provide enough time to fix remaining problems in the event that these tests find significant issues? Is there enough time?

Mr. LANGSTON. Sir, the majority, as I reported earlier, of our operational evaluations on functional end-to-end tests are to be completed this June. What we have scheduled and what was represented on those charts are backup, secondary testing periods for us to capture time to go back for any systems that we have found problems in and for those few systems where we were not able to complete the full remediation prior to the period of the first phase of our end-to-end testing period. So, we feel confident that we will have time to repair those systems.

And we also, of course, are testing our contingency plans—both our system contingency plans and our mission function contingency plans—to ensure that we can operate should we have any conditions that arise related to that.

And if I could comment on your last question to Mr. Rhodes. I have in front of me 5 pages of web printout that comes from the Coast Guard web station—web page—that talks about the over 50 manufacturers that provide commercial receivers. And what you find on these pages is both the point of contact, a phone number, a fax number, and generally a web address so that they can—get more information on the receivers made by that manufacturer.

I could also make available——

Mr. HORN. Madame Chairman, I'd like to have that material put in the record at this point.

Mr. LANGSTON. Thank you, sir.

Chairwoman MORELLA. Without objection, so ordered.

[The information follows:]

http://www.navcen.uscg.mil
www.laafb.af.mil/smc/cz

Testimony to Science Committee's Subcommittee on Technology and the Committee on Government Reform's Subcommittee on Government, Management, Information, and Technology

Y2K in Orbit: Impact on Satellites and the Global Positioning System

May 12, 1999

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Mr. LANGSTON. And I would also be glad to submit the web page addresses for both the Coast Guard page and the Air Force DOD pages that reflect this information if you would like.

Mr. HORN. Yes.

Chairwoman MORELLA. Seeing no objection, that will also be part of the record.

[The information follows:]

HOME SYSTEMS POLICY MARITIME SEARCH CONTACT U.S. COAST GUARD NAVIGATION CENTER

GPS Manufacturers

The following sites are not under the control of the U.S. Coast Guard Navigation Center. Please read our disclaimer.

Manufacturer Name	Address	Points of Contact	Phone Number	Fax Number	Web Address
3S Navigation	23141 Plaza Point Dr. Laguna Hills, Ca 92653		1-714-830-3777		www.3snavigation.c
Allen Osburne Associates	756-J Lakefield Road NWest Lake Village, CA 91361	DR. Robert Snow	1-805-495-8420	1-805-373-6067	www.aoa-gps.com
Apelco Marine Electronics	46 River Road Hudson, NH 03051		1-603-881-9605	1-603-881-4756	
Arbiter Systems, Inc.	1324 Vendels Circle Suite # 121 Paso Robles, CA 93446		1-805-237-3831	1-805-238-5717	www.arbiter.com
Ashtech Products (Magellan)	471 El Camino Real Santa Clara, CA 95050		1-408-615-5100	1-408-615-5200	www.ashtech.com
Austron, Inc.	PO Box 14766 Austin, TX. 78761-4766		1-512-521-2313	1-512-251-9685	www.austron.com
Azimuth Ltd.	15 Hataasia St. PO Box 2497 Raanana 43654 Israel		+972- 9 904-134	+972 9 429-548	www.azimuth.co.il
Ball Efratom Division	3 Parker Irvine, Ca. 92718	Lee Chenoweth	1-714-770-5000	1-714-770-2463	
Bancomm-Timing Division of Datum, Inc.	6781 Via del Oro San Jose, Ca 95119-1360	Rich Bailey	1-800-348-0648		www.datum.com
Bendix/King	General Aviation Avionics Div. 400 N Rogers Road Olathe, Ks 66062-1212	John Hill	1-913-782-0400	1-913-791-1302	
Canadian Marconi Company	600 Dr. Frederik Philips Blvd Ville St. Laurent Quebec H4M 2S9 Canada	Jim Bruceor	1-514-748-3148	1-514-748-3055	www.mtl.marconi.ca
Centennial Technologies	37 Manning Road Billerica, Ma. 01821		1-508-670-0646	1-508-670-9025	

Commercial Equipment	Rockwell Semiconductor Systems 4311 Jamboree Rd. Newport Beach, Ca 92660		1-714-833-4600	1-714-833-4078	
Corvallis Microtechnology Inc.	413 SW Jefferson Ave. Corvallis, Or 97333		1-506-752-5456	1-503-752-4117	www.cmtinc.com
Del Norte Technology, Inc.	1100 Pamela Drive Euless, Tx 76040	Devra Fuller	1-817-267-3541	1-817-354-5762	
Eagle Electronics	PO Box 669 Catoosa, Ok 74015		1-918-437-6881	1-918-234-1700	
Furuno Electric Co., Ltd.	9-52 Ashihara-cho 662 Nishinomiya City Japan	Hitoshi Taniguchi	+81 798-63-1074	+81 798-66-0281	www.furuno.com
Furuno USA, Inc	4400 N.W. Pacific Rim Blvd. Camas, WA 98607, USA Tel: Fax:		1-360-834-9300	1-360-834-9400	www.furuno.com
Garmin Corp.	1200 East 151st Street Olathe, Ks 66062	Tim Casey	1-913-397-8200	1-913-397-8282	www.garmin.com
Geotronics of North America Inc.	911 Hawthorn Drive Itasca, Il 60143	Paul Hahn	1-630-285-1400	1-630-285-1410	
Honeywell	Commercial Flight Systems Group 8840 Evergreen Blvd. Coon Rapids, Mn 55433		1-612-957-4010		
hopf Elektronik GmbH	Nottebohmstr. 41 D-58511 Lüdenscheid	Mr. Bernhard Rega	+49-2351-938686		www.hopf-time.com
II Morrow Inc.	2345 Turner Road. SE Salem, Or 97309	Gary Read	1-503-391-3411	1-503-364-2138	www.iimorrow.c
Interphase Technologies	1201 Shaffer Road Santa Cruz, Ca 95060		1-408-477-4944		
Interstate Electronics Corp.	1001 East Ball Rd. Anaheim, Ca 92803		1-714-758-00500	1-714-758-4148	
ITT Avionics	500 Washigton Ave. Nutley, Nj 07110	Larry Peterson	1-973-284-3094	1-973-284-3334	
Japan Radio Co. Ltd	Akasaka Twin Tower 17-22 Akasaka 2-Chome Minato-Ku, Tokyo 107 Japan	Shin Matsuo	+81 33-584-8838	+81 33-584-8878	www.jrc.co.jp
Japan Radio Co. Ltd	2301 Horizon Dr. Fort Worth, Tx 76177		1-800-231-5100	1-817-837-8051	www.jrcc.com

JcAir	400 Industrial Parkway Industrial Airport, Ks 66031		1-913-764-2452	1-913-782-5104	www.jcair.com
Leica AG	CH-9435 Heerbrugg Switzerland		+41-71-70-33-84	+41-71-72-14-61	
Leica Navigation and Positional Division	23868 Hawthorne Blvd. Torrance, Ca 90505		1-310-791-5300	1-310-791-6108	
Leica, Inc	3155 Medlock Bridge Rd Norcross, Ga. 30071		1-404-447-6361	1-404-447-0710	www.leica-gps.com
Lowrance Electronics, Inc.	12000 E. Skelly Dr. Tulsa, OK 74128-2486		1-918-437-6881	1-918-234-1703	
Magellan System Corp.	960 Overland Court San Dimas, Ca 91773		1-909-394-5000	1-909-394-7050	www.magellangps.c
Marinetex	2076 Zanker Road San Jose, Ca 95131	Thomas Ko	1-408-441-1661	1-408-441-0809	
Micrologic Inc.	9174 Deering Ave. Chatsworth, Ca 91311	Michael McDermott	1-818-998-1216	1-818-709-3658	
Motorola GPS Products	4000 Commercial Avenue Northbrook, Il. 60062		1- 888-298-5217	1-847-714-7325	www.oncore.motoro
NavStar Systems Ltd.	Mansard Close Westgate Northants NN5 5DL UK		+44-1-604-585-588	+44-1604-585-599	
NavSymm Positioning Systems	85 W Tasman Dr. San Jose, Ca 95134		1-800-486-6338	1-408-428-7972	
Northstar Technologies	30 Sudbury Rd. Acton, Ma 01720		1-508-897-6600	1-508-897-7241	
NovAtel Inc.	1120 - 68th Avenue N.E. Calgary, AB Canada T2E 8S5		1- 403-295-4900	1-403-295-4901	www.novatel.com
Odetics, Inc.	Precision Time Division 1515 S. Manchester Ave. Anaheim, Ca. 92802-2907		1-714-785-0400	1-714-776-6363	
Omnistar	8200 West Glen Houston, Tx 77063		1-713-785-5850	1-713-785-5164	
Philips Navigation A/S	Prags Boulevard 80 Dk-2300 Copenhagen S Denmark		+45-32-883626	+45 32-883-930	
Premier GPS Inc	1003-D 55th Ave NE Calgary, Alberta T2C 2W7 Canada		1-403-295-8879	1-403-274-3021	

