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NASA/NSF Panel Report on

Satellite Communications Systems and Technology

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NASA/NSF PANEL ON SATELLITE COMMUNICATIONS SYSTEMS AND TECHNOLOGY

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INTERNATIONAL TECHNOLOGY RESEARCH INSTITUTE
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The World Technology Evaluation Center (WTEC) and its companion Japanese Technology Evaluation Center (JTEC) at Loyola College provide 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 JTEC and WTEC. Paul Herer, Senior Advisor for Planning and Technology Evaluation at NSF's Engineering Directorate, is NSF Program Director for JTEC and WTEC. Other U.S. government agencies that provide support for the program include the National Aeronautics and Space Administration, the Department of Energy, the Department of Commerce, and the Department of Defense.

JTEC/WTEC's mission is to inform U.S. policy makers, strategic planners, and managers of the state of selected technologies in foreign countries in comparison to the United States. JTEC/WTEC assessments cover basic research, advanced development, and applications/commercialization. Small panels of about six technical experts conduct JTEC/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 universities and in industry/government 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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EXECUTIVE SUMMARY

The National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF) commissioned a panel of U.S. experts to study the international status of satellite communications systems and technology. The study covers emerging systems concepts, applications, services and the attendant technologies. The panel members travelled to Europe, Japan and Russia to gather information first-hand. They visited 17 sites in Europe, 20 sites in Japan, and four in Russia. These included major manufacturers, government organizations, service providers, and associated R&D facilities. The panel's report was reviewed by the sites visited, by the panel, and by representatives of U.S. industry. The report details the information collected and compares it to U.S. activities.

The panel's principal conclusions are:

1. ***The United States has lost its leading position in many critical satellite communications technologies***. Table 1 shows that the United States is currently behind or even with its international competitors in most of the key technologies. Furthermore, due to research and development projects now underway abroad, the United States is likely to fall behind Japan, and to a lesser extent Europe, in most of these technologies in the next five to fifteen years.

2. ***The market share of the U.S. satellite communications industry is at risk*** Currently, the U.S. industry retains a leading position in the marketplace -- a position largely founded on technologies and capabilities developed in the 1960s and 1970s. However, the United States is losing ground with respect to a wide range of technologies and systems that will be key to future communications markets.

These developments have come about largely because Europe and Japan view satellite communications as critical to their future economic growth, and have acted accordingly. European and Japanese government policies are designed to nurture their satellite communications industries both directly and indirectly. The absence of comparable policies in the United States in recent years is one factor contributing to our declining competitive position. Table 2 compares government policies with respect to satellite communications in Europe, Japan, and the United States.

Table 1
U.S. Scorecard in Advanced Satellite Communications Technologies

U.S. TECHNOLOGY LEAD	
High Data Rate Satellite Communications	
USATs and Personal Communications Transceivers	
Small Satellites	
Space Applications for High Temperature Superconductivity	
On-Board Processing	
U.S. TECHNOLOGY TIE	**WITH**
Traveling Wave Tubes	Europe
Electric Propulsion	Japan & Russia
Spacecraft Antennas	Japan & Europe
Intersatellite Links	Japan
Autonomous Control Systems	Japan & Europe
U.S. TECHNOLOGY LAG	**LEADER**
HEMT Technology	Japan
Free Space Optical Communications	Japan & Europe
Advanced Batteries	Japan
Solar Array Systems	Japan
Solid State Power Amplifiers (FETs)	Japan
Pointing and Positioning Systems	Japan
Large Scale Deployable Antenna Systems	Japan and Russia
Advanced System Design and Long Range Planning Concepts	Japan
New Application Development	Japan

Table 2
Comparison of Government Roles

	Europe	Japan	U.S.
Policy	Strong	Strong	Moderate
Planning	Moderate	Strong	Weak
Advanced Development	Strong	Strong	Moderate
Support of Industry	Strong	Strong	Weak
Support of International Systems	Strong	Strong	Weak

SCOPE

Technology Focus. This is not a market or industrial process study but rather a survey of advanced technology now under development for commercial use in the satellite communications field. All aspects of satellite communications were considered, including fixed, broadcast, mobile, personal communications, navigation, low earth orbit, small satellites, etc.

Advanced vs. Current Satellite Communications Technology. The focus of the study is on experimental and advanced technology being developed in R&D and demonstration programs rather than on today's production capabilities. Although launch vehicles and spacecraft technologies are considered, the primary focus is on technologies and applications unique to the field of satellite communications. Most of the technology reviewed in this study is five or more years away from implementation in operational systems.

Overseas Focus. The panel has surveyed European, Japanese, and, to a lesser extent, Russian systems and technologies. The panelists' extensive knowledge of U.S. and Canadian industry has been used as a benchmark for that evaluation. But the panel did not formally review U.S. technology, and made no U.S. site visits.

