Outcomes and Implications for U.S. Radio Technology 2

WARC-92 considered a host of issues that were technically complex, interrelated, and contentious. Many of these issues were left over from previous WARCs, but the conference also considered frequency allocations for a number of new services and technologies. As a result of the month-long deliberations, conference delegates reached agreement on a broad range of allocation and regulatory issues. This chapter examines the outcomes of WARC-92, the factors that contributed to the success and/or failure of U.S. proposals, and the implications WARC-92 decisions will have for the development of radio technology in the United States and the making of future radiocommunication policy.

FACTORS COMPLICATING ASSESSMENT OF WARC-92 OUTCOMES

Although the United States achieved many of its objectives for WARC-92, U.S. proposals were generally less successful than popularly reported, How much less is open to debate. Members of the delegation leadership point cut that the United States was very successful in ‘‘opening the door’ to several important new services, and on many issues of lesser importance, U.S. proposals were accepted by WARC-92. These officials take a long view of the process of international spectrum management, and note that additional gains will be pursued at future conferences. They do not see the fact that the United States did not get everything exactly as proposed as a failure, but rather as an expected outcome and as part of a longer-term U.S. strategy in international spectrum policymaking.

Many factors complicate an evaluation and analysis of the decisions reached at the conference. Some of these factors are technical, some procedural, and some interpretive. In addition, as economic, technical, and political needs change, policies regarding radiocommunication services and the effects of those policies can be expected to change as well. As a result, assessing the future of specific services is difficult and somewhat speculative. The discussion below presents the most likely developments in these technologies and services based on current knowledge of technical details, negotiations, and political priorities.

Differences in Interpretation

Evaluation of the outcomes of WARC-92, or any other international conference, is complicated by differences in perspective and interpretation. Different people, depending on their job or affiliation, have different perspectives, and as a result, interpretations and evaluations of events and decisions can vary significantly. Defense Department evaluations may differ from Federal Communication Commission (FCC) assessments, which could be wholly different from an analysis by someone in the private sector. Even among the members of the U.S. delegation—who supposedly all have U.S. interests at heart-this divergence of opinions exists.

In describing and analyzing the implications of any international conference, there is a tendency for those involved to simplify the issues and put the best possible light on the outcomes achieved. Since the close of WARC-92, government and private sector representatives have endeavored to accentuate the positive results of the conference while downplaying negative outcomes. In some cases, this ''positive spin' makes issues easier to understand. In other cases, however, ''spin'' can cloud the issues, covering possible strategic or policy errors and making assessments of U.S. performance more challenging. In the case of WARC-92, the effects of ''spin'' have been compounded by the complexity of the decisions made and the secrecy surrounding several of the issues—it is difficult to evaluate results when they are not necessarily final or well-defined.

In addition, it is important to remember that WARCs are negotiations, and as is the case for almost any international negotiations, it is unreasonable to expect that one side will get all it desires. Such was the case for WARC-92. In order to fairly evaluate the outcomes of the conference, it is important to understand how specific goals for the negotiations were developed and what strategies were used to pursue them. In some cases, for example, negotiating positions (based on amounts of spectrum requested) were established that might have been more extreme than was actually needed. These proposals might not have been expected to succeed entirely, but were put forth as bargaining chips in order to provide negotiating room. In such cases, a narrow analysis that simply compares proposals with results may lead to an overly negative judgment about the outcomes of WARC-92 for the United States.

Procedural Issues

The problem of assessing WARC-92 outcomes is exacerbated by the way decisions are reached at WARCs and the way the international Table of Frequency Allocations is written. In WARC negotiations, frequencies are allocated to specific radio services and become part of the international Table of Frequency Allocations (see figure 1-1). However, footnotes are often added to these allocations that further define or constrain how, when, or where individual services can be used and by which countries.[1]

[1] Footnotes to the international Table of Frequency Allocations, just like the footnotes in this report, further describe or limit the allocations listed in the table. They are designated by number and letter-731X (see figure 1-1 in chapter 1, which shows a sample page from the international Table of Frequency Allocations, including how footnotes are presented). Footnotes are used for a variety of purposes, including to specify power levels, reference relevant resolutions, and allocate additional services. Footnotes are also used by a country (or countries) to preserve some measure of national sovereignty when they disagree with the allocations that were made internationally. These country footnotes can make alternative or additional allocations or can limit operations within those countries.

Often, adding footnotes to the allocations table is the only way to reach agreement. A country (or countries), for example, may decide that it cannot agree with an allocation that has been agreed to internationally because of its existing uses. The dissenting country will attempt to have a footnote placed in the allocation table noting its use of the frequencies or making an alternative allocation that applies only to it. At WARC-92, for example, the members of the International Telecommunication Union (ITU) decided to allocate the 1452-1492 MHz band to the Broadcasting-Satellite Service-Sound (BSS-Sound) on a coprimary basis. The United States, however, in order to protect domestic aeronautical telemetry uses—aircraft testing and weapons development—placed a footnote (in the form of an alternative allocation) that prohibits those frequencies from being used in the United States for BSS-Sound. In addition to footnotes, WARCs also adopt resolutions and recommendations that set conditions on the use of some frequencies that will affect how allocations can be implemented. Resolutions and recommendations also identify areas requiring further technical study by the International Radio Consultative Committee (CCIR) (see appendix C for a select list of WARC-92 resolutions and recommendations).

WARC-92 made many important changes to the international Table of Frequency Allocations, but also inserted many footnotes that will constrain the use of those new allocations.[2] In fact, delegates at the conference had a joke about the number and complexity of the footnotes they had agreed to: ''what the allocations giveth, the footnotes taketh away. " At the close of the conference, a representative of Canada remarked that he was glad the conference was over so he could go home and determine just what he had agreed to. Olof Lundberg, Director-General of Inmarsat, echoed this sentiment after the conference ended: "I think all of us who want to be players in new areas have a challenging time ahead to find out to what degree this spectrum is usable. Thus, concentrating only on the allocations that were adopted could lead one to conclude that the results of WARC-92 were more favorable for the United States than they actually are. A thorough analysis of the decisions of the conference requires careful consideration not only of the allocations, but also of the sometimes technically complex, sometimes deliberately vague footnotes that accompany the allocations.

Technical Issues

Finally, in analyzing the outcomes and implications of WARC-92, several important technical caveats must be noted that will affect how and when WARC-92 decisions will be implemented, First, many of the technical details that will affect the future of these services and technologies are still undecided, and will be negotiated amongst the stakeholders over the next several years. In addition, WARC-92 called for the CCIR, which studies technical matters relating to radio technology, to conduct studies on many of the systems and services addressed at the conference. These studies will guide future revisions of the decisions made at WARC-92.

Second, the decisions and allocations made at WARC-92 are not cast in stone. Although WARC-92 has been described as the last of its kind, it will not be the last world radiocommunication conference, and future conferences will very likely change, reverse, or otherwise modify the decisions and allocations made at WARC-92. According to the recent restructuring of the ITU (see chapter 3), future world radio conferences will take place every 2 years-each dealing with a single topic or very limited range of topics. It is likely (and required in some cases) that these conferences will modify the allocations and foot-

[2] For mobile services, e.g., more than 30 new footnotes were added that define power levels and sharing criteria, limit usc to certain countries, and specify dates for implementation.

[3] **Quoted in** Bob Chapin, ''Inmarsat: MSS Evolution or Revolution?" *Satellite Communications,* August 1992, p. 36.

notes made at WARC-92 based on CCIR studies and as a result of new technological developments.

In addition, the decisions made at WARC-92 will be subject to continuing interpretation (and reinterpretation to fit changing national priorities) over the next two decades. Since many of the services (and systems) discussed at WARC-92 are still being developed, their operational characteristics are still unknown, Consequently, the procedures and regulations that govern their use will likely change over time as experience sharpens understanding.

The implications of WARC-92 are also difficult in some cases to foresee because of the long transition times involved. The ITU often makes allocations effective 10 or 15 years in the future in order to give existing users of the bands adequate time to move to other frequencies. So, for example, the full force of some of the decisions of WARC-79 are just now beginning to be felt. Likewise, some WARC-92 allocations are not scheduled to come into effect until 2007—15 years from now. It may take almost that long to work through the nuances of the WARC-92 footnotes, and in that time, technology will have continued to advance rapidly. Radio services will have gone through several generations of improvements, and new applications will have been developed. Policies, rules and regulations will continue to evolve in response to technology developments. For these reasons, evaluating the outcomes of WARC-92 is, in one sense, premature. Rather, the outcomes of WARC-92 must be examined as one piece in a longer process that stretches out for many years before and after.

U.S. OBJECTIVES FOR WARC-92

The general goals for the United States at WARC-92 were to enhance the competitive position of the United States in radiocommunication technologies and services, and allow new radio services and technology systems to be developed as quickly and flexibly as possible. In pursuit of these goals, the U.S. delegation had several objectives for WARC-92:

- Support allocations for new services, such as low-Earth orbiting satellites (LEOS), BSS-Sound, and general satellite service (GSS), as well as the expansion of allocations for existing services, such as the Mobile-Satellite Service (MSS) and high-frequency broadcasting (HF).
- Protect important domestic radio operations by preventing new services from operating in the same bands and interfering with the incumbent services. This was an important concern for allocations in the L-band (approximately 1.4-1.6 GHz), the 14.5 -14.8 GHz band, and the frequencies just above 21.4 GHz, among others.
- Assure that new and existing allocations are more flexible and less constrained by regulation-allowing U.S. companies to exploit their technical strengths in international markets.
- Promote development of new radiocommunication technologies, an area in which the United States is a world leader.

In some cases these objectives conflicted with each other. During the domestic preparations for WARC-92, for example, U.S. policymakers were forced to choose between protecting the important civilian and military uses of the L-band for aircraft and weapons testing and promoting new digital broadcasting technologies that had been proposed by the private sector. In such cases, intense policy disputes erupted, the undercurrents of which carried over into the conference.

The sections below discuss the most important allocation issues debated at WARC-92.[4] Each

[4] Other matters besides new allocations for radio services were discussed at WARC-92. However, the main focus of the conference was on allocations, and allocation issues consequently are the focus of this report. For a full discussion of the U.S. positions for WARC-92, negotiating issues, and final results, see U.S. Department of State, *United States Delegation Report: World Administrative Radio Conference, International Telecommunication Union, Malaga-Torremolinos, Spain, 1992,* publication 9988, released July 1992.

Box 2-A—Primary and Secondary Radio Services

When radio frequencies are allocated to a specific radio service by the countries of the International Telecommunication Union at a WARC, the service is also given a class of service, usually either primary or secondary. These designations define the rights and responsibilities each service has in its allocated frequencies. When two or more services share the same band of frequencies, as is often the case, these class designations also describe how the services should relate to each other in terms of sharing and coordination.

Primary radio services have full rights to use any or all of the radio frequencies that have been allocated to it, unless modified by a footnote to the international Table of Frequency Allocations. Such a footnote could specify certain countries in which the service may not operate or could specify certain technical constraints such as maximum levels of power allowed. When two primary services share the same frequencies, they must coordinate their use, if necessary, to ensure that interference is minimized.

Secondary radio services are not allowed to cause interference to primary services and cannot claim any protection from interference from primary services. They must accept interference from a primary service if it occurs.

When developing and implementing a new service, a primary allocation is preferable since it confers certain rights and protections. Secondary allocations, on the other hand, can constrain development of a new service. In simple cases, secondary services must conform to the requirements of the primary services using the band. This may require systems planning to offer a new service to be redesigned or substantially modified, which can be costly in terms of time and money. System modifications can often reduce system capacity, coverage, or quality. If a new secondary service is not able to share with the existing primary services, it is not permitted to operate.

SOURCE: Office of Technology Assessment, 1993. Complete definitions and further information on radio services can be found in 47 CFR 2.104.

section provides a brief background on the service and technology, discusses the U.S. proposals and how well they fared at WARC-92, and examines the implications for the service now that agreements have been reached.[5]

HIGH-FREQUENCY BROADCASTING

Background

The frequencies from 3 to 30 MHz are referred to as the high-frequency band or, more commonly, the shortwave band. Because radio waves in these frequencies can travel long distances (beyond the horizon), they are extensively used by amateur radio operators, international government (Voice of America, British Broadcasting Corporation, and Radio Moscow) and private (religious) broadcasters, and for national and international aviation, maritime, and emergency communications.[6] Many developing countries use these bands primarily to provide domestic point-to-point communications.

International broadcasters typically transmit news and information services and religious programming as well as music. Many countries, including the United States, use shortwave broadcasting to champion their political, cultural, and economic beliefs around the world. In this role, HF broadcasting is viewed by many nations as an

[5] All information on U.S. proposals comes from U.S. Department of State, *UnitedStates Proposals for the 1992 WorldAdministrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum,* Department of State publication 9903, July 1991.

[6] Although more than 100 countries currently use HF frequencies to broadcast information programming internationally, large-scale international broadcasting is limited to perhaps a dozen (mostly industrial) countries, including Australia, Cana&, China, Cuba, France, Germany, Japan, the Netherlands, Russia, the United Kingdom, and the United States. For a brief discussion of the history of international HF broadcasting, see James Wood, "Growth Explosion in International I-IF Information Broadcasting," *Telecommunications Policy, vol.* 15, February 1991, pp. 22-28.

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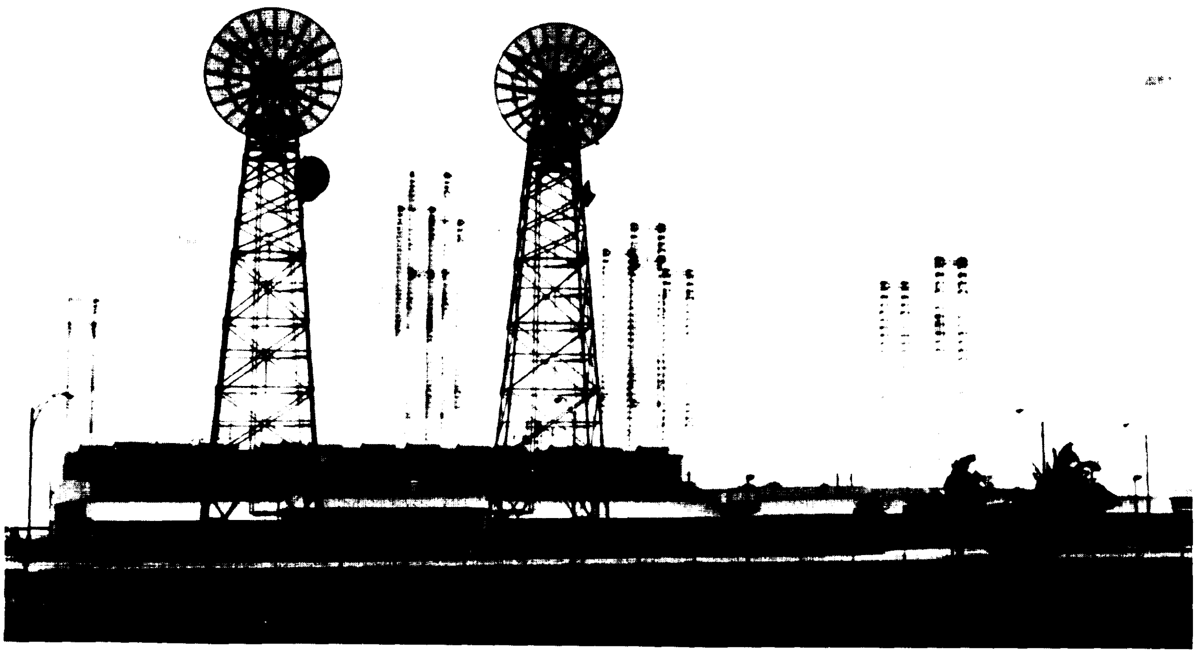
U.S. Information Agency



The United States uses high-frequency broadcasting towers like these in the Phillipines to transmit radio programs around the world.

important tool of foreign policy. In the past, for example, HF broadcasting was instrumental in delivering propaganda programming during times of war. This function was important during the Cold War, but today, the overt propaganda content of the broadcasts has been toned down and more emphasis is put on communicating American values and viewpoints. The United States currently broadcasts more hours of international programming than any other country.

For many years, the amount of spectrum allocated to HF broadcasting has been recognized by most countries as critically inadequate, especially in the most valuable (and congested) bands below approximately 10 MHz.[7] Part of the reason for this congestion is simple numbers-there are more broadcasters than available frequencies. Planning exercises conducted for the 1987 High Frequency Broadcasting WARC (HFBC-87), for example, indicated that more than 50 percent of all HF broadcasting needs submitted by member countries could not be adequately met, and between 25 and 35 percent of these needs could not be met at all.[8] In 1990 the National Telecommunications and Information Administration (NTIA), concluded that 2 to 4 times more spectrum (depending on specific frequency bands and modulation techniques) was needed to meet

[7] The bands below 10 MHz are especially coveted by broadcasters and other HF users because they are much more reliable than the frequencies above 10 MHz. Frequencies above 10 MHz that are used for long distance communication are often affected by sunspot activity, which varies by the time of day and by season. When this happens, the broadcasters in the upper bands reset their transmitters to the lower frequencies, causing even more interference and congestion.

[8] WARC-92 Industry Advisory Committee, "Final Report of Informal Working Group Number l," report submitted to the Federal Communications Commission Apr. 24, 1991.

current HF broadcasting requirements. The International Frequency Registration Board (IFRB) reached similar conclusions in its report to WARC-92.[9]

One reason behind the great demand for HF frequencies is that multiple frequencies are often needed to deliver programming to a given geographic area over the course of a day. Different frequencies have distinct transmission characteristics that make them suitable for long-range transmission during specific hours-different frequencies, for example, are used at night and during the day. Thus, in order to provide continuous coverage to a specific region or city, frequencies must be changed as the day progresses. For example, Voice of America (VOA) uses seven frequencies to deliver programmingg to Beijing, China. The problems in providing adequate coverage to an area as large as China or Africa are enormous and achieving adequate quality and coverage may require many different frequencies.

The international regulatory system also contributes to the congestion of the HF broadcasting channels. HF broadcasting is not regulated, for example, as AM/FM radio is in the United States—where one station is assigned to one channel in a specified geographic area. This assignment process substantially reduces interference between stations. International HF broadcasting, on the other hand, has much less stringent limits. Although the use of specific frequencies is supposed to be coordinated internationally, and the FCC regulates U.S. broadcasters, in other countries broadcasters often transmit anytime, anywhere they want-as long as the band is allocated to HF and they follow the international Radio Regulations (and sometimes even this is not adhered to).[10] Some of the most sought-after frequencies can have as many as 10 stations operating on them.

U.S. Proposals

The United States made several proposals relating to HF allocations and regulations. First, based on the need for additional frequencies for HF broadcasting, and in order to balance the amount of spectrum available in the ITU's 3 regions (see figure 1-2), the United States proposed to allocate an additional 1325 kHz in ITU Region 2, and an additional 1125 kHz in Regions 1 and 3. The following additional HF broadcasting allocations were proposed for Region 2:

5900-5950 kHz	13800-13900 kHZ
7200-7525 kHZ*	15600-15700 kHZ
9350-9500 kHz	17450-17550 kHz
11550-11650 kHz	18900-19300 kHZ

***The United States** proposed to add only 125 kHz in this band for ITU Regions 1 and 3 in order to align the HF broadcasting bands worldwide (existing HF broadcasting allocations in these regions exceeded those in Region 2). This accounts for the difference in total proposed allocations.

All these allocations except the 18900-19300 kHz would be contiguous with existing HF broadcasting bands.

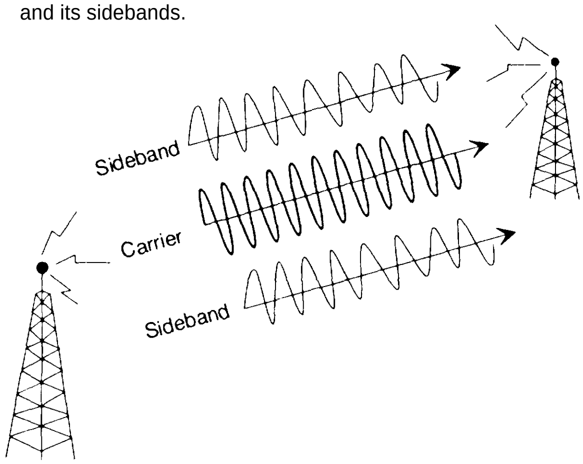
In addition, the United States proposed that all new allocations be required to use a transmission

[9] U.S. Department of Commerce, National Telecommunications and Information Administration, *Spectrum Required for HF Broadcasting*, NTIA Report 90-268, October 1990. Internation.al Telecommunication Union, Document 4 of WARC-92, Malaga-Torremolinos, Spain, February 1992.

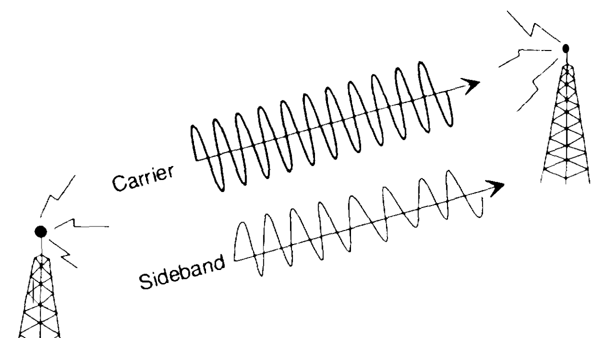
[10] The International Frequency Registration Board does have to be notified that such operations are beginning, but the IFRB has no real power to prevent stations from operating on any frequencies they want.

Figure 2-l—Single Sideband Modulation

In order to transmit information using radio waves, the reformation to be sent (music or voice) IS impressed onto a carrier wave. As a result of this process, sidebands are created that actually contain the music or voice Information of the signal. Radio receivers extract the music or voice reformation from the carrier and its sidebands.



When both upper and lower sidebands are transmitted, the method IS called double sideband modulation.



In smgle-sideband modulation, either one of the sidebands IS removed from the modulated carrier. Only the carrier and one sideband are transmitted.

SOURCE: Office of Technology Assessment, 1993, adapted from Harry Mileaf, cd., *Electronics One* **(Rochelle Park, NJ: Hayden Book Company, Inc., 1976),**

technique called reduced carrier single-sideband (SSB) modulation (see figure 2-1).[11] SSB reduces the amount of spectrum each radio signal/station needs, thereby allowing more users to share the band.[12] In order to encourage the early use of SSB, the United States also proposed advancing the date (agreed to at HFBC-87) when all broadcasting must be converted to SSB from the year 2015 to 2007.

Finally, the United States proposed to align the differing regional HF broadcasting and amateur radio service allocations around 7 MHz—creating a worldwide allocation for HF broadcasting at 7200-7525 kHz. A procedure for reaccommodating existing services displaced by these changes was also proposed.

Results

United States HF proposals achieved mixed results at WARC-92. The conference allocated only 790 kHz of additional spectrum to HF broadcasting, of which 200 kHz is located in frequencies below 10 MHz (the most congested portion of the HF bands). The remaining 590 kHz was allocated between 11 and 19 MHz. All the newly allocated bands are allocated on a worldwide basis (see table 2-l).

Two significant limitations were put on the use of these new frequencies. First, they cannot come into operation until April 1, 2007. At that time, broadcasting will become the exclusive primary service operating in the bands. Point-to-point and mobile services, however, will be able to use the bands after this date, but only within the boundaries of a country and only on a low-power, noninterference basis. WARC-92 Resolution 21 defines the conditions for the phase-in of the broadcasting service in these newly allocated bands.

11 Currently, most international shortwave broadcasting uses a transmission technique called double sideband.

12 Contrary t. intuition, the increase in spectrum availability would not be 2:1. NTIA estimates gains of about 1.8:1, while the ITU/IFRB estimates that the efficiency gain would be approximately 1.5:1, meaning that 2 existing double-sideband channels could be converted into 3 new SSB channels.

Table 2-1—WARC-92 High-Frequency Broadcasting Allocations

Frequency	Amount	Frequency	Amount
5900-5950 KHz	50 KHz	11600-11650 KHz	50 KHz
7300-7350 KHz	50 kHz	12050-12100 KHz	50 KHz
9400-9500 KHz	100 KHz	13570-13600 KHz	30 KHz
		13800-13870 KHz	70 Khz
		15600-15800 kHz	200 KHz
		17480-17550 KHz	70 KHz
		18900-19020 KHz	120 KHz
	200 KHz		590 KHz

SOURCE: Office of Technology Assessment, 1993.

Second, WARC-92 prohibited use of these additional bands until a process for planning the HF broadcasting spectrum has been completed. This restriction is defined in Resolution 523, which also calls for a WARC to establish planning procedures. However, United States HF broadcasters believe that planning will be meaningless until more spectrum is allocated, The United States entered a formal reservation in the Final Acts of WARC-92 to protest the small amount of spectrum allocated to HF broadcasting and other limitations put on use of the bands.[13]

On its other HF proposals, the United States was more successful. WARC-92 did agree that all new bands should be required to use SSB transmission, but did not accept the U.S. proposal to advance the date for conversion of all HF broadcasting to SSB from 2015 to 2007. The conference did, however, adopt Recommendation 519, which recommends that the next WARC again consider advancing the date for replacing current double-sideband transmissions with more spectrum-efficient SSB techniques. WARC-92 did not accept the U.S. proposal for aligning the world's HF broadcasting bands around 7 MHz, but Recommendation 718, proposed by Mexico and supported by the United States, was adopted that calls for a future conference to address the issue. Finally, WARC-92 accepted U.S. proposals for reaccommodation procedures and secondary status for freed and mobile users in the HF bands. WARC-92 also adopted Recommendation 520 that member governments take steps to shut down HF broadcasters who are using frequencies outside the designated HF broadcasting bands.

Discussion

DOMESTIC ISSUES

In the domestic preparation process for HF broadcasting, the primary issue was how much additional spectrum the United States should propose to be reallocated for HF broadcasting uses. This debate pitted private broadcasters and several agencies of the Federal Government (U.S. Information Agency (USIA)/VOA and Radio Free Europe/Radio Liberty) against other U.S. Government users, including the Departments of Treasury (Coast Guard) and Justice (Federal Bureau of Investigation).

During the preparations process, the FCC's Industry Advisory Committee (IAC) recommended that 2455 kHz of additional spectrum be allocated for HF broadcasting. Defense and other government HF users proposed far smaller amounts, and a compromise of 1325 kHz was tentatively

13 ''In the view of the United States of America, this Conference failed to make adequate provision for the HF needs of the broadcasting service, particularly below 10 MHz, despite an earnest effort to do so. The IFRB's Report to the Conference shows that broadcasters' requirements far outnumber the channels available in the bands between 6 and 11 MHz (where spectrum is urgently needed) and that planning will not work effectively without additional and adequate HF spectrum. Therefore, the United States of America reserves the right to take the necessary steps to meet the HF needs of its broadcasting service. ' International Telecommunication Union, *'Declarations," WARC-92 Document 389-E, Malaga-Torremolinos, Spain, Mar. 3, 1992, p. 29.

reached. What happened next is disputed, but final proposals included only 1325 kHz. USIA and VOA, joined by private broadcasting interests, complained to NTIA that this amount was inadequate, and proposed an additional 60 kHz. Other government agencies, including the Coast Guard and Federal Bureau of Investigation, opposed this addition, citing the use of the specified band for drug interdiction activities. NTIA agreed with these agencies, and rejected VOA appeal—the final proposal to WARC-92 was for 1325 kHz. In an attempt to force official U.S. proposals to include more spectrum for HF broadcasting, VOA, representing government and industry broadcasters, took its case to the National Security Council (NSC) in early January 1992.[14] NSC did not act on VOA's request until after WARC-92 had ended, effectively nullifying VOA's appeal.

The clash over allocations for HF broadcasting has become controversial. Different players in the debate hold conflicting views of what happened and when: What information was shared? When were decisions made and who made them? How carefully were the factors surrounding the issue considered? Because the debate involved existing government use of the HF bands, much of the preparations and debate regarding HF broadcasting allocations were conducted in the Interdepartment Radio Advisory Committee (IRAC), the deliberations of which are largely restricted from public view.[15] The issues surrounding the battle over additional HF spectrum and its implications for long-term U.S. radiocommunication policy development are discussed in chapter 1.

Ultimately, the domestic battles over HF broadcasting proposals most likely had no effect on the WARC-92 outcome. Even if the United States had proposed more spectrum, as did the Europeans, it is unlikely that the developing countries would have agreed to any further allocations. A few analysts disagree. They believe that if the United States had been able to develop a proposal with even more additional spectrum for HF broadcasting in a timely manner, and had joined others (the Europeans) in promoting such new allocations prior to WARC-92, that additional spectrum could have been obtained. Whether it was the result of conscious strategy or not, going into the conference with more modest proposals now makes the outcome look better than it would have if the United States had proposed the larger amount of spectrum VOA and the private broadcasters wanted.

An additional area of domestic disagreement involves the implementation of SSB technology. This conflict again involves VOA and private broadcasters, on the one hand, and other government agencies on the other. Although VOA supports the conversion to SSB in principal, and is, in fact, installing SSB-compatible transmitters, it is concerned about how and when the transition to SSB can be accomplished. VOA's position is that the cost of SSB radio receivers currently prevents their rapid adoption by VOA's listeners, and until adequate numbers of SSB radios are in use, they will resist ceasing their double-sideband

[14] NSC is a last resort for resolving issues that could not be resolved in the regular WARC preparation processes. It has no specific expertise in radiocommunication matters and no individual who specializes in telecommunication issues.

[15] The Interdeparment Radio Advisory Committee (IRAC) was formed in 1922 to coordinate the Federal Government's use of the spectrum. It is now located in the Commerce Department and consists of approximately 20 to 25 representatives from those Federal agencies who are the most active users of radio technologies. IRAC serves in an advisory capacity to NTIA in matters of radiocommunication policy and spectrum management. For more information on IRAC and its role in the WARC-92 preparation process, see U.S. Congress, Office of Technology Assessment, *The 1992 WorldAdministrative Radio Conference: Issues for U.S. International Spectrum Policy,* OTA-TCT-BP-76 *(Washington* DC: U.S. Government Printing Office, November 1991).

(DSB) transmissions.[16] Typical shortwave (HF) radio receivers are relatively inexpensive, but SSB receivers, which are being manufactured today (although not in mass market quantities), cost $175 and up, far beyond the means of most VOA listeners around the world.[17] VOA's position also may be related to a desire to move eventually into satellite (BSS-Sound) delivery of its programming. Rather than forcing its listeners to endure two format changes in the coming years, VOA may prefer to move directly into BSS-Sound delivery of its services, leapfrogging a technology (SSB) they see as only an interim (and very expensive) step.[18]

These disagreements indicate a larger policy and institutional battle that is being fought between private/government broadcasters and other Federal Government spectrum users in the arena of international frequency allocation. Defense interests are especially reluctant to reallocate spectrum for HF broadcasting (public and private) because they control much of the HF spectrum allocated for government use, and they do not want to give up any more frequencies than necessary. As a result, the HF broadcasting community reports being consistently overwhelmed in government decisionmaking processes such as the IRAC preparations for WARC-92. The issue appears to be one of agency mission. Defense-and security-related communications appear to have assumed a higher priority than international broadcasting, despite a National Security Directive (NSD-51) that affirms the important role of international broadcasting in foreign policy and supports its continued mission. Battles of this type can be expected to continue until guidelines are developed that allow government policymakers to weigh competing spectrum claims based on clearly-defined policy goals.