Pulsearch Navigation Systems Inc	6815 40th St. SE. Bay E. Calgary, Alberta T2C 2W7 Canada		1-403-720-0277	1-403-720-0044	
Raytheon Marine	46 River Road Hudson, Nh 03051	Mike Mitchell	1-603-881-5200	1-603-881-4756	www.raymarine.com
SCI Systems, Inc.	Government Division 8600 S. Memorial Parkway Huntsville, Al. 35802	Rich Wylly	1-205-882-4800	1-205-882-4652	
Sercel Incorporated-USA	17155 Park Row PO Box 218909 Houston, Tx 77218	Lynn D. Weems	1-713-492-6688	1-713-492-6910	
Sercel-France	16 rue de Bel Air B.P. 439 44474 Carquefou Cedex France	Pichot	+33 40-30-19-48	+33-40-30-19-48	
SiRF Technology	3970 Freedom Circle Santa Clara, CA 95054	Kanwar Chadha	1 408 969-9307	1 408 980-4705	www.sirf.com
SI-TEX Marine Electronics Inc.	Suite 800 11001 Roosevelt Blvd St. Petersburg, Fl 33716	Phil Johnson	1-813-576-5734	1-813-576-5547	www.si-tex.com
Sokkia Corporation	9111 Barton St. Overland Park, Ks 66214	Norm Whitted	1-913-492-4900 x155	1-913-492-0188	
Sony Corp. of America	1 Sony Dr. Park Ridge, NJ. 07656	Kenneth Turner	1-201-930-1000	1-201-930-7179	
Spectrum Geophysical Instruments	Suite 200 1900 W Garvey Ave. S West Covina, Ca. 91790		1-714-544-3000	1-714-544-8307	www.spintime.com
Stanford Telecommunications	1221 Crossman Ave. Sunnyvale, Ca. 94088-3733	Brad Anderson	1-408-745-0818	1-408-745-0390	
Starlink Inc.	Suite 202 6400 Highway 290 E. Austin, Tx 78753		1-512-454-5511	1-512-454-5570	
Telecom Solutions	85 W Tasman Dr. San Jose, Ca. 95134		1-408-433-0910	1-408-428-7998	
Topcon America Corp.	65 W Century Road Paramus, NJ		1-201261-9450	1-201-387-2710	
Topcon Europe	Essebaan 11 2908 LJ Capelle a/d Yssel Netherlands	Mark Lammerts	+31-10-4-58-50-77	+31-10-4-58-50-45	

Trak Systems Division	Trak Microwave Corp. 4726 Eisenhower Blvd Tampa, Fl 33634	Earl Fossler	1-813-884-1411	1-813-884-0981	
Trimble Navigation Ltd	645 N Mary Ave. Sunnyvale, Ca 94086		1-408-481-8000	1-408-481-8214	www.trimble.com
True Time, Inc	2835 Duke Ct. Santa Rosa, Ca 95407		1-707-528-1230	1-707-527-6640	
Universal Avionics Systems Corp.	3260 E Lerdo Road Tucson, Az 85706		1-520-295-2300	1-520-295-2395	www.uasc.com

Mr. LANGSTON. Thank you.

Mr. HORN. I was interested when you mentioned contingency program. I'm assuming you are not using the United States Post Office, but the rest of the Executive Branch say the Post Office is their contingency on delivery of checks and so forth if electronic means do not work. And then we had a hearing with the Post Office and we found out the Post Office has no contingency plan. So I think you might be way ahead of everybody else when you are coming to contingency plans, and you won't have to depend on the Post Office no matter how able they are.

Thank you, Madame Chairman.

Chairwoman MORELLA. Thank you, Chairman Horn.

I am now pleased to recognize Mr. Larson from Connecticut.

Mr. LARSON. Thank you, Congresswoman Morella, and I compliment you again on this hearing this morning.

And I want to thank the members of the panel, and I apologize for having arrived late.

And I just have a general question. And, in fact, if you've gone over it already and it is part of the record, truly, I can catch up on that, but can you explain to me how this rollover takes place in August and what the ramifications of the August rollover is? Is that a testing of all of our satellite systems? How does that really unfold?

Mr. RHODES. Well, the GPS keeps time onboard each of the satellites. And what it keeps track of are the weeks and the seconds within the weeks. And the maximum number of weeks that it can count up to is 1,024; it can't go to 1,025. And if it is at 1,022, it just counts up to 1,023, 1,024, and then back to 0.

What that does is there's an internal clock; there is an internal timer, and it just keeps ticking away. It is not tied to a day; it is not tied to a date; it is not tied to anything specific on a calendar. It is just an incrementer. It is like an egg timer that is working in reverse; it is counting up instead of counting down. Well, when it gets to 1,024, the bell rings and it starts over again. That is the problem—the condition in a nutshell.

Mr. LARSON. Is this a glimpse—I guess, you know, in talking with staff, is this a glimpse or a precursor to what could happen with respect to Y2K, or is this apples and oranges? What, you know——

Mr. RHODES. This actually happens in a lot of different systems. The reason that it has come to the forefront in GPS is that the general populous uses GPS. I was describing earlier, you know, Forest Service uses it. There are fire departments, emergency services, telecommunications networks that are synchronized to GPS, so there are lots of—it is in the public more than some other satellites. But this goes on in satellite systems all over.

Mr. LARSON. So it is not a direct—it is not directly analogous to what happens in Y2K? And so in August, there is no need for concern that this will just flip, go back to zero, and start all over again?

Mr. RHODES. The satellites—there is no concern with the satellites. There is no concern with the ground segments. The concern, itself, is with what you individually own and how you use what you individually own. If you have your own GPS receiver——

Mr. LARSON. I see.

Mr. RHODES [continuing]. And it is old, you know, it is older than 5 years, you may have a problem with it.

Mr. LARSON. Okay.

Mr. RHODES. But it is easily replaced. That is where——

Mr. LARSON. And is there information out on that, and significant and, you know? Is that carried on websites?

Mr. RHODES. Yes, as Dr. Langston pointed out——

Mr. LARSON. And I apologize. I am sure you probably may have gone over this already, and so I——

Mr. RHODES. No, that is fine. As he was just discussing, the Coast Guard has their website, and the United States Air Force has their website which lays out the defense and civil, so it is the ones that have been procured by the Defense Department, as well as the ones that are available commercially.

Mr. LARSON. In fact, the Coast Guard Academy is in my home State of Connecticut, out of New London, and I was planning on doing a visit down there. Is that where the website emanates from or is it from another?

Mr. LANGSTON. Sir, I'm not certain of where it emanates from, but as you know, it doesn't really matter where——

Mr. LARSON. Matter where——

Mr. LANGSTON [continuing]. A website emanates from.

Mr. LARSON [continuing]. Exactly.

Mr. LANGSTON. They are accessible by all.

I do not have the exact information for you on what notice to mariners have been put out by the Coast Guard, but I'm certain that the Coast Guard has done notice to mariners to help them be aware of this problem as well, so I am sure that we are doing as much as possible to notify everybody about the need to fix or check their receivers.

And if there is at all a rosy side to this particular end-of-week rollover problem, it is that there will be some additional awareness brought to the public for events or discontinuities that occur early on in August as opposed to——

Mr. LARSON. To January.

Mr. LANGSTON [continuing]. Moving on into the 2000 rollover date; yes, sir.

Mr. LARSON. Thank you very much.

Chairwoman MORELLA. Thank you, Mr. Larson.

We've been joined by Mr. Weiner, from New York, and also from Ms. Biggert, who is the Vice Chair of the Government Management Subcommittee.

So I am going to defer to you and recognize you, Ms. Biggert, and then, Mr. Weiner.

Ms. BIGGERT. Thank you, Madam Chairman. I, too, apologize for not being here for the testimony. I think we have so many meetings that it is running from one to the other, but I apologize.

This is a general question. For example, with the satellites, most of—I would assume that—or with NASA—that the technology is really up to date more so than our toasters or our heating thermostats and things, so is that true? Is there a lot—has there been a lot less to do to ensure that there is Y2K readiness?