Other Limitations. This report is focused on commercial satellite technology, and does not attempt to review military, defense-related, or other confidential satellite communications capabilities in either the United States or other countries. The report covers both government and industrial research and development programs. The panel has attempted to account for structural differences between the countries studied with respect to the mix of public and commercial efforts.

BACKGROUND

Satellite communications technology is a tremendous force for change and innovation. From the first satellite telephone call, to the moon landing in 1969, to today's global coverage of the Olympics with more than 3 billion viewers, satellites have helped create a world community. From $300 trillion annually in worldwide electronic funds transfers to hundreds of millions of airline reservations, satellites play critical roles in finance, business and international trade. Despite growth in fiber optic cables, some 60% of all overseas communications is satellite based. Today, more than 200 countries and territories rely on about 200 satellites for domestic, regional and/or global linkages, defense communications, direct broadcast services, navigation, data collection, and mobile communications. Satellite communications is the largest and most successful of all commercial space enterprises -- it is currently a $15 billion per year business which could grow to $30 billion per year within the decade.

In the mid 1960s, when satellite communications first became a commercial reality, the United States was not just the leader, but was predominant in every aspect from launch vehicles to satellite technology. The agreements under which the International Telecommunications Satellite Organization (INTELSAT) was established were originally negotiated on an interim basis only, giving the United States a dominant leadership role. Japan and Europe felt they would need a number of years to enter seriously into the field. Today, more than a quarter of a century later, conditions have changed dramatically.

FINDINGS

The global satellite communications industry is now entering a new phase of expansion. While growth in fixed satellite services has slowed, broadcast and mobile communications will experience explosive growth over the next ten years. Services and revenues could triple or even quadruple by early in the next century. It is thus a matter of great concern that, on the eve of this renaissance in satellite communications, the U.S. technology base in this field is now at risk. Without changes in U.S. R&D policy, the United States will soon fall behind Japan and be locked in a contest with Europe for second place.

Several countries have introduced or are introducing advanced operational satellite communications systems ahead of the United States, particularly broadcast and mobile systems, and have taken the lead in critical areas of technology. The effects are not readily apparent in today's orders for communications satellites, in which the United States still leads. However, the United States lags in many areas of advanced research and technology development from which commercial applications will derive in the next five to fifteen years.

In the course of its work, the panel encountered a rapidly shifting environment with respect to satellite communications around the world: the market is expanding and diversifying; many new applications are under development; and many different types of technologies and system architectures are emerging, including small satellites in low earth orbit, multi-purpose orbiting megastructures, and highly specialized satellite designs. Concepts in satellite manufacturing based on mass production, akin to making VCRs, exist alongside traditional methods for building one-of-a-kind products. European and Japanese satellite communications technologies are emerging rapidly.

The detailed results of this study are presented in-depth in the full report, but some general observations are presented below:

Major Disparities in the Allocation of Resources

The European Space Agency (ESA) and the Japanese National Space Development Agency (NASDA) both devote about 10% of their total budgets to space communications and related activities. NASA, on the other hand, allocates less than 1% to R&D in this area. Figure 1 shows the dramatic differences in resource allocation, particularly over the last five years. Only the funding for the Advanced Communications Technology Satellite (ACTS) program, which manifests itself as a "bump" in the graph of U.S. expenditures, temporarily diminishes this strong disparity in relative funding levels. This disparity is even more significant considering that the total budgets for the Japanese and European space programs are significantly less than that of the United States.

Major Differences in Research and Developmental Programs

The difference in major flight-based experimental communications satellite programs is striking. Figure 2 depicts such programs in the United States, Europe and Japan for the past decade as well as a decade into the future. It shows that the United States has had only one truly major research program, namely ACTS. In contrast, Europe and Japan each have had several flight-based research programs in the past ten years, and will continue in this direction in the next decade.

Service Trends

Of the three general satellite communications service categories -- fixed, mobile and broadcast -- only the fixed satellite service (FSS) may be said to be a mature service, providing global coverage since the late 1960s. FSS traffic growth has now slowed to a rate of about 10% per year. Within the FSS, VSAT systems (very small aperture terminals) are expanding rapidly, but their demand on satellite capacity is light. The greatest potential area for expansion of fixed services is in high data rate (HDR) communications (i.e., 155 Mbits/sec or higher) for data transfer, networking, and HDTV, to complement the growing global network of fiber optic cables. Little interest has been expressed by terrestrial carriers in HDR satellite service, except for cable restoral service. European and Japanese satellite operators are looking to the United States for leadership in HDR communications via ACTS, and would like to cooperate with the United States in developing trans-oceanic HDR links.