INTERNATIONAL ISSUES

Unlike many other allocation issues, the debate at WARC-92 over new HF broadcasting allocations echoed past ITU differences between the developed and developing countries. For more than a decade, the United States and many other industrialized countries have been advocating increasing HF broadcasting allocations in order to meet the growing needs of international HF broadcasters. These past efforts achieved only limited success.

Historically, developing countries, who use the HF bands for fixed (point-to-point) domestic telecommunication services, have opposed expanding the allocations for HF broadcasting. They fear that such uses would interfere with or limit their point-to-point HF systems, and that increased use of these frequencies for broadcasting could make their existing equipment unusable-jeopardizing their investments in that equipment. They want to continue to use HF for domestic communications and they want to protect their investments. Many countries are also concerned about increased foreign broadcasting into their territories.

At WARC-92, these historic divisions persisted as a large and determined block of develop-

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16 "USIA does not oppose conversion to SSB, which it sees as offering spectrum efficiency and possibly generator-fuel savings, provided its listeners have SSB-compatible receivers. . . USIA has consistently insisted that two related problems, the introduction of SSB-compatible transmitters and the introduction of SSB-compatible receivers, must be resolved prior to the final abandonment of DSB in favor of SSB...The high cost of SSB-compatible receivers, especially in the Third World, maybe a significant factor in delaying the conversion from DSB. Until and unless adequate numbers of SSB-compatible receivers are in the hands of audiences, broadcasters, and more importantly the governments that in most cases pay their bills, will be unwilling to cease DBS operations. " Review comments of Walter La Fleur, Director, Office of Engineering and Technical Operations, Voice of America, letter to David P. Wye, OTA, Nov. 18, 1992, p. A-2.

17 Some analysts maintain that the Price of SSB receivers would come down substantially when they were manufactured in true mass market quantities. Others believe that the price of the receivers would still be prohibitively high.

18 It should be noted that new BSS-Sound receivers will also be very expensive when they are first introduced.

ing countries staunchly opposed allocating any more frequencies to the HF broadcasting service. The industrialized countries, including the United States and Europe as well as the Russian Federation and Japan, supported increasing the allocations. The Europeans, in fact, submitted a common proposal for new HF spectrum that exceeded even the amount proposed by the United States. Discussions over the allocation proposals at the conference were intense, and negotiations quickly became focused on the most valuable and congested frequencies below 10 MHz. After a number of formal and informal meetings and much discussion "of f-line," a compromise package was worked out that included the allocations noted above.

Although the allocations by WARC-92 fell short of U.S. objectives, the United States supported the compromise package. U.S. delegates participating in the HF negotiations felt that further discussion would be useless, citing extensive opposition to any further allocations. Developing country opposition also blocked other U.S. proposals. The U.S. proposal for advancing the conversion date for SSB, for example, met stiff resistance from the developing countries, and some developed countries, who were concerned that they could not afford to refit or replace their equipment any faster than the original date of 2015.

This case points out the difficulty of balancing domestic and international factors in developing proposals. Domestic users need more spectrum, which led the United States to propose large additional allocations. Many (primarily developing) countries, however, oppose expansion, meaning that a smaller proposal might have had better chances for success internationally. U.S. proposals represented an attempt to strike a balance between these two conflicting forces.

Issues and Implications

FREQUENCY ALLOCATIONS ARE STILL INADEQUATE

From the U.S. perspective, despite the allocations made at WARC-92, the amount of spectrum allocated for HF broadcasting is still inadequate. This means that the HF broadcasting bands will continue to be congested and subject to high levels of interference among stations around the world. Furthermore, the limitations placed on the implementation of the new HF broadcasting frequencies mean that these bands will not be available for HF broadcasting for at least 15 years. Given the shortage of spectrum that currently exists, the decisions made at WARC-92 will not solve broadcasters' immediate needs.

Several long-term questions regarding HF broadcasting remain. How can the United States best meet its HF broadcasting requirements given the limitations and restrictions of the WARC-92 allocations? What constraints, if any, will the inadequacy of allocations put on future U.S. HF broadcasting activities? Will future international broadcasting services require more high frequency spectrum or can other technologies be used to alleviate the shortage?

The options available to the United States are limited. According to the U.S. reservation in the Final Acts of WARC-92, the United States will take all steps to meet the needs of its broadcasters. In practice, this may mean that U.S. broadcasters will use the frequencies allocated at WARC;-92 immediately, in spite of the implementation date of 2007. Despite ITU agreements and resolutions that prohibit broadcasting in frequencies out of the specified bands, many countries, including the United States, have been forced to use bands other than those allocated to HF broadcasting to meet their domestic HF broadcasting needs.[19] In the future the United States may be forced to expand

[19] Number 342 of the Radio Regulations permits such operations provided they do not cause interference to the allocated services. International Telecommunication Union, *Radio Regulations* (Geneva, 1982).

its use of prohibited frequency bands in order to meet its broadcasting requirements.

PLANNING

Planning the HF broadcasting spectrum is closely linked to the amount of spectrum that has been allocated for HF broadcasting. From the U.S. perspective, any attempt at planning before adequate spectrum is allocated would be difficult and most likely unsuccessful. The United States will fight attempts to plan the spectrum until it believes that allocations are adequate and/or until an adequate planning system is developed.[20]

Aside from arguments that insufficient spectrum exists for planning, the United States has historically opposed *a priori* planning of the spectrum. Government officials believe that such planning reduces the flexibility to meet as yet undefined future needs and leads to inefficient utilization of spectrum resources, U.S. spectrum policymakers may also fear that because spectrum is in such limited supply, and because the United States is the world's largest user of the HF spectrum, that ITU planning could force U.S. HF broadcasters to give up frequencies in order to make room for other countries. Thus, it is unclear in any case if the United States would ever support the formal planning of the HF broadcasting bands. From the perspective of developing countries, like the past battle over geosynchronous orbital slots for satellites, this is a question of equity and fairness they have been pursuing for some time, and which continues to be important to them. The issue of HF planning will continue to be contentious for many years.

SINGLE-SIDEBAND TRANSMISSION

Single-sideband transmission is not a new technology. Amateur radio operators, the military, and some marine and aeronautical users have been using it for many years. Converting these types of (point-to-point) radiocommunication systems to SSB is easier than for mass market broadcasting operations because commercial services and the military have greater financial resources and the ability to more completely control the transition process—allowing them to implement transmitters and receivers simultaneously. Broadcasters, on the other hand, directly control only the transmission of the signal; they cannot force listeners to buy new radios.[21]

Although SSB radios are available, they are not a truly ''mass market" product. Currently, SSB receivers are available commercially for $175 and up in the United States. These prices will slow the widespread introduction of these radios in the developing nations of the world. If and when mass market economies are realized, the price of SSB radios will fall, Whether such radios will be produced cheaply enough to sell worldwide, and when, however, are open questions. Developing a market for such products will be difficult until more broadcasters (are forced to) start using SSB transmissions for their programming. The conversion to SSB in the United States will continue to be a difficult issue. Because of this, broadcasters will probably continue to insist that sufficient numbers of SSB-compatible receivers be in the hands of their listeners before abandoning DSB in favor of SSB systems.

BSS-SOUND

The congestion in HF broadcasting bands and the relatively low reliability and quality of some of the frequencies is pushing international broadcasters to look for alternative means to deliver programming. An important future possibility in international broadcasting is the deployment of

20 Despite efforts to date, the development of a computerized planning model has not been successful. Systems that have been developed so far have suffered from various technical flaws that made them unacceptable to ITU members. It is unclear how vigorously further development efforts are being pursued.

21 Broadcasters are faced with a chicken-egg scenario. Consumers do not have SSB radios and do not want to buy them until there 1S Sufficient programming to listen to. Broadcasters will resist broadcasting to listeners who cannot hear them-unless they are forced to. One possible solution is to develop inexpensive dual-mode radios capable of receiving both SSB and DSB transmissions.

broadcasting systems that use satellite technology. Such systems would cover larger areas than terrestrial transmitters, and if such systems are licensed and operated regionally and/or globally, they could replace traditional HF broadcasting as the medium of choice for international broadcasters.[22] The deployment of only a small number of satellites could beam hundreds of channels of programming around the world, thereby relieving some, if not all, of the current congestion of the HF broadcasting bands. Many HF broadcasters, including VOA, see the future of international broadcasting in satellites. Direct broadcasting from satellites could provide worldwide coverage for U.S. broadcasters that is more complete, reliable, and of higher quality than that available with HF technology.

One important issue that will have to be addressed at future ITU meetings before BSS-Sound international broadcasting can go forward is the legitimacy of cross-border satellite transmissions. Currently, HF broadcasting across national boundaries is internationally recognized as a legitimate activity, although some countries do attempt to jam foreign transmissions entering their territories. There is currently no similar broad acceptance of international satellite broadcasting activities, and the impossibility of conforming satellite coverage areas strictly to national boundaries could cause serious difficulty in implementing such systems on a regional or worldwide basis.[23] Some countries, who want to exercise tight control on the flow of information into their countries, will seek to impose restrictions. U.S. broadcasters would prefer that future satellite-based international broadcasting be considered in the same way that HF broadcasting is today. This would allow them maximum flexibility in reaching listeners around the world.

BROADCASTING SATELLITE SERVICE-SOUND

Background

BSS-Sound refers to the delivery of audio programming (music, news, sports) from satellites directly to consumer radios. While no BSS-Sound services are operating yet, the systems now being developed would use digital technology to broadcast CD--or near CD-quality programming to listeners using radio receivers that would be portable/mobile and low-cost.[24] A key feature of satellite broadcasting is that it allows programmers to broadcast their signal over a wide area-the entire United States, for example-as opposed to the limited range of today's conventional terrestrial transmitters. Some developers of BSS-Sound systems plan to augment the satellites with terrestrial transmitters that would improve reception in urban areas (between buildings, in tunnels, etc.). Because these systems will send their signals in a digital format, the term digital audio broadcasting (DAB) has come into widespread use (especially in the United States) to describe this next generation of radio broadcasting, and, in fact, DAB is now commonly used to describe both satellite and terrestrial digital broadcasting systems.

Proponents of BSS-Sound see many markets for the new digital services. They are planning a variety of programming targeted to groups of users with different musical tastes, ethnic and cultural backgrounds, and special interests—groups that may not be able to support a local

22 NTIA made this argument in opposing further allocations for HF broadcasting.

23 In fact, No. 2674 of the Radio Regulations stipulates that "all technical means available shall be used to reduce, to the maximum extent practicable, the radiation over the territory of other countries unless an agreement has been previously reached with such countries.' ITU, *Radio Regulations*, op. cit., footnote 19, p. RR30-2. Whether or not this regulation requires prior consent of countries before satellite broadcasting can be beamed into them is a topic of debate in U.S. radiocommunication policy circles.

24 Because existing AM/FM radios use analog technology, they will not be able to receive the new digital BSS-Sound signals. Consumers will have to buy new (digital) radios in order to listen to the new services.

radio station, but when aggregated across the country, make a national service possible. This concept is analogous to the programming philosophy of cable television.

In addition to audio programmingg, the transmission of data services directly to users is also being explored. Proponents envision broadcasting data services to support educational needs, paging operations, and navigation and traffic management systems for the Nation's cars and highways. In addition to purely domestic services, international broadcasters see BSS-Sound technology as an important new way to transmit radio programming around the world—a service that would allow them to reach listeners with higher quality than the HF broadcasting they use today.

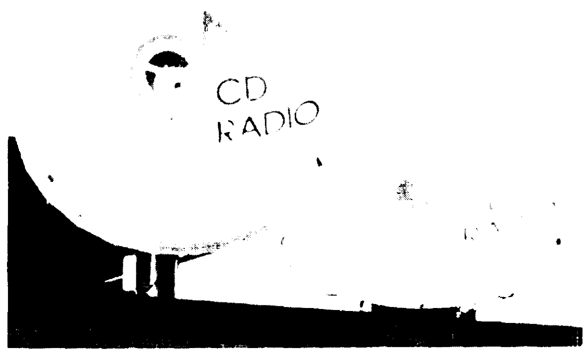
BSS-Sound applications have been studied internationally for at least 25 years. The members of the ITU first considered allocating frequencies for BSS-Sound services at the 1979 WARC. That conference and subsequent WARCs, however, were not able to agree on specific allocations, and as a result, the matter was deferred for consideration by WARC-92.

U.S. Proposal

Because of the contentious nature of the debate in this country over allocations for BSS-Sound, the U.S. proposal for this service was submitted to the ITU after the formal package of U.S. proposals was submitted in July 1991. The United States proposed that the 2310-2360 MHz band be allocated for BSS-Sound and complementary terrestrial broadcasting services on a worldwide basis.

Results

The U.S. proposal was not adopted as a worldwide allocation. Instead, WARC-92 adopted three different allocations for BSS-Sound (see figure 2-2 and table 2-2), making the development of a common worldwide BSS-Sound system/standard unlikely.[25] First, WARC-92 allocated 40 MHz of spectrum for BSS-Sound and complementary terrestrial systems at 1452-1492 MHz on a coprimary worldwide basis. However, 30 countries, including many countries represented by the Conference of European Postal and Telecommunications Administrations (CEPT), indicated through a footnote (722AAA) that BSS-Sound services will have to operate on a secondary basis until April 1, 2007. This will likely preclude the introduction of these services in those countries until that date. In addition, the United States, holding to its original proposal, added a footnote (722B) that allocates the 1452-1525 MHz band only to the fixed and mobile services-no BSS-Sound or terrestrial DAB services will be permitted in that band in this country. The United States was the only country that made such a stipulation, which was to protect existing aeronautical telemetry users. Second, a number of countries, including Japan, China, and the Russian Federation, allocated (through footnote 757A) the 2535-2655 MHz band for BSS-Sound on a coprimary basis. Finally, the United States, joined only by India, inserted another footnote (750B) allocating

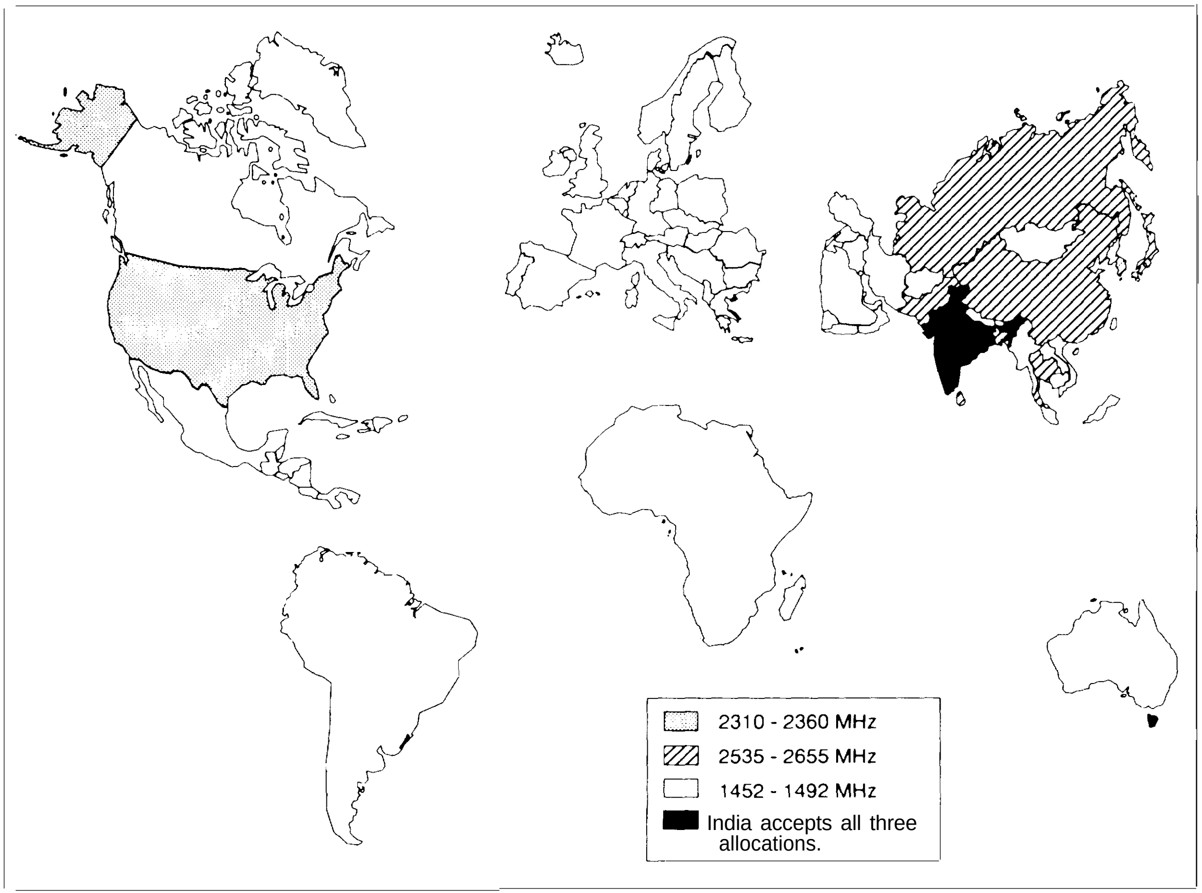


Satellite CD Radio

Satellite dishes such as these will beam digital quality radio programming up to satellites that will then retransmit it across the country.

[25] WARC-92 did agree that all BSS-Sound systems would be required to use digital transmission technology.

Figure 2-2—WARC-92 Allocations for Broadcast Satellite Service-Sound



NOTE: Only Belarus, Russia, and Ukraine are included from the former Soviet Union.

SOURCE: Office of Technology Assessment, 1993.

the 2310-2360 MHz band for BSS-Sound, Thus, there are three BSS-Sound allocations that could eventually be used.

WARC-92 also adopted two resolutions pertaining to BSS-Sound. Resolution 528 called for another conference, preferably before 1998, to plan BSS-Sound services, develop procedures to coordinate BSS-Sound with complementary terrestrial (DAB) services, and review criteria for sharing the spectrum with other services. In the interim, new BSS-Sound applications may be implemented, but only in the upper 25 MHz of the allocations, and only according to existing coordination requirements. Terrestrial DAB services

Table 2-2—Population Distribution of WARC-92 BSS-Sound Allocations

Allocations	Population (milllions)
1452-1492 MHz	**3,135**
No restrictions	**2,584**
Not until 2007	**551**
2310-2360 MHz	**1,087**
2535-2655 MHz	**2,719**

NOTE: Because India accepted all three allocations, the actual numbers of listeners for each allocation will vary depending on which allocation(s) India uses.

SOURCE: Office of Technology Assessment, 1993, based on data provided by Voice of America.

may also be introduced, but only after coordinating with countries whose existing services might be affected. This 25 MHz limit should allow some services to use the spectrum, but the number of systems that could share the frequencies may be limited.

Resolution 522 notes that BSS-Sound services could be provided by either geosynchronous or non-geosynchronous orbit satellites, and requests that the CCIR study the sharing criteria for BSS-Sound systems using different orbits and between BSS-Sound and other services in order to develop coordination procedures and avoid harmful interference between systems and services.[26] The resolution also requests that the ITU's Administrative Council place this matter on the agenda of a future WARC. This resolution responds to the development of low-Earth orbiting satellite (LEOS) systems and the many unknowns regarding systems using this new technology.

WARC-92 also adopted Resolution 527, which calls for a future WARC to consider the development of terrestrial DAB in the VHF broadcasting bands (existing FM radio bands) for Region 1 and interested countries of Region 3. This is in response to the plans of several European countries to begin digital sound broadcasting on an interim basis in those bands. The resolution also requests the CCIR to begin the relevant technical studies (including system characteristics, propagation, and sharing criteria) associated with the introduction of such services.[27]

Discussion

The idea of broadcasting radio programming directly from satellites is not new, dating back at least 45 years.[28] The introduction of digital technology, however, and the promise of static-free radio programming gave new impetus to BSS-Sound and DAB development efforts in the 1980s. The European Commission took the lead in developing digital radio technology with its Eureka 147 DAB project, which was first demonstrated at the 1988 WARC. U.S. efforts to develop DAB and BSS-Sound technology have lagged behind European efforts, and U.S.-developed systems are only now being demonstrated.

DOMESTIC BACKGROUND

The development of DAB systems has taken two forms in the United States. Originally, a small number of companies proposed satellite-based (BSS-Sound) systems that would use frequencies in the L-band (roughly 1.4-1.6 GHz) to transmit their programming. Because these types of systems, like Eureka 147, would use frequencies other than the traditional AM/FM broadcasting bands, they are often referred to as 'out-of-band' systems. The first U.S. company to formally announce such a system in the United States was Satellite CD Radio.[29] As currently planned, the Satellite CD system, which was proposed in 1989,

26 In this case, non-geosynchronous orbits refer primarily to elliptical, and not low-Earth orbits. Because LEOS only remain in range of a receiver for a period of minutes, some analysts doubt whether audio services could be provided by LEOS.

27 International Telecommunication Union, *Final Acts of the World Administrative Radio Conference (WARC-92)*, provisional version, Malaga-Torrernolinos, Spain, March 1992, p. 116. Hereafter, ITU, *Final Acts.*

28 The concept of using satellites to transmit programming was presented by Arthur C. Clarke in 1945 (Arthur C. Clarke, "Extra-Terrestrial Relays," *Wireless World*, October 1945). The more modem concept of BSS-Sound was considered at previous WARCs in 1979, 1985, and 1988. See OTA, *WARC-92*, op. cit., footnote 15.

29 At about the same time, Radio Satellite Coloration (RadioSat) designed a system that would have used the MSAT system planned fOr operation by American Mobile Satellite Corp. (AMSC) and the Department of Defense global positioning system. The system planned to provide entertainment, communications, and navigation services primarily to car radios on a nationwide basis. Services to be delivered included: interactive digital audio entertainent; data broadcasts, including traffic and weather advisories; navigation information; and two-way voice and data communications. Because of what RadioSat terms "unlawful' behavior on the part of AMSC, RSC was never able to negotiate for frequencies with AMSC and has terminated development of the RadioSat system. RSC has filed suit against AMSC charging violations of the Communications Act of 1934 and the Sherman Antitrust Act.

would use two satellites to broadcast up to 30 channels of CD-quality music to subscribers who would pay a $5 to $10 monthly fee. The system, which will serve only the United States, is scheduled to begin operation in 1997. In December 1992, five other companies submitted applications to the FCC to offer satellite radio services—American Mobile Radio Corp. (a subsidiary of the American Mobile Satellite Corp.), Primosphere L. P., Loral Aerospace Holdings, Inc., Sky-Highway Radio Corp., and Digital Satellite Broadcasting Corp.[30]

Because out-of-band DAB solutions would create a completely new set of radio broadcasting frequencies, many broadcasters have strongly opposed the development of such systems, claiming that they would destroy the American tradition of local broadcasting. Primarily, these broadcasters fear the competition that a national radio service might pose to their local operations. New national radio programs could conceivably take away listeners and advertising revenues that would otherwise go to support local broadcasters.

In addition, broadcasters believe that the more rapid development of out-of-band DAB might put them at a technical disadvantage in using digital technology. To counter these perceived threats, broadcasters have demanded guaranteed access to any new spectrum that would be opened for terrestrial (out-of-band) DAB use.[31] Although no frequencies have been allocated specifically for terrestrial DAB, the FCC did allocate frequencies for BSS-Sound (satellite use only) at 2310-2360 MHz. However, the problem of allowing existing users access to new frequencies will recur if the United States considers additional allocations for terrestrial systems (see below).

Largely in response to local broadcasters' concerns, several companies began developing DAB technology that would work "in-band"—using the same frequencies now used by existing AM/FM radio stations. Such systems would allow terrestrial broadcasters to upgrade their facilities to digital quality at less cost than out-of-band solutions and with minimal disruption to the industry. Today, almost all U.S. terrestrial DAB development remains focused on in-band solutions.[32]

Gannett, CBS, and Group W Broadcasting, for example, formed a partnership (USA Digital Radio) to develop an in-band, DAB system dubbed Project Acorn. This system would send the digital audio signal over the same channel as the existing AM/FM analog signal, but at a reduced power level that would not interfere with the simultaneously transmitted analog signal (see figure 2-3). Demonstrations of the system were scheduled for the end of 1992, with an experimental system planned for mid-1993.[33] Another DAB solution has been proposed by Strother Communications and Lincom Corporation. The Strother/LinCom solution is also in-band, but broadcasts the digital signal in "guard bands''-fiequencies on either side of existing FM channel that are left unused in order to guard against interference from stations on adjacent channels. The system also sends a digital signal that is much weaker than the

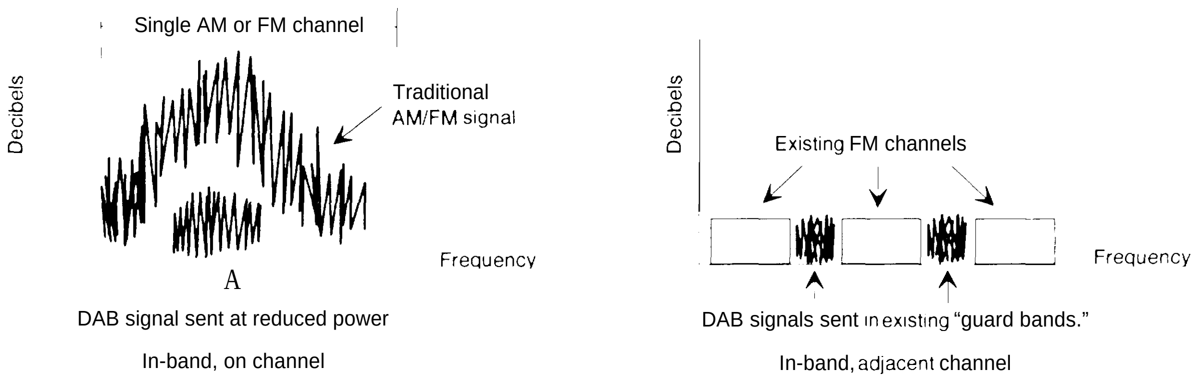
30 These applications were tentatively accepted by the FCC in March 1993, ''FCC Accepts Satellite DARS Application, " *Telcom Highlights International, vol.* 15, No. 10, Mar. 10, 1993. Later in March, Loral Aerospace withdrew its application as part of an agreement to enter into a partnership with Satellite CD Radio.

31 Originally, before in-band DAB systems were being developed, L-band frequencies were considered for both satellite and terrestrial DAB. Broadcasters wanted their access to these frequencies guaranteed so that they could compete in digital services with any new competitors-otherwise they feared they would be effectively shut out of and unable to compete with the new technologies and services. This situation is analogous to the current demands of cellular carriers to be allowed to provide personal communications services.

32 Edmund L. Andrews, "Digitat Radio: Static Is Only Between Owners," New *York Times, May 6, 1992,* p. D8.

33 Daniel Ehrman, Vice President, Finance and Business Affairs, Gannet Broadcasting, personal communication, June 2, 1992.

Figure 2-3—Proposed In-band Digital Audio Broadcasting Systems



SOURCE: Office of Technology Assessment, 1993.

analog signals in order to avoid interference. Other companies developing terrestrial DAB systems include Mercury Digital, AT&T, the Massachusetts Institute of Technology and General Instrument.

WARC PREPARATIONS

The development of a proposal for BSS-Sound was the most difficult in the domestic WARC-92 preparation process.[34] Many interest groups in both the private sector and the Federal Government took strong positions on the issue, The majority of the private sector, as indicated by the FCC in its Report on WARC-92, favored an allocation for BSS-Sound in the L-band (between 1430 and 1525 MHz), as did many foreign countries.[35] The U.S. aerospace industry, the Department of Defense and its aerospace contractors and many local terrestrial broadcasters resisted this proposed allocation. Aerospace industry representatives, both civilian and military, vehemently oppose any new use of the L-band, due to its importance for aircraft and weapons systems testing and the unknowns associated with developing a new radiocommunication service/ system.

During WARC-92 preparations, the U.S. broadcasting industry was tom by bitter internal disagreements over the future development of DAB and the U.S. BSS-Sound proposal. Proponents of satellite-delivered DAB favored frequency allocations in the L-band. Initially, the National Association of Broadcasters (NAB), which represents local broadcasters, supported this approach. However, a significant number of local broadcasters strenuously opposed the allocation of radio frequencies for a new satellite audio broadcasting service, arguing that many local broadcasters were already experiencing financia1 difficulties and that the establishment of a competing, national service would undermine the ability of local broadcasters to attract advertising revenues. In January 1992, the NAB dropped its support for L-band proposals. Eventually, the opponents of an L-band allocation prevailed, and a compromise allocation was proposed at 2310-2360 MHz.

[34] See OTA, *WARC-92*, op. cit., footnote 15.

[35] This band is currently allocated in the United States to mobile (shared by both Federal Government and nongovernment users, but limited to aeronautical telemetering and telecoremand of aircraft and missiles), radiolocation (for military use only), and freed services (allocated on a secondary basis for government use only). The S-band is not as extensively used for aeronautical telemetry as is the L-band.

WARC NEGOTIATIONS

At WARC-92, the U.S. proposal has been described as 'dead on arrival. ' There was almost no international support for this allocation going into the conference, and despite the best efforts of U.S. negotiators, only India supported the U.S. position in the Final Acts of WARC-92. Opposition to the U.S. proposal came from all parts of the world. Canada, for example, has been developing terrestrial DAB systems that would use L-band frequencies, and Mexico has indicated that it will develop similar systems in the next several years. The CEPT countries also opposed the U.S. proposal, initially proposing allocations in the 2570-2620 MHz band, and later supporting allocations in the L-band.[36] Other countries, including China, Japan, and the Russian Federation favored an allocation around 2500 MHz, in order to protect their existing uses of the L-band.

At the conference, the primary debate was over where the BSS-Sound allocation should be located-in the L-band (1.5- 1.6 GHz) or the S-band (2.0-2.5 GHz). The debate was difficult because each band has specific advantages and disadvantages.[37] Discussion focused on questions of technology (propagation), economics (cost of receivers), but more practically on the politics of spectrum management—the tension between protecting existing services on the one hand and promoting new technologies and services on the other. L-band allocations were opposed by many countries, including the United States, Japan, and some European countries, because the bands are already heavily used for other radio services. In Japan, the bands are allocated to important mobile services. In the United States, the band is used for aircraft and weapons testing. Moving these existing users to other frequencies would cost millions of dollars.