Whoever wants to answer.

Mr. HELM. Well, thank you; that is an excellent question.

Representing the commercial space community, yes, certainly our systems are much more sophisticated, and I believe that we right in the design phase would not have allowed in our satellites a critical timing mechanism that would be related to a date. All of our timing mechanisms within our spacecraft may have an epic date or a reference date, but their timing mechanisms, usually timing in parts of a second, and they are not date-sensitive. They are not related to a specific calendar date, so we won't foresee any problems within the commercial space segment.

Ms. BIGGERT. Is there a problem, then, as far as working with other systems? We hear about the others with the utilities or, you know, the electricity or something where there will be a failure someplace else that would affect—will that affect you also? Are there other systems that you have no control over that could affect the——

Mr. HELM. Well I think we have heard some excellent commentary from Mr. Rhodes who—and also from Dr. Langston. As you go perhaps down lower in the communities—and I was thinking earlier about a person who has a GPS receiver in Alaska, for example, but is not perhaps computer literate who is not on the Internet. If we need to inform that person that they may have a problem—they may have a mine up in Alaska that where they are using GPS equipment, but they are not on a computer network. Well, that is an information problem that we need to make sure that the information gets out, and the public—and I commend, again, these kinds of hearings that bring to our society an awareness that there are potential problems.

Certainly—and as I said in my testimony—as we also get overseas, outside of the United States and outside of the more established communication systems, I think we may see some problems, although I don't believe that they are going to be a major effect on either commerce or society, although there are certainly going to be some outages.

Ms. BIGGERT. For example, like in our military bases overseas, do they really have to be self-sufficient then to be able to ensure that on the rollover of January 1, that they will continue to operate?

Mr. LANGSTON. To the degree possible, ma'am, we certainly try to make our bases self-sufficient. However, the reality is that all of our bases are dependent upon external services, particularly power and sometimes fuel and sometimes food and sometimes other services such as garbage disposal, from their local community. So one of our major efforts within the Department is to validate and certify all of the installations throughout the Department—there are over 600, as I have reported—and try to verify that we are in good shape. Now in every case, that is not possible, because every local community is not capable of guaranteeing to us that they can provide power, water, et cetera.

We are particularly interested in our overseas bases and the support from host nations for critical services to those bases. And we have an activity ongoing right now working with the State Department and working with our internal DOD folks to validate the relationships between those host nations and our local bases. And we will continue to work that throughout the year.

Ms. BIGGERT. Thank you.

I guess even in the United States I think it is very difficult to find a generator to use as a supplement right now, that they have been sold out for quite awhile. It would be a good business to be in.

Thank you very much.

Thank you, Madame Chairman.

Chairwoman MORELLA. Thank you, Ms. Biggert.

I wanted to acknowledge the presence of Mr. Wu, from Oregon; Mrs. Maloney, from New York; Mr. Smith, from Texas.

You can see that we've got—we do have many, many meetings taking place, but the members of these subcommittees have been very responsible in looking at the record and following these issues thoroughly.

Before I defer to one of them, I wanted to ask you, Dr. Langston, how much money has DOD spent on Y2K compliance? And is it enough? I mean do you need more?

Mr. LANGSTON. Madam, we have reported to OMB in our last quarterly report that we've expended $3.7 billion on Year 2000. That includes the receipt of over $900 million in the supplemental funds for Y2K, plus monies that have spent throughout the previous years up to that point when supplemental money was added into the repair bill.

Chairwoman MORELLA. Are you in good shape now?

Mr. LANGSTON. We believe that, with the addition of the $165 million remaining supplemental from the $1.1 billion supplemental, that we will be capable of repairing and completing the job of Y2K. However, Dr. Hamre, our Deputy Secretary, has said independent of whatever monies are received through the Congress, this is still our number one priority, and we will make it a priority to spend money to make these repairs no matter what. And we have not asked for additional monies.

Chairwoman MORELLA. You know I remember when the first request was put in for money, the estimates for the entire Y2K remediation was like $2.3 billion? My, how that, like topsy, has grown and filtrated.

Do you intend to ask for anymore money?

Mr. LANGSTON. No, ma'am; at this point, we do not intend to ask for anymore.

I would just comment that one of the reasons that the dollar figures have grown is, as people understand that it is much more ingrained as a problem than had been originally thought, and as we have gone into these significant end-to-end testing environments where we have marshalled a large amount of resources to verify and build confidence to help mitigate this risk that has been part of what has caused the bill rise.

Chairwoman MORELLA. I have other questions I would like to submit to you, but I'd like to—since we are going to be going to vote, and I see no need to keep the Committee going after the vote—maybe I will defer to my colleagues to see if there is any specific question they would like to ask. Ms. Maloney?

Mrs. MALONEY. I have just one; yes.

Chairwoman MORELLA. May I defer, Mr. Horn, to Mrs. Maloney——

Mr. HORN. Yes, please.

Chairwoman MORELLA [continuing]. For a quick question?

Mrs. Maloney, you have a question?

Mrs. MALONEY. Just a very brief question, but first I'd like to really compliment the leadership of the gentlelady and the gentleman. They have really followed the Y2K problem, the challenge, just with great determination and have made, I think, a tremendous, positive impact on the challenge of being prepared. And you just keep on it. Connie, and, Steve, you are doing a great job.

I would like to ask Dr. Marvin Langston this question—from the Department of Defense, on March 26, 1999, the Office of Management and Budget distributed a list of 42 high-impact federal programs. And on that list, the Department of Defense has two programs—military hospitals and military retirement. And can you tell us what DOD is doing to assure that these high-impact areas are addressed and that your state- and private-sector partners will be ready in time so that these important federal benefits will not be disrupted.

Mr. LANGSTON. Yes, ma'am. Thank you for that question. That list of high-impact systems is derived based on the impact that those systems potentially have on citizens, and they were not put on the list based on our specific remediation for those systems.

So, in those two particular systems—the federal retirement system—that is a system that has been remediated and validated, and our hospital support systems are also fully remediated and validated. And, in fact, in our hospital systems, the only remaining activity is buying medical testing devices of which we are repairing or replacing as many as possible. And as we get to the end of the period of time, there will be some numbers, because this is a significantly large number—in the hundreds of thousands—that will not be completely repaired or replaced, and they will be, therefore, taken offline prior to the Year 2000 rollover. And we will operate our hospitals with the smaller numbers of medical devices.

And so we feel confident in all cases related to those areas that we are in good shape.

Mrs. MALONEY. That is great. Thank you.

Chairwoman MORELLA. Ms. Biggert, did you want to add any final note?

Ms. BIGGERT. No, Madam Chairman.

Chairwoman MORELLA. Are we doing anything to assist the Russians or any of the other nations that are so behind us with regard to defense? I mean are we using any of our expertise—if I could get a brief comment on that.

Mr. LANGSTON. Yes, ma'am. We have actually a team, again, for the third visit to Russia en route right now to a follow-on meeting with Russia. We are particularly interested in the nuclear weapons relationship and shared early warning, or what we are calling the Center for Strategic Stability. And we are actually working to get the Russians to join us to have people in country in a shared stability center in Colorado to support making sure that they have information about our early warning systems and that they can share that with their weapons controllers so that there is no miscommunication that could cause accidental launches.

We also are working very diligently with NATO to work through all of the NATO countries to make sure that they step up to and support the Year 2000 problems as much as possible. In some cases, they have gotten a late start, and we are helping them in every way possible. And we will also outreach, as I said, to all of the countries that are host-nation support countries to our bases overseas.

Chairwoman MORELLA. I hope that you will all feel free to contact these Subcommittees if there is anything that we need to do or any word that we need to get out, any situations that you think we can assist with, in terms of probing or whatever might be necessary.

But I want to thank Mr. Holcomb and Dr. Langston, Mr. Helm, Mr. Rhodes for being with us. And we will submit questions to you; that is adequate. Thank you very much.

And the Subcommittees are now adjourned.

[Whereupon, at 11:34 a.m., the Subcommittees were adjourned.]

[Information regarding Global Satellite Communications Technology and Systems follows:]

International Technology Research Institute
World Technology (WTEC) Division

WTEC Panel Report on

Global Satellite Communications Technology and Systems

Joseph N. Pelton, Panel Chair
Alfred U. Mac Rae, Panel Chair
Kul B. Bhasin
Charles W. Bostian
William T. Brandon
John V. Evans
Neil R. Helm
Christoph E. Mahle
Stephen A. Townes

December 1998

International Technology Research Institute
R.D. Shelton, Director
Geoffrey M. Holdridge, WTEC Division Director and ITRI Series Editor

4501 North Charles Street
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WTEC Panel on Satellite Communications Technology and Systems

Sponsored by the National Science Foundation and the National Aeronautics and Space Administration of the United States Government.

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INTERNATIONAL TECHNOLOGY RESEARCH INSTITUTE
World Technology (WTEC) Division

WTEC at Loyola College (previously known as the Japanese Technology Evaluation Center, JTEC) provides assessments of foreign research and development in selected technologies under a cooperative agreement with the National Science Foundation (NSF). Loyola's International Technology Research Institute (ITRI), R.D. Shelton, Director, is the umbrella organization for WTEC. Paul Herer, Senior Advisor for Planning and Technology Evaluation at NSF's Engineering Directorate, is NSF Program Director for WTEC. Several other U.S. government agencies provide support for the program through NSF.

WTEC's mission is to inform U.S. scientists, engineers, and policymakers of global trends in science and technology in a manner that is timely, credible, relevant, efficient, and useful. WTEC's role is central to the government's effort to measure its performance in science and technology. Panels of typically six technical experts conduct WTEC assessments. Panelists are leading authorities in their field, technically active, and knowledgeable about U.S. and foreign research programs. As part of the assessment process, panels visit and carry out extensive discussions with foreign scientists and engineers in their labs.

The ITRI staff at Loyola College help select topics, recruit expert panelists, arrange study visits to foreign laboratories, organize workshop presentations, and finally, edit and disseminate the final reports.

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WTEC Panel on

GLOBAL SATELLITE COMMUNICATIONS TECHNOLOGY AND SYSTEMS

FINAL REPORT

December 1998

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Alfred U. Mac Rae, Panel Chair
Kul B. Bhasin
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ABSTRACT

This report reviews the status of satellite communications systems and technology research and development around the world, with particular focus on comparisons between the United States and other leading industrialized countries. Topics covered include a review of market forces and future drivers at work in the satellite communications industry today, key technology trends around the world, relevant policy and regulatory issues including standards and protocols, and opportunities for international cooperation. The report also includes site reports for visits conducted by the panel to leading research laboratories and systems developers in North America, Europe (including Russia), Japan, and Korea. Additional material is provided from secondary sources on relevant activities in Brazil, India, and Israel. The panel's conclusions include the following: (1) many European and Asian governments are maintaining or increasing funding of commercial communications satellite R&D while the United States does not appear to be supporting R&D at the level necessary to maintain its leading market share position in this growing business; (2) the United States is the leader in the manufacture, insertion of new technology, and development and finance of new commercial communications satellites, but crucial new technologies, systems concepts and regulatory patterns will need to be developed to maintain this lead. Further, the United States now lags in the satellite launch service area, and this must be viewed with concern; (3) commercial communications satellite services are rapidly becoming a large and global business, increasing from $11 billion in 1992, to $20 billion in 1996 to a projected figure of $75 billion in 2005; (4) there is a critical need in the United States for long-term satellite and high frequency research—the continued U.S. leadership role in this industry is dependent on the creation of a strong, long-term R&D program to support future needs of new technology as the communications capability of the satellites improves; and, (5) opportunities for international cooperation can facilitate the global development of new satellite technologies, systems and standards. These and other conclusions are reviewed in detail in the panel's executive summary.

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ACKNOWLEDGEMENTS

I would like to thank the U.S. government sponsors of this study: Paul Herer, and Steve Goldstein of the National Science Foundation, and Ramon De Paula of the National Aeronautics and Space Administration. We are very much indebted to our panel chairs, Joseph Pelton, and Alfred Mac Rae, for their dedication and leadership over the course of the study, and to the Executive Board and members of the Editorial Review Board for their comments and support. All of the panelists are due great credit for their invaluable contributions of time and intellect to this project. Although the study was certainly a group effort, individual study team members were responsible for specific chapters and devoted much time and energy to make these a success. Authors and their specific contributions to the various chapters are detailed below. Thanks also to William Ivancic of the NASA Lewis Research Center, who contributed to the onboard processing section of Chapter Three, and Prakash Chitre of COMSAT Laboratories, who contributed to the TCP/IP section of Chapter Four. It was both an honor and pleasure to work with such an illustrious and affable group. Finally, we are extremely grateful to all of our hosts and correspondents around the world who took the time to share their work with us, as well as their insights and vision of the future of this exciting field.

Sincerely,

Geoffrey M. Holdridge
WTEC Division Director and ITRI Series Editor

Outline of the Study, Including Authors of Specific Chapters

Executive Summary: Alfred Mac Rae and Joseph Pelton

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Chapter 3:	Christoph Mahle, (editor), Kul Bhasin, Charles Bostian, William Brandon, Alfred Mac Rae
Chapter 4:	Christoph Mahle (editor), Kul Bhasin, Charles Bostian, William Brandon, John Evans, Alfred Mac Rae
Chapter 5:	Kul Bhasin, Joseph Pelton, John Evans
Chapter 6:	Neil Helm, (editor), Charles Bostian, Christoph Mahle, Alfred Mac Rae

PREFACE

In 1992 NASA and NSF commissioned a panel of U.S. satellite engineers and scientists to study international satellite R&D projects in order to evaluate the long-term presence of the United States in this industry. The 1992-3 study that resulted concluded that the United States had lost its leading position in several critical communications satellite technologies. In the five years since that study, the satellite communications industry has become an even larger industry than most had predicted, increasing from $11 billion in 1992 to $20 billion in 1996. Far from being supplanted by fiber or other communications networks as some suggested would happen, satellite technologies and architectures are expanding as more countries establish communications satellite capabilities. Thus, while it appears certain that satellites will continue to play a crucial part in the transmission of information, the question remains whether the United States will be able to keep pace with advances in especially Europe and Japan.

With the technological advancements of the industry and its worldwide growth, NASA and NSF commissioned a panel to extend the scope of the earlier study and to include Korea in addition to North America, Europe and Japan. Reports on the burgeoning satellite technology industry in Brazil, India and Israel are also discussed in this study. I accompanied the panel on many of its site visits and was impressed by the growth of the satellite industry that has taken place in the last five years. The international scope of the industry is such an important aspect now that all concerned agreed we should title this report, *Global Satellite Communications Technology and Systems*. The report also expands upon the 1992-93 study and includes policy and regulatory issues that are becoming increasingly important to this global industry.

As with the first panel, the members selected for this study are experts in their fields, each having decades of experience in satellite communications. Many of the panelists have participated in both studies and several of the team were personally responsible for many of the pioneering developments in satellite communications that made the United States predominant in this field for so many years.

The study team found that many European and Asian governments are increasing the funding of commercial communications satellite R&D and are posing a serious challenge to U.S. preeminence in several important areas. The United States continues to be at the forefront in the development of new technologies and the manufacture of new communications satellites. Current levels of research and development funding do not guarantee that this will remain the case. Similarly, the United States is no longer the major provider of satellite launch services and there is a critical need for lower cost and more reliable launch vehicles. In short, if the U.S. communications satellite industry is to remain vibrant, greater funding by both industry and government will be necessary.

NASA certainly recognizes the role it must play in ensuring that the U.S. communications satellite industry remains strong. This study is one means to help encourage and support the research and development of technologies that are crucial to the U.S. aerospace industry. This report suggests, for instance, that there are many opportunities for international cooperation and collaboration among government and industry. Such collaboration is not only beneficial but will be essential to the continued strength and growth of the industry in the United States. In recognition of the global importance of satellite communications, NASA took part, in March 1998, in one of the first U.S. trans-Pacific experiments, an event that linked the continental United States, Hawaii, and Japan. Similar experiments are planned in the near future. It is increasingly clear that satellite technology will be a crucial component of communications architectures that will also include wireless and fiber optic networks. Now that the satellite industry is truly global it is imperative that networks provide "seamless" integration of services to the numerous users throughout the world who will depend upon such services for everything from news gathering and education to medical diagnosis.

I wish to thank all of the members of the NASA/NSF Panel on Satellite Communications Technology and Systems for their untiring efforts, especially considering their exhausting travel schedules. Their work on this report is, as you will find, truly impressive. We are especially grateful to the panel's co-chairs, Joseph N. Pelton of the Center for Applied Space Research at George Washington University and Alfred U. Mac Rae of Mac Rae Technologies and the former Director of AT&T Skynet Satellite Communications Laboratory. Paul Herer of NSF deserves special thanks for his invaluable assistance and his strong support. Very special thanks goes to our report editor, Geoff Giffin, for his many constructive suggestions in the report organization and his invaluable contribution in editing and correcting the report. Finally, I would like to offer particular thanks to the ITRI staff at Loyola College. Their attention to the day-to-day details of the study contributed greatly to the quality of the effort. In particular, I would like to thank Geoff Holdridge, Cecil Uyehara, Aminah Grefer, Duane Shelton, and Chris McClintick for their support and careful management of this complex project.

Ramon DePaula
National Aeronautics and Space Administration
Washington, DC
December 1998

FOREWORD

Timely information on scientific and engineering developments occurring in laboratories around the world provides a critical input to maintaining the economic and technological strength of the United States. Moreover, sharing this information quickly with other countries can greatly enhance the productivity of scientists and engineers. These are some of the reasons why the National Science Foundation (NSF) has been involved in funding science and technology assessments comparing the United States and foreign countries since the early 1980s. A substantial number of these studies have been conducted by the World Technology Evaluation Center (WTEC) managed by Loyola College through a cooperative agreement with NSF.

The purpose of the WTEC activity is to assess research and development efforts in other countries in specific areas of technology, to compare these efforts and their results to U.S. research in the same areas, and to identify opportunities for international collaboration in precompetitive research.

Many U.S. organizations support substantial data gathering and analysis efforts focusing on nations such as Japan. But often the results of these studies are not widely available. At the same time, government and privately sponsored studies that are in the public domain tend to be "input" studies. They enumerate inputs to the research and development process, such as monetary expenditures, personnel data, and facilities, but do not provide an assessment of the quality or quantity of the outputs obtained. Studies of the outputs of the research and development process are more difficult to perform because they require a subjective analysis performed by individuals who are experts in the relevant scientific and technical fields. The NSF staff includes professionals with expertise in a wide range of disciplines. These individuals provide the expertise needed to assemble panels of experts who can perform competent, unbiased reviews of research and development activities. Specific technologies such as telecommunications, biotechnology, and nanotechnology are selected for study by government agencies that have an interest in obtaining the results of an assessment and are able to contribute to its funding. A typical WTEC assessment is sponsored by several agencies.

In the first few years of this activity, most of the studies focused on Japan, reflecting interest in that nation's growing economic prowess. Then, the program was called JTEC (Japanese Technology Evaluation Center). Beginning in 1990, we began to broaden the geographic focus of the studies. As interest in the European Community (now the European Union) grew, we added Europe as an area of study. With the breakup of the former Soviet Union, we began organizing visits to previously restricted research sites opening up there. Most recently, studies have begun to focus also on emerging science and technology capabilities in Asian countries such as the People's Republic of China.

In the past several years, we also have begun to substantially expand our efforts to disseminate information. Attendance at WTEC workshops (in which panels present preliminary findings) has increased, especially industry participation. Representatives of U.S. industry now routinely number 50% or more of the total attendance, with a broad cross-section of government and academic representatives making up the remainder. Publications by WTEC panel members based on our studies have increased, as have the number of presentations by panelists at professional society meetings.

The WTEC program will continue to evolve in response to changing conditions. New global information networks and electronic information management systems provide opportunities to improve both the content and timeliness of WTEC reports. We are now disseminating the results of WTEC studies via the Internet. Twenty of the most recent WTEC final reports are now available on the World Wide Web (http://itri.loyola.edu) or via anonymous FTP (ftp.wtec.loyola.edu/pub/). Viewgraphs from several recent workshops are also on the Web server.

As we seek to refine the WTEC activity, improving the methodology and enhancing the impact, program organizers and participants will continue to operate from the same basic premise that has been behind the program from its inception, i.e., improved awareness of international developments can significantly enhance the scope and effectiveness of international collaboration and thus benefit the United States and all its international partners in collaborative research and development efforts.

Paul J. Herer
Directorate for Engineering
National Science Foundation
Arlington, VA

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EXECUTIVE SUMMARY

INTRODUCTION

In 1992, the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) commissioned a panel of U.S. satellite engineers and scientists to study international satellite R&D projects to evaluate the long-term presence of the United States in this industry. The 1992/1993 study covered emerging systems concepts, applications, services and the associated technologies in Europe and Japan. The principal conclusions of that study were that the United States had lost its leading position in several critical communications satellite technologies and that the U.S. business lead in this market was at risk.

NASA and NSF recognized that major changes occurred in the global satellite communications business in the intervening five years, and in 1997 commissioned a new panel to undertake another worldwide study of this industry. This 1997/98 study differs from the one conducted in 1992 by including market, regulatory and policy issues in addition to technology and systems. In contrast to the 1992 study when only sites in Europe and Japan were visited, this study included site visits to many institutions in North America as well as in Europe and Asia. This panel was composed of individuals representing industry, academia and government organizations, half of whom were also on the 1992 panel. The panel either visited or conducted interviews with 61 satellite manufacturers, service providers and R&D laboratories, in 14 countries in North America, Asia and Europe.

This report details the information collected in the site visits, provides supplementary information on communications satellite markets and technology, projects trends, provides a perspective of this increasingly global business, and compares satellite communications activities in other countries to those in the United States. In addition, the report has benefited from review by an independent panel, composed of experts from industry, government and academia.

PRINCIPAL OBSERVATIONS AND CONCLUSIONS

1. **The panel observed that many European and Asian governments are maintaining or increasing their funding of commercial communications satellite R&D. The U.S. government, on the other hand, does not appear to be supporting such R&D at the level that is necessary to continue the leading U.S. market share position in this growing business. The current level of NASA R&D funding in this area is barely adequate to meet the competitive challenge posed by other nations. There is a critical and growing need for new technology in this technology-intensive industry. Continued funding for the long-term R&D programs at NASA, DOD, and NSF is crucial to the continued success of the U.S. commercial satellite communications industry in the next century.**

   NASA and Department of Defense (DOD) R&D funding of previous decades played a key role in building the technology base that is the foundation of the current market success of the U.S. satellite communications industry; continued NASA and DOD R&D in this area will be critical to its future success. DOD support for satellite communications R&D (several hundred million dollars per year) does bring considerable benefits to the commercial sector, but is focused on DOD requirements. The character of NASA's R&D program and its benefits to the commercial satellite communications industry differ from the DOD program, particularly with regard to pressing commercial issues such as protocols and standards, which are especially important for the interoperability of the terrestrial and satellite communications networks, spectrum allocation, and the use of satellites in the global information infrastructure (GII). NSF has supported programs at universities that have benefited satellite communications also. This work, especially on high speed materials and devices as well as protocols, needs to continue. The members of this panel are concerned that cutbacks in government support and funding of long-term satellite and high frequency research work may eventually result in the erosion of the dominant position that the United States now enjoys, and in the loss of the benefits this industry brings to the United States in terms of high paying jobs and positive contributions to the balance of trade.

While U.S. manufacturers are developing short-term, or competitive, technologies, they recognize that longer term work is being neglected. As a result of the panel's investigation into technology and new markets, it has identified several possible candidates for long-term U.S. government supported R&D that will enable U.S. industry to maintain its lead in the development and manufacture of the commercial communications satellites of the future. They include:

- batteries and fuel cells
- high power components and structural elements
- materials and structures for numerous electronic devices, including solar cells and high frequency devices (>20 GHz)
- materials that are light in weight and strong for structural applications
- devices and structures for phased array and multiple spot beam antennas for use on the ground and in space
- radiation resistant device structures and circuits
- techniques, materials and structures for the transfer and dissipation of heat
- optical components and sub-systems
- networking technology for the seamless integration of high data rate communication satellites and terrestrial facilities
- large, deployable antennas (> 25 meters in diameter)

2. **The United States is the leader in the manufacture, insertion of new technology, development and finance of new commercial communications satellites, but foreign competition is increasing and this point needs to be addressed for the United States to maintain this lead. Further, the United States has lost its preeminence in the satellite launch service area and this must be viewed with concern. In addition, there is a critical need for lower cost and more reliable launch vehicles.**

Today, the U.S. aerospace industry is strong. Not only have the traditional leaders such as Hughes, Space Systems Loral, and Lockheed Martin grown stronger, but there is new strength coming into the competitive commercial satellite communications sector from Motorola, Boeing/Rockwell, Raytheon and elements of technical and systems strength from Ball and TRW. In addition, numerous other companies, many of them small, play a vital role by supplying components and sub-systems to the industry. U.S. companies lead the global manufacture of large commercial communications satellites. However, the manufacturing base is expanding to other parts of the globe as foreign companies are entering this market by providing the above-mentioned U.S. companies with piece parts and sub-systems. In addition, we are seeing the emergence of a stronger international presence in the manufacture of satellites, with Matra Marconi, Alenia Spazio, Alcatel, Mitsubishi, Toshiba and NEC all competing for this business.

The strongest evidence of growing foreign participation in the satellite industry is in launch services. Here, the United States is no longer the leader. Approximately half the large commercial satellite launch service business is provided by Arianespace (dominated by the European Union), with the United States a close second, followed by Russia. China and Japan have entered this business, and several new companies are emerging, such as the SeaLaunch international consortium. Countries as well as international consortia will contend for future launch service business. Despite the increased number of new launch service providers, the cost of launches has not decreased appreciably and there is a need for a concerted effort to develop lower cost access to space. In addition, launch failures occur too frequently. This is a concern to the investment community, since these failures add cost to the communications services and uncertainty to the dates of service. More reliable launch services need to be introduced into this industry.

Finally, we are seeing new and specialized development of satellite communications technologies and systems in space and on the ground in such countries as India, Israel and Korea, which could grow into important elements of the space communications business over the next ten years.

3. **Commercial communications satellite services are rapidly becoming a large and global business, increasing from $11 billion in 1992, to $20 billion in 1996 to our projected figure of $75 billion in 2005.**[1]

The satellite communications service industry has grown more rapidly than was forecast in the 1992/1993 WTEC study. This growth has been a global phenomenon as the economies of the world have improved, requiring increased communications services for both business and consumer markets. The recent large and rapid expansion of business and consumer terrestrial mobilé and Internet communications services has opened new opportunities for satellites. Mobile and Internet transport and access businesses, in particular, have stimulated the demand for new multi-satellite constellations to serve this market on both an international and regional scale. Growth in these areas, coupled with the global increase in TV viewership and high data rate transport, has been responsible for the recent and future anticipated growth. There is also new demand for integrated satellite/terrestrial communications that will enable the transport of information seamlessly across these transport media. These large and rapidly growing satellite based business opportunities have attracted the attention of government and industrial interests of many countries, and these nations are making significant investments of new capital to enable them to participate in this growth market. Many countries have allocated funds for satellite R&D projects to ensure their long-term presence in the commercial satellite industry. The expansion of satellites into new applications and the increased global demand for satellite communications services have attracted the attention of the investment community. This has resulted in the formation of new satellite service providers and stimulated mergers and acquisitions, the creation of new companies, the formation of global partnerships and the privatization of formerly public satellite service organizations. The United States in particular leads the way in proposals for new services and new satellites and in the innovative financing of new ventures to provide these services.

4. **New technology is being inserted into commercial satellite communications at an increasingly rapid pace.**

In the past, commercial communications satellite manufacturing and service provider organizations tended to be conservative and to be hesitant about inserting new technology into satellites. This has changed in response to the immediate need to serve customers' burgeoning demand for entertainment programming (TV), mobile communications and access to high bandwidth Internet data. Industry is inserting new technology into satellites at a rapid pace. Recent examples include onboard processing and switching, more efficient solar cells, higher power components, more efficient heat dissipation techniques, electric-based station keeping thrusters, intersatellite links, large antennas, phased array antennas, antennas with numerous spot beams and improved TWTAs. Increasingly, the satellite is no longer being viewed as a simple "bent pipe" but as an important component of a large global communications networking system, requiring interoperability between the satellite and terrestrial components and thus compatible protocols and standards. This integration of satellites into the global

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[1] These figures are satellite-related revenues for telecommunications and include estimated "retail sales" where possible.

network will require the satellite industry to assume large software operations and develop new end-user services.

5. **Aerospace communications companies worldwide are expanding from their traditional role as equipment vendors into the end service provider business.**

Traditional satellite manufacturers such as Hughes and Loral are in the transponder lease business and Lockheed Martin is in the launch services business. However, these manufacturers are now becoming directly involved in providing end-services to the consumer, which is very much in evidence with DBS, mobile satellite services and Internet access businesses. The most significant change will come with the deployment of $50 to $80 billion worth of new multimedia, high data rate satellites early in the next decade. The new satellites, which will operate at the very high Ka and V-band frequencies, will provide services using very small micro-terminals or ultra-small aperture terminals. Unlike today's VSATs, these small terminals will provide a "universal service" for fixed or mobile customers requiring wide or narrow band services and will connect home and business users at the expected low cost of under $1,000 per terminal, with an objective of less than $250.

6. **Commercial communications satellites are increasingly being used to provide services directly to the end-consumers, creating a potentially large terminal industry.**

In the past, the principal customers for communications satellite services were large communications carriers, PTTs and medium to large sized businesses. This emphasis is changing rapidly into a business that will be dominated by the needs of the end-consumers, individuals located in homes and small businesses, often in competition with established communications and cable TV carriers. As such, the terminals, whether they be handheld units or units with small antennas attached to the home and connected to indoor electronics, will be manufactured in large quantities and cost less. The terminal business, especially the new multimedia, high data rate networks, has the potential to exceed the size of the satellite manufacturing and launch business. Mobile communications, access to Internet data, and television and entertainment programming provided by satellites will drive these satellite based consumer electronics markets.

7. **Satellite manufacturing is attaining maturity and is starting to follow manufacturing procedures that are similar to those used by the automobile industry.**

Satellite manufacturers do use some in-house manufactured components and sub-systems, but they are increasingly becoming dependent on the supply of many items from low cost, highly reliable global suppliers. Satellites are assembled, tested and shipped from facilities that place emphasis on concurrent engineering, computer aided design, quality concepts, expedited materials flow, low cost and rapid delivery time. While U.S. companies continue to dominate the manufacture of communications satellites, other nations are rapidly acquiring the expertise to compete effectively with the United States. In addition, it is now relatively common for companies located all over the globe to apply their expertise, focus on the development, manufacture and delivery of specific components and/or sub-systems and ship them to the satellite manufacturers. These niche players have been quite successful. No longer does a satellite manufacturer make everything, or almost everything that goes into a satellite. The manufacturers now shop around the globe for many of these specialty items. The competitive advantage goes to those companies that can manufacture at lowest cost and demonstrate the highest reliability and the shortest delivery time, all the while maintaining proprietary design concepts and inserting proprietary new technology into their satellites. The industry has matured to the point where companies do their own short-term development, often concurrent with manufacturing. In many instances, they just buy the technology. The manufacture of satellite components and sub-systems is becoming a global business.

The advent of constellations containing numerous satellites, such as Iridium LLC, Globalstar LP and ICO Global Communications Holdings, has also added a new approach to the manufacture of satellites. These satellites are constructed on assembly lines. The study team saw eight being manufactured at a time at both Motorola (Iridium) and Alenia Spazio (Globalstar) facilities. These satellites contained many off-the-shelf components and sub-assemblies manufactured by other companies. Complete testing tends to be done on a few satellites to verify design concepts, while sample testing is done on the rest of the satellites to assure that the quality control processes are intact. Common buses and design concepts, along with improved manufacturing processes, have reduced the delivery time of large geosynchronous (GEO) satellites to 18 months, or less, a major improvement over the typical three year delivery time of five years ago.

8. The increased global interest in the use of satellite based communications systems has created a demand for spectrum and orbital slots that exceeds availability. In addition, there is competition for much of this spectrum from terrestrial wireless systems.

A plethora of (apparently) "paper satellites" (a term referring to the filing of claims for spectrum allocation and orbital slots that may never be used) often creates contention between the communications interests of nations and companies, which is not resolved easily. Joint allocation of spectrum with satellite and terrestrial communications systems also creates interference problems that are not easily resolved. While the Federal Communications Commission (FCC), World Radio Communications Conference (WRC) and the International Telecommunications Union (ITU) have sought to settle many of these issues and disputes, it is expected that these problems will get progressively worse as the demand for space communications services increases. New procedures to resolve these issues need to be developed.

9. Future development of commercial satellite communications appears to hinge on key regulatory, trade, spectrum, and inter-operability and standards issues as much as new technology development—and here government leadership and initiative will be the key.

The opening up of world trade in telecommunications services will affect the satellite communications industry in many important ways. New competitors and new trade entrants are as likely as not to use wireless and satellite systems to accomplish their goals. Despite gains under the new World Trade Organization's General Agreement on Telecommunications Services there are still some difficulties in achieving direct satellite access to global markets. In the area of spectrum, new ways of allocating frequencies over broader multi-purpose service categories and new techniques to mitigate interference with both other satellites and with terrestrial service facilities need to be developed and then agreed to globally. Perhaps most critical is the need for inter-operability standards to seamlessly connect new satellites with terrestrial networks for public telephony, wide-band services and many forms of Internet access and commercial systems. In all of these areas, governmental initiative will be needed since commercial action alone cannot forge urgently needed new global agreements. The commercial use of the U.S. military controlled Global Positioning System (GPS) is an issue that needs to be resolved, especially in Europe where there is concern that military priorities will conflict with critical commercial applications.

10. Opportunities for international cooperation can facilitate the global development of new satellite technologies, systems and standards.

The highly competitive nature of the global satellite communications industry often makes international cooperation in the development of key technologies difficult. Nevertheless, there are opportunities for international cooperation, especially in the form of demonstrations of satellite services. An active international program to make satellite communications a vital part of the global information infrastructure is an area where such cooperation would be beneficial to the industry. Global demonstrations of broadband state-of-the-art digital applications for health, education, museums, entertainment, trade and business services, emergency recovery, and Internet based networking are some of the examples which can be vehicles for the development and agreement of interoperability standards and frequency allocations. In addition, such international demonstrations can be useful tools to stimulate the development of new equipment and new satellite services.

11. **There is considerable R&D work being done around the world on the understanding and development of protocols and standards to ensure the seamless interoperability of satellite and terrestrial communications transport facilities.**

    The global network of the future will include terrestrial wireline and wireless facilities as well as satellites. Thus it is important that all these facilities be capable of operating together to provide the services that the customers expect. To achieve such a single global network, it is imperative that there be common protocols and standards, to avoid having a communications system composed of fragmented parts, each with its own protocols and proprietary standards. Since many of the protocols and standards currently in use were introduced for terrestrial communications, it has become necessary for the satellite service providers to work in this area to ensure their interoperability with the terrestrial network, especially for high bit rate applications. TCP/IP, the Internet protocol, and ATM, the current transport protocol of choice for multimedia transport, are receiving considerable attention by R&D institutions throughout Europe, Asia, the United States and Canada. This is driven in part by interest in developing a global information infrastructure (GII) offering high bandwidth services around the world. While considerable more R&D on this subject is needed, early experimental results of high bandwidth ATM and TCP/IP over properly conditioned satellite links have been successful.

BACKGROUND

The observations and conclusions presented in this report are quite different from those of the previous study. At that time, it was thought that the U.S. satellite communications industry had lost its leading position in several critical satellite technologies and that its leading market position was at risk. This has not happened. While there is no doubt that European and Japanese companies have become more active in the global satellite business, the United States continues to be the dominant source of large communications satellites and leads in the introduction of new services in a rapidly growing market. In the short five years between these studies, new markets have infused vitality into this business. The strong U.S. financial environment is an important factor in the establishment of this business position. While new technology certainly is important, market factors are driving the business. However, technology continues to be very important and has to be considered as an important factor in enabling U.S. industry to be so dominant in the manufacture of communications satellites. New technology, based on R&D programs of past years, is being inserted into satellites at an unprecedented pace. In addition, technology that has been developed by U.S. firms for terrestrial communications systems is being applied to satellite systems. *The panel is concerned that the present leadership position of the U.S. satellite industry, which is greatly influenced by three decades of far- sighted investment in R&D programs by government agencies, is in jeopardy due to inadequate funding of long-term R&D. This inherently technology-intensive industry is dependent on long-term R&D for its future vitality.*

The past five years have been exciting ones for worldwide communications, including the commercial communications satellite industry. This excitement has been fueled by the rapid growth in personal mobile wireless communications, the explosive growth of the Internet, the need for high data rate communications and the global growth in television viewing. In addition, the improved global economy and the increase in wealth of previously weak countries have created a demand for an expanded global communications infrastructure. The industry has experienced numerous legislative and regulatory changes, a host of mergers, acquisitions, and corporate realignments, and the privatization of government-dominated terrestrial and satellite service carriers. We have seen marked growth in many indicators of the health of the global satellite communications industry in the last five years, including:

- increases in the number of satellites manufactured
- increased participation in the manufacture of these satellites and associated components and subsystems by companies located in numerous countries
- increases in the number of satellite launches
- an increase in the number of organizations participating in the launch service business
- increased penetration of satellite based services into the consumer market
- the rapid insertion of new technology into satellites by an industry that previously had been very conservative

Satellite based communications is by far the largest commercial application of space and is growing at an impressive pace. It is attracting the attention of the world's financial institutions, entrepreneurs and nations around the world that are looking to expand their global markets. The United States needs to continue its active role in the support of these markets. Table ES.1 provides a breakdown of this business by service categories.

Table ES.1
Profile of Satellite Systems by Service Category

Service	Service Description	1992	1996	Projected 2005
FSS	Conventional	$10 billion	$14 billion	$29.5 billion
Broadcast	DTH, DBS	$0.5	$3	$17
Multimedia, broadband	Internet access, multicast...	-	-	$13
Mobile	Maritime, aero, global & regional	$0.8	$2.5	$12.5
Other	Store/forward/paging/DARS	$0.1	$0.2	$2.5
Total services		**$11.4**	**$19.7**	**$74.5**

SCOPE

Technology Focus

The primary focus of the 1992 study was on R&D for future commercial satellites. This was appropriate at that time. New services that were dependent on new technology were introduced only when the R&D was well advanced and the technology was proven to be reliable, preferably with flight experience. Under those circumstances, it was much easier to predict the evolution of satellite technology and thus the availability of new services based on this technology. Markets, more than ever before, now drive this business. The approach to technology has changed considerably since the 1992 report. Under the driving force of market demands, new technologies are being inserted into satellites and new technologies are being developed or adapted for specific markets, often concurrently with manufacturing, at an unprecedented rate. Long-term work has not been neglected, especially in Japan and Europe, where there is an emphasis on the use of experimental satellites to test out technology and new service concepts. In addition, there is an increased emphasis on the improvement of manufacturing processes. While the primary focus of this panel's site visits was on the benchmarking of technology compared to what exists in the United States, the scope of this study was broadened to include both short- and long-term technology research and development, systems research including software, manufacturing technology, and terminal technology. Also included is material on markets and launch technology.

Market Focus

This report has a much greater emphasis on market drivers and market trends than did the 1992 report. The exciting growth of the satellite based communications industry is being driven by market forces and not by technology. Technology, on the other hand, is viewed as an enabler. As a whole these market forces are a direct consequence of the growth of terrestrial communications, with satellites covering those applications that utilize their strengths, namely providing identical information to many customers at a time, transporting thin route traffic, and serving both fixed and mobile customers anywhere on the globe. This report covers those market factors that have led to the increased use of commercial communications satellites. In addition, it covers the dynamics of an industry that is characterized by new start-ups, consolidations and mergers, creative financing, the role of banking institutions, and the formation of international partnerships.

Regulatory and Legislative Focus

The increased demand for orbital slots and spectrum and the need to acquire spectrum on a worldwide basis rather than just nationwide, have created an increased focus on the importance of regulatory issues in our study and such issues are covered in this report. The privatization of many of the markets and related legislative action have also had an impact on the industry, which is also part of the report.

Global Focus

This report has a global focus. Since an important objective of this study was to benchmark global technology and markets compared to the United States, we visited numerous institutions all over the world, albeit selectively. We visited sites in North America, Europe and Asia and interviewed representatives from South America, Africa, and Israel.

Limitations

As is the case of the 1992 report, the present study focused on commercial communications satellite technology and markets and did not attempt to review military and defense satellite technology, either classified or unclassified, in the United States or elsewhere. U.S. military spending on satellites is currently $8 billion per year, and development work is estimated at several hundred million dollars annually, of which a small portion is for R&D applicable to future commercial communications satellites. This is more than the NASA spending devoted to communications satellite R&D, but hardly enough to support a growing technology-dependent business in the United States. This study did not cover important commercial space applications such as weather reporting and forecasting, surveillance and image capture. Also, no attempt was made to cover commercial GPS technology, which is experiencing widespread use for navigation, mapping, surveying and position determination. All site hosts were provided with the opportunity to comment on the draft reports to make factual corrections and to eliminate any material that contained proprietary information.

PERSPECTIVE ON THE INDUSTRY

The fortieth anniversary of the launch of Sputnik was observed while this panel was in the midst of its activities. Satellites have come a long way since then. So has the general area of communications technology, which has been transformed from analog to digital. In the past few years, we have seen impressive growth in wireless communications for mobile voice, data, and paging. This has not gone unnoticed by the satellite business community. Satellites are ideally suited to provide mobile communications. Several new systems have been proposed to provide this service to customers located over the entire globe. The systems depart from the traditional GEO located satellites by including numerous satellites in a constellation located at LEO or MEO, often with on-board processing, switching and even intersatellite links. These systems are linked into the terrestrial communications network, requiring the establishment of innovative local partnering and financial relationships that make these constellations truly global. Table ES.2 lists the characteristics of the constellations of the principal, large, mobile satellite service providers. Not included in this table are the regional GEO satellites that will provide mobile services.

Table ES.2
Proposed New Global Satellite PCS Systems

Parameter	Iridium	Globalstar	ICO-Global	Ellipso	ECCO
No. of active satellites	66+6 spare	48	10 +2 spare	14 + 3 spare	11 + 1 spare
No. of satellites per orbit plane	11	8	5	2 inclined and 1 equatorial	1 (initially)
No. of orbit planes	6	6	2	4 and 6	11
Orbit altitude (km)	750	1,414	10,355	N.A. 8,040 equatorial	2,000
Orbit inclination	86.5°	52°	45°	116.5°	0°
Number of spot beams/satellite	48	16	163	61	32
Reported cost ($ billion)	4.7	2.5	4.6	0.91	1.15

The explosive growth of Internet traffic may have a profound impact on the future use of satellites. Satellites are now transporting this traffic and there is every indication that "you ain't seen nothing yet." The satellite industry has responded to this new market by proposing new systems designed specifically for the end customers. As in the case of satellite mobile communications systems, most of these systems involve multi-satellite constellations. Their seamless connectivity with the terrestrially dominated Internet requires new approaches to standards and protocols, which are discussed in chapter 4 of this report. These systems propose to operate at Ku, Ka, V and the mm-wave bands to meet the burgeoning demand for new spectrum and the high bandwidth required to provide these Internet services. Also under consideration is the use of optical links for space to earth and earth to space communications. Table ES.3 lists some of the new Ka-band systems that have been proposed to serve this Internet access market.

Both mobile and high data rate communications satellites have terrestrial competitors. The cellular industry is expanding rapidly all over the globe. Iridium will initiate service in the fourth quarter of 1998, Globalstar in 1999 and ICO in 2000.[2] It will be interesting to follow their penetration into the mobile market. In the case of Internet access, several high data rate technologies are vying for this market, including xDSL, cable modems, wireless cable (TV), LMDS, MMDS, DEMS, and HALE platforms, in addition to satellites. To be successful it is important for satellite service providers to move rapidly to take advantage of a window of opportunity that may last for just a few years. If they do not, the terrestrial services will become so entrenched that it will be a challenge to acquire customers. In the event that the satellite systems do not provide broadband service in the next few years, a major question is, can these satellites services make an effective business by serving those customers that do not have ready access to the terrestrial Internet communications infrastructure? Hughes, with its DirecPC, is already in the high data rate Internet access market, with others to follow shortly.

[2] Based on company announcements. Press accounts differ slightly.

Table ES.3
U.S. Licensed Ka-band Global Satellite Communications Systems

Company	System	Orbit	Coverage	No. of Satellites	Satellite Capacity (Gbps)	Intersatellite Link	Onboard Switching	Capital Investment ($ billion)
Lockheed Martin	Astrolink	GEO	Global	9	7.7	1 Gbps	FPS	4
Loral	Cyberstar	GEO	Limited Global	3	4.9	1 Gbps	BBS	1.05
Hughes	Galaxy/ Spaceway	GEO	Global	20	4.4	1 Gbps	BBS	5.1
GE Americom	GE*Star	GEO	Limited Global	9	4.7	None	BBS	4.0
Morning Star	Morning Star	GEO	Limited Global	4	0.5	None	None	0.82
Teledesic	Teledesic	LEO	Global	840*	13.3*	1 Gbps*	FPS*	9*

* Original design numbers

Several proposals have been made to use High Altitude (~12 miles) Long Endurance (HALE) platforms to provide communications services. The allocation of spectrum for their use further complicates the already high demand for frequencies and the potential interference with terrestrial radio communications.

Multicasting is an Internet based terrestrial service that is growing rapidly. It is a business that is a natural for satellites. It features the simultaneous transfer of identical information, such as stock quotations, electronic newspapers and magazines, etc., to many customers at a time; a strong point of satellites. However, a return link is required to enable the customers to obtain additional information or even to place orders to purchase advertised products. The terrestrial Internet network is not ideally suited to provide numerous customers with identical information, but new distribution algorithms are being developed to solve this problem. The DBS industry, with its established distribution and service channels to the customers with small antennas, is well positioned to enter this market.

As is the case with many services based on new technologies, the establishment of effective distribution channels is a major challenge to these satellite service providers, especially for those serving the end-consumer.

TECHNOLOGY TRENDS

Most of the time during the WTEC panel's site visits was devoted to discussions and demonstrations of new technology and visits to manufacturing facilities. Not surprisingly, there was a general consensus among the hosts and WTEC panelists on the technology that was needed for the successful application of satellites to the new markets. To meet these needs, there is a general willingness to insert new technologies onto satellites without the need for numerous test flights. This is a marked departure from past approaches to the insertion of new technology into commercial satellites.

The manufacture of satellites has also changed considerably in the past few years. Increasing competitiveness together with an increased number of viable competitive manufacturers has placed a greater emphasis on cost containment and a resultant focus on the improvement of manufacturing facilities and processes. Typically, parts and sub-systems are obtained from low cost, reliable sources and assembled and tested in modern facilities, much like the model for manufacturing by the automobile industry. The use of CAD, quality processes, material flow procedures, concurrent engineering, common buses, and new assembly and testing techniques is being emphasized. The successful manufacturers combine proprietary technology, sound design, manufacture and test practices to achieve low costs and short delivery times. Delivery times for large GEO satellites have been reduced to 18 months by using common buses and improved manufacturing processes. Most impressive are the changes that have occurred as a result of the assembly line-like manufacture of the multi-satellite constellations of Iridium, Globalstar, ICO, and Teledesic. At both Motorola (Iridium) and Alenia (Globalstar) the WTEC panelists observed eight satellites being manufactured at a time on assembly lines that were organized for large production capacity (for satellites), with emphasis on short delivery times and improved reproducibility.

New technology for GEO located satellites is driven by the need to increase on-board power to serve the consumer market. High power enables the end user to use small, low cost ground terminals. The emphasis is on the achievement of higher power without increasing weight and cost. High power, more efficient TWTAs are replacing SSPAs at C-band for many applications. Epitaxial GaAs/Ge solar cells, with efficiencies of >20%, are replacing Si cells, followed by cascade cells, composed of layers of different III-V compound materials, with efficiencies that promise to approach 35%. Innovative, large area solar cell arrays that look like pleated window shades or even blankets are being developed. Deployable heat radiators are being developed also. Progress in new batteries has been slow, with the high pressure nickel-hydrogen batteries continuing to be the preferred source of DC power. Work is being done to increase the number of charge/deep discharge cycles for the Li-ion battery system, but this work is progressing slowly. Shaped reflector antennas are in common use and have resulted in the elimination of considerable heavy microwave hardware. Electric ion propulsion engines for station keeping are in use, and considerable work is being done to improve their efficiency. Large, 12 meter antennas are being put onto regional mobile communications satellites.

The use of on-board processing and switching, as in the case of Iridium and many of the Internet access satellites, is the biggest step in the insertion of new technologies onto satellites. These satellites will be mini switchboards in the sky, supported by millions of lines of real-time software onboard the satellite and on the ground, a new phenomenon for satellites. The high data rate satellites face the challenge of being part of a large global system that is dominated by terrestrial technology. At these high data rates, latency sensitive protocols must be modified, or new ones developed, to obtain seamless interoperability with the terrestrial network. Intersatellite links are being used as well. The WTEC study team saw considerable work on optical intersatellite links (ISL), with the goal to increase the useable bandwidth of these links. The team also saw work on the development of high temperature superconducting devices, especially for the eventual manufacture of more highly selective filters.

The advent of end-consumer satellite services is a boon and a challenge to the terminal manufacturers. Low cost is the key factor in the acceptance of many of these services. Lightweight handheld mobile phones and pagers are essential. Low cost, two way, phased array, small size terminals are needed to serve the high data rate markets. DARS (Digital Audio Radio Services), a satellite based service, will also benefit from phased array antennas. While manufacture in great numbers is the critical step in the achievement of low costs, there is a need for new technologies also. Some candidates are single chip, high frequency integrated circuits, which appear to be a possibility with the recent advances in the use of Si/Ge alloys on silicon integrated circuits; phased array antenna components; Ka-band components, especially SSPAs; sharp filters; and software based multiple protocol terminals.