Mobile and broadcast satellite services (MSS and BSS) most clearly exploit the advantages of satellite communications over terrestrial means, consume large amounts of satellite capacity, and are growing very rapidly (over 20% per year). Significant R&D and commercial activity in this area is underway in Europe and Japan, far more than in the United States. Satellite broadcast services are extending

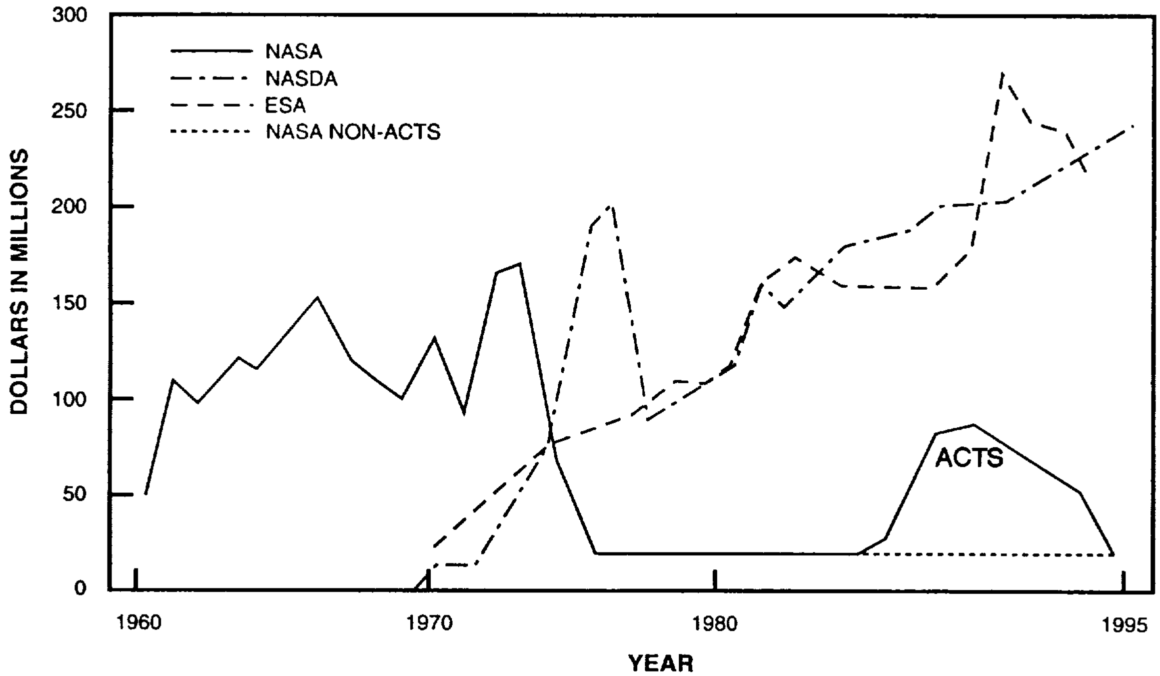

Figure 1. Annual Funding for Satellite Communications Programs

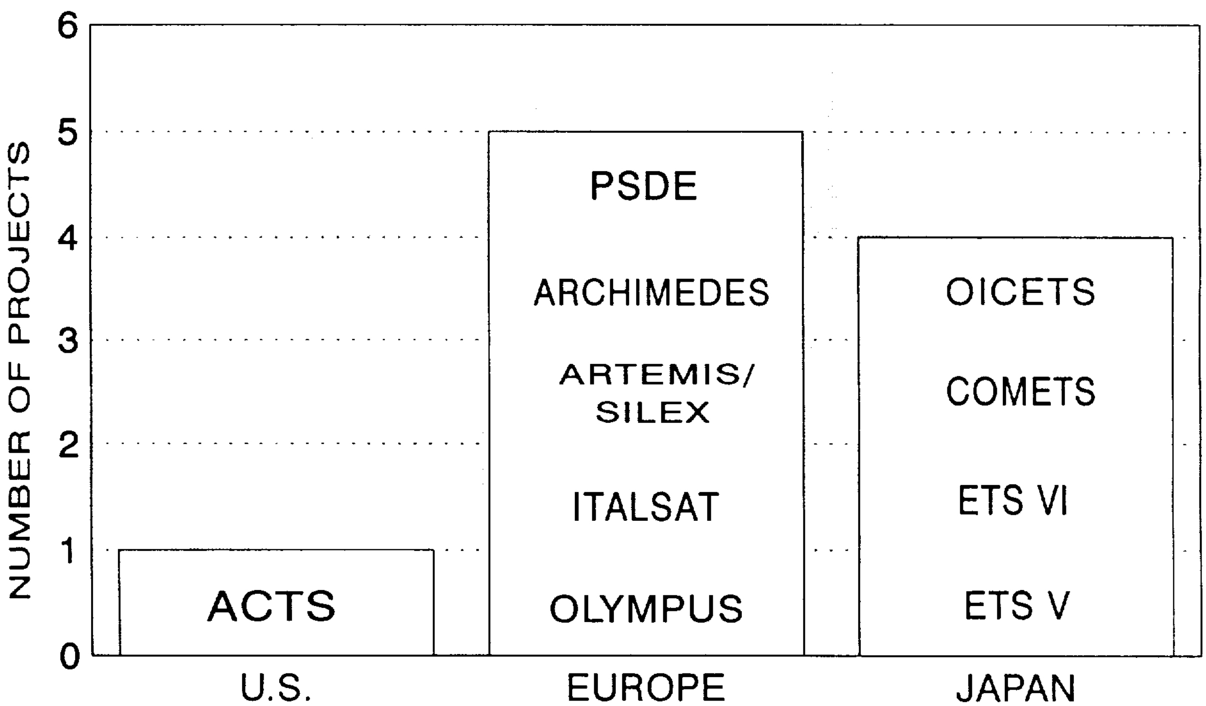

Figure 2. A Comparative View: Experimental Communications Satellite Projects in the United States, Japan, and Europe

rapidly to third world countries. The International Maritime Satellite Organization (INMARSAT), which has been providing maritime service for over a decade, has recently extended its service to aircraft and land-mobile vehicles. Perhaps the most exciting, and certainly the fastest moving, field is personal communications services (PCS) via satellite using handheld transceivers similar to those used in cellular radio. U.S. industry is pioneering this area. LEO, MEO and GEO (low earth, medium earth and geostationary earth orbit) systems are all under study and/or development for personal communications.

New Applications and Markets

Markets, applications and technologies are diversifying into GEO, MEO and LEO systems, and both very large scale and small, lower cost satellite designs are emerging. Under these changing conditions, the need for clear targeting of research for the future has become increasingly important. Clear understanding of new applications and markets is strategically even more important. Promotion of new applications and stimulation of markets seem to be more aggressively pursued overseas, especially in Japan, than in the United States. For example, Japan's initiative in direct broadcast satellite (DBS) service began after the United States, but today there are some six million Japanese subscribers in an operational system and ten thousand receivers to test HDTV broadcasting via DBS satellites.

Planning, Systems, and Advanced Technology Studies

A noticeable difference and a serious problem is the lack of planning in the United States. There is no commitment and no mechanism to pursue long-range systems and technology studies in satellite communications, as is being done systematically in Japan and fairly well in Europe. Equally important is the subsequent need to develop and follow detailed technology road maps designed to accomplish or execute the identified system goals. The Japanese COMETS program and possible follow-on programs now under consideration reflect a clear commitment to long term systems goals in the areas of space broadcasting and mobile satellite services. Likewise, the European OLYMPUS, ARTEMIS, and ARCHIMEDES programs reflect strategic commitments to these same areas.

Government / Industry Roles