POST-WARC ACTIVITY

Since WARC-92 ended, BSS-Sound and DAB regulatory and development efforts in this country have been moving slowly, largely due to the ''wait-and-see' strategy the FCC and NAB pursued immediately following the conference. However, the FCC has taken several actions in the DAB/BSS-Sound debate. In October 1992, the FCC proposed to allocate the 2310-2360 MHz band for BSS-Sound (but only for satellite use) in this country, a decision that was later formalized. This action boosted the prospects of Satellite CD Radio, and, as noted above, prompted other companies to enter the race for BSS-Sound. The FCC's allocation, however, has not dampened the development of in-band, terrestrial DAB systems.

Ironically, the allocations made by WARC-92, and the obstinate U.S. position on L-band, have focused more attention on in-band DAB systems in the United States. Initially, most of the private sector favored an allocation in the L-band.[38] When that band was not allocated in this country, attention shifted to in-band solutions, which had become better defined as the WARC preparations process went along. Several companies are now developing in-band DAB systems, including those noted above.

Regarding satellite DAB, NAB opposed a Satellite CD Radio request for an expedited FCC rulemaking to allocate the 2310-2360 MHz band for BSS-Sound, stating that the world course for digital radio, satellite and terrestrial, remains unclear.[39] At the same time, NAB encouraged the development of an in-band system for DAB that

36 A total of 18 CEPT countries jointly submitted the CEPT proposal.

37 Most BSS-Sound proponents and radio engineers believe that the frequencies around 1.5 GHz are technically better suited fOr satellite-delivered DAB than higher frequencies. Propagation characteristics are better at L-band-at the higher S-band frequencies, signals are more likely to be scattered or blocked by buildings, trees, etc. Because of this, some analysts believe that S-band may only be suitable for satellite transmission.

38 See especially Annex B of Industry Advisory Committee, "Final Report: WARC'92,'' submitted to the FCC, Apr. 30, 1991.

39 ''NAB Opposes Satellite CD Radio Request for Expedited BSS-Sound Allocation Rulemaking,' *Telecommunications Reports,* June 8, 1992, p. 30.

would improve the quality of both AM and FM stations. If that effort was to fail, NAB apparently believes that L-band is more attractive for BSS-Sound than the S-band allocation the U.S. indicated at WARC-92.

The Electronic Industries Association (EIA) established a task group in August 1991 to develop a standard for DAB in this country. The standard agreed to by EIA will be submitted to the FCC as a proposed U.S. standard. The group is composed of specific system proponents, broadcast representatives, and manufacturers. In late 1992, the group solicited proposals for systems to be tested as part of the recommendation process, and actual testing of proposed systems is scheduled to begin sometime in 1993.[40]

Internationally, the United States continues to be active in the work of the CCIR'S study group on BSS-Sound issues. In preparation for future CCIR meetings on BSS-Sound, industry and private sector representatives formed a working group in August 1992 to develop U.S. positions. The main focus of the group will be on future topics the CCIR should study in preparation for the future radio conference on DAB called for in Resolution 528.

A few companies have been authorized to provide BSS-Sound services in other parts of the world. The first, WorldSpace Corp. (Afrispace, Inc.), was granted an experimental license by the FCC in 1991 to provide radio services in Africa. After regulatory delays resulting from WARC-92, Afrispace now plans to launch its AfriStar-1 satellite in 1995, and has signed up 3 broadcasting companies that will use 5 of its 36 channels.[41] CaribSpace Ltd., a subsidiary of WorldSpace, has been granted a license from the government of Trinidad and Tobago to provide similar services in the Caribbean.[42]

Issues and Implications

The questions involved in assessing the future of BSS-Sound and DAB far exceed the allocations issues debated at WARC-92. The allocations made at the conference set the stage for the future development of new digital radio services, but the allocations are only one part of a much larger constellation of policy problems related to the future development of radio technology and the evolution of the radio broadcasting industry in this country. The decisions to be made about how to implement WARC-92 allocations implicitly shape future, broader policy decisions, and cannot be considered separately from them.

The case of BSS-Sound/DAB represents a missed opportunity for the United States. Based on the reported needs and requirements of the Defense Department and its (politically) powerful allies in the aeronautical telemetry industry, and pressure from the Secretary of Defense, the United States was forced to take a position counter to the majority of the world. The problem is not that the Department of Defense won, ' but rather that the (policy) process for determining needs and evaluating competing needs was largely hidden from view. What should have happened was an objective and thorough review of the existing use of the band compared with the potential benefits to American industry, leadership, and consumers of participating in a new worldwide broadcasting system.

The extent to which this was done is unclear. NTIA officials maintain that proper policy procedures were followed and that L-band allocations for BSS-Sound were not pursued because support for the concept and those particular allocations was weak. However, it is difficult to discern in this case if there was a formal policymaking process, and if it was followed. Because of the sensitive nature of the bands involved and the

40 Steven Crowley, consulting engineer, personal communication, July 6, 1992.

41 Daniel Marcus, "AfriSpace Satellite Plan Runs Into 2-Year Delay," *Space News, vol.* 4, No. 2, Jan. 11-17, 1993.

42 *Telecommunications Reports,* "*CaribSpace* Gets License for Satellite Radio System From Trinidad and Tobago Government' vol. 58, No. 36, Sept. 7, 1992.

closed nature of the IRAC process, it is impossible to determine how thorough and objective the evaluation of the competing uses of the band was. Questions remain about who did the comparing, what factors they used (and how each was valued), and what inputs were considered from both sides.

The stakes in the BSS-Sound debate are too important to let things develop without further policy analysis and debate. Mexico, and especially Canada, are planning to move ahead with (terrestrial) DAB plans in the next several years. Meanwhile, the United States risks falling behind in this potentially lucrative opportunity for U.S. manufacturers and service providers and this potentially important method for disseminating U.S. programming and information overseas. The consequences are clear:

> If DAB is established internationally years prior to introduction in the United States, our international competitiveness would be put at risk while the public would be denied access to an important new service.[43]

DOMESTIC ISSUES

After a less-than-satisfactory outcome at WARC-92, domestic efforts to develop BSS-Sound and DAB continue. The United States, because of its existing use of the L-band spectrum and its strong tradition of local broadcasting, has been forced into a dual approach to DAB development. This dual approach is shaped in part by history and in part by technology, which has become an important driver of the DAB/BSS-Sound debate. Some companies are concentrating on developing in-band systems for terrestrial use while others are focusing on satellite-delivered out-of-band systems. No system currently being developed effectively integrates existing broadcasting infrastructure with new satellite technology.

This divided approach reflects the two perspectives that drive the BSS-Sound/DAB debate. On the one hand, many people raised in the traditional broadcasting industry tend to see the issue as one of new satellite services versus traditional local broadcasters. This group is most concerned with developing terrestrially-based DAB solutions that will preserve the existing radio services and industry structure while bringing technical innovation to the industry. On the other hand, the proponents of satellite-delivered DAB have a slightly different set of concerns than the broadcasters. They are most concerned with bringing new services to the public and making a range of broadcasting services available to previously underserved areas.

The allocations made by WARC-92 and U.S. response(s) to them confined this duality. This *de facto* approach was not the result of any carefully thought out policy initiative to improve U.S. radio quality or diversity, but rather an attempt to avoid hard choices by letting marketplace forces decide a technology "winner." Unfortunately, this tactic has slowed the development of DAB technology, and may prevent the United States from entering this new field early on—allowing other countries to develop the expertise, hardware, and software that will make them the leaders in this new technology/service area, not the United States. This unofficial strategy has important long-term consequences for the future of the broadcasting industry in the United States, and it is unclear whether U.S. policymakers recognize, and are willing to confront, the many factors at work. To date, the larger issues of how these new digital technologies will impact the future (and structure) of the radio broadcasting industry in this country have been ignored by policymakers.

Short-term Issues--The most immediate question facing U.S. policymakers and regulators is how future digital radio services will be offered. The FCC has taken the first step toward defining the future of radio broadcasting in this country by

[43] Testimony of John R. Holmes, in Hearings before the Subcommittee on Telecommunications and Finance of the Committee on Energy and Commerce, House of Representatives, 102d Congress, Nov. 61991, p. 8.

adopting the allocations the United States pursued at WARC-92. Other issues that remain to be resolved include how many competing BSS-Sound systems could the U.S. population support? Will these competing systems share listen*ers,* or will subscribers be locked in to one provider? Should other ways of providing BSS-Sound services, such as advertiser-supported, nonprofit, or public broadcasting, be encouraged, and how can this be done? Should future terrestrial DAB services use the same band as satellite, or should they use the existing AM/FM band?

For example, the development of in-band systems poses several issues for policy makers. One concern is the distinction between AM and FM broadcasters. Because of the differences in spectrum currently allocated to AM and FM stations (10 kHz vs. 200 kHz, respectively), developing in-band digital solutions for FM radio has been much easier than for AM. Because of this, many industry analysts expect that AM DAB will not be able to achieve the same quality as FM DAB.[44] Due to such predictions, some AM station owners have promised to block any standard that disadvantages them relative to FM. On the other hand, FM station owners will resist any technology that brings AM radio broadcasting up to the quality of FM and hence into more direct competition.[45] Some observers believe that such feuding among broadcasters could potentially slow the development of terrestrial DAB technology, and cause the United States to fall (further) behind in the development of such technologies and systems—reducing or removing any chance the United States may have to be a world leader in the production of DAB equipment and the operation of DAB services.

Alternatively, if future *terrestrial* DAB services are allocated (additional or alternative) spectrum outside the traditional AM/FM bands, future licensing of such systems would pose the FCC with a challenge similar to the decision facing it in the personal communication service (PCS) licensing proceeding.[46] Should existing broadcasters be allowed into new spectrum to offer DAB, or should this new spectrum be opened only to new service providers? This is more than a technical or economic question, which will require the FCC, with the input of the Congress, consumers, and industry to decide.

Long-term Issues-Such issues indicate a number of longer-term questions for regulators and policymakers. Should all broadcasters have an equal shot at DAB technology? How can new forms of competition in radio services be promoted while acknowledging (but not necessarily protecting) the role and investments of local broadcasters? How can the traditional strength of the U.S. local broadcasting industry be complemented by the new technologies of satellite delivery? What should the future structure of the U.S. broadcasting industry look like?

The most difficult long-term issue facing policymakers is how BSS-Sound and DAB will affect the (local, terrestrial) broadcast industry. Satellite broadcasting directly to listeners has the potential to dramatically reshape the broadcast industry in this country. Depending on a number of technical, economic, and political choices that will be made in the next several years, BSS-Sound services could complement local program-

W Edmund L. Andrews, op. cit., footnote 32.

45 The issue is money. Over the years, FM radio &, gained popularity over AM because of its higher quality. As a result, more people listen to FM stations, and licenses for FM stations are more valuable. Digital technology, with its immunity to noise and high quality, would wipe out the differences in quality between AM and FM stations: Bringing all stations into quality parity and bringing down the value of FM licenses will at the same time raising the value of AM licenses. Broadcasters who have invested hundreds of thousands (or even tens of millions) of dollars in an FM station will oppose anything that would jeopardize that investment.

46 In that case, the FCC must decide whether to allow cellular operators to provide PCS, taking advantage of their technical and marketing experience, or bar the cellular operators from entering the PCS market in order to foster more competition in the mobile services industries.

ming, be limited to serving niche markets, or emerge as a substantial competitor to local broadcasters.

In some countries and in some systems, terrestrial and satellite DAB may develop as complementary parts of one broadcasting system. In the United States, however, it now seems likely that the two industries will remain separate--the established broadcast industry controlling terrestrial DAB, and the new startups controlling satellite services. It is likely that these technologies will continue to develop on separate tracks, although the relative timelines for the development of each is far from certain. This divided approach may prevent the United States from pursuing a comprehensive approach to improving radio broadcasting quality and diversity, while at the same time extending its reach and flexibility. Countries adhering to one (in this case most likely L-band) allocation for both terrestrial and satellite programming may have an advantage in building a more flexible broadcasting system.

As both BSS-Sound and terrestrial DAB systems come into operation, the challenge for the FCC will be to fashion a radio broadcasting industry that takes advantage of both satellite and terrestrial DAB technologies. The question is: Are the services inherently competitors, or could they be (structured to be) complementary? NAB and the local broadcasters tend to see satellite delivery of audio services as a potential competitive threat.[47] However, it may be possible to set the rules for BSS-Sound such that the services are complementary, rather than competitive. A possible analogy may be the dual nature of cable television—local television stations and cable channels exist alongside "superstations" and nationwide cable channels that cater to specific interests. Nationwide services may be able to supplement existing local services or cater to nationwide niche audiences that are too small to support local broadcasting, but when aggregated can support a broadcasting service. Ethnic or religious groups may provide audiences for such programming. Nationwide coverage would also fill in gaps in coverage of various programming formats-not every person in America can get the kinds of radio station he or she wants, and not every market has 10, 15,20 or more stations with a variety of formats available. For the more remote listener who would like to hear classical music, a satellite-delivered service may be the only real option.

Industry fears that nationwide satellite audio programming will destroy the broadcasting industry must be taken seriously. However, a larger policy question remains: if the radio industry is doing so poorly—stations closing, revenues dropping-why save it? The industry should be prepared to present a good case for preserving its privileges based not on past history-there can be little doubt of the historical importance of local radio stations, but on the prospects for future performance. Society in the 1990s and beyond is changing rapidly, and the Nation's radio listeners are entitled to a radio system that best meets their needs. The public interest may need to be redefined to include not only local, but also national and international programming g and services.

INTERNATIONAL ISSUES

The international issues surrounding the implementation of BSS-Sound and DAB services are complex, and at present there are more questions than answers about the future of digital radio broadcasting services. As a result, the future of DAB/BSS-Sound and the impacts of the three BSS-Sound allocations is uncertain. Perhaps

47 They note that if digital-quality satellite services are authorized and made available before local broadcasters can implement terrestrial digital broadcasting systems, this would represent unfair competition. John Abel, for example, stated that some local and satellite services could exist side-by-side, and local broadcasters could compete "if we have the same opportunity as the satellite broadcaster in providing DAB. " Testimony of John Abel, in Hearings before the Subcommittee on Telecommunications and Finance of the Committee on Energy and Commerce, House of Representatives, 102d Congress, Nov. 6, 1991, p. 14.

most importantly, until a future conference can be held to plan BSS-Sound, only the top 25 MHz of the allocations can be used to provide BSS-Sound services .48 This effectively means that the number of potential service providers in the band will be very limited, at least until the requested WARC is held.[49] In addition, the entire world, with the exception of about a dozen countries, agreed to the L-band allocation, although in some countries, including most of Europe, the services may not be able to be offered until 2007.[50] Although the United States is not wholly responsible for these outcomes, U.S. actions contributed to an allocation structure that is less than ideal from a global service perspective. The division of the world into three different BSS-Sound allocations could have a number of detrimental effects on the future of the BSS-Sound industry.

Manufacturing—From a manufacturing standpoint, multiple allocations mean that makers of portable radios and radios for cars will be forced to build three different types of receivers. Although the different radios may share some common parts, the radio receiving equipment will have to be different. And if different formats and standards are used for the transmission of DAB, manufacturing difficulties will become even more severe. The division of allocations and possibly standards will lead to production that is not as efficient since manufacturing efforts will have to be divided.

For the United States, the impacts of this division on manufacturing will be limited since ‘‘there is almost no production of VCRs, camcorders, tape players and recorders, radios, phonographs, or CD players in the United States.”[51] The impacts on the makers of radios for U.S. cars, GM-Delco, for example, is also likely to be slight. It remains to be seen if domestic manufacturers will produce alternative radios for installation in vehicles destined for export. Development of a strong domestic BSS-Sound industry, however, could enhance and expand this country’s reputation as a leader in the development and operation of satellite communications systems. The actual benefits of this new technology for the United States, however, are less clear, since the technical details of U.S.-designed and built systems would have to be modified to work in other parts of the world.

International Broadcasting—The impacts of multiple allocations on international broadcasting are likely to be more severe. Because up to three sets of frequencies could be used for BSS-Sound around the world, the development of a global satellite radio broadcasting service will be difficult. Instead, regional BSS-Sound systems are likely to become the focus of development efforts, and coordination between countries using different allocations could be difficult.[52] The United States, for example, is expected to have a hard time coordinating its aeronautical telemetry servi-

48 See Resolution COM4/W, ITU, *Final Acts*, op. cit., footnote 27. In the final numbering of Resolutions and Recommendations, COM4/W became Resolution 528.

49 The Satellite CD Radio (SCDR) system, for example, uses 21 MHz of spectrum, but can only share with one other operational system. The plan proposed by SCDR would accommodate up to eight satellites (approximately 4 competing providers), but would use the whole 50 MHz of the U.S. 2310-2360 MHz allocation. Cutting the available spectrum in half would presumably limit the number of competing providers to two.

50 Numbers of countries per allocation, however, is only one indication of the potential impacts of these allocations. When judged (roughly) by population served by each allocation, the disparity between allocations lessens significantly (see table 2-2). L-band allocations could serve up to 3,2 billion listeners, the U.S./India allocation up to 1.1 billion, and the other S-band allocation up to 2.7 billion. These numbers are changeable because India, with over 800 million people, accepted all three allocations. Figures are based on numbers provided to OTA by the Voice of America.

51 U.S. Department of Commerce, International Trade Administration, *U.S. Industrial Outlook* ’92 (Washington, DC: U.S. Government Printing Office, January 1992).

52 However, from a hardware/system perspective, the impacts of this division will be limited since satellite systems are already routinely designed to serve regional areas.

ces—testing for (military) aircraft and weapons systems—with Canada and Mexico. These countries plan to use the worldwide allocation to provide DAB services, although initially only through terrestrial transmission systems. This means that Canadian and Mexican L-band systems will have to be coordinated with U.S. aeronautical telemetry users, and any U.S. system that is deployed using the S-band allocation will have to be coordinated with Mexico and Canada. It is possible that this will put pressure on the government to simply drop the U.S. position on L-band and adopt the world allocation.[53]

In addition, an important issue in the implementation of BSS-Sound systems, especially in the area of new entertainment and information services, is the question of cross-border information flows. Because of the nature of satellite transmission, it is very difficult to limit a satellite's signal (its footprint) to conform to national boundaries. Some countries may resist (or jam) unwanted transmissions from outside their borders. WARC-92 did not address this question, since the primary focus of the meeting was to agree on allocations for the service. However, it is expected that a future conference will take up the issue.[54]

For U.S. international broadcasters who see BSS-Sound as a way to extend their coverage and give their listeners higher quality, the impacts of different allocations are unclear. Any international broadcaster that decides to put up its own satellite system to achieve worldwide coverage will have to adapt its satellites and its system design to conform with the varying allocations. It is also possible that international broadcasters could lease transponders on regional systems—this would relieve them of having to engineer their own system, but would also relinquish their direct control of their transmissions.

Listeners--Finally, the impacts of different BSS-Sound allocations on listeners are likely to be minimal, except for international travelers. Common allocations and equipment have benefited consumers in the past because they can use their radios anywhere in the world-current broadcasting frequencies are global, and AM and FM are standard modulations schemes. When BSS-Sound systems come into operation, listeners will have to buy new DAB-compatible radios, which will be slightly different depending on where they live.

The cost for DAB/BSS-Sound receivers is expected to follow the example set by other consumer electronic technologies-it will likely start out very high initially, but fall quickly as demand improves and mass market economies are achieved. Most analysts expect the cost of such receivers to be no more than high-end AM/FM cassette players available today. The cost for a radio station to upgrade its facilities in order to offer DAB programming is less clear. The cost in this case will depend on how advanced/up-to-date the station's existing technology is—is there a lot of equipment that must be changed out, or does the station already have some of the digital equipment necessary to

53 The initial terrestrial focus of the Canadian and Mexican systems may be a blessing for the United States. Terrestrial systems will be easier to coordinate than satellite systems since their limited range means they will affect U.S. telemetry operations only near the borders. Eventually, however, these systems may also be delivered via satellite, at which time coordination and interference problems will become much more difficult. Some observers note that the introduction of satellite DAB services in Canada and Mexico would seriously degrade aeronautical telemetry services, perhaps making them unworkable. The long transition time to sateUite-delivered DAB services, however, should provide adequate time for U.S. telemetry operations to move to higher bands. Another serious concern in the implementation of these systems is their effect on U.S. radioastronomy activities, which use very sensitive receivers in the frequencies just below those now allocated for BSS-Sound.

54 Resolution 527 takes note of the problem by noting No. 2674 of the Radio Regulations, which states: "In devising the characteristics Of a space station in the broadcasting-satellite service, all technical means available shall be used to reduce, to the maximum extent practicable. the radiation over the territory of other countries unless an agreement has been previously reach with such countries. ' ITU, *Radio Regulations,* p. *30-2*, op. cit., footnote **19.**

support DAB operations? Estimates range from $50,000 to $150,000.[55]

One important policy consideration, in this country and internationally, is to lay out a realistic transition plan that will allow a smooth and orderly phase-in of terrestrial and satellite DAB service in whatever band(s) are used. Following past practice, for example, new DAB radios may be required to be able to receive regular AM/FM transmissions.

TERRESTRIAL MOBILE SERVICES

The mobile telecommunications service industry is still in its formative stages—mobile and mobile-satellite technologies continue to evolve and new systems are proposed regularly.[56] Because of this volatility, it is difficult to predict what the industry will look like in 5, 10 or 15 years. Different proponents have different perspectives on the future of mobile services, and no one really knows yet how the pieces will fit together. The final structure of the mobile services industry will depend largely on market forces. Consumers will decide which services—satellite, PCS, cellular, mobile data—will be successful and which will not.

One of the fastest-growing segments of the mobile telecommunications industry is terrestrially-based radio systems serving mobile users (in cars, trucks, ships, aircraft, and on foot). Since its introduction in 1983, for example, cellular telephone service has amassed more than 9 million subscribers in the United States, and recent statistics released by the Cellular Telecommunications Industry Association show an annual growth rate approaching 40 percent.[57] Some estimates of the potential revenues from mobile services run into the tens of billions of dollars annually.[58]

The boom in demand for mobile telecommunications services has given rise to a confusing array of new technologies and systems. Countries and businesses around the world have proposed new mobile applications that will deliver a wide variety of new (and old) services, including paging and messaging, telephone, facsimile, data communications, and even imaging and video. In the United States, for example, hundreds of companies have applied at the FCC for radio frequencies to deliver future PCS.[59] In Europe and Japan, government authorities have given mobile services high priority in domestic spectrum allocations. As a result of the growing demand for services and spectrum, WARC-92 was charged with allocating additional spectrum for new and emerging mobile services.

Future Public Land Mobile Telecommunications Systems

BACKGROUND

The focus of WARC-92'S attention to mobile services was on Future Public Land Mobile Telecommunications Systems (FPLMTS).

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55 Testimony of John R. Holmes, op. cit., footnote 43, P. 9.

56 In ITT-J parlance, "mobile' refers only to terrestrially-based mobile systems. ''Mobile-satellite service' (MSS) refers to mobile services provided via satellite. MSS is discussed in the next three sections.

57 Breed on statistics compiled in the frost 6 months Of 1992. "CITA's Biannual Survey Shows Record Industry Growth in First Half of 1992," *Telecommunications Reports,* vol. 58, No. 36, Sept. 7, 1992.

58 Studies estimating the potential value of these new markets must be viewed with caution as data and its interpretation is highly subjective. A study conducted by Market Intelligence predicts that worldwide sales of cellular phones, pagers, and accessories witl reach $6.2 billion by 1998. "Study Says World Markets for Cellular Phones, Pagers Will Reach $6.2 Billion by 1998, " *Telecommunications Reports, VOL 58, No. 37,* Sept. 14, 1992. Another study conducted by Alexander Resources, Inc., for example, puts potential revenues at over $10 billion in 1999 for wireless local exchange services alone. *Telephony,* June 29, 1992, (untitled box), p. 11. A study by Datacomm Research Co. projects potential revenues for cellular data services will reach $1 billion by 2001. ''Datacomm Study" *Telecommunications Reports, vol. 58, No. 36,* Sept. 7, 1992.

59A partial list of the companies that have applied at the FCC to offer such services can be found in OTA, *WARC-92,* appendix C, op. cit., footnote 15.

FPLMTS refers to a concept being developed in the CCIR primarily by European radiocommunication interests for delivering mobile telecommunications services in the 21st century. Although clear service definitions and specifications have not yet been developed, FPLMTS is currently conceived as a terrestrially-based system (perhaps supplemented with satellite technology) using large towers located throughout a region to provide an array of voice, data, and video services to mobile users. The Europeans view FPLMTS as the successor to the Global System for Mobile communications (GSM—formerly Groupe Speciale Mobile)---a pan-European digital cellular system that is currently being deployed across Europe.[60] In order to ensure that future mobile systems would have adequate spectrum, the Europeans pursued allocations for FPLMTS at the 1987 Mobile WARC (MOB-87), but the issue was carried over to WARC-92.

U.S. PROPOSAL

The United States made no specific allocation proposals for FPLMTS, citing the extensive existing allocations available for mobile services, uncertainty over just what FPLMTS is, and the possibility of making FPLMTS-like services available through standard-setting and common (global) interoperability requirements rather than through a new frequency allocation. In its statement on FPLMTS in the official U.S. WARC-92 proposals, the United States noted the work being done to develop FPLMTS internationally, but opposed the allocation of new frequencies for the system(s).

RESULTS

WARC-92 did not formally allocate any frequencies for FPLMTS, but it did identify 230 MHz that is ‘intended” to be used for FPLMTS—1885-2025 MHz and 2110-2200 MHz. This “identification” was made in footnote 746A—FPLMTS does not appear in the actual allocations table. Debate over whether frequencies would be “allocated,” “identified,” or “intended” for FPLMTS use was intense (see discussion below). Related to the work on FPLMTS, WARC-92 also upgraded the mobile service to coprimary status (in Region 1) in the 1700-2290 MHz band. This created a primary worldwide allocation for mobile services from 1700 to 2690 MHz.

WARC-92 also adopted Resolution 212, which notes the ongoing study of FPLMTS characteristics and calls on the CCIR to continue its work in order to develop “suitable and acceptable technical characteristics for FPLMTS that will facilitate worldwide use and roaming, and ensure that FPLMTS can also meet the telecommunication needs of the developing countries and rural areas.”[61] The resolution does not specify dates for implementation nor any relevant operating parameters. It does, however, identify the frequencies 1980-2010 MHz and 2170-2200 MHz as the bands where a satellite component of FPLMTS is expected to be necessary by the year 2010.

DISCUSSION

Domestic Issues-The debate over the future of mobile telecommunications services in this country has been as intense as the negotiations in Spain over FPLMTS. In the United States, there are many different visions of the future of terrestrially-based mobile services. Cellular, cable, and telephone companies are all looking toward the next generation of mobile telecommunications, and there is a confusing array of ideas about how these new services will be provided and what applications they will offer. Proponents and

60 Although GSM has been plagued with delays relating to standardization of equipment, 17 countries plan to begin offering services in 1992 and have 4 million users in 1994. The completed network is expected to be operational by the late 1990s and have 20 million subscribers by the year 2000. Foreign Broadcast Information Service, *JPRS Report*, Feb. 20, 1992, p. 17; Apr. 3, 1992, p. 20; and Apr. 28, 1992, p. 11.

61 International Telecommunication Union, *Addendum and Corrigendum to the Final Acts of the World Administrative Radio Conference (WARC-92)*, provisional version, Malaga-Torremolinos, 1992, p. 17.

analysts talk about micro-cellular systems, CT-2 (2nd generation cordless telephones), and PCS. In addition to these land-based systems, various satellite systems are being planned to offer an array of data and voice services (see the sections on MSS below).

Much of the debate and development of new mobile communications services in this country has focused on PCS, which many consider the U.S. equivalent of FPLMTS. PCS has emerged as an umbrella term that encompasses a wide variety of systems and services, but basically, PCS is a wireless phone and data service that will allow users to send and receive phone calls and/or messages using small lightweight (and eventually inexpensive) handsets similar to today's cellular phones. Current concepts of PCS systems are as varied as the companies proposing them. Some analysts foresee PCS installations in limited geographic areas such as shopping malls, airports, college campuses, and downtown commercial centers--essentially complementing current cellular systems. Others predict wider uses, including vehicle as well as pedestrian communication. These systems would compete with cellular systems, and have even been considered as an alternative to traditional wired telephone service. The FCC has chosen a broad definition for PCS—referring to it as a "family" of new communication services-in order to not prejudge the outcomes of the various development efforts.[62]

The FCC has two separate proceedings that will affect the future of PCS. These proceedings are now being considered simultaneously. The frost, a Notice of Inquiry on PCS released in June 1990, has been the subject of many comments and an en bane hearing in December 1991.[63] In July 1992, the FCC adopted a notice of proposed rulemaking (NPRM) in this proceeding affirming the need for PCS, proposing allocations for data and voice services, and asking for additional comments on licensing, competition, and spectrum requirements. The FCC deferred action on the frequencies to be allocated to PCS, wanting to gather further comments in the emerging technologies proceeding (see next paragraph).

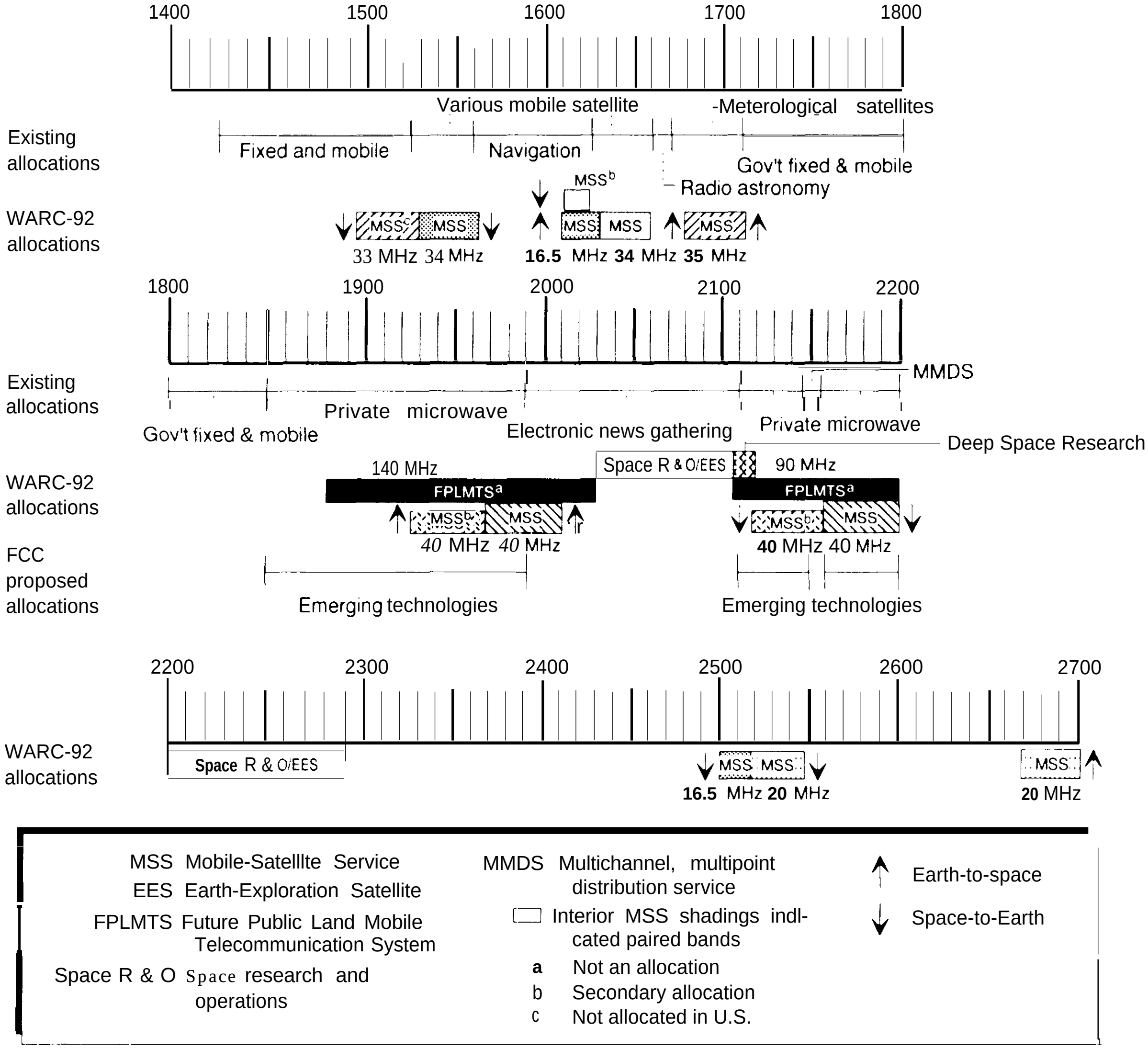
The second proceeding focuses on an FCC proposal to reallocate frequencies in the 2 GHz band in order to create a "spectrum reserve' for emerging technologies.[64] This proceeding was formally begun in January 1992 and in October 1992 the FCC adopted a Report and Order and Third NPRM in the proceeding finally proposing the frequencies to be made available to emerging technologies and outlining transfer plans for incumbent users. PCS is expected to be one of the major users of these bands. All but the lower 35 MHz of this reserve overlaps with the FPLMTS/mobile allocations made at WARC-92, meaning that the FCC could implement FPLMTS/PCS in up to 185 MHz (see figure 2-4). Thus, if a worldwide FPLMTS-like service does develop, the United States will be able to use the same frequencies as the rest of the world. A worldwide primary allocation is desirable because it would make it easier to interconnect various national systems and to develop a worldwide mobile communication system that would allow individuals to use their portable telephones anywhere in the world. Instead of countries using different frequencies for their mobile services, all countries could use the same broad band of frequencies—allowing manufacturers to produce handsets that

62 Cements of Thomas Stanley, FCC Chief Engineer, Feb. 23, 1993.

63 Federal Communications Commission, ''Amendment of the Commission's Rules to Establish New Personal Communications Services," *Notice of Inquiry,* Gen. Docket No. 90314, released June 28, 1990.

64 Federal Communications Commission, ''R~evelopmentof the Spectrum to Encourage Innovation in the Use of New Telecommunications Technologies, ' *Notice of Proposed Rule Making*, ET Docket 92-9, released Feb. 7, 1992. The FCC proposed to reallocate 220 MHz of spectrum in the 18501990 MHz, 2110-2150 MHz, and 2160-2200 MHz bands. It is important to note the timing of this action-just after the start of WARC-92.

Figure 2-4—WARC-92 Frequency Allocations From 1400-2700MHz



NOTE: This chart is not complete. Not all International Telecommunication Union services are shown, and some have been edited for presentation. Many footnotes will affect the allocations presented. The WARC-92 allocations shown are the allocations as interpreted by the United States, and are not necessarily applicable to other countries.

SOURCE: Office of Technology Assessment, 1993, based on a figure supplied by Motorola.

will work worldwide. Issues regarding standards, protocols, and interoperability between different national systems will have to be negotiated in order to achieve a truly worldwide service.

The FCC's proposal to reallocate frequencies in the 2 GHz band in order to accommodate new technologies has become highly controversial. On one side are the incumbent users of the bands who want to protect their existing point-to-point operations and who would prefer not to move to other frequencies. These users include: the rail-road companies and public utilities--operators of oil and gas pipelines and electric power transmission lines-which use these frequencies to monitor and control their operations and provide trouble reports during emergencies; public safety agencies-police, fire, and ambulance-which use these frequencies as part of their everyday missions;[65] and common carrier microwave operators who use the frequencies to relay point-to-point communications traffic, often as a backup to long-distance fiber optic lines or to interconnect cellular telephone cells. On the other side are the potential new users of the spectrum, most notably the hundreds of companies that have applied to the FCC to provide new personal communication services. Because of the favorable transmission characteristics of these frequencies, they are ideally suited to delivering these types of new mobile services.

The debate over the FCC's spectrum reserve and its reallocation of the 2 GHz band illustrates the findings and lessons presented in chapter 1. Fundamentally, the debate is one of old versus new—how to balance the legitimate requirements of the existing users against the desire to promote the development of innovative technology systems and services. Each side is able to muster convincing arguments to support its case. The utilities and railroads point to their extensive use of the bands and the important functions that these systems control, especially in times of emergency when reliable and instantaneous communications are vital to control potentially dangerous situations such as power surges, gas leaks, and train derailments. Their systems are often extensive, and have provided reliable communications for many years. Moving to other frequencies, they claim, would create problems because the other frequencies to which they could move are often already crowded, the equipment using those new frequencies is less reliable, and replacing so much equipment would be prohibitively expensive.[66] Changing to other Communication media, such as fiber optics or satellite, often is not possible from an engineering or reliability standpoint, and would cost many millions of dollars.

The proponents of PCS, on the other hand, promise an array of new communication services that would serve millions of users, produce billions of dollars in revenue, and promote the competitiveness of U.S. companies in international radiocommunication markets. They claim that the frequencies allocated to the existing services are not heavily used in all parts of the country and that they can design and engineer their systems to share spectrum where necessary.

Because of the huge financial stakes involved and the potential revenues (and jobs) new services could generate, the FCC's proposal quickly became political. The utilities, feeling that the FCC had not taken adequate account of their views, took their case to members of Congress sympathetic to the concerns of the industry and the public safety agencies. The issue moved beyond technical concerns, and the controversy turned into a political test of wills as much as a debate over technology.

Throughout the dispute, most of the stakeholders indicated that they would be willing to compromise. Utilities and others said they would be willing to share the bands under the right conditions, or they would change frequencies if a suitable transition plan was developed. Their primary concerns were the reliability of the new systems and the cost of moving to other bands. The proponents of PCS indicated a willingness to share the bands and to develop systems that would not interfere with the existing users. They agreed, in principle, to finance the cost of moving the existing users to other bands. Finally, in October 1992, the FCC adopted a decision that

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65 It is important to note that public safety uses would not be forced to leave the band as would the utilities and private/common carrier microwave users.

66 Estimates vary from $125,000 to $200,000 per channel. See, e.g., "FCC to Delay Proceeding on Highly Controversial Spectrum Reallocation Plan," *Washington Telecom Week, vol.* 1, No. 1, Apr. 3, 1992.

outlined a plan, originally proposed by utility company representatives, for accommodating both interests.[67] The FCC is still collecting and reviewing comments on this issue—no final decision has been reached.

International and WARC-92 Issues-In the past decade, the development of terrestrial mobile communications systems has become a key focus of European telecommunications policy. The geography of Europe-the relatively small size of the countries-lends itself to terrestrial mobile solutions. Satellite systems, on the other hand, cover areas that many Europeans believe are too large for Europe.[68] Issues such as cross-border communications and control of such a network make satellite solutions politically difficult. Despite the drive toward a unified Europe, nations still want to keep some control over their domestic radiocommunication policies, and individual domestic terrestrial mobile systems, even though connected through the umbrella of GSM, fit these needs. As a result, FPLMTS was a key issue for the Europeans at WARC-92. CEPT proposed FPLMTS allocations at 1900-2025 MHz and 2110-2200 MHz.

The FPLMTS debate at WARC-92 presented the United States with a dilemma. It wanted to support the future development of mobile services, and ensure that U.S. PCS services could flourish in the future, but it also wanted to ensure that the spectrum could be used as flexibly as possible, and not be tied to one concept, especially a European concept like FPLMTS. The U.S. position managed to combine the two. Just before WARC-92, the FCC adopted a NPRM proposing frequencies that could be used for emerging telecommunications services such as PCS.[69] The frequencies identified in that NPRM overlapped with the frequencies to be considered for FPLMTS at WARC-92. This action gave the United States an important source of leverage internationally-showing U.S. support for the (international) development of mobile services in the 2 GHz band, but also allowing it to maintain its opposition to explicit allocations for a system that had yet to be defined.

U.S. opposition to formal FPLMTS allocations was based on several factors. First, a large amount of spectrum is already allocated to (terrestrial) mobile services.[70] U.S. spectrum managers believe that such allocations are sufficient to meet future mobile communication needs. Furthermore, U.S. delegates took the position that FPLMTS services could be provided under the existing mobile allocations without setting aside a specific band of frequencies for FPLMTS.[71] In addition, in contrast to the terrestrial focus of the Europeans, U.S. Government and much private sector interest in new mobile services is largely concentrated on satellite-based systems. Satellites are seen as a more efficient way to reach consumers in sparsely populated areas outside the range of terrestrial cellular systems and as a way to allow mobile users to easily ‘‘roam” beyond

67 Federal Communications Commission, ‘ ‘Redevelopment of Spectrum to Encourage Innovation in the Use of New Telecommunications Technologies,” *First Report and Order and Third Notice of Proposed Rulemaking,* FCC 92-437, Oct. 16, 1992,

68 A satellite beam of only 500 kilometers, approximately what is being described for some LEOS applications, could potentially reach into several countries in Europe.

69 Federal Communications Commission, *Notice of Proposed Rule Making,* Op. cit., footnote 64.

70 The international Table of Frequency Allocations contains a primary mobile allocation in Region 2 in the bands 1668.4-1690 MHz and 17002690 MHz.

71 The formal proposal for FPLMTS states in part that ‘‘tec~~ standards such as modulation p arameters, protocols, and channelization schemes will be just as important as an allocated band in facilitating any requirements for global roaming. These standards and protocols may obviate the need for a common worldwide band for international roaming. We believe that it is premature to designate a frequency band until the CCIR has progressed further in its work. ” U.S. Proposals, op. cit., footnote 5.

72 Presently, a cellular customer who travels outside of his/her local system must often make previous arrangements with the cellular carriers involved and/or dial complex access codes in order to use the systems.

their home system.[72] Finally, the United States opposed specific allocations for FPLMTS because of the lack of a clear definition for exactly what FPLMTS will be. This position is consistent with the general U.S. commitment to keep radio service allocations as flexible as possible so as not to preclude development of innovative new systems and technologies, Allocating spectrum to a service that is currently so poorly defined, and whose spectrum needs are still vague, U.S. spectrum managers believe, would not be an efficient use of the spectrum, and could conceivably lock the world into this inefficient use for many years.

One unacknowledged, although likely, reason for U.S. opposition to FPLMTS is related to trade and competitiveness. The European countries, with GSM, are ahead of the United States in the deployment of advanced digital cellular technologies. American opposition to FPLMTS may represent an attempt by the government and industry to slow down European development efforts in order to allow the United States to "catch up. " Although U.S. technology is second to none, regulatory requirements and the lack of aggressive policy designed to promote U.S. mobile applications has held back the development of a nationwide mobile communications service.

At the beginning of WARC-92, the United States did not support FPLMTS, but did not actively oppose it. U.S. negotiators report they were willing to compromise on FPLMTS in return for concessions by the Europeans on the mobile-satellite service (MSS) allocations the United States wanted for big LEOS and other MSS services. However, as the conference progressed, neither side was willing to compromise much, and negotiating stances hardened. It became clear that U.S. opposition to FPLMTS and European opposition to MSS/LEOS would have to be resolved together. Each side used its opposition to the other's proposal as leverage in the negotiations. Unfortunately, the obstinacy of both sides prevented such a deal from being struck easily.

The final wording of the footnote authorizing FPLMTS caused much debate. FPLMTS proponents urged the conference to ''designate' or "identify" the bands for FPLMTS, but opponents, including the United States, opposed this wording, believing that it was too strong and too closely approached an actual allocation of frequencies for FPLMTS. As adopted, the footnote reads that these bands are ''intended for use. . .by FPLMTS.''[73]

ISSUES AND IMPLICATIONS

The difficulty of predicting the future of mobile services is illustrated by the simple difficulty of even defining what the terms and acronyms mean. The United States, for example, would not support allocations for FPLMTS at WARC-92 because no delegate from Europe could really explain what FPLMTS is. It is a concept, one that has only vague meaning now and will continue to evolve as time passes and needs, technologies, and institutional relationships become clearer.

Although the United States opposed FPLMTS allocations at WARC-92, the outcome of the FPLMTS debate for the United States may, in the long term, turn out to be a "success." The frequencies identified for use by FPLMTS internationally largely match those that have been proposed by the FCC for similar services in this country. Using these frequencies will enable the United States to more easily fit into an international FPLMTS service, thereby opening an important long-term opportunity for the growing U.S. mobile communications industry.

International Issues-The development of terrestrial mobile services in the 21st century is unclear on many fronts. The new technologies and systems for mobile communications are just now being designed and implemented. The European countries have been aggressive in develop-

[73] ITU, *Addendum and Corrigendum, op. cit., footnote 61, p. 17.*

ing and implementing policies that promote the development of new mobile services. As a result, the rollout of GSM, after a slow start, is picking up speed. The European Commission has also issued a directive requiring member countries to allocate spectrum for Digital European Cordless Telephone (DECT) service.[74]

Regulatory Barriers: From a regulatory perspective, several issues will confront FPLMTS proponents as they develop systems. First, the ITU has traditionally allocated spectrum only to categories of radiocommunication services, not to specific types of systems such as FPLMTS. Upgrading FPLMTS to a service could be difficult, especially given U.S. opposition. Because the concept of FPLMTS is not well-defined, it is unclear what rights and obligations FPLMTS system operators will have and be subject to. Such legalistic distinctions, however, are not likely to stand in the way of FPLMTS development if no country objects.

Furthermore, the footnote authorizing FPLMTS states that "[s]uch use [for FPLMTS] does not preclude the use of these bands by other services to which these bands are allocated. " How this limitation will be interpreted, and what effect it may have on other services and negotiations among countries remains to be worked out. Unlike other footnotes designed to protect existing services, it does not explicitly protect existing services from interference or indicate that FPLMTS systems will have to accept interference without recourse (a secondary status). This essentially creates a vague new category of operation (neither primary nor secondary) applicable only to FPLMTS.

Finally, the technical details of FPLMTS are just starting to evolve. Many observers expect that if and when a unified concept of FPLMTS does emerge, it will come slowly and initially be terrestrially-based. Any satellite component of FPLMTS cannot come into operation until 2010, and then will be subject to stringent coordination requirements that were laid out for new mobile satellite systems in Resolution 46.

The result is that the implementation of FPLMTS is essentially uncharted territory. Arrangements will have to be worked out as individual systems come into operation, or, more likely, further regulations and operating parameters may have to developed at a future world radiocommunication conference. For example, as noted in Resolution 211, the CCIR has determined that FPLMTS will not be able to share spectrum with the Space Services (see section below). Thus, the potential impact of FPLMTS on space communications will be very carefully watched by the world's space agencies. In addition, some of the frequencies identified for FPLMTS are also allocated to MSS. Sharing concerns could seriously constrain or limit the future development of FPLMTS.

Marketing Uncertainties: The future of FPLMTS is cloudy from a market perspective as well. While predictions about the potential of personal wireless communications systems are not in short supply, demand may be. There are already several different types of mobile systems operating and under development in Europe, including GSM, CT-2/Telepoint, and personal communication networks (PCN).[75] It remains to be seen if all these mobile services will be viable. In the United Kingdom, for example, Telepoint services-in which users carry portable phones that can only make calls, not receive them-failed to attract many subscribers and the industry is

74 The band designated for DECT/PCS is 1.880-1900 MHz, which overlaps the WARC-92 designated FPLMTS bands. Each EC country has implemented the allocation as required. See Kurt Wimmer, "Global Development of Personal Communications Services, " *Communications Lawyer, summer* 1992.

75 John Williamson, "U.K. PCN Rubber Hits the Road, " *Telephony,* vol. 222, No. 14, Apr. 6, 1992, p. 7.

76 There is only one remaining Telepoint operator (Hutchinson) in the United Kingdom. It now has 9,000 base stations in operation and expects to build 3,000 more. Kurt Wimmer, personal communication% Nov. 20, 1992.

struggling to stay alive.[76] PCN trials have also been beset by difficulties, but at least two systems are expected to begin operations over the next year. However, the slow start of PCN in the United Kingdom does not seemed to have caused other countries to abandon PCN--Germany and France are both moving ahead with their PCN plans,

The total size of the market for mobile services may not support many competing technologies and systems. GSM operators, for example, often view PCN as a threat since it represents ''another purchasing option. '[77] The wide variety of mobile systems-GSM, PCN, CT-2, microcellular, various satellite systems that are being planned-may cause consumer confusion similar to that being experienced in the evolution of technologies for playing prerecorded music. In that case, a number of competing formats (cassettes, Digital Audio Tape, Digital Compact Cassettes, Compact Discs, Sony's Minidisc, etc.) maybe causing consumers to resist merely buying the latest technology. A similar trend toward confusing and competing mobile telephone systems may cause consumers to resist buying until the market shakes out and one system becomes dominant. The battle between GSM and PCN in Europe could preview similar conflicts between cellular and PCS in the United States.

Domestic Issues—In the United States, the development of future terrestrial mobile services is similarly unclear. The cellular industry, which has been a world leader since its inception in 1983, and continues to add subscribers at a rapid pace, is now struggling to improve and expand its systems. In contrast to the GSM plans of Europe, there is no settled plan in this country to provide one unified cellular system, and technical and billing problems still exist when cellular users "roam' outside their home systems,[78] In addition, the cellular industry is in the middle of a heated battle over the choice of a standard for the industry that would cover the next generation digital cellular systems now being designed.[79] Such difficulties threaten to slow the development of future mobile services in this country, and have led some analysts to conclude that the United States now trails Europe in the deployment of advanced mobile technologies.

Like FPLMTS internationally, the FCC faces a similar problem defining the future of mobile communications for the United States. Is the American conception of PCS similar to the United Kingdom's PCN? Or is it more general? Does it compete with cellular or complement it? At different points in time, and depending on who was asked, the answer to any of these questions could be ''Yes, ' ''No,' or 'Maybe.' Recognizing the inherent uncertainty and danger in pigeonholing a new technology/service, the FCC has so far adopted the widest possible definition for PCS—it is all things to all people.

One of the more difficult questions facing U.S. regulators and policymakers is the relationship of U.S. PCS systems to FPLMTS. Should the United States support FPLMTS? If PCS is developed before FPLMTS begin operating, should FPLMTS be made compatible with PCS? How?

77 GSM and PCNs are quite similar technically. GSM operates in the 900 MHz band, and PCNs (in Europe) "essentially are GSM at 1.8 GHz instead of 900 MHz. " John Williamson, ''GSM Bids for Global Recognition in a Crowded Cellular World," *Telephony,* vol. 222, No. 14, Apr. 6, 1992, p. 37.

78 McCaw Cellular Communications, Inc. and southwestern Bell Corp. did announce plans to make cellular service available nationwide by negotiating with local franchises across the country to ensure common service standards that would allow seamless transitions between different service areas. GTE Corp., Bell Atlantic, NYNEX, and Ameritech have also announced a nationwide cellular plan that would challenge McCaw's system. Mary Lu Carnevale, ''GTE, Baby Bells Issue Challenge to Cellular One, " *Wall Street Journal,* Feb. 11, 1992, p. B 1.

79 The battle is between Time Division Multiple Access (TDMA), which was ''officially'' chosen by the Cellular Telecommunications Industry Association (CTIA), and Code Division Multiple Access (CDMA), which, although less developed than TDMA, has caught the attention of some large cellular providers due to its promised larger capacity gains over TDMA. CTIA is now evaluating both technologies. For a discussion of the TDMA vs. CDMA debate, see Global *Telecom Report,* ''*TDMA* Has Been Selected as Standard, but CDMA Is Gaining Visibility and proponents, " vol. 8, No., 2, July 27, 1992.

Should the United States continue to oppose FPLMTS if it appears that it will not be compatible with PCS? What are the implications of the U.S. building a system (with all necessary standards and protocols) not supported by other nations of the world? As other countries outside of Europe adopt GSM as the standard for next-generation mobile communications, some analysts fear that the United States may become surrounded and outnumbered by GSM users. It may also be possible that-looking beyond GSM—FPLMTS will "encircle" PCS as well. The risks and advantages of such an outcome, and the policies leading to it, should be carefully weighed while policy can still be adapted to fit the international context.

The case of mobile communications points out a serious tension in American telecommunications policy. It must somehow balance the need for aggressive policy with a philosophical commitment to marketplace solutions. Aggressive policymaking that sets clear direction could provide focus to U.S. development efforts and allow U.S. companies to compete more effectively abroad. Many members of the private sector called for such leadership during WARC-92 preparations, a call that went largely unanswered. The disadvantage to this approach is that choosing the "wrong" policy direction may commit U.S. interests to a technology path that does not endure.

Unfortunately, unlike the Europeans, the United States has no coherent policy to guide the development of mobile services, nor even any general direction that could guide policymaking. The United States is committed to a policy that lets the market decide. So far, some would argue, the development of cellular technology has been remarkably successful-judging by increasing numbers of users and revenues. Such success, however, when judged in an evolving international context, may be short-lived. Many technologies, including PCS, MSS, cellular, and LEOS, are now fighting for spectrum (see figure 2-4) and customers, and time may be working against U.S. interests.

The United States can no longer afford to let the market decide-the potential for these new services is too important in terms of benefits to the American consumer, the revenues that could be generated, and the boost to American competitiveness that a focused approach to mobile communications could provide. U.S. spectrum managers and policymakers must make strategic decisions and hard choices to avoid the kinds of self-destructive technology battles that have held back other communications services-AM stereo, and now digital cellular standards. More aggressive oversight and guidance (leading to unified action) is needed if the United States is to effectively move forward in pursuit of world mobile communication markets. Otherwise, domestic battles may destroy America's ability to wage the war abroad.

SATELLITE MOBILE SERVICES

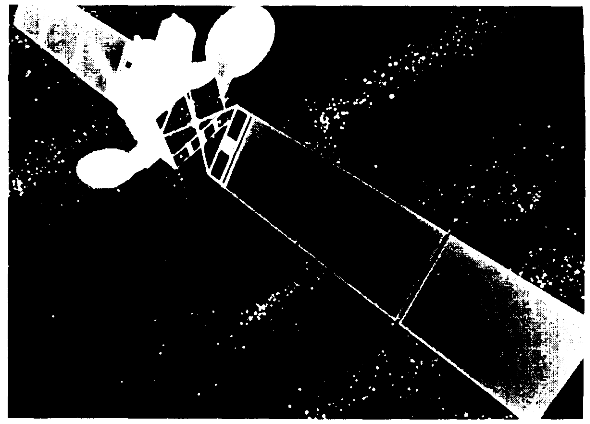
In addition to terrestrially-based mobile communication services, companies around the world have proposed to use satellites to deliver mobile services. For communications providers, satellite-based systems offer ubiquitous coverage of large (hundreds or thousands of miles across) areas, the remotest of which may be uneconomical for terrestrial systems to reach. Satellite-based communication systems have also become increasingly attractive to users because advances in technology have produced smaller, lighter, and less expensive user equipment and a wider range of applications, including telephony, remote data collection, data communication, position determination, etc. At WARC-92, ITU members considered allocations for three types of MS S-each offering overlapping services, but using different system configurations and user equipment. The following three sections discuss: geosynchronous MSS, LEOS systems planning to offer data services, and LEOS systems planning to offer telephone services.

Mobile-Satellite Services[80]

BACKGROUND

Since the mid-1980s, consumer demand for MSS has grown rapidly. Comsat's mobile services revenue, for example, rose from 14 percent of total revenues in 1988 to 20 percent in 1990.[81] Proponents of MSS see satellites as an economical and efficient way to deliver telecommunication services to users across wide areas. They point alternatively to the congestion of many cellular systems as evidence of the demand for such services and to the lack of nationwide mobile services as an advantage of satellite delivery. As a result, the demand for additional spectrum for MSS has grown dramatically both domestically and internationally.

The development of MSS in this country dates back to the early 1980s. In 1985, the FCC released a NPRM to allocate frequencies and develop regulatory and technical policies that would foster the development of MSS.[82] As a result of that 2-year proceeding, the FCC reached two important conclusions: 1) given the limited amount of spectrum then available, MSS services, including aeronautical, land, and maritime applications, could only be efficiently and economically provided by one licensee, and 2) the sole licensee should be a consortium of the applicants who had previously applied to provide MSS. As a result of this decision, the American Mobile Satellite Corporation (AMSC) was formed and granted the sole license in the United States to provide MSS



Intelsat

Satellites in geosynchronous orbit 22,300 miles above Earth are being used to provide a variety of mobile communication services to aircraft, ships, and vehicles.

in the 1545-1559 MHz and 1646.5 -1660.5 MHz bands.[83] As currently conceived, AMSC's MSAT system will cover all of North America, and will offer a range of services, including nationwide mobile telephone service, paging, data communication, and position location services to land, maritime, and aeronautical users (trucking or shipping companies, for example). AMSC also plans to provide communications for civil aviation, including air traffic control and flight management communications to support safety services and airline passenger telephone calls. In 1992, AMSC began offering data messaging services using leased satellite capacity from Comsat. Customers using this service will even-

80 Although MSS technically refers to all types of mobile satellite systems, including LEOS, in this section MSS will refer only to geosynchronous satellite systems. LEOS systems are discussed separately below.

81 Andrew Lawler, "Political, Economic Changes Draw New Markets," *Space* News, vol. 3, No. 3, Jan. 27-Feb. 2, 1992.

82 For a discussion of the history of domestic and international MSS issues, see John Davidson Thomas, "International Aspects of the Mobile Satellite Services," *Federal Communications Law Journal,* vol. 43, December **1990.**

83 Currently, the major stockholders of AMSC are Hughes Communications, Inc., McCaw Cellular Communications, Inc., and Mobile Telecommunications Technologies Corp., which together control approximately 90 percent of AMSC shares. The FCC's actions in this proceeding, including the validity of the consortium approach, have been challenged repeatedly on legal grounds. Although the court did reverse and remand the order establishing AMSC, the FCC subsequently reasserted the legitimacy of the consortium approach and the awarding of the sole MSS license to AMSC. Members of the aeronautical community appealed these decisions, but the case was dismissed on procedural grounds. The court, however, did note its concern over the FCC's authority to mandate licensee consortiums. "FCC, AMSC Get Victory by Default. . .," *Telecommunications Reports,* vol. 59, No. 5, Feb. 1, 1993.

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Box 2-B—Glossary of Satellite Terms

Throughout this report, many different terms are used to refer to different components of satellite communications systems. In many cases, the same thing will have many different names, each of which can be used more or less interchangeably. While some of these terms may have specific legal/regulatory or technical/engineering meanings, they are often mixed in colloquial speech. The following brief descriptions identify some of the terms that are used.

Antenna: An antenna is a part of the transmitter/receiver system that is used for radiocommunications. Antennas come in a variety of shapes and sizes. The term can refer to the simple 8-inch cellular antenna mounted on many cars or it can be used to refer to the TV antennas many people have on their houses. It is even used to refer to the larger more complex antennas used to communicate with satellites. A satellite dish, for example, is one form of satellite antenna.

Dish: A satellite transmitter/receiver. Since many satellite antennas are shaped like a large dish, they are often referred to as dishes. *See also* transmitters and receivers.

Downlink: Refers to the direction a radio signal travels as it moves from the satellite to the ground. In many International Telecommunication Union (ITU) documents, downlink frequencies will be identified as space-to-Earth or S-E. In figures and tables downlink frequencies are often distinguished by an arrow pointing down. Downlink is also often used as shorthand for an Earth station that receives signals from a satellite. *See also* uplink.

Space stations: Another term, sometimes used in the ITU vocabulary, for a satellite (not to be confused with manned space stations).

Transmitters and receivers: There are many names for the devices that communicate with satellites: station, receiver, terminal, and unit. Usually these terms refer to the antenna and the related electronics of the system. Often they are modified according to the specific function of the device: ground station, Earth station, and fixed station usually refer to larger satellite dishes mounted in one stationary location. User terminal or unit refers to any radio device used by an individual. There are two types of user terminals—portable (handheld) or mobile (mounted in a vehicle) communications. These devices are also sometime known as mobile Earth stations.

Uplink: Refers to the direction a radio signal travels as it moves from the ground (or an airplane) to a satellite. ITU documents frequently identify these frequencies as Earth-to-space, or E-S. In figures and tables, uplink frequencies are often distinguished by an arrow pointing up. Downlink is also often used as shorthand for an Earth station that sends signals to a satellite. *See also* downlink.

SOURCE: Office of Technology Assessment, 1993.

tually be switched over to AMSC'S satellite, which is expected to launch in late 1994.

The major global player in MSS is the Internationa1 Maritime Satellite Organization (Inmarsat). Inmarsat is an international cooperative owned by more than 60 countries, including the United States, who hold investment shares in the organization. Comsat is the official U.S. signatory to Inmarsat and the only authorized seller of Inmarsat services.[84] Although it was originally established in 1979 to serve the communication needs of ships-at-sea, Inmarsat has gradually

84 Inmarsat itself is not permitted to provide land or aeronautical mobile services in the United States, It does offer some maritime services.

expanded the scope of its activities to include international aeronautical communication services (begun in 1989), and land mobile communication services. Today, land mobile users make up 25 percent of Inmarsat's customers.[85]

U.S. PROPOSALS

Winning support for MSS proposals was among the highest U.S. priorities at WARC-92. Under the umbrella of MSS, the United States had a number of interests to protect and promote, and these gave rise to several different proposals. The priorities (listed in no particular order) for the United States in MSS were to:

1. Convert the specific mobile satellite services (aeronautical, land, and maritime) into "generic" MSS, while providing adequate protection and priority for aeronautical and maritime safety communications;
2. Obtain new spectrum for MSS; and
3. Prevent reallocation of the 1435-1525 MHz band now used for aeronautical telemetry to MSS or BSS-Sound (see section on BSS-Sound for discussion).

Generic MSS—In the past, the ITU had subdivided the various mobile satellite services into three separate categories-aeronautical, land, and maritime-each with its own allocations. The United States first proposed that these separate allocations be merged into a single "generic" allocation at the 1987 WARC on mobile services (MOB-87), That proposal was not accepted by MOB-87, and the issue was carried over to WARC-92.

The WARC-92 U.S. proposal for generic MSS was premised on the belief that ''the current service specific allocations in the 1.5/1.6 GHz bands are too restrictive to permit flexible usage to adapt to dynamic changes in communication needs. We recognize, however, that special provisions are necessary so that safety services will be protected from interference, and that these services will be ensured priority access over other communications in these bands. ' '[86] The current division of MSS, U.S. spectrum managers believe, leads to inefficient use of the spectrum because radio frequencies cannot be transferred quickly enough for use by the most-demanded services-leaving some services with too much spectrum, while others face spectrum shortages and congestion. In order to eliminate this form of structural inefficiency, the United States proposed to merge the specific MSS (aeronautical, land, and maritime) into generic MSS, while providing special protections and preemptive access to the safety services. Government spectrum managers believe that such safeguards would be adequate to protect safety needs of the aeronautical and maritime communities.

U.S. proposals targeted a total of 61 MHz for conversion to generic MSS. The United States proposed to reallocate the Land Mobile-Satellite (LMSS) and Maritime Mobile-Satellite Service (MMSS) bands at 1530-1544 MHz (downlink) and at 1626.5 -1645.5 MHz (uplink) to MSS.[87] And in the bands 1545 -1559 MHz (downlink) and 1646.5 -1660.5 MHz (uplink), the United States proposed to reallocate the Aeronautical Mobile-Satellite (Route) Service (AMS(R)S) and LMSS to MSS.[88]

Additional MSS allocations--In addition to these changes, the United States sought additional allocations for MSS. As noted above, the United States proposed to make 19 MHz of spectrum at

85 Ellen Messmer, ''Inmarsat Ready to Challenge Iridium,'' *Network World, Mar. 16, 1992.*

86 U.S. proposals, op. cit., footnote 5, p. 4.

87 In order t. balance amount of spectrum available for uplinks and downlinks, the United States also proposed to allocate the band 1525-1530 MHz to the mobile-satellite service (space-to-Earth). See below. This proposal includes priority access for maritime safety communications as indicated in the proposed footnotes that accompany the frequency proposal.

88 This proposal provides priority access with real-time preemptive capability for the Aeronautical Mobile-Satellite (Route) Service. This access was proposed in a footnote accompanying the allocation proposal.

1626.5 -1645.5 MHz (uplinks) generic. The companion (paired) generic MSS downlink band for these frequencies at 1530-1544 totaled only 14 MHz.[89] Consequently, the United States proposed to add 5 MHz (1525-1530 MHz) to the newly generic MSS downlink band at 1530-1544 MHz, thus balancing the amount of spectrum available for both uplinks and downlinks.

The United States also proposed new worldwide allocations of 80 MHz (40 MHz each for uplinks and downlinks) for MSS. The proposed allocations were 2110-2130 MHz and 2160-2180 MHz (downlinks), and 2390-2430 MHz (uplinks). For ITU Regions 1 and 3, the United States also proposed to allocate (through footnotes) the bands 2500-2535 MHz (downlink) and 2655-2690 MHz (uplink) to MSS. Finally, the United States proposed an allocation footnote to add MSS to the 1850-1990 MHz band. This addition was intended to provide future spectrum for MSS operations, including LEOS systems.[90]

RESULTS

United States MSS proposals enjoyed mixed results at WARC-92. The U.S. proposal to convert existing aeronautical, maritime, and land mobile satellite service allocations into a generic MSS allocation worldwide was generally not successful—WARC-92 let stand the existing divisions between the specific services (see figure 2-5). This outcome was not surprising given past opposition. International support for maintaining a separate band of frequencies for satellite services serving airline routes was especially strong.

The United States achieved part of its goal, however, by inserting two footnotes in the crucial bands indicating that MSS would be allocated on a primary basis in this country and several others.[91] Footnote 726C allocates 1530-1544 MHz and 1626.5 -1645.5 MHz on a primary basis, but only in Argentina, Australia, Brazil, Canada, Malaysia, Mexico, and the United States, and maritime distress and safety services have priority. The effect of this footnote is to make MSS primary in all of North America. Footnote 730C allocates the 1555-1559 MHz and 1656.5 -1660.5 MHz bands to MSS, but only in the United States and Argentina, and provides priority access to AMS(R)S.

Regarding new MSS allocations, some of the U.S. proposals were accepted, some were not. New spectrum was allocated to MSS in a number of bands (see box 2-C and figure 2-4), but the new allocations are modified, and in some cases severely constrained, by a complex array of footnotes that specify power levels, coordination requirements, and implementation dates. Because of these limitations, the United States entered two reservations in the Final Acts of WARC-92 complaining g about the "unduly restricted allocations" for MSS and the delay in making some of the new allocations available. Through these reservations the United States maintains its rights to use the bands as it deems necessary in order to meet the needs of mobile satellite systems in this country.[92]

DISCUSSION

Domestic Issues-U.S. proposals were driven by the increased demand for mobile services in this country (and the perceived latent demand worldwide), the large geographic areas involved,

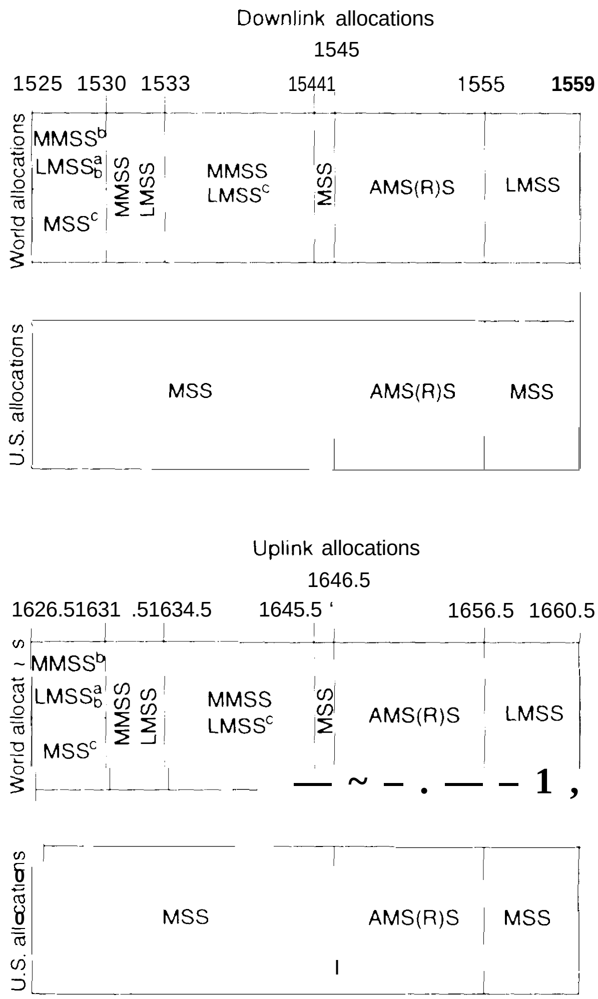
89 Satellite services are often allocated in paired bands. This means that all communications signals going to the satellite in one band will be transmitted back to Earth in the companion band.

90 The United States also wanted t. use these bands for future personal communications services development and wanted to reserve the band for possible satellite augmentation of terrestrial PCS systems.

91 Footnote 726C allocates the bands 1530-1544 MHz (downlink) and 1626.5 .1645.5 MHz (uplink) to MSS on a primary basis in Argentina, Australia, Brazil, Canada, the United States, Malaysia, and Mexico. Footnote 730C allocates the bands 1555-1559 MHz and 1656.5- 1660.5 MHz to MSS, but only in the United States and Argentina. Provisions are made to protect and provide emergency access for maritime (and other) safety communications.

92 International Telecommunication Union, WARC-92, Document 389-E, Mm. 3, 1992, P. 29.

Figure **2-5—WARC-92** L-Band Mobile-Satellite **Service Allocations**



[a] **Secondary**
[b] **In Region 1 only**
c In Regions 2 & 3 only

KEY: AMS(R)S=Aeronautical Mobile-satellite (Route)Service, LMSS=Land Mobile-Satellite Service, MMSS-Maritime Mobile-Satellite Service, MSS=Mobile-Satellite Service.

SOURCE: Office **of Technoloyg Assessment, 1993.**

and the rapid development of satellite technologies. AMSC's stated need for more spectrum--so that it could compete with other international satellite systems—was an important consideration.[93] In addition, the desire to foster the development of this newly emerging, and poten-

[93] The Limited amount of spectrum allocated to MSS worldwide prior to WARC-92, combined with the number of counties/companies planning to launch MSS systems made sharing the spectrum essential. As a result of preliminary negotiations with some other countries, AM and the Federal Government believed that there simply was not sufficient spectrum to support all the competing systems, including AMSC. Without adequate spectrum, AMSC would have had serious difficulties offering the number and quality of services it had planned.

Box 2-C—WARC-92 Allocations for the Mobile-Satellite Service

WARC-92 allocated frequencies for MSS in a number of bands (see figure 2-4 for an overview of these new allocations):

1525-1530 MHz (downlink)—These frequencies were reallocated to MSS in order to supplement the downlink band at 1530-1559 MHz and match the amount of spectrum (34 MHz) previously allocated to MSS uplinks at 1626.5-1660.5 MHz. The allocation in Regions 2 and 3 is to MSS on a coprimary basis. In Region 1, however, the allocation is limited to Maritime MSS coprimary and Land MSS on a secondary basis. Use of these bands (1525-1559 MHz and 1626.5-1660.5 MHz) is subject to coordination and notification procedures set out in Resolution 46.[1]

1530-1559 MHz (downlink)—the United States proposed to make the frequencies in this band part of a generic MSS allocation, reallocating the individual (land, maritime, aeronautical) mobile satellite services to general MSS. These proposals were not accepted by the conference. However, the United States (joined importantly by Canada and Mexico) did succeed in inserting a footnote (726C) in the allocations table that makes MSS an additional primary allocation in 1530-1544 MHz (downlink) and 1626.5-1645.5 MHz (uplink), with account taken of distress and safety services. The United States (joined by Argentina) also inserted footnote 730C, which makes MSS coprimary in the 1555- 1559 MHz band, but gives priority to aeronautical safety communications (AMS(R)S).

1626.5-1660.5 MHz (uplink)—The United States also proposed to make these frequencies part of a global generic MSS allocation, a proposal that was again rejected by the world community. Use of these bands remains allocated to the individual MSS services (with MSS at 1626.5-1631.5—see figure 2-5). The United States inserted a footnote (726C) allocating 1626.5-1645.5 MHz to MSS, but giving priority access to maritime distress and safety systems. Footnote 726X makes these frequencies subject to the provisions of Resolution 46. In addition, the band 1645.5-1646.5 MHz is limited to distress and safety communications (footnote 734B). Footnote 730C makes MSS

[1] The United States, joined by the United Kingdom, entered a reservation in the Final Acts of WARC-92 stating that they "will not accept any commitments for this form of coordination arising from omission of the term "non-geostationary" in the text of certain footnotes [726X]. . ." International Telecommunication Union, WARC-92, Document 395-E, Mar. 3, 1992, p. 4. Thus, the United States may not abide by the decision of the conference with regard to coordination of these bands when geostationary satellite systems such as AMSC's are involved.

tially important and profitable industry, and to keep America at the forefront of satellite technology and services, quickly made MSS proposals one of the most important priorities for the United States and a major focus of U.S. WARC-92 preparations and negotiations.

Although many in the Federal Government, including NTIA, support the concept of generic MSS allocations, U.S. proposals for converting the individual mobile satellite services (aeronautical, maritime, and land) into a generic allocation for MSS were generally opposed by the individual user communities, both domestically in the U.S. preparation process and at the WARC itself (see below).

International and WARC-92 Issues-The United States has been fighting the battle of generic MSS since the mid-1980s. Inmarsat has opposed the idea, and the international aeronautical community, which wants to maintain a separate band for aeronautical safety communications or at least ensure that safety communications are protected from interference and continue to have priority access to satellite communication channels in the event of an emergency, has been especially critical of the generic concept. They believe that the rise of commercial MSS will eventually reduce the amount of spectrum available for aeronautical safety communications and subject such communications to increasing intera primary allocation in 1656.5-1660.5 MHz in the United States and Argentina, with priority access given to aeronautical safety services (AMS(R)S).

1492-1525 MHz (downlink)—The United States did not propose these frequencies for MSS, but (only in Region 2) they were allocated. The United States, in order to protect its existing use of the band for flight testing of aircraft and weapons systems, inserted footnote 722B to maintain the U.S. use of the frequencies only for fixed and mobile applications. In addition, WARC-92 paired this allocation with frequencies allocated at *1675-1710 MHz* (uplink- Region 2 only) to MSS on a coprimary basis (shared primarily with meteorological services). The latter frequencies can be used in the United States.

1930-1970 MHz (uplink)—This band was allocated to MSS (in Region 2 only) on a secondary basis, but this allocation is also part of the band of frequencies that is intended for use by FPLMTS. That intention, however, does not preclude the use of the band by other allocated services.[2] This band is paired with frequencies in the *2120-2160 MHz* band (for the downlink, again in Region 2 only), also on a secondary basis, which is also identified for use by FPLMTS.

1980-2010 MHz (uplink)—This band was allocated on a worldwide basis to MSS coprimary with mobile and fixed services, but in Region 2, an additional allocation was made to MSS at 1970-1980 MHz, bringing the total allocation to 40 MHz in Region 2. These allocations are also part of the band of frequencies that is intended for use by FPLMTS. That intention, however, does not preclude the use of the band by other allocated services.[3] WARC-92 paired this band with downlink frequencies in the *2170-2200 MHz* band. Additional allocations were made at 1970-1980 MHz (uplink) and 2160-2170 MHz (downlink), but only for Region 2.

Footnote 746X states that use of these bands for MSS shall not begin before January 1, 2005, and that such use is subject to the provisions of Resolution 46. In another footnote the United States pushed up the earliest date for implementation in this country to January 1, 1996.

2500-2520 MHz (downlink)—This band was allocated on a primary worldwide basis, to be paired with *2670-2690 MHz*. Use of this band cannot begin before 2005 and is subject to the provisions of Resolution 46.

[2] See footnote 746A.

[3] See footnote 746A.

SOURCE: Office of Technology Assessment, 1993.

ference. While U.S. spectrum managers maintain that adequate safeguards can be built into technology and accomplished through rule changes, representatives of the aeronautical community in both the United States and in international aviation organizations, such as the International Civil Aviation Organization (ICAO), are skeptical that such protection can be provided through either technical or procedural means. They are concerned that air safety (and existing investments in equipment) will be compromised if civil aviation users are forced to share spectrum with commercial MSS providers .94 The maritime community is similarly concerned that future development of MSS services in the bands could degrade the future worldwide Global Maritime Distress and Safety System (GMDSS). To date, the arguments against generic MSS have been more persuasive internationally.

94 Domestically, the battle between AMSC and the aeronautical community continues. ARINC, Inc., and other groups have filed suits challenging AMSC'S license, and they continue to doubt the ability of AMSC to ensure the reliability and preemptive access of aeronautical satellite communications required by the FCC and international rules. The FCC recently declined to adopt standards for such operations, leaving it instead to AMSC to design the system itself. *Telecommunications Reports*, ''FCC Adopts Technical Standards, Licensing Requirements for Aircraft Earth Stations, " vol. 58, No. 37, Sept. 14, 1992.

The negotiations over additional allocations for MSS were some of the most contentious of WARC-92. The greatest difficulty in negotiating new MSS allocations was in overcoming the resistance of other countries who were trying to protect their existing services. Many countries believe that (U. S.) satellite systems will cause interference to the existing services in the bands—just as the maritime and aeronautical communities believe that such systems will cause interference to their systems.

This difficulty was compounded by the opposition of the European bloc to any new U.S. MSS allocations. Even before WARC-92 began, battle lines had been drawn between the United States, for whom MSS was a high priority, and Europe/CEPT, which generally opposed U.S. MSS allocation proposals. At the conference, both sides refused to compromise, and despite some promising rumors, negotiations remained deadlocked for 3 weeks. Only 3 days before the end of WARC-92, no agreement had been reached, and the heads of delegations for the principal countries involved tried to negotiate a solution. Finally, in the last hours of the conference (between 2 AM and 7 AM), a deal was struck in which European opposition to MSS was dropped in return for U.S. concessions on FPLMTS.

ISSUES AND IMPLICATIONS

Allocation Issues-WARC-92 outcomes represent a step forward for the U.S. MSS industry, but successes were limited, and several issues will likely be revisited. Most significantly, some new spectrum was allocated for MSS use. However, while the additional spectrum allocated to MSS is important, the proponents of these new systems, both in the United States and abroad, believe that the frequencies allocated to MSS are still inadequate. Around the world, a number of countries are developing MSS systems (both regional and global in scope), each with its own spectrum needs. These needs, however, greatly exceed the amount of spectrum currently allocated to MSS. In addition, some of the new bands allocated to MSS by WARC-92 cannot be used before 2005-too late to accommodate all the systems now being developed.[95] The limited amount of additional spectrum that was allocated to MSS at WARC-92 and the limitations placed on the new allocations mean that this issue will almost certainly be revisited at a future world radiocommunication conference. MSS proponents believe that restrictions could be reduced as the systems come into operation, and more spectrum may be allocated as demand for the service increases.

As a result of the difficulty in coming to agreement on MSS issues, many footnotes were inserted into the allocations covering MSS. These footnotes modify the allocations in many ways—setting specific dates, varying the allocations in different countries, specifying coordination requirements, etc.—all of which serve to protect existing services, but which also constrain the introduction and/or operation of mobile satellite systems and services. Moreover, because of the technical detail in the MSS footnotes and the sometimes vague way in which they were written, these footnotes are subject to continuing interpretation.

Serious economic concerns underlie the MSS footnotes-concerns that are not amenable to technical frees and that will only be solved through intense negotiation. Years will be needed to develop, interpret, and negotiate the practical meaning of some of them. To what extent this will slow the development of mobile satellite services is uncertain. The U.S. Government and AMSC have already begun the process of coordinating U.S. MSS services worldwide.

The general failure of the U.S. generic proposals could constrain the development of future global MSS systems in the L-band. The **fact that MSS exists in a generic sense only in North**

95 This date is noted in footnote 746X. The United States, feeling this date was too far in the future, succeeded in inserting another footnote in the table of allocations (746U) that moves up the date at which MSS services can begin in the United States to Jan. 1, 1996.

America (in 1525-1544 MHz and 1626.5 -1645.5 MHz—footnote 726C) or only in the United States (in 1555-1559 MHz and 1656.5 -1660.5 MHz—footnote 730C) means that any global MSS system the United States might put into orbit must conform to the international allocations when operating in other countries. It remains to be seen how serious this restriction will be. AMSC, for example, plans to serve only North America, and is constructing its system accordingly-it will not be affected directly by the regional allocations in Regions 1 and 3. The United States will undoubtedly press for generic allocations in these bands at future conferences in order to allow more flexible uses of these frequencies by a variety of satellite services. This position will likely continue to be opposed by the aeronautical and maritime communities until such time as the technical viability of providing them priority access to MSS frequencies can be proven.

Competition with Terrestrial Services—The impacts of MSS services on terrestrial mobile services is unclear. Both of these delivery systems will provide essentially the same services—telephone, paging, and data communications. The most important question facing mobile service proponents is: is the overall market for mobile communication services large enough to support many different technologies and companies? The market will ultimately decide if MSS becomes a mass market consumer service or a service targeted to niches such as trucking companies, fleet management services, and/or national paging services.

Some analysts have commented on the ability of future satellite services to provide competition to cellular telephone operators—and the beneficial effects this competition would have on prices and service. While such competition could have beneficial effects, it is not yet clear if MSS systems will compete directly against cellular systems or if MSS could provide effective competition to the cellular providers in more than a few markets or niche applications. The strategy of some MSS providers (including big LEOS), at least publicly, is to provide services that "complement" the existing cellular systems by targeting areas not served by cellular systems and/or individuals who frequently roam between different cellular systems. If these services prove successful, however, it is likely that the satellite companies will begin to compete with the cellular telephone companies for the same customers.

Future of the U.S. MSS Industry---Given the additional spectrum allocated to MSS at WARC-92 and the likelihood that additional spectrum for MSS will be made available at future WARCs, the domestic structure of the U.S. MSS industry and the policies governing it should be immediately reviewed. The questions involved in determining the future of MSS in this country are complex and will require high-level policy decisions that take account of many important technical, economic, and political factors. This issue graphically demonstrates the importance of having a framework in place through which to develop consistent and aggressive policies that would support the development of mobile (including terrestrial and satellite) services in this country.

Several domestic MSS issues remain unresolved. Fundamentally, the decision facing the FCC and the Congress is how much competition to allow in the MSS industry. AMSC has been licensed for several years as the sole provider of MSS (in the bands 1545—1559 MHz and 1646.5-1660.5 MHz) in the United States, but its role and very existence continue to be challenged in court.[96] Furthermore, the additional spectrum allocated to MSS at WARC-92 calls into question the

96 AMSC, and the rationale for establishing a consortium approach for MSS, has been challenged in court and survived SO far. If the FCC and AMSC lose, the U.S. MSS industry (which essentially is AMSC) could be seriously set back. AMSC has been the focal point of U.S. coordination discussions internationally, and satellites arc already being constructed. If AMSC is invalidated, or if MSS services are opened for (additional) applications, deployment of MSS in this country could be delayed.

FCC's original rationale for granting only one MSS license-namely that there was only enough spectrum to support one licensee.

Since its creation, the FCC has carefully protected and supported AMSC. Some observers hypothesize that since the FCC created AMSC, it feels responsible to defend it against all threats—domestic and foreign. However, although the FCC's desire to protect AMSC and promote the development of a costly and risky new service is a laudable goal, the conditions that led to that decision have changed and will continue to evolve. The rapid development of alternative MSS technologies (LEOS), for example, and the FCC's support of them undermines AMSC's and the FCC's arguments that AMSC must be initially protected from competition in order to survive. LEOS systems will provide similar services and presumably compete head-to-head with AMSC in many markets and service segments.

Such developments call into question the belief that the protection of AMSC as a regulated monopoly is in the best interests of the citizens of the United States. On one hand, government and AMSC officials believe that the regulation and protection of AMSC are necessary to ensure that the system/company can survive and begin offering services. If AMSC was not protected and ultimately failed, there would be no mobile satellite service in this country, and the United States would suffer a serious setback in the international negotiations now going on to work out spectrum sharing arrangements among the proposed MSS systems. In addition, if AMSC were to fail, and no company or system could quickly take its place, Inmarsat could step in to provide services--on a monopoly basis with monopoly prices.

On the other hand, entry of Inmarsat into U.S. markets could be beneficial to American consumers if a "level playing field" for competition could be created and maintained. As noted above, Inmarsat has been aggressively expanding its role and customer base for the last several years, and has targeted land mobile telecommunications as an **area** for future growth. International paging using Inmarsat satellites is expected to begin in 1994, and the organization has announced plans to provide telephone and other services in competition with the U.S. LEOS providers (see below). When the FCC allocates additional spectrum to MSS in conformance with WARC-92 decisions, Inmarsat could potentially provide services in competition with AMSC—if it were allowed into U.S. markets. However, if a worldwide system such as Inmarsat was permitted to operate in the United States, it would reduce the amount of spectrum available for U.S. domestic systems—perhaps making their services difficult or impossible to deliver.

A true commitment to competition and its presumed benefits-lower prices and better quality-require that the possibility of opening the U.S. market to other MSS providers—both domestic and foreign—be examined. If AMSC is to continue to operate under protected monopoly status, the reasons for such an important policy decision must be carefully and openly examined in the light of evolving domestic and international considerations. It may be possible, given the availability of new spectrum, to open up MSS in the United States to even greater competition. With the procompetitive atmosphere that now exists at the FCC, in Congress, and in the executive branch, such a monopoly approach seems out of place. This debate points out the intricate and complex interconnections between (developing goals for) radiocommunication policy, WARCS, and trade policy.

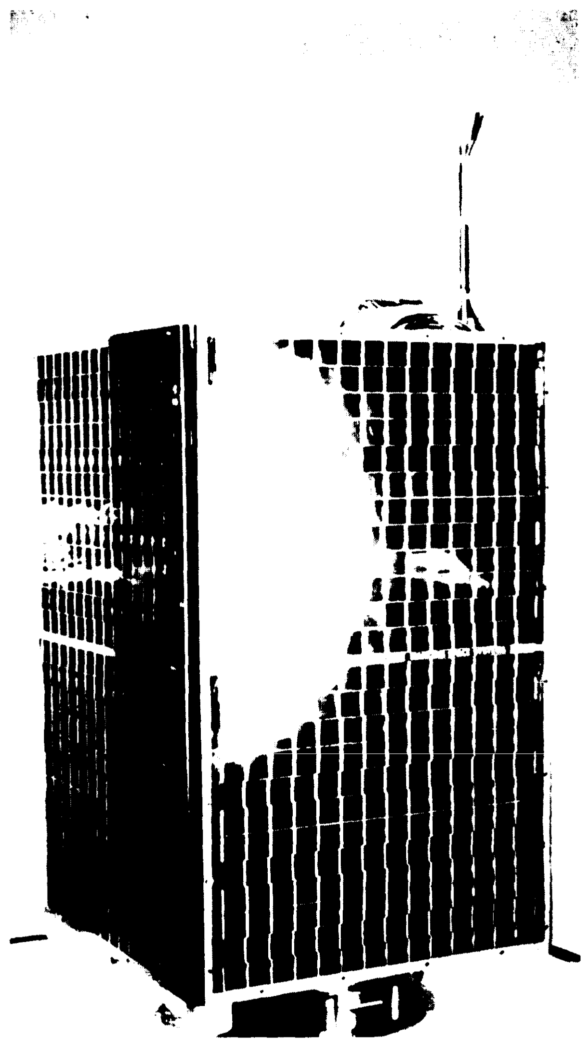
■ Little LEOS

BACKGROUND

One of the greatest booms in the use of wireless technologies has come in the demand for data communication and simple messaging applications. The growth in paging services and the more recent explosive growth in portable data communications-for service technicians in the field, for example-indicates a large, and as yet, unexploited market for wireless data communication services.[97] In order to meet this perceived demand, several U.S. companies have proposed to use networks of low-Earth orbiting satellites to deliver two-way data, messaging, and position determination services worldwide. Because these systems will operate in frequencies below 1 GHz (in the VHF/UHF bands), and because they will use very small satellites, they are often referred to as "little LEOS," in order to distinguish them from similar networks of LEOS that plan to operate in frequencies above 1 GHz and deliver voice services as well as data (see section on "big LEOS" below).

Current designs for the little LEOS systems envision networks of up to 24 satellites flying in orbits only several hundred miles above the Earth.[98] Depending on complexity, these satellites are expected to cost from $6 to $10 million each. On the ground, satellite dishes called network gateways located throughout the world will relay messages and data to the satellites that will then retransmit the information down to individual users who will receive it on small handheld terminals (see figure 2-6). Users will be able to send short messages back through the satellites to the gateways for delivery to other mobile users or through the public telephone network to family and friends or their company. Trucking companies, for example, could use the systems to locate cargoes or trucks, and to communicate with employees.

Little LEOS systems plan to offer a variety of communications services. The most basic service initially might be domestic one-way paging. The most advanced applications will allow users to send and receive messages on small, portable hand-held units that resemble large calculators



Volunteers in Technical Assistance, Inc.

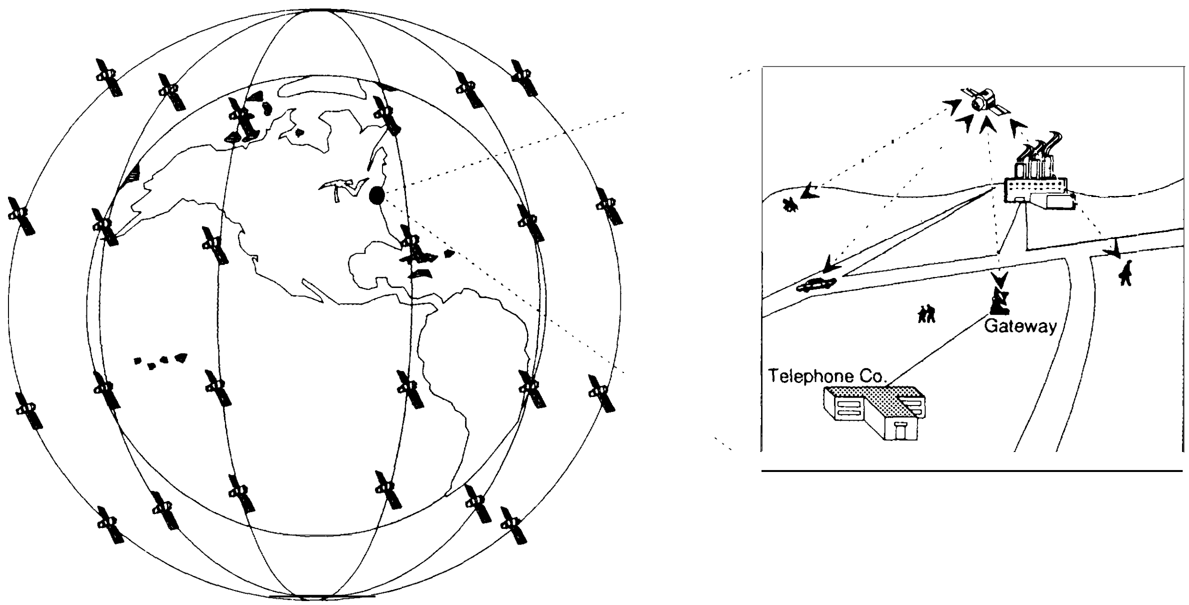
Small satellites such as this one, which is less than 4 feet tall, will bring data communications services to people around the world.

with an antenna attached. These handsets will be able to receive and transmit messages of up to 200 characters, determine the users' location to within

97 See, for example, U.S. Department of Commerce, National Telecommunications and reformation Administration, *Telecom 2000: Charting the Cour.refer a New Century,* NTIA *Special* Publication **88-21 (Washington, DC: U.S. Government Printing Office, October 1988).** A number of radio-based data communication networks are already operating in this country, including ARDIS (Motorola/IBM) and Ram Mobile Data (Ram/BellSouth), and the FCC has proposed allocating 20 MHz of spectrum for wireless data communication as part of its proceeding on PCS, op cit., footnote 63. Severat companies bave also announced plans to market data services that would use existing cellular telephone systems.

98 Geosynchronous-orbiting satellites, by contrast, are located 22,300 miles above the Earth.

Figure 2-6-Generic Little LEOS System



SOURCE: Office of Technology Assessment, 1993.

100 meters or less, and are expected to be relatively inexpensive (depending on features, current estimates range from $50 to $400). User terminals could also be installed in cars, trucks, and boats or even be integrated with a vehicle's radio system. An advantage offered by the little LEOS systems over terrestrially-based data services is their ability to supply location information to users and for other service providers. Lost hikers or boaters and stranded motorists, for example, could use the systems to send distress signals giving their exact location. Police could use such systems to find stolen cars. Finally, such systems can provide environmental or industrial monitoring by allowing stationary units to transmit weather or leak detection data to a central location.[99] The kinds of features a user wants will determine the type and cost of equipment needed.

U.S. PROPOSALS

As a result of discussion in the FCC's Industry Advisory Committee and between industry and government interests, the United States proposed allocations for MSS to be used by little LEOS systems in three bands. The bands proposed were: 137-138 MHz (downlink), 148-149.9 MHz (Uplirlk), and 400.15-401 MHz (downlink).

RESULTS

By most accounts, the United States did well with its little LEOS proposals. The frequencies the United States wanted were allocated, but some only on a secondary basis. Additional frequencies the United States did not propose were adopted for LEOS use, and interim coordination procedures for little LEOS operations were agreed to.

99 Such uses could also be two-way: the sensors could be polled for an immediate reading. Alan Pittman, "FCC Starts Pager Race," *Washington Technology,* vol. 7, No. 1, Apr. 9, 1992, p. 30.

WARC-92 allocated 137-138 MHz for little LEOS downlinks. However, in order to protect existing services, the band was broken up into subbands, some of which are primary while others are secondary (see figure 2-7). This spectrum will be shared on a coprimary basis with space operations and research services and meteorological satellite operations, and with fixed and mobile services (both secondary).

The 400.15-401 MHz band was also allocated for LEOS downlinks. This band will be shared with the meteorological aids and satellite services and space research services on a coprimary basis and space operations on a secondary basis. LEOS services may operate freely in these two bands as long as they stay below a certain level of power (so as not to interfere with existing services). However, if the signal from the satellite exceeds that "trigger" level (it is too powerful when it reaches the ground), the little LEOS service provider must coordinate the system with existing users (see discussion of Resolution 46 below).

The band 148-149.9 MHz was allocated for LEOS uplinks on a coprimary basis with fixed and mobile services. However, in order to protect existing services, WARC-92 put limitations on LEO operations in this band that are stricter than for the downlinks. First, conference delegates agreed that "the mobile-satellite service [including LEOS services] shall not constrain the development and use of fixed, mobile and space operation services in the band 148- 149.9 MHz."[100] Second, the power levels of the mobile user terminals cannot exceed a specified level (in countries which have not allowed the service), which is very low—lower than limits on the other bands. And unlike the power levels specified in the 137-138 and 400.15-401 MHz bands, the limits in this band are absolute. If a country has not permitted the system to operate within its borders, the power levels in the offended country may not exceed these limits under any circumstance.

Orbital Communications Corp.

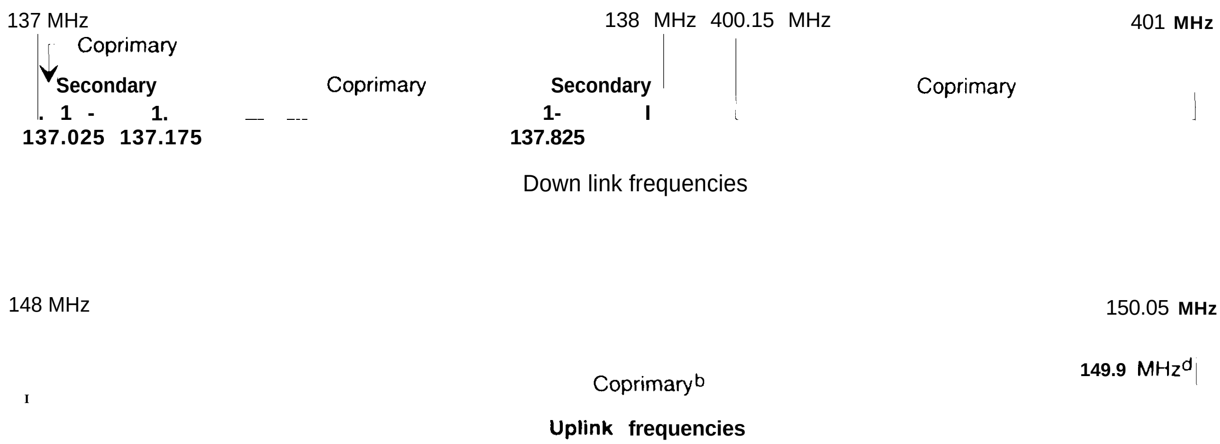
Hand-held terminals will enable consumers and business users to send and receive short messages around the world and determine their location anywhere on Earth to within 100 meters.

More importantly, many countries (including most of Europe, many African nations, Canada, Russia, and others, but *not* including the United States) have effectively made these LEO uplink frequencies secondary (see box 2-A for a discussion of the differences between primary and secondary status for radio services) in their countries by inserting a footnote into the international Table of Allocations stating that:

> [s]tations of the mobile-satellite service in the band 148-149.9 MHz shall not cause harmful interference to, or claim protection from stations

[100] ITU, *Addendum and Corrigendum,* op. cit., footnote 61, p. 1.

Figure 2-7—WARC-92 Little LEOS Frequency Allocations



a Downlinks are subject to coordination according to Resolution 46 if they exceed Certain power levels.
b Secondary in more than 70 countries. See footnote 608Z.
c User terminals have power limits to avoid interference across national boundaries.
d Use of the 149.9-150.05 MHz band is limited to land systems, and remains secondary until January 1, 1997.

NOTE: The coordination procedures outlined in Resolution 46 apply to LEOS systems operating in any of these bands.

SOURCE: Office of Technology Assessment, 1993.

> of the fixed or mobile services in the following countries [more than 70 out of the ITU's 166 countries are listed]. . . .[101]

Coordination between LEOS uplinks and the domestic services in these countries will be required.

In addition to the proposals made by the United States, WARC-92 allocated additional frequencies for little LEOS operations. The band 149.9-150.5 MHz, which is limited to land mobile use, will be shared on a co-primary basis with radionavigation-satellite services. Any LEOS service in this band may not constrain the radionavigation services, and will be on a secondary basis until Jan. 1, 1997. In response to proposals made by the Russian Federation, a secondary allocation was adopted for MSS in the bands 312-315 MHz (uplink) and 387-390 MHz (downlink), which can be used for non-geostationary systems. Any little LEOS system will have to share these bands with freed and mobile services, and cannot cause interference to existing services.

Finally, WARC-92 adopted Resolution 46, which outlines interim procedures for introducing and coordinating LEOS systems with existing services. Each of the bands allocated for use by little LEOS is subject to the procedures and limitations contained in Resolution 46, which will remain in effect until permanent procedures and regulations are adopted at a future world radio conference. As noted above, in the 137-138 MHz and 400.15-401 MHz bands, coordination is required only in cases where the signal power of a satellite received at the Earth exceeds a certain level.[102]

DISCUSSION

Domestic Background—Prior to WARC-92, four companies applied to the FCC to build little

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101 ITU, *Addendum and Corrigendum*, footnote 608Z, op. cit., footnote 61, p. 1.

]02 The limit is -125 dBW. This limit may be changed by a future conference if it proves either too restrictive for LEOs or does not offer enough protection to existing services. Since none of the LEOS systems are operational yet, determiningg exact power requirements and sharing criteria is extremely difficult. As systems are implemented, and levels of interference can be measured and analyzed, these requirements and criteria may change. Special note is also taken to protect radio astronomy services in nearby bands.

Box 2-D—U.S. Little LEOS Applicants

Three companies have applied to the FCC to build LEOS systems supplying messaging, data communication, and position determination services: Orbcomm, Starsys, and VITA.[1] Each of these applicants has been granted a license to build and operate an experimental system. Below are snapshot descriptions of the three little LEOS systems.

Orbital Communications Corp. (Orbcomm)—a subsidiary of Orbital Sciences Corp., Orbcomm's system would consist of 24 satellites orbiting the Earth in three planes at 785 kilometers. The system will provide three basic types of service: one-way emergency alerting, such as leak detection or medical alerts; one-way location services for cars, trucks, ships, or individuals; and two-way messaging and data communication. Orbcomm expects to serve a variety of user terminals ranging in cost from $50 to $400 in addition to a monthly subscription price of $5 to $45/month and individual usage charges. Total cost of the system is estimated at $100 million. The service is expected to begin operation in 1993, and be fully operational in 1994-95.

Starsys, Inc.—jointly owned by ST Systems Corp. and North American CLS (Collecte et Localisation par Satellite), a wholly-owned subsidiary of CLS of France.[2] The Starsys system will use 24 satellites orbiting at approximately 800 miles. Like Orbcomm, Starsys plans to offer a variety of data messaging and location information services, including emergency alerts, worldwide paging/messaging and (vehicle) fleet tracking. These services will not be available to consumers directly from Starsys, but through "customer service bureaus," which will buy capacity from Starsys and resell it to end users. Cost of the Starsys user terminals will vary from $75 to $250 depending on functions, with expected annual charges estimated at $150 in addition to usage charges. The Starsys experimental system began operation in August 1992, and an "Early Entry Program" using existing satellites is already being offered to businesses. The fully operational system is expected to cost approximately $200 million and be operational by 1995 at the earliest.

Volunteers in Technical Assistance (VITA), Inc.—is a nonprofit organization that provides technical information and assistance to developing countries. VITA's system is technically different than either Orbcomm or Starsys in that it plans to operate two satellites in fixed orbits serving approximately 1,000 stationary ground terminals. The system will be managed by a single control center near Washington, DC, and will not use regional gateways. VITA plans to provide data transfer services to developing countries, allowing users to transfer technical information as well as provide disaster relief services. Each VITA satellite is expected to cost $1.0 to $1.5 million, while the cost of the ground stations is estimated to be $4,000 to $6,000. VITA's experimental system has been operating since 1990, and the fully operational system is expected to be completed by 1996. Usage fees have not yet been set.

[1] A fourth company, Leosat, Inc., applied for a license to build a system, but its application was dismissed on procedural grounds. Leosat filed for reconsideration of its application, but that appeal was denied.

[2] There is some question over who controls Starsys, Inc. North American CLS owns 95 percent of Starsys, Inc., and the other 5 percent is owned by ST Systems Corp. Because of this split, Starsys' opponents, especially Orbcomm, maintain that Starsys is really a French company, with direct ties to the French Government, and should be prohibited from receiving a license to operate in the U.S. according to the Communications Act of 1934 (47 U.S.C., section 310). However, Starsys has already been granted an experimental license by the FCC—setting a precedent that will be difficult to reverse. No final determination on Starsys eligibility has yet been made by the FCC, although it will have to address the issue before granting Starsys an operating license.

SOURCE: Office of Technoloyg Assessment, 1993.

LEOS systems: Leosat, Inc.; Orbcomm, a subsidiary of Orbital Sciences Corp.; Starsys, jointly owned by ST Systems and North American CLS (Collecte et Localisation par Satellite); and Volunteers in Technical Assistance (VITA), Inc. (see box 2-D).[103] These companies were active in

[103] Leosat's application was dismissed by the FCC on procedural grounds. Leosat appealed the dismissal, but was denied in January 1993.

promoting U.S. proposals for little LEOS both before and at WARC-92.

The rivalry between these companies before the conference was intense, particularly between Starsys and Orbcomm and between Leosat and the others. Each challenged the other's technical plans and system configuration. Orbcomm also raised serious questions about possible foreign (government) ownership of Starsys, a factor that would make Starsys ineligible for a U.S. license under section 310 of the Communications Act of 1934.[104] Starsys, while acknowledging French interests in the company, maintains that U.S. concerns control the board of directors, thus making the company eligible for a license. The FCC has so far declined to rule on Orbcomm's accusations, and is proceeding with its actions.[105] Although the issue has not been resolved, the FCC has already awarded Starsys an experimental license. This may be in violation of the Communications Act, which makes no distinction between experimental and operational licenses. Observers point out that by awarding the experimental license, the FCC may have created a precedent that will be hard to reverse.

WARC Negotiations—WARC delegates credit much of the success of the little LEOS proposals to the work done prior to the conference by U.S. representatives traveling to other counties to explain the LEOS concept, how it works, and what the benefits could be. In many cases, this work was undertaken by individual representatives of the little LEOS proponents on behalf of their own or their clients' systems. Little LEOS proponents worked hard to educate individual countries on the specifics of little LEOS systems, seeking to allay those countries' concerns that these services would interfere with their existing uses of the band. At least some of this preconference work was done outside the framework of the official bilateral or multilateral talks the U.S. Government held with many countries.

Some observers have noted that U.S. Government representatives initially did not discuss little LEOS in meetings with foreign countries. Several possible reasons for this relative lack of interest on the part of the government have been noted. First, little LEOS were not one of the highest priority items for the United States. A second rationale that has been advanced is that some government interests were not happy with the bands that had been chosen for little LEOS and would have been happier if the bands were not allocated at all. An additional explanation is that the government representatives who participated in these initial preconference meetings did not have the expertise to discuss little LEOS topics in detail. These theories are reinforced by the fact that few industry people were involved in early negotiations.[106]

Just before WARC-92 convened, Ambassador Jan Baran brought together the little LEOS proponents to address the heated rivalry among the proponents during the preparation process in the United States. These meetings laid the groundwork for successful cooperation among the little LEOS applicants at WARC-92. At the conference, private sector representatives played an important role in building support for U.S. proposals and relaying status reports to government spokesmen and delegation leaders. Communication between these two groups was reportedly very good, and paid substantial benefits in rebuffing attempts by the Russian Federation and French delegations, among others, to limit little LEOS allocations.

At WARC-92 some, especially European, countries, were extremely protective of existing serv-

104 47 U.S.C.A., section 310.

105 Federal Communions Commission, Tentative *Decision in the Matter of Request for Pioneer's Preference in Proceeding to Allocate Spectrum for Fixed and Mobile Satellite Services for Low-Earth Orbit Satellites,* FCC 92-21, released Feb. 11, 1992, p, 5.

106 It should be noted that little LEOS applicants did participate in many of the multilateral meetings that were held prior to WARC-92, including various CCIR meetings and the CITEL WARC-92 preparation meetings.

Table 2-3—Chronology of Little LEOS Actions

September 1988.	Volunteers in Technical Assistance (VITA) files application **for experimental LEOS system.**
February-October 1990.	**Orbcomm, Starsys, VITA, and Leosat file applications to construct LEOS systems.**
October 1991	**FCC releases Notice of Proposed Rulemaking on establishment of little LEOS service and allocation of frequencies.**
January 1992.	**FCC awards pioneer's preference to VITA.**
March 1992.	**WARC 92 adopts allocations for little** LEOS systems.
April 1992.	FCC issues experimental licenses to Orbcomm and Starsys.[1]
	FCC asks for comments on establishing an advisory committee **for little** LEOS.
	Leosat application dismissed.
May 18, 1992.	Orbcomm, Starsys, and VITA file joint comments proposing new little LEOS **rules.**
July **23, 1992. . . . .**	**FCC establishes an advisory committee for little LEOS (official title: "Below 1 GHz Negotiated Rulemaking Committee").**
August 10, 1992.	**First meeting of little LEOS advisory committee.**
September 16, 1992.	**Last meeting of little LEOS advisory committee.**
January 1993. ., ...	**FCC allocates frequencies to little LEOS, and proposes technical rules to govern little LEOS systems.**

[1] VITA has held an experimental license since 1989.

SOURCE: Office of Technology Assessment, 1993.

ices, and wanted to constrain little LEOS operations as much as possible. This opposition accounts for the adoption of footnote 608Z, which limits little LEOS to secondary status in many countries in the 148- 149.9 MHz band. Although not ideal, this allocation was apparently acceptable to the three U.S. proponents. U.S. representatives were successful in reaching out to many developing countries and convincing them to support the U.S. proposals.

Post- WARC *Activity—Domestic Actions:* Once allocations were made by WARC-92, efforts to launch little LEOS systems moved back to the United States and into high gear. The FCC took an aggressive approach toward implementing the little LEOS systems (see table 2-3); issuing experimental licenses to Orbcomm and Starsys, granting a pioneer's preference to VITA, and establishing an advisory committee to help it establish the rules and regulations that will govern little LEOS systems (see appendix E). The FCC's proceeding on the frequencies to be used by little LEOS concluded in January 1993, when the FCC adopted the allocations proposed at WARC-92 as the domestic allocations for little LEOS services, At the same time, the FCC proposed rules, based on the results of its negotiated rulemaking process, to govern little LEOS services.

After WARC-92 ended, the little LEOS companies, partners at WARC-92, once again became rivals. As before, some of the most contentious issues surrounding the implementation of little LEOS services are those that involve technical challenges and protests the companies have leveled against each other. It should be noted, however, that the companies (Orbcomm, Starsys, and VITA) were able to put aside their differences long enough to work out proposed service rules and sharing arrangements to submit to the FCC.

International Interest: On the international front, interest in little LEOS has been strongest among the developing countries, who see satellite communication as an important way to reach areas with inadequate or no communication services. As of early 1993, at least three other countries were actively developing little LEO systems, France's Centre National d'Etudes Spatiales (CNES-the French equivalent of NASA) has already launched the frost satellite in a proposed little LEOS system called Taos. Although currently not funded, the concept for the full system calls for six satellites to be operational in 5 years serving up to 1.5 million users worldwide.[107] In Mexico, LeoSat Panamericana has begun experiments and plans to begin offering services in 1995.[108] Smolsat—a consortium of space companies based in the Russian Federation—has already launched the first six LEOS (two of which are for commercial use) of a proposed 36-satellite system known as "Gonets."[109] Beginning in 1995, the system plans to provide high-speed data services including electronic mail and fax transmission serving transportation and other industries. The Gonets system plans to add intersatellite links in 1997, enabling voice services to be provided globally, at a total cost of $300 million. Although this system will not compete with U.S. little LEOS providers for the same spectrum, it could compete with U.S. system (s) to provide the same types of services around the world.[110]

ISSUES AND IMPLICATIONS

WARC-92 significantly boosted the prospects for little LEOS technologies and services. However, several obstacles remain, and difficult issues must be resolved before little LEOS services become available throughout the world. Services are expected to be implemented frost in the United States and then spread to other countries. Current plans call for U.S. services to begin sometime in 1994.

Sharing Concerns--The most important issue facing little LEOS proponents involves interference and sharing. Sharing concerns have several dimensions. First, the new little LEOS systems must share with the existing users of the frequencies, both domestically and internationally. This is likely to be the largest problem standing in the way of the implementation of little LEOS services. The frequencies in which the little LEOS will operate are already used by some countries, including the United States, for space operations and research and meteorological services (in 137-138 MHz and 400.15-401 MHz), and various point-to-point and mobile applications (in 148-149.9).[111] In order to protect existing services, WARC-92 limited little LEOS to secondary status in parts of the 137-138 MHz band (see figure 2-7), limited power levels, and, as noted above, more than 70 countries downgraded little LEOS to secondary status in their countries in the 148- 149.9 MHz (uplink) band. The latter declaration could cause serious difficulties for potential little LEOS service providers if foreign governments are unwilling or unable to coordinate the LEOS uplinks with their own uses.

Domestically, U.S. Government agencies want to protect their existing services from harmful interference by little LEOS. The National Oceanic and Atmospheric Administration (NOAA), for example, operates weather satellites in the

107$ 'French Hope to Launch Global Data-only Mobile Communications System," *Space Commerce Week*, vol. 9, No. 40, Oct. 19, 1992.

108 Plans for LeoSat Panamericana's system call for 24 satellites serving Latin America. It will offer the same types of data messaging and paging services as the U.S. LEOS companies. Manuel Villalvazo, "LeoSat Panamericana: Latin American Communications on the Move," *Satellite Communications*, November 1992.

109 "Russian Firms Launch Initial Satellites of LEO System," *Satellite News*, July 27, 1992, p. 5.

110 The Russian system will use 312-315 MHZ for its downlinks and 387-390 MHz for uplinks. Both bands are allocated to MSS on a secondary basis, and must share with existing fixed and mobile services. Because these bands are used for Defense Department communications, the system will not be allowed to operate in the United States.

111 Radio astronomy interests are also particularly concerned about possible interference from little LEOS into their space observing instruments. Although these instruments operate in slightly higher frequencies (150.05-153 MHz and 406.1-410 MHz), use of radio frequencies is not precise and often can spill over into adjacent channels. Radio astronomers fear that little LEOS operations will spill over into their frequencies and disrupt their receiving equipment, which is very sensitive. This prompted WARC-92 to adopt language in footnote 599A that instructs countries to "take all practicable steps to protect the radio astronomy service in the 150.05-153 MHz [and 406.1-410 MHz] band from harmful interference. . . ."

137-138 band. Discussions have already begun to coordinate the use of these frequencies. The 148-149.9 MHz band is currently allocated domestically only for government (military) use. The Air Force, for example, plans to extend its meteorological satellite system in the 400 MHz band.

International sharing may also be difficult due to the existing uses of the bands and the degree of opposition to the U.S. proposals, especially in the 137-138 MHz and 148-149.9 MHz bands. Canada, for example, although it supported other U.S. little LEOS proposals, joined footnote 608 Z---making little LEOS secondary in Canada. This action was taken in order to protect its extensive paging operations in the 148-149.9 MHz band. Because these systems have to penetrate buildings to ensure complete coverage, they are also very high power, and since they are often concentrated near the U.S. border, coordination between Canada and the United States will be necessary. These uses must be taken into account by little LEOS proponents as they design their systems and by the FCC as it implements rules governing little LEOS services.

The secondary status of LEOS operations in some bands is an important concern for potential little LEOS providers, both at home and abroad, While the effects of these limitations are not known, since the services are not yet operational, they are potentially serious. Secondary status makes sharing with existing users more complicated, and coordination issues become more difficult, although probably not insurmountable.

Little LEOS providers maintain that they can operate within these limitations, but the real possibility exists that the primary services in the bands, especially the fixed and mobile services in the 148-149.9 MHz band could overwhelm them. As long as this secondary status exists, little LEOS services will remain threatened, potentially dampening investment in these systems and retarding development. Despite such difficulties, each company is moving ahead with its negotiations for foreign licenses.[112]

The second major sharing concern facing the competing little LEOS providers is that they must share the newly allocated spectrum among themselves. Although the spectrum allocated to little LEOS is limited, the FCC has stated its intention to allow as many providers as possible to use the bands, and is committed to having at least three competing providers. Indications are that this sharing can be accomplished among the existing applicants, However, it is less clear how potential future providers will be accommodated in the bands. It is possible that future applicants-both domestic and foreign—may have a difficult time using spectrum that has already been divided up between the three U.S. companies. This is an important concern in foreign countries considering launching their own systems. The EC's Communications Directorate has requested talks with the United States to discuss its concerns that the U.S. systems not become *de facto* standards/monopolies in the little LEOS bands (see section on big LEOS below). The FCC's negotiated rulemaking proceeding did not resolve these questions, but they are expected to be addressed by the FCC in its upcoming NPRM on the little LEOS service rules and licensing procedures. A final resolution of this issue may have to wait until systems are operating and real usage and interference levels can be measured.

International Licensing—The question of international licensing of little LEOS systems is crucial. Little LEOS providers will have to gain approval from every country in which they plan to operate.[113] The problem is that satellite footprints (the areas within which transmissions can be received) do not respect national boundaries—transmissions spill over borders, and systems

112 Orbcomm, for example, reports that it has agreements with 11 countries and is in negotiation with 11 more to establish its service.

113 Both uplink facilities (gateways) and user terminals will have to be licensed. The way this licensing is accomplished will depend on each country's regulations (and politics), and will have to be negotiated on a country-by-country basis.

cannot just be turned off at the border. In the worst case, if a country opposes the system, and refuses to license a LEOS system, the little LEOS services would technically be prohibited from operating in that country. For a concept that is premised on worldwide coverage, a patchwork of ''safe' nations in which the system can operate would be complex to engineer, and could undermine the economic viability of the system. Operating a LEOS system in an area such as Europe, for example, which has a number of very small countries, may make provision of service to some countries, but not others, (technically) very difficult.[114] Only one dissent from a country in a strategic geographic location could effectively preclude service for a number of countries.

Foreign countries will have several concerns over the licensing of little LEOS systems, and negotiations will be complex. Political, technical, and economic issues will all be in play, and the ability of the little LEOS providers to convince foreign countries to license such services will depend on several factors. First, all countries will want to protect their existing systems and applications that will be sharing the band with the new little LEOS systems. The little LEOS providers must convince these countries that their proposed systems either will not cause interference to existing services or can be engineered to share the spectrum with them.

Secondly, the contractual obligations of the licensing country and the service provider will have to be delineated. European nations especially are concerned that little LEOS systems may siphon use (and hence revenues) away from the public telephone network—an important source of revenues they want to protect. Many issues will be considered: Who will build and pay for any required infrastructure in the country, such as a satellite gateway facility? How will revenues generated by these new services be distributed between the companies and the countries in which they operate? If a system is offering services in a country, that country could demand a portion of the revenues generated in return for licensing the system. If a country maintains a gateway to the system, revenue sharing would be easier to monitor than if a country is served by a gateway in a neighboring country. Such negotiations will have to be conducted on a country-by-country basis, a process that will be time-consuming and legally complex.

Finally, on a purely political level, the manner in which the FCC rules governing such services are written (and enforced), the ways the systems actually operate, and the dictates of the Communications Act of 1934 may have an impact on which countries support and license them. If other countries that may intend on launching their own little LEOS systems perceive that FCC rules are written and the initial U.S. little LEOS applicants will operate in such a way that inhibits other (foreign) systems from sharing the spectrum with them, those countries may refuse to license the U.S. systems. A potentially more significant problem has to do with section 310 of the Communications Act of 1934.[115] Under that act, licensing of companies owned or controlled by foreign nationals or governments is severely restricted. Other governments may be reluctant to grant U.S. companies licenses to operate in their country when foreign companies are not allowed to obtain licenses in the United States.[116]

Markets--The potential market for little LEOS-type services is large. However, several long-term questions remain that could limit the marketing appeal (and the revenue-producing ability) of little LEOS services. First, because of the limita-

114 Providing adequate signal levels in one country while still respecting the power limitations in those neighboring countries who have chosen not to license the service may require painstaking engineering design and coordination.

115 47 U.S.C.A. section 310.

116 This provision applies only t. the provision of common carrier, broadcasting, and some aeronautical services. In part to avoid this problem, Starsys has indicated that it will apply to the FCC to be licensed on a non-common carrier basis.

tions on little LEOS operations due to footnote 608Z, little LEOS services are not likely to become available in those 70+ countries in the near future. The effect of this footnote may eliminate Europe as a potential market. The question then becomes: can little LEOS survive on the markets that are left? The U.S. little LEOS applicants believe that they can. The size of the remaining markets, however, will determine that success or failure and as yet, the real demand for LEOS-type services is not well-known.

From a U.S. competitiveness perspective, footnote 608Z may actually be positive. Because the footnote made LEOS a secondary service in Europe it also effectively excludes European companies from launching competitive systems. With only a secondary allocation, it is extremely unlikely that any European companies would build (or find support to build) such a system. Even if a system were built, it would likely take many years of negotiations, and some countries might have to renounce footnote 608Z. By the time this occurred, one or more U.S. systems would already be operating and would have a substantial jump on the market and an installed base of customers and equipment.

The most serious marketing problem for the little LEOS will likely be competition from other mobile data service providers. In the United States, terrestrially-based data communication systems, such as Ram Mobile Data, Ardis, and CoveragePlus, as well as private systems, are already providing mobile data services in most large urban markets. In addition, Qualcomm's OmniTracs system is already serving the Nation's trucking companies with nationwide position location and data messaging services.[117] The installed base of customers and equipment could make it difficult for little LEOS to attract sufficient customers to be profitable.

In addition to these established companies, little LEOS systems may also face competition from the proposed big LEOS systems, which plan to offer data services in addition to their primary voice service. While little LEOS services could be less expensive than similar services provided by big LEOS, it is possible that big LEOS will be able to match service prices since the cost of providing data services (in addition to their core voice service) will likely be nominal. Many consumers may want (and be willing to pay for) voice services instead of data-only services. On the other hand, little LEOS services may undermine the big LEOS (data and messaging) services, due to their lower costs and earlier implementation.

The current rush to put little LEOS services into operation represents a desire on the part of the applicants to get such systems into operation as soon as possible in order to capture the unmet needs of today's consumers and businesses. If a large enough market can be captured initially, before big LEOS come into operation, little LEOS systems could become and remain profitable. However, if their services do not achieve adequate levels of market penetration quickly, and if their costs are too high, little LEOS survivability in the face of competition from big LEOS maybe questionable.

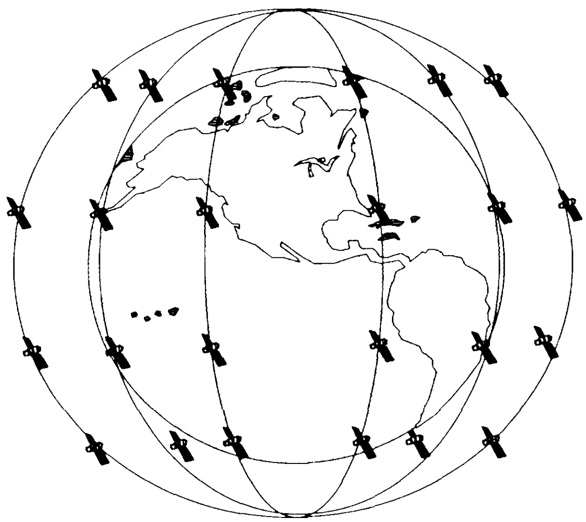
As a result of such pressures, little LEOS systems may be reduced to serving primarily rural areas or niche markets with special communication needs. Services, for example, could eventually be limited to business applications, such as vehicle location and traffic management services, fleet management services for freight companies, and data communication services for service personnel or emergency relief agencies.

Technology and Cost Considerations-As with all low-Earth systems, little LEOS satellites will have to be constantly replaced as older satellites reach the end of their lifetimes (approximately 5 to 7 years).[118] This means that for as long as the system operates, new satellites will have to

117 "Will LEO Allocation (@m Door to Mobile Data, AVL Competition?" *LundMobile Radio News,* vol. 47, No. 4, Jan. 22, 1993.

118 NASA has also raised the possibility that existing space debris may pose a threat to LEOS systems.

Figure 2-8-Low-Earth Orbit Satellite System



This generic low-Earth orbiting satellite system demonstrates how such systems can achieve near-worldwide coverage. The actual systems have orbits that differ in altitude, number of satellites in orbit, number of orbital planes, and shape of the orbit.

SOURCE: Office of Technology Assessment, 1993.

be designed, built, and launched on a continuing basis. Some have likened this to an assembly line for satellites. As a result of this long-term commitment, several issues need to be recognized. First, the cost of constructing and launching the initial network of satellites is only part of the total cost of the system. Because satellites will have to be constantly replaced, revenues must also cover the ongoing costs of design, construction, and launching. These costs must be borne as long as the system is in operation. Given the marketing questions raised above, this could be a challenge. Second, although little LEOS systems do not necessarily need a full network of satellites to operate, access to services using less than the optimum number of satellites would be degraded. The system could operate, but some areas might receive poor coverage and the time when a user could actually contact a satellite would be reduced. If a string of launch failures occurs, any LEOS system will be in jeopardy.

Big LEOS[119]

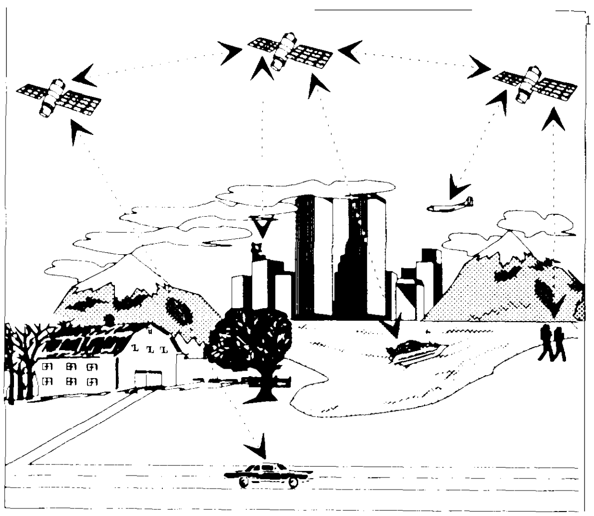
BACKGROUND

In addition to the data and positioning services being developed by the little LEOS companies, another class of LEOS systems has been proposed that would provide telephone service almost anywhere in the world. These LEOS systems, which will operate in frequencies above 1 GHz, have been dubbed "big LEOS." Like the little LEOS, big LEOS systems will use a network of many satellites-from 12 to 66 depending on the type of orbit—to provide service around the globe (see figure 2-8). These satellites will be larger and more complex than little LEOS satellites, and, as a result of their added capabilities, will also be more expensive ($10 to $20 million). On the ground, control centers will administer the system and manage the satellites, and a number of gateway stations located in different countries will be connected to the public telephone network—allowing users to receive calls from and make calls to anyone with a (regular wired) telephone (see figure 2-9). One advantage of big LEOS over conventional geosynchronous satellite systems for phone service is that, because the low-Earth satellites are much closer to the Earth (generally less than 1,000 miles compared with more than 22,300 miles), they avoid the annoying delay in conversations caused by the long trip the signals have to make between the Earth and the geosynchronous satellite and back.

Big LEOS systems promise to provide voice and data communications where none exist now (in remote mountains, for example), or in coun-

119 Technically, the systems discussed in this section are not all *low*-Earth orbiting systems. TRW's Odyssey system, fOr e-pie, plans to use medium-Earth orbits, and Ellipsat plans elliptical orbits. As a result, official government terminology uses the term "non-geosynchronous' when referring to these systems. Because these systems have been colloquially referred to as ''big LEOS'' for several years, OTA will continue to use the term in this section to refer to all proponents for these types of systems.

Figure 2-9-Generic Big LEOS System



NOTE: Intersatellite links will be used only by Motorola's Iridium system.

SOURCE: Office of Technology Assessment, 1993.

tries in which the communications infrastructure is not well-developed. These satellite systems would allow such countries to connect their citizens with each other and to the outside world, while avoiding the high (often prohibitive) cost of building a wireline communications infrastructure. Other potential markets for big LEOS services include international tourists and business travelers, emergency relief organizations, government agencies, and various international associations,

Motorola, Inc.

Dual-mode portable telephones, such as this prototype from Iridium, will first attempt to connect to a local cellular system. If no system can be accessed, the telephone will then use the satellite system to complete the call.

U.S. PROPOSALS

The big LEOS concept was first formally proposed after the topics for WARC-92 were finalized (see table 2-4). As a result, big LEOS were not specifically included in the WARC-92 agenda. However, prior to the conference, U.S. representatives were able to convince other ITU members that LEOS systems are only a different way of providing MSS, and should be considered as part of the MSS negotiations.

In anticipation of their inclusion in the WARC-92 debate, allocations for big LEOs were considered in the various U.S. domestic preparations processes, and in its final *Report* on WARC-92 proposals, the FCC! identified bands that it recommended for LEOS use. The FCC proposed:

- Upgrading MSS to primary status in 1610-1626.5 MHz (Uplink) and 2483.5-2500 MHz (downlink);
- Allocating through a footnote the 1613.8-1626.5 MHz band to MSS downlinks on a

Table 2-4-Chronology of Big LEOS Actions

November 1990.	Ellipsat Corp. files application to contruct Ellipso I.
December 1990.	Motorola inc. files application to construct Iridium.
May 1991.	TRW, inc. files application to construct Odyessy.
June 1991	. Constellation Communications, Inc. files application to contruct Aries. • Loral Qualcomm Satellite Services., Inc. files application to construct Globalstar. . Ellipsat Corp. files application to construct Ellipso II.
July 1991-February 1992.. . .	Applicants file for Pioneer's Preference.
February 1992.	WARC-92 adopts allocations for MSS (big LEOS).
August 1992.	. FCC declines to grant Pioneer's Preference to any particular applicant. . FCC grants experimental licenses to Motorola, Inc., Constellation Communications, Inc., and Ellipsat Corp. . Notice of Proposed Rulemaking proposes allocations for big LEOS services. . FCC releases public notice on negotiated rulemaking for big LEOS.
January-March 1993.	Big LEOS Advisory Committee deliberations.
Summer 1993...	Planned launch of experimental systems.

SOURCE: Office of Technology Assessment, 1993.

secondary basis in order to permit bidirectional use of the band; 120 and

- Allocating through a footnote the 1850-1990 MHz band to MSS on a primary basis.[121]

In the initial U.S. proposals to the ITU, these recommendations were included as part of the MSS proposals, and although LEOS are not specifically mentioned, the proposals did note the use of MSS allocations for LEOS services, and U.S. intentions to use the bands for LEOS operations were made clear to foreign delegates prior to the conference.

RESULTS

U.S. allocation proposals were relatively successful, but a number of footnotes limit the power the systems can use and prohibit big LEOS systems from causing interference to (some) other users of the band-effectively reducing big LEOS operations to secondary status in relation to those other users. Stringent coordination requirements were also adopted. These conditions were acceptable to U.S. big LEOS proponents, but they may be revisited in the future if they prove too restrictive. In summary, WARC-92 decided to:

- Upgrade MSS (including, but not limited to LEOS) to coprimary status at 1610-1626.5 MHz (uplink) and 2483.5-2500 MHz (downlink), subject to the coordination procedures specified in Resolution 46 (see below).[122] In order to protect the services currently using the band, WARC-92 set limits (according to footnote 731X) on the power the mobile telephones can use. This footnote also prohibits MSS operations from interfering with aeronautical navigation and freed services, including the Russian GLONASS satellite navigation system (see box 2-E). Users of big LEOS mobile telephones cannot interfere with or claim protection from these existing services. This provision effectively makes MSS/big LEOS services secondary to these other services, even

120 This proposal responds directly to the plans of Iridium to use the band fOr two-way communication.

121 In order to preserve flexibility, no direction (uplink or downlink) was specified for this band.

122 User handsets transmitting up t. a satellite cannot exceed specific power levels that vary according to whether or not the frequencies will be shared with the Russian satellite navigation system, GLONASS. For signals being transmitted down from LEO satellites, WARC-92 set a ''trigger'' level—if the power of the signal exceeds that level, LEOS systems would have to coordinate with existing users. If the signal's power remains under the limit, however, no coordination is required.

Box 2-E—GLONASS

GLONASS is the global satellite navigation system that is being developed by the Russian Federation. When completed in 1996, GLONASS will consist of a constellation of 24 satellites circling the Earth in three orbital planes. It will provide position location and navigation services to cars, trucks, ships, and individuals. Currently, there are 14 satellites in operation, and 9 more awaiting launch. Together with the U.S. Global Positioning System (GPS)[1], GLONASS is expected to form the basis for implementing the future Global Navigation Satellite System (GNSS) concept.[2] The civil aviation industry is currently examining the potential of such a system for increasing safety and efficiency as part of a Future Air Navigation System (FANS) concept.[3]

U.S. aviation interests have been working with USSR and Russian Federation representatives for some years to analyze the potential of coordinating the GPS and GLONASS systems and develop the details of a coordinated system. Many elements of the systems have already been finalized and would be very difficult to change at this late date in the process. Representatives from Russia have participated in some of these activities and have reportedly provided helpful input for the work of the U.S. groups.[4] In addition, the United States has a study group (International Radio Consultative Committee National Study Group 8-D) chaired by NTIA looking at the issues involved in coordinating GPS and GLONASS.

[1] There are 20 operational GPS satellites serving over 100,000 boaters worldwide. The system also was extensively used during Operation Desert Storm. When completed in mid-1993, the system will consist of 21 operational satellites and three in-orbit spares. The total cost of the system, including building and launching the satellites and developing the receivers, will approach $8 billion by the year 2000. William Harwood, "GPS Satellite Launches Resume After Hiatus," *Space News*, vol. 3, No. 8, March 2-8, 1992; and Debra Polsky, "Ground Stations to Correct GPS Inaccuracies," *Space News*, vol. 3, No. 18, May 11-17, 1992.

[2] Current concepts of GNSS envision the two systems supplementing each other rather than operating as one integrated system. Equipment on airplanes would be capable of receiving, combining, and processing signals from both systems. Although the systems could operate independently (and, in fact, were originally designed that way), by utilizing both systems, it is believed that GNSS will be more accurate and reliable than either system could be on its own. Each system will be able to back the other up, thereby eliminating holes in the coverage of one system or the other. Two systems also increases reliability because of the ability to cross-check between them. Finally, use of the two systems may also improve accuracy because the GLONASS signal is not purposely degraded as is the DoD-controlled GPS.

[3] However, there are some in the airline industry who would prefer to build a completely new GNSS from scratch rather than rely on a DOD-controlled system that will be free, but only for 10 years. Robina Riccitiello, "Civilian GPS Users Eye Future System," *Space News*, vol. 3, No. 18, May 11-17, 1992.

[4] There are at least three forums in which GPS/GLONASS coordination activities are underway: the Airlines Electronics Committee has already developed standards for a combined GPS/GLONASS receiver, RTCA has a special committee (SC-159) that is developing the sole means navigation concepts for GPS, and the Department of Transportation has an agreement with the former USSR to develop international receiver standards for GPS/GLONASS. Russian representatives have been active in all these forums to varying degrees. Larry Chesto, Director, Telecommunications Systems, Aeronautical Radio, Inc., personal communication, July 7, 1992.

(Continued on next page)

though MSS services technically have a primary allocation.

- Adopt a secondary allocation for MSS downlinks at 1613 .8-1626.5 MHz, subject to the conditions of Resolution 46.[123] This allocation allows the 1613.8 -1626.5 MHz band to be used for bidirectional communication between the users and the satellites.
- Elevate the Radio Astronomy Service to primary status in the 1610.6-1613.8 MHz band.[124] In addition to this upgraded status, WARC-92 also modified footnote 733E to

123 Power limits apply to the 1613.8-1626.5 MHz secondary allocation, but LEO systems will have to coordinate regardless of power level.

124 In this band, aeronautical radionavigation, radiodetermination-satellite, MSS, and radioastronomy all share primary status.

Box 2-E—GLONASS—(Continued)

The GLONASS system presently operates in the 1596.9-1616 MHz band. However, the Russian Federation has notified the International Frequency Registration Board (IFRB) that it intends to introduce an expanded GLONASS-M system that will operate in the 1596.9-1620.6 MHz band. This will complicate and/or limit the use of the band by LEOS systems, by making coordination necessary in a larger portion of the band. The implementation of the GLONASS-M system may cause special problems for Iridium, which has said it will only operate in the portion of the band that GLONASS does not use. The full GLONASS-M system would limit Iridium to approximately 6 MHz (1620.6-1626.5 MHz), an amount of spectrum which may not be sufficient for the system to operate. However, the United States and more than 20 other countries have filed objections to the proposed rollout of the GLONASS-M system, and it has yet to be coordinated under ITU rules.[5]

In addition to the big LEOS systems that plan to use this band, radio astronomers have been using the band for years to support their research on the universe. They have long protested the GLONASS system because of the interference it could cause to very sensitive operations at 1612 MHz. The United States is a world leader in radio astronomy research, and U.S. spectrum managers and radiocommunication policymakers will have to find a way to accommodate the needs of both the aviation and scientific communities.

Although there is some dispute about what U.S. representatives knew about GLONASS-M and when, it nevertheless appears that U.S. delegates were caught off guard by the announcement of GLONASS-M. The then-USSR had previously filed with the IFRB for a satellite system that would occupy the band 1597-1616 MHz. These are the bands the big LEOS proponents and the government had accounted for in their planning. However, these bands were apparently tentative because Russia, at the beginning of WARC-92, indicated that it intended to expand the frequencies used by the system so that the full GLONASS-M system would operate in the range 1596.9-1620.6 MHz. Such an expansion and use is in accordance with the international Table of Frequency Allocations, which permits such operations up to 1626.5 MHz.

Complicating the picture for U.S. interests is the uncertainty surrounding the future of GLONASS itself. Due to the political and economic turmoil in the former USSR, there is some concern in the United States that GLONASS may not survive or its full implementation could be delayed. A total of 20 of the initial satellites are already built, but the short lifespan of the satellites means that the continued viability of the system will depend on a continual replenishment of satellites, and a continual drain on Russian resources.

[5] The original GLONASS system has been coordinated internationally under ITU rules. The fact that this coordination has been completed gives the system some protection from interference as specified in footnote 731X. This same protection, however, does not apply to the frequencies planned for use by the GLONASS-M system. Unless and until the system is coordinated internationally, which seems unlikely given the opposition already filed against it, the frequencies (1616-1620.6 MHz) will not be protected from interference. This gives some hope that U.S. big LEOS systems will be able to use these frequencies.

SOURCE: Office of Technology Assessment, 1993.

prevent harmful interference to radio astronomy services from MSS and radiodetermination-satellite services.

The U.S. proposal for the 1850-1990 MHz band was not accepted. However other additional spectrum was allocated to MSS which could be used for LEOS services (see section on the Mobile-Satellite Service, above).

WARC-92 also adopted Resolution 46 to establish interim procedures for announcing and coordinating new non-geostationary satellite systems. Because these systems are still being developed, their technical parameters are not final, and the methods for sharing spectrum between new LEOS services and existing (terrestrial and space) services have not yet been developed. These interim procedures were adopted to allow the ITU adequate time to study the problems and develop appropriate sharing criteria. In the meantime, LEOS systems can be deployed, allowing engineers to gain practical experience and knowledge about what service rules and interference criteria will be required to enable systems to share the spectrum. Permanent regulations governing sharing will be adopted by a future conference called for in the resolution.

DISCUSSION

Domestic Background—Ellipsat Corp. and Motorola, Inc. first formally proposed LEOS systems providing voice communications in late 1990--too late to be included in the formal agenda of WARC-92 (see table 2-4). Shortly thereafter, three additional applicants--Loral Cellular Systems Corp., Constellation Communications, Inc., and TRW, Inc.— applied to the FCC to construct other big LEOS systems (see box 2-F for a description of the big LEOS applicants and table 2-5 for a comparison of their systems).[125] Despite their lack of formal standing on the WARC-92 agenda, big LEOS quickly became one of the focal points of U.S. proposals and preconference negotiations. U.S. companies have historically been very strong competitors in satellite communications, and the emergence of the big LEOS concept before the conference presented the United States with an important opportunity to extend its lead in satellite technology and services and shore up its role in mobile technology, which many observers believe is slipping given European progress in implementing GSM.

Two basic concepts were originally proposed for big LEOS systems (see figure 2-10). In the simpler of the two, proposed by all the firms except Motorola, the LEOS would function primarily as relays in the sky. A user would place a call through the LEO satellite, which would then transmit it to the nearest Earth gateway station for connection through the long distance and local lines of the public telephone system. No switching between satellites would be required.

Motorola's Iridium system, by contrast, is much more complex. It was first designed as a satellite-only system in which a caller would send his/her call to the satellite, which would then pass it from satellite to satellite until it reached the satellite closest to the intended recipient of the call. That satellite would then transmit the call to the intended person's portable phone, or relay the call through the public telephone network via a network gateway station.[126] Because of the intersatellite linking and switching that Iridium requires, the system requires sophisticated satellites and software to control it.

In response to concerns by U.S. telephone and cellular providers and criticism from foreign telephone companies that satellite-only phones would bypass foreign telephone systems and deprive them of valuable telephone revenues, all the big LEOS proponents began developing "dual-mode" handsets-mobile telephones that will be capable of using either cellular or satellite systems.[127] The phone will frost attempt to connect to a local cellular system. If the user is not in an area with cellular service, or is out of range of the nearest system (or if the terrestrial system is busy), the phone will then connect to the satellite network. Dual-mode handsets will resemble today's portable cellular telephones, and are expected to cost from $500 to $3,000.

125 AMSC also applied to the FCC for permission to construct a system using the same bands, and is participating in the negotiated rulemaking regarding big LEOS systems.

124 Since its original introduction, Motorola has refined this concept in response to criticism that such a system would bypass existing telephone systems, an unacceptable outcome to many foreign (and U. S.) governments and telephone companies. See the discussion of "dual-mode" phones below.

127 Foreign telephone companies have some leverage over U.S. companies because they are often owned by or closely allied With their governments-who control frequency allocations the U.S. companies need to operate.

Box 2-F—LEOS Systems Using Frequencies Above 1 GHz

The development of a new generation of wireless communications services has been sparked by recent advance in the technology of low-Earth orbiting satellites. In 1990 and 1991, five U.S. firms applied at the FCC to construct LEOS systems. At WARC-92, the international telecommunication community allocated certain sections of the frequency spectrum to be used by LEOS systems worldwide.

These systems plan to offer telephony, data, and position determination to a target market that includes cellular telephone users, nations with underdeveloped telecommunication systems, and international travelers, business people, and organizations. Systems will use an integrated combination of LEOS, terrestrial gateway stations, dual-mode handsets and existing cellular systems and the public telephone system to deliver services.[1] Although the services they plan to offer are similar, each of the proposed big LEOS systems are technically different. The five U.S. systems currently under development are:

1. **Iridium, Iridium Inc.**—Originally, Iridium proposed a constellation of 77 satellites. However, after receiving an FCC experimental license in August 1992 the system has been modified to include only 66 satellites placed in a circular orbit at an altitude of 421.5 nautical miles in 6 polar orbits (11 satellites in each orbital plane). Transmission will be provided through a time division multiple access modulation scheme, and will use the L-band frequencies allocated at WARC-92 for both up- and downlinks. Users will be able to communicate through portable, dual-mode handsets that will either connect to existing cellular service, if available, or through its unique satellite linking system. The estimated cost for the handset is $3,000 and $3.00/minute for service use. Company officials expect that Iridium will be fully operational by 1998 at a cost of $3.37 billion, the highest of the five proposed systems.
2. **Aries, Constellation Communications, Inc.**—Aries plans a worldwide LEOS system that is projected to reach 2.9 million subscribers by the year 1996. It will use a constellation of 48 satellites orbiting at 550 nautical miles, transmitting through a handset that will cost approximately $1,500. Aries has proposed a CDMA modulation scheme and will use the L-band frequencies for uplinks and S-band frequencies for downlinks. In August 1992 the FCC awarded Aries an experimental license, and the expected launch date of the first satellite is summer 1993. The total projected operational cost of the Aries system is $292 million.
3. **Globalstar, Loral/Qualcomm Satellite Services, Inc.**—Globalstar will initially operate with a smaller constellation of 24 satellites for continental U.S. coverage. As international market demands and authority is granted, an additional 24 satellites will be deployed to expand Globalstar coverage worldwide. Satellites in this system will orbit the Earth at 750 nautical miles. Globalstar has also proposed a CDMA modulation scheme and will use the L-band frequencies for uplinks and S-band frequencies for downlinks. Transmission is achieved through the use of two types of relatively inexpensive handsets-single mode or dual mode. Price of the units is expected to be $700 when produced in mass market quantities. Globalstar expects to be fully operational by 1998 at a total cost of $829 million.
4. **Ellipso, Ellipsat Corp.**—Unlike other big LEOS systems, Ellipso requires a constellation of 24 satellites orbiting in an elliptical pattern, only offering service to the U.S., including Hawaii, Alaska and other U.S. territories. Ellipsat has also proposed a Code Division Multiple Access (CDMA) modulation scheme and will use the L-band frequencies for uplinks and S-band frequencies for downlinks. It expects to be partially operational by mid-1994 and fully operational by 1997 at a total cost of approximately $410 million. The Ellipso handset is expected to cost $1,000 for a new unit or $300 for an add-on to an current cellular handset. The estimated service subscription for Ellipso is $.50 per minute.
5. **Odyssey, TRW, Inc.**—The Odyssey system plans to offer service to North America alone, utilizing a constellation of 12 satellites operating in the L-,S-, and Ka-bands. The satellites will orbit at an altitude of 5,600 nautical miles, substantially higher than the other systems. Some have labeled this a medium-Earth orbiting satellite system (MEOS). User handsets will be dual-mode, and are expected to cost approximately $1,000 once economies of production are realized. TRW, Inc. expects Odyssey to be fully operational by mid-1996, at a cost of more than $1.3 billion.

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[1] Iridium also uses intersatellite links for transmitting long-distance phone calls.

NOTE: In addition to subscriber costs, consumers will pay an additional existing terrestrial service charge when transmitting through those lines.

SOURCE: Office of Technology Assessment, 1993, based on information supplied in applications to the Federal Communications Commission.

Table 2-5—Big LEOS (Low-Earth Orbiting Satellite Systems)

System	Holding company	Technology partners	cost
Odyssey	TRW, Inc.	N/A	$1.3 billion
Iridium	Iridium. Inc., subsidiary of Motorola Satellite Communications. Inc., subsidiary of Motorola. Inc.	McDonnell Douglas (launch vehicle); General Electric Co. (ground stations): Motorola, Inc. (electronics) Raytheon (antennas) Lockheed (satellites)	$3.37 billion
Ellipso	Ellipsat Corporation, subsidiary of Mobile Communications Holdings. Inc.	Fairchild Space & Defense Corp. (satellites and ground stations) Israel Aircraft Industries	$410 million
Aries	Constellation Communications. Inc.	Defense Systems. Inc. (satellites): MicroSat Launch Systems, Inc. (launch vehicle): Pacific Communications Sciences, Inc. (system & software)	$294 million
Globalstar	Loral Qualcomm Satellite Services, Inc., subsidiary of Loral Aerospace Corp. & Qualcomm, Inc. (joint venture)	Loral Aerospace Corp. (space segment): Qualcomm, Inc. (ground segment)	$748 million

Technology and Service Characteristics of Big LEOS

System	No. of satellites	Geographic coverage	Modulation	Handset cost	Service cost	Market estimates	Operational date
Odyssey	12	**North** America	CDMA	$1,000	N/A	N/A	Mid-1 996
Iridium	66	Global	TDMA/FDMA	$2,000-3,000	$3.00 p/rein	6 million	1998
Ellipso	24	U.S. & Territories	CDMA	$300 (add-on)[a] $1,000 (new unit)	$0.60 p/rein	18 million	Mid-1994
Aries	48	Global	TDMA/CDMA/FDMA	$1,500	N/A	2.9 million	1996
Global star	24 (first generation) 48 (second generation)	U.S. (first generation) Global (second generation)	CDMA	$700 (dual-mode) $600 (single-mode)	$0.30 p/rein	3,4 million	1997

[a]Add-on to existing cellular handset.

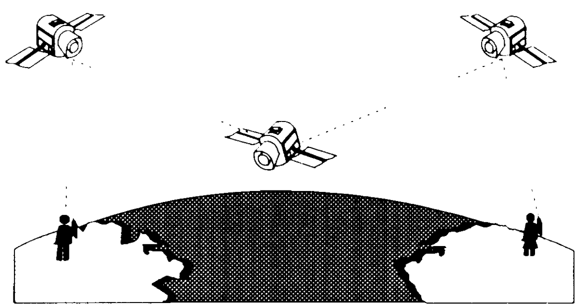
KEY: CDMA= code division multiple access, FDMA=frequency division multiple access, TDMA=time division multiple access

SOURCE: Office of Technology Assessment, 1993, based on information provided in system applications to the FCC,

Figure 2-10-Satellite-Linked Mobile Phones: Two Approaches

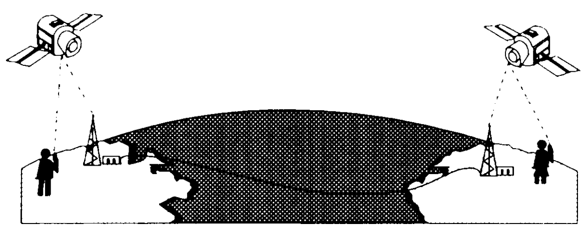
Motorola's Original Iridium Plan

A fleet of sophisticated satellites in low-Earth orbit pick up mobile phone calls from anywhere on Earth and could relay them from satellite to satellite, bypassing long-distance companies. Motorola has had difficulty developing a satellite with all the technical capabilities needed that could be launched at a practical cost.



Competing Satellite Plans

The satellites' only role is to link mobile phones to regional ground stations. Calls are switched and routed between ground stations over long-distance phone lines. Far fewer satellites are needed, especially if unpopulated areas and oceans are not covered, and the satellites can be much simpler in design.



SOURCE: Office of Technology Assessment, 1993, based on Motorola, Loral, from *The New York Times,* Aug. 26, 1992, p. D5.

In addition to the differences in basic concept, the Iridium system, which has been the focus-— fairly or unfairly-of most of the press attention to LEOS, differs in several respects from the other big LEOS systems. First, it plans to use many more satellites. The original Iridium concept called for 77 satellites, but in August 1992, that number was reduced to 66 as a result of improvements in satellite design. Second, Iridium plans to use time division multiple access (TDMA), a transmission technique that Motorola began developing for future digital cellular telephone systems, while the other four applicants plan to use code division multiple access (CDMA). Third, the *original* concept for Iridium envisioned a system that would not use the local telephone system or existing cellular networks. Rather, it would have bypassed terrestrial systems completely unless the number being called was a regular wired telephone (see figure 2-10). As noted, Motorola retreated from this bypass-oriented design in the face of harsh criticism from foreign governments and telephone companies, and is now developing a dual-mode mobile telephone. Finally, Iridium requires extremely sophisticated satellites that can route calls much like the switching centers used for public telephone service-making them substantially larger and costlier than the satellites of the other applicants. Because of the complexity and cost of the system, Iridium's usage charges are expected to be much higher per minute than its competitors ($3.00/minute as opposed to approximately $0.50, minute). Motorola points out, however, that users of the other big LEOS systems will have to pay long distance telephone rates in addition to the charge for using the satellite service, making the total cost of a phone call comparable.

In addition to the companies profiled in box 2-F, several other firms are planning or would like to use the big LEOS spectrum. AMSC, for example, has applied at the FCC to use the frequencies to support its geostationary system. Inmarsat has announced plans for Project 21, a global satellite telecommunications service that would provide mobile services to users at sea, in the air, and on land. Project21 has not been given final approval, but Inmarsat is conducting technical and marketing studies, and has already begun working with equipment manufacturers to develop specifications for its handheld phones.[128] Inmarsat predicts the market for satellite phones will reach 2 million by the end of the century, but also believes that in order to be successful, these (types of) services must serve domestic users—international travelers are not a large enough market to justify the systems. A final decision of whether to proceed is expected in July 1993, and tentative plans call for the system to begin offering services by 1998. In anticipation of moving ahead with the project, Inmarsat has filed to use the frequencies allocated at WARC-92 for MSS.[129]

Finally, Celsat, Inc. proposed to build and operate a ''Hybrid Personal Communications Network" called Celstar that would operate in either L- or S-band.[130] Celstar would combine terrestrial and space technologies into a "super' cellular system that would use two geostationary satellites and many ground stations to supply voice, data, compressed video, and position determination services to as many as 750,000 users at a cost of $0.25/minute (for telephone service). Costs for satellite construction and launch are estimated at $660 million, while lightweight user handsets will cost $500.[131] Plans call for the terrestrial portion of the system to begin operating by 1993, with the satellites coming into operation in 1996. Celsat's petition to use the L-band frequencies for its system was denied by the FCC in August 1992.

In order to speed the development of service rules and technical parameters for big LEOS systems and services, the FCC in August 1992 asked for comments regarding the formation of an advisory committee to develop draft proposals for FCC consideration.[132] This process was first used to help the FCC develop the rules arid specifications guiding the development and operation of little LEOS systems (see appendix E). The big LEOS committee began its work in January 1993, and finished in April 1993. The final report of the committee will be submitted to the FCC for consideration as it writes a formal NPRM, which is expected to be released in May 1993. After the

Magellan Systems Corp.

The U.S. Global Positioning System uses a network of satellites that allows users (in aircraft, on ships, or in vehicles) to determine their location almost anywhere on Earth.

128 Like the phones proposed by the U.S. big LEOS applicants, Inmarsat's handsets (I nmarsat-P terminals) will be duaI-mode. They are expected to cost around $1500.

129 The specific frequencies are: 1616- 1626.5 MHZ, 2483.5 -25(N MHz, and 1980-2010 MHz, all of which could be 'Seal by both geosynchronous and LEO satellite systems. See also, Ellen Messmer, ''INMARSAT Ready to Challenge Iridium,'' *Network World*, Mar. 16, 1992, p. 21; ''INMARSAT Files for Frequencies Following WARC, *Telcom Highlights International*, March 25, 1992, p. 17.

130 Celsat has filed an application at the FCC for reallocation of these frequencies, but no application for authority to construct the system has yet been filed. See Celsat, Inc., *In the Matter of Amendment of Part 25 of the Commission's Rules for an Allocation of Frequencies and Other Rules for a New Nationwide Hybrid Space/Ground Cellular Network for Person al/Mobile Communications Services: Petition for Rulemaking*, before the Federal Communications Commission, RM No. 7927.

131 Renee Saunders, ''Celsat Joins Mobile Satellite Contenders, " *Space News*, Feb. 17-23, 1992, p. 4.

132 Federal Communications Commission, "FCC Asks for Comments Regarding the Establishment of an Advisory Committee to Negotiate Proposed Regulations, ' CC Docket No. 92-166, released Aug. 7, 1992.

NPRM process is completed, the FCC hopes that the process of licensing providers of big LEOS service can be completed quickly.

As of April 1993, the big LEOS companies were in the process of completing design plans, building strategic and manufacturing partnerships, trying to convince foreign governments of the value of big LEOS, and searching out potential technology partners.

WARC-92 Negotiations-Big LEOS was one of the most difficult and complex issues debated at WARC-92. In broad terms, the debate pitted the United States and its allies against the Europeans and their supporters. U.S. support for the big LEOS concept was very strong and obtaining frequency allocations for these new systems was the highest U.S. priority at WARC-92. Many countries supported the U.S. position, especially developing countries who had become convinced of the potential benefits such systems could provide.

Before WARC-92 opened, U.S. and CEPT positions on MSS and big LEOS hardened, and preconference negotiations were unproductive. At the conference, negotiations continued to be difficult.[133] Both sides tried to find ways to tradeoff support for each others' systems, but such compromise was hard to achieve. A deal was struck only in the last hours of the conference.

Complicating the U.S. negotiating position on big LEOS was the support the United States had given to the Global Navigation Satellite System (GNSS) concept. GNSS is an international satellite system concept now being developed to provide global navigation services to aircraft, and that is designed to replace a confusing patchwork of different terrestrially-based systems around the world. The United States, along with ICAO and the former USSR, has been actively involved in the development of this concept since the rnid-1980s. Proponents expect that GNSS will use two satellite systems, the U.S. Global Positioning System (GPS) and the Russian GLONASS system (see box 2-E) to provide precise position determination and other navigation information to aircraft flying anywhere in the world.[134] The system is expected to increase safety, e.g., preventing disasters such as the downing of a Korean airliner over Russian airspace in 1983, and efficiency, by allowing planes to be spaced closer together on routes and allowing them to fly the most fuel/time efficient routes.

U.S. support for GNSS/GLONASS dates back to 1987. At the 1987 Mobile Services WARC, the U.S. opposed an L-band allocation for Aeronautical Public Correspondence (APC—see below) because it thought such use would interfere with the U.S. GPS and thereby threaten the operation of GNSS. At WARC-92, however, the United States not only supported, but proposed, frequency allocations for big LEOS that would use some of the same frequencies as GLONASS. This policy switch seriously underrnined U.S. support of the GNSS system in international eyes, and led many frustrated domestic and international aviation officials to question why the United States

133 EC observers, for example, believing that the CEPT countries had given up too much on little LEOS, pushed CEPT to take a hard position on big LEOS allocations.

134 Also being discussed is a potential European satellite aeronautical navigation system. European officials have reportedly shown some reluctance to use either the U.S. DoD-controlled GPS system or the Russian (Ministry of Defense's) GLONASS system. "International Air Traffic Control May Go From Radar to GPS,' *Telcom Highlights International,* vol. 14, No. 23, June 3, 1992. p. 17.

was willing to jeopardize years of work on GNSS.[135] Big LEOS proponents, on the other hand, believe that it is possible for both services to share the band, and that the U.S. positions were not mutually exclusive.

Some analysts and delegates believe that U.S. support for commercial big LEOS systems over GLONASS/GNSS at WARC-92 not only damaged U.S. integrity internationally-making it harder to "sell' U.S. positions at future conferences-but may also have set a bad precedent for future conferences. ITU members may try to reallocate frequencies used by the U.S. GPS system.

ISSUES AND IMPLICATIONS

LEOS promise universal communications anywhere in the world, Brochures touting these services and the popular press extol the benefits to the world community and the technical marvels they represent. Such systems are also expected to generate huge revenues for services providers and equipment makers-estimates easily reach into the billions of dollars per year. At present, U.S. companies lead the world in the development of LEOS technology. However, a number of hurdles remain to be overcome before these services can be made available to the citizens of the United States and the world.

International Allocations and Licensing—Inter-nationally, the biggest potential problem facing the providers of big LEOS services is that they must obtain licenses in every country in which they plan to operate. Although international allocations for MSS/big LEOS were agreed to at WARC-92, those allocations must now be adopted by individual ITU member countries before the new systems can begin operations. Furthermore, there is no guarantee--even if the international allocations are adopted—that foreign countries will license all or even any of the U.S. companies that have proposed big LEOS services.

The possible implications of U.S. big LEOS proposals began to draw the attention of foreign telecommunications regulators and policymakers even before the end of WARC-92. European Community officials fear that the U.S. licensing process "ultimately will become a worldwide mandate, '[136] and that U.S.-operated systems will dominate this emerging market-precluding the introduction of (non-U. S.) competing systems.[137] At the conference, the EC Commission delivered a letter to Ambassador Baran, head of the U.S. delegation, requesting talks on the subject after WARC-92 ended. Informal talks were held in late summer of 1992, but no formal agreements were reached and no actions were taken as a result of the meeting. Among the issues discussed: licensing procedures in the United States and Europe, shared use of spectrum by existing and future systems, and domestic procedures for interconnecting satellite networks with the domestic

135 In the domestic preparation process, U.S. aviation interests opposed MSS/big LEOS allocations that they believed would threaten GLONASS/GNSS. They were not successful in having their views accepted, but they received assurances about protecting GLONASS in the FCC's final Report. The Report stated: "the Commission has been unable to determine the extent of [GLONASS] operations above 1610 MHz. Therefore, we have not been able to assess the potential for interference to GLONASS in the 1610-1626.5 MHz range. However, if it is determined that GLONASS is operating extensively above 1610 MHz, the U.S. Delegation will have the flexibility to modify the U.S. proposal to protect GLONASS."

The real meaning of those assurances in practice, however, became clouded at WARC-92. It became clear that GLONASS will operate above 1610 MHz, and the delegation did negotiate some protections for the system relating to allowable power levels, However, such protection was inadequate in the view of the domestic aviation community, who continue to feel that the United States was not truly committed to protecting GLONASS at the expense of the commercial big LEOS systems. See Federal Communications Commission "An Inquiry Relating to Preparation for the International Telecommunication Union World Administrative Radio Conference for Dealing With Frequency Allocations in Certain Parts of the Spectrum," *Report,* Gen Docket 89-554,6 FCC Rcd 3900 (1991), p. 15.

136 Daniel Marcus, "EC Fears Prompt Satellite Talks," *Space News,* vol. 3, No. 20, May 25-31, 1992, p. 1.

137 The licensing of big LEOS is unique in the history of international telecommunications because, although licenses will be granted by the FCC (a U.S. regulatory agency), the services these systems will offer will be global in scope-seemingly putting the FCC in the position of granting *de facto* international licenses.

telephone system in each country. Despite these talks, the Europeans generally remain cool to American big LEOS systems.[138] Consequently, the big LEOS providers are engaged in extensive efforts to persuade foreign spectrum managers that their systems pose no threat to established services. Ultimately, the survival of big LEOS systems will depend on how successfully they can lobby foreign governments.

If some countries decide not to allocate the spectrum agreed to at WARC-92, or not to license big LEOS systems—in order to protect existing systems, for example--it could seriously jeopardize the viability of the systems. Big LEOS companies could be faced with a patchwork service in which some countries would have service and others would not. The customer base and coverage of the system would be reduced, and the operator of the system would have to find some way to actually turn the system off over offended countries. While it is technically feasible to do this, software solutions will be extremely complex and expensive. In addition, differing amounts of spectrum are allocated in different countries, and adequate frequencies might not exist in some cases for multiple systems. Such scenarios may make operating a true global system technically unrealistic.

Frequency Coordination **and Sharing—** Spectrum sharing and coordination in the big LEOS frequencies is expected to be even more difficult than the problems faced by little LEOS. Because of the limited amount of spectrum allocated to LEOS at WARC-92 and the bandwidth requirements of the systems themselves, only a limited number of such systems can be accommodated worldwide, a fact recognized by the delegates to WARC-92 in Resolution 70.[139] This recognition also led the conference to adopt Resolution 46, which defines interim coordination procedures for LEOS and calls for future study by the CCIR.

Domestic *Coordination:* Frequency sharing and coordination problems faced by big LEOS services split along two dimensions. First, the five big LEOS proponents must find ways to share the allocated spectrum amongst themselves. Given the relatively small amount of spectrum allocated, and the relatively large (compared with little LEOS) bandwidth requirements of voice services, this could prove to be a substantial challenge. Complicating this problem, the big LEOS companies have proposed different transmission modulation schemes. Iridium, as noted above, plans to use TDMA, which Motorola is also developing for digital terrestrial cellular services. The other four applicants have proposed to use CDMA to provide their services. Because these two forms of modulation are different, they cannot use the same frequencies. The negotiated rulemaking proceeding at the FCC attempted to work out a compromise on this issue, but discussions were not successful. Ultimately, the FCC will have to decide how best to accommodate the needs of all the applicants. Unless one side or the other relents, it must find some way to allow both CDMA and TDMA transmissions to be used.

A number of commenters have pointed out that the ability of the four CDMA systems to share amongst themselves may also be limited. Limitations on power and hence capacity, according to one commenter, are ‘‘certain only to increase the effective cost per circuit for each system, increase the ultimate price to the end user, and possibly jeopardize the viability of one or more of the competing applicants. ’ ’[140] Perhaps for this reason, some analysts have suggested that a consortium, like AMSC, may be one alternative to providing big LEOS services.

In addition, any future big LEOS system will have to share the bands with the services already

[138] ‘‘Satel Conseil Examines WARC Results, Especially LEOS, ’ *Mobile Satellite Reports, vol. 6, No. 21,* Oct. **12, 1992.**

[139] ITU, *Final Acts,* op cit. foomote 27, p. 117.

[140] Celsat, op. cit., footnote 130, p. 46.

using the frequencies. Observers have pointed out that sharing with existing services may be possible or more easy to negotiate if the other services are willing to compromise and work with the U.S. big LEOS providers. If such cooperation is not forthcoming, and if their consent to share the bands is not obtained, many believe that, as currently designed, big LEOS will not be able to share spectrum in the short term.[141] Over the next several years, as technology is developed to work around such constraints, big LEOS could come into operation, but they would be years late and equipment would likely be much more expensive than originally planned. Either one of these possibilities could conceivably derail these systems.

For example, the bidirectional use of the 1613.8 -1626.5 MHz frequency band by Iridium may cause serious sharing problems. As noted above, the downlinks that Motorola plans to use for Iridium were granted only secondary allocations at WARC-92. The CCIR has tentatively recommended that systems using these frequencies should not cause interference to systems operating on a primary basis. ''The recommendation would prevent Iridium-which will have a secondary downlink at 1613.8-1626.5—from interfering with other primary and secondary users in the band.[142] This fact, combined with the high power levels characterizing Iridium's TDMA system, ''virtually precludes the possibility of Iridium sharing spectrum with any other satellite system—U.S, or foreign. ''143 The CCLR called for additional studies to examine the problems.

GLONASS: The most difficult international frequency coordination problem will be with the Russian GLONASS system.[144] Although **both types** of proposed big LEOS systems may interfere with GLONASS, Iridium appears to present more severe and difficult sharing problems because of the concentrated signal power of Iridium's TDMA modulation scheme. Motorola has said that it cannot share with GLONASS and will seek to operate in frequencies not used by the system. ''MSS industry observers saw the limits imposed on the big LEO allocations as favoring the four applicants who proposed to operate in separate uplink and downlink bands, while raising potential problems for the Iridium system.[145] The four CDMA companies believe that they can share with GLONASS, but there is concern that with all four systems functioning, interference might become a problem. Theoretically, the CDMA systems could use the entire 1610-1626.5 MHz band, while Iridium, which plans to use TDMA bidirectionally can only use that portion of the band not used by GLONASS.[146]

One specific potential problem is the operation of the user terminals in the uplink allocation at 1610- 1626.5 MHz. Interference from these portable telephones could be just as serious as interference from the satellites, and could make coordination of big LEOS systems difficult since the primary status of the existing services gives them advantages in negotiations. GLONASS receivers, for example, which are to be mounted on the top of the aircraft, are very sensitive. Although the

141 The basis of this belief is the extremely restrictive power levels (power flux density (PFD) limits) that *have* been placed on LEOS operations. While current proponents claim that they can share the spectrum, other analysts believe that more sophisticated and expensive equipment-now just being designed-will be necessary.

142 ''CCIR Sees Problems With Bi-directional Operation of Iridium,'' *Satellite* News, vol.16, No. 5, Feb. 1, 1993, p. 4.

143 Ibid.

144 Because the U.S. GPS system uses frequencies in a lower frequency band (1565.1585 MHz), it will not be affected by the big LEOS systems.

145 ''U.S. 'Big, Little LEOs' Get Allocations at WARC. . .," *Telecommunications Reports, Mar. 9, 1992,* p. 14.

146 What frequencies GLONASS will actually be using when fully operational is still not clear. Shortly before WARC-92, the Russians filed plans at the ITU to use frequencies up to 1620 MHz, thus leaving Motorola with only 6.5 MHz in which to operate. It is unclear if Iridium could operate (with adequate quality and capacity) with this limited amount of spectrum.

receivers would be partially shielded from interference from mobile telephones by the body of the plane, when the aircraft is turning and banking (especially during landing and takeoff), the GLONASS receiver could be exposed to interference from nearby user terminals.[147] In order to limit interference from the handsets and protect the existing services in the band, WARC-92 (footnote 731X) put restrictions on the transmission power from user terminals. Design and implementation of big LEOS systems under these constraints will be technically challenging, but should be possible.

Implementation of big LEOS systems will face two critical issues vis-a-vis GLONASS. First, some arrangement must be worked out with GLONASS officials to insure that U.S. big LEOS will be able to operate effectively across the entire frequency band allocated at WARC-92. Motorola officials have said that they cannot share with GLONASS or GLONASS-M (an expanded version of GLONASS). This prompted the United States to oppose attempts to implement GLONASS-M. Alternatively, the frequency allocations and assignments made by the FCC will have to work around the GLONASS system, Second, the United States would have to oppose more stringent power limits than those defined in footnote 73 1X. Because no LEOS systems are operating, it is difficult to judge the real effects of any potential interference they may cause to existing systems. In practice, it is possible that the limits on big LEOS power set out by WARC-92 are not strict enough—the U.S. delegation was successful in negotiating limits that were at least workable in the interim. In that case, the members of the ITU may decide to make the limits more stringent. However, if the power limits are made much stricter, big LEOS proponents believe that their systems may not be able to operate.

Continued U.S. Government support of the big LEOS concept puts it in a difficult position regarding the use of the L-band frequencies, The United States now supports two systems/users competing for the same frequencies: GLONASS, which is viewed by the Federal Aviation Administration (FAA) as an integral part of the future global navigation system, and big LEOS. At least two related consequences of the U.S. actions at WARC-92 must be considered. First, what, if any, backlash could be taken against the U.S. GPS system at future international meetings? Second, from a broader perspective, what effect will big LEOS systems really have on GLONASS, and was promoting big LEOS a sufficient reason to risk the future of the GNSS system?

This issue highlights the policymaking gap that exists in U.S. international radiocommunications policymaking. In this case, powerful commercial interests with little more than a conceptual plan and initial technical designs were able to undermine an established, U.S. Government (FAA)-sanctioned, civil aviation initiative that is already partially finalized globally and is already operating. No public proceeding assessing the advantages of one versus the other was held, and no accountability for the policy shift has been assigned. The mechanism by which this decision/shift was made is invisible, and the reasons so far undocumented.[148]

Radio Astronomy: Another potentially difficult sharing problem will have to be worked out between the big LEOS providers and the world's radio astronomers. Radio astronomy is now allocated on a primary basis in the 1610.6- 1613.8 MHz band, and is protected from interference by two newly modified footnotes (733E and 734). Footnote 733E specifically protects radio astronomy operations from interference from MSS (including LEOS) systems. Since radio astronomy

147 In interpreting data on interference and sharing, therefore. it is important that these problems be taken into account and that computer models do not assume an aircraft flying level.

14S Although such conflicting policy decisions are normally worked out in discussions within the Interdepartment Radio Advisory Committee and between NTIA and the FCC, it is not clear to what extent NTIA was aware of the implications of FAA's support of the GLONASS system.

uses extremely sensitive receivers and requires precise measurements, almost any interference caused to radio astronomy services could be serious. Big LEOS proponents believe that the position determination capabilities of their systems will be sufficient to protect radio astronomy applications.[149] The radio astronomy community generally does not share that confidence.

The real issue in this case, however, maybe the political support enjoyed by each side. Radio astronomers do not have the economic clout of private sector industries, and hence their political leverage is limited. In cases where interference is a problem, it is possible that the complaints of radio astronomers will be accorded less importance than the concerns of commercial ventures.

Market Considerations-Aside from the technical and regulatory questions plaguing the development of big LEOS, a more fundamental problem has not been adequately addressed. What is the market for these types of services? Will big LEOS services be profitable in the long term? A number of assumptions underlie predictions about big LEOS services that have not been adequately analyzed. These assumptions need to be examined in order to assess the market potential for big LEOS services and the viability of such services in the long term.

The question of potential market size for satellite telephony must be put into context—users do not care how their service is delivered, whether by satellite (LEOS or geosynchronous), cellular, or emerging personal communication services. Thus, the critical questions are: What is the market for mobile services? What other technologies will compete? What portion of the overall market can LEOS services realistically expect to capture? Inmarsat, for one, estimates the worldwide market for satellite mobile phones will reach 2 million by the year 2000.[150] Early estimates put the dollar value of mobile satellite services (including both large and small LEOS) at $1 billion by 1995 rising to $9 billion by 2000.[151] However, cutting through the hype of promotional brochures and presentations on big LEOS services to realistically assess expectations is difficult. And while initial projections made by the companies in their original applications would lead one to believe big LEOS will be serving millions of users in a few years, a number of doubts remain, and most analysts question the market analyses done so far. An examination of the marketing projections filed with the companies' initial applications reveal a wide range of market estimates for essentially the same service.

In an ironic twist, the big LEOS proponents themselves may have limited their potential revenues by promoting a dual-mode approach. In systems with dual-mode designs, the user's portable phone will first search the airwaves for a local cellular service, and if no such service is found, the system would then automatically switch to the satellite system. The problem is that if the phone finds the local system, as it will most of the time in the United States, Europe, and many other developed (and some developing) nations, the satellite system will not be used, and no revenues will be generated.

A dual-mode approach (using U.S. handsets) could also draw the ire of foreign cellular carriers who may operate on different frequencies than the United States. When the dual-mode phone attempts to connect to a cellular system in a foreign country, it may not be capable of operating on the

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1@ Since radio astronomy facilities are usually located in remote parts of the world, interference from user terminal s is expected to be minimal. Some proponents have suggested that since radio astronomy receivers are located at well-known positions, the big LEOS systems could use the position determination capability built into their systems to actually turn off user terminals that get too close to such facilities. Signals from the satellites, however, represent a much more serious problem as they cannot avoid a particular area.

150 "Inmarsat Satellite Telephone Venture Launched," *Telcom Highlights International,* vol. 14, No. 43, Oct. 28, 1992.

151 Data here was reported in "Mobile Satellite Communications Market to Pass $1 Billion in 1995,' *Telcom Highlights International,* Feb. 6, 1991. Study was conducted by International Resource Development, Inc., and based on the expectation that services would start in 1994 or earlier,

local frequencies, and would switch to the satellite system, bypassing the local cellular carrier. Many types of dual-mode phones may have to be produced to work in various countries-defeating one of the purposes of ubiquitous worldwide coverage.

A similar problem that may decrease the potential markets for the dual-mode satellite services is the potentially divided nature of the future installed base of cellular users. Depending on which service consumers use, they may be served by either a CDMA or TDMA cellular system. This prior use may constrain which satellite system a user can subscribe to--TDMA users would have to use Iridium (and only Iridium) while CDMA users could choose between the other four (if they all survive), but could not use Iridium. In order to promote maximum flexibility, users might have to use a tri-mode phone, which is not (yet) being developed.

Thus, the big LEOS service providers could be limited to marketing essentially to areas without cellular service. Current populations may not be able to support deployment and continuing operation of a $1 to $4 billion LEOS system. Basing expensive systems on speculative projections seems optimistic at best, and an invitation to financial disaster at worst. Compounding the problem is that there is not one, but potentially six companies vying to offer these services. Clearly not all are viable or will survive.

International Markets; A significant part of the justification for big LEOS services is their ability to serve the communication needs of countries with underdeveloped terrestrial communications systems. This marketing pitch was used to great advantage at WARC-92 to build support among the developing countries. However, some observers question whether such benefits will actually flow to those countries.[152] These countries (and their citizens) do not have substantial financial resources and the big LEOS equipment and services are expected to be very expensive initially. Motorola's Iridium phone, for example, is expected to cost $3,000 when introduced, falling to about $1,500 when mass produced. In the United States, the average consumer is relatively affluent, with an average per capita income (1988 dollars) of $16,444.[153] For much of the rest of the world, however, consumers are not so well off. The per capita income in the Central African Republic, for example, is approximately $376, meaning that the average consumer would have to work 4 years to buy a phone. Even if national governments buy the phones, who will pay for the services? At $3.00/minute it would take 17 hours of labor just to make a 1 minute phone call! 154 In any case, these numbers are not well quantified, and require more analysis before foreign market potential can be realistically estimated. [155]

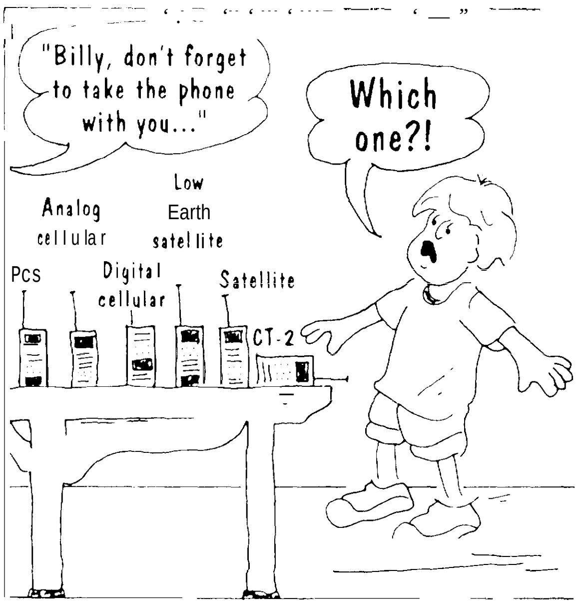
Basing projected subscribership and/or revenues on international travelers is also risky. Such travelers are likely to stay in major cities where they will have access to local wired infrastructure as well as local cellular providers (assuming they have a dual-mode phone capable of working in the country in which they are traveling)-further shrinking the potential market for satellite services. If they cannot use the local cellular provider, they would use the satellite system. However, local or national cellular providers in foreign

152 Some more cynical analysts believe that, in fact, the big LEOS providers have little interest in serving developing counties because they realize that profits will be slim at best. Instead, these analysts believe, the applicants will concentrate their development and marketing activities in the most industrialized countries. If anything, they believe, users in developed countries will end up subsidizing users in developing countries. From this perspective, advertising the benefits for developing countries is little more than good public relations and a way to win international support.

153 per capita income figures provided by Mark S. Hoffman (ed.), The *World Almanac and Book of Facts: 1992* (New York: Pharos Books, 1991).

154 Assuming that the average consumer in the Central African Republic works 40 hours a week, 52 weeks a year.

155 Some observers predict that recovering any significant revenues from the developing countries may take as long as 10 years.



Susan Hoffmeyer

countries will strongly object to this form of bypass, unless a revenue sharing plan is in place.

Finally, counting Europe and Japan as potential markets is risky for two reasons. First, both are already deploying terrestrial systems that would directly compete with big LEOS services. Second, licensing big LEOS services in Europe could be extremely difficult, as demonstrated by CEPT opposition to U.S. proposals at WARC-92, European countries have serious doubts about allowing mobile satellite services to share with their existing terrestrial (mobile) services, and will likely take steps to protect and promote their systems at the expense of, especially U. S., competing satellite-based systems.

Envisioning such global systems without European connections is even more difficult. Such systems may not be able to survive without access to European markets. Motorola, for example, has said that ''we do not see Iridium without European participation,'' and, consequently, is busy trying to convince European governments that Iridium poses no threat to their existing or planned systems, including FPLMTS.[156] Thus, talks between EC and U.S. radiocommunication officials are crucial to the success of U.S. big LEOS systems.

Domestic Markets: Leaving aside international markets, even marketing big LEOS services in the United States could be difficult. As noted above, mobile phone users will not care how their service is provided—by satellite, cellular, or PCS—and the mobile phone market may not be big enough to support many competing technologies and companies. Cellular telephony, for example, has a big head start in coverage and in signing up customers. Cellular telephone service is available to over 80 percent of the U.S. population, and covers approximately 60 percent of the country (excluding Alaska).[157] If big LEOS companies plan to draw customers away from cellular companies they may have a difficult time unless they can show that their service is of better quality, cheaper, or different than cellular. In the meantime, the cellular industry will move ahead with its own improvements. Coverage will improve as more rural cellular systems are built, roaming between cellular areas will become easier, and capacity and quality will improve as digital cellular systems are implemented.[158]

Inmarsat: The prospect of Inmarsat entering the market for mobile satellite services presents its own set of problems for U.S. regulators and policymakers. Originally, Iridium announced that it would like to sell satellite capacity to, partner with, or complement Inmarsat. Inmarsat, however, seems clearly focused on providing its own

156 Comments of Mike Pellon, quoted in Andrea.s Evagora, ''CEPT: Radio Interference,' *Communications WeekInternational, July 20,1992,* p. *4.*

157 Elliot Hamilton, Economist, Economic Management Consultants, Inc., personal communication, July 29, 1992.

158 McCaw Cellular, for example, is in the process of building a nationwide cellular network through agreements with local cellular operators throughout the country.

system in competition with Iridium.[159] This poses a Policy dilemma for the U.S. Government: should it support Motorola and its $3+ billion system, or should it side with Inmarsat, in which the United States holds a major interest through its signatory, Comsat?

This increasingly bitter battle has reached the highest levels of the U.S. Government, Motorola points out, and others agree, that Inmarsat, which is a consortium primarily funded by government-owned and/or controlled 'signatories, ' could use its influence and current position as a supplier of mobile services worldwide, to politically block out new, private sector competitors.[160] Others believe that the potential entry of Inmarsat into the MSS business has stifled, and will continue to depress, investment in private satellite systems, as investors wait to see what Inmarsat will do. Even if U.S. systems do begin offering services before Inmarsat, they believe, Inmarsat may be able to arrange incentives such as tax breaks that would give it an unfair global advantage. This could ultimately result in a (worldwide) monopoly for Inmarsat and high prices and poor quality for consumers.[161] This is one reason some observers believe it is important to support AMSC—to provide competition to Inmarsat.

Currently, the FCC is pushing ahead with big LEOS licensing in order to help U.S. systems become operational quickly, an important consideration from a marketing perspective. Timely licensing of U.S. systems could provide them with an important competitive advantage to offset the global (political) support that Inmarsat could muster. This approach could also allow the United States to avoid having to support one side over the other. U.S. systems could come into operation first, and then the United States could support the entry of Inmarsat into the business as an enhancement to competition.

Technology Issues-In addition to the questions raised over frequency coordination and sharing, questions have been raised over some of the technical details of the individual systems.[162] This section will not analyze the technical feasibility of each system in detail since each proponent continues to refine their technical plans and make improvements in their original system design. Instead, it identities broad concerns about the technical details of the systems-issues that must be addressed by all proponents to develop a viable system.

One of the most serious concerns facing big LEOS operators is the limits WARC-92 placed on the power these systems can use. Because the systems are not yet operational, questions have been raised about the power requirements and whether the satellites will be able to deliver the power needed to effectively provide the proposed services.

Related to the question of power, one of the more difficult technical problems involves the ability of the systems to penetrate buildings.[163]

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159 Patrick McDougal, Inmarsat director of strategic planning, said that 'they will be fighting for the same customers.' Quoted in 'Special Report— Satellite Competition Heating up in Europe, Asia, ' *Satellite News,* vol. 15, No, 11, Mar. 16, 1992, p. 7.

160 See, for example, a report prepared for Iridium, Inc. by Nathan Associates, Inc., ''Inmarsat's Project 21 and U.S. Policy," June 5, 1992.

161 Ibid.

162 Mitre Corporation, for example, completed an initial analysis of the technical feasibility of the various LEOS systems based on tick original applications at the FCC. The report notes numerous instances in which proponents' claims-about satellite coverage areas, weight, and system communications capabilities cannot be verified. However, the report also concludes that none of these technical issues seemed "insurmountable." Mitre does not expect any of the big LEOS systems to be operating before 2000. W.J. Ciesluk, L.M. Gaffney, and N.D. Hulkower, et al, ''An Evacuation of Selected Mobile Satellite Communications Systems and Their Environment, ' The Mitre Corp., Bedford, MA, April 1992.

163 Although engineers are divided on this problem, a number of issues that require further research remain to be resolved. One issue involved is where the testing should actually be conducted. Circular orbital paths converge as they approach the North and South Poles. This means that the satellites in those orbits will be closer together, meaning that a satellite is more likely to be closer to the user and more able to give a good signal. If testing is conducted in these areas, as opposed to around the equator, results will likely be too positive. Relying on tests conducted only in the United States or Europe will lead to false assumptions about service availability and quality in other parts of the world.

Unlike cellular telephony, which is terrestrially-based and has radio waves that travel along the ground, satellites, which will be flying high above the ground, may not have suitable angles for penetration into buildings. Because of the frequencies involved, a clear line-of-sight may be needed to the satellite, requiring users to either go outside or stand at a window. The problem is compounded by the nature of LEOS themselves; they are not stationary with respect to the Earth-the line-of-sight will change as the satellite passes through its orbit. Furthermore, as the satellites travel in their orbits toward the equator, they will spread out; i.e., some areas will be further from the satellite than those directly beneath its orbital path.[164] See figure 2-8, for example. In those far away cases, direct line-of-sight to the satellite may be a necessity for any communication. More testing is needed.

Yet another issue, although not strictly technical, is that of replacement satellites. The 5-year lifespan of the LEO satellites is relatively short compared with the 15-year lifespan of most geosynchronous satellites, That means that replacement satellites will have to be built and launched *continuously* as long as the system operates. The often-overlooked ongoing nature of these enterprises raises two major concerns. First, the costs of the systems as addressed in their applications are merely the initial costs of bringing the system into operation. The companies operating these systems will also incur substantial recurring costs of maintaining the system—building and launching new satellites.

Second, the ability of the system to operate continuously will depend on a continuing supply of new satellites. If, for any reason, the satellites cannot be built, cannot be launched, or fail in orbit, the system's reliability and integrity will be jeopardized. Some analysts have suggested that to meet such launch requirements, a very high launch reliability will be necessary, a level that is presently above current averages. Given the nature of some of the (emergency) services expected to be provided by these systems, such a level of risk will require careful monitoring by government agencies to ensure continued system reliability and quality.

Iridium, because of its complexity, poses several unique technical questions. Some analysts cite a number of technical factors that lead them to believe that Iridium probably will not be viable in the near term. For example, Iridium's plans call for satellites to communicate not only with users and gateways on the ground, but to transfer calls between satellites. This additional feature increases the complexity and weight of the system, and introduces unique technical challenges for Motorola that do not concern the other proponents. First, the satellites are much more complex and difficult (and costly) to build-they will be essentially switching centers in the sky.[165] Second, the software to control the complex switching (intersatellite links) envisioned in Iridium is a major development challenge.

All the applicants for big LEOS systems will be retuning and improving their system and satellite designs until formal rules are adopted and licenses granted by the FCC. With the recent changes in its system design, Motorola officials hope to refocus attention on the promise of the system rather than its past troubles. Changes in the system do not necessarily indicate fundamental weaknesses in the technology as much as continual improvements in the system design.

As a result of the above concerns, investment financing for big LEOS companies has been very hard to generate.[166] The worldwide economic downturn, combined with the regulatory, technical, and market uncertainties associated with the

164 Because of its elliptical orbit, Ellipsat has a different set of concerns about the positioning Of its satellites.

165 The satellites of the other systems function essentially as a ''bent Pipe' '--merely relaying signals that are sent from the ground. They will encompass few, if any, switching functions.

166< 'On the Trail of Investors: LEOs Face Financial World