The panel found considerably more interest and support for satellite communications and a stronger relationship between the governments and industries in Europe, Japan, and Russia than in the United States. As indicated in Table 2, and detailed in the full report, the European Space Agency, individual European countries, and Japan all have industrial policies that support satellite communications. Japan has a comprehensive planning program in which both government agencies and private industry are engaged. The European planning effort, although not as well organized, is still quite ambitious. The United States has no recognized plan for the development of satellite communications, nor even for fitting satellite communications into the national information infrastructure.

Europe and Japan have advanced technology development programs which provide direct support to industry, in most cases aimed at developing specific national capabilities. Perhaps most significant of all is the extent to which European and Japanese governments and industry work hand-in-hand to promote regional and national interests in international systems -- a good example of which is the heavy support given by ESA and Japanese government agencies to the development of advanced technology for the INMARSAT mobile and personal communications program.

Threats

This panel's year-long review of overseas capabilities in satellite communications has revealed many potential threats to U.S. industry. These threats include a slipping base in advanced satellite communications technologies across a wide range of disciplines, rapidly changing markets and applications, and a lack of effective long term systems planning and related technology road maps to the future. Most of all, there is a dearth of mechanisms for effective long term R&D directed at advanced technologies in which industry, government and universities can play an effective ongoing role.

Opportunities

The United States still holds an industrial lead in today's satellite communications market measured in spacecraft construction and flight hardware sales. This is a result of large investments in many areas of space technology over the last three decades. However, the U.S. space technology base is being depleted rapidly. Also, the position of its launcher industry has eroded considerably in the last five years.

The United States certainly has competitive industrial practices and a reasonably good but aging infrastructure for test and integration. Given these and other factors noted herein, there is good reason to believe that today's threats could be counteracted. If the available opportunities are realized, the United States could maintain its industrial leadership and recover from the effects of its slipping advanced technology base.

In summary, the members of this panel have identified a number of serious and growing risks to the U.S. satellite communications industry, but opportunities exist for future initiatives that could allow the United States to maintain its leadership role.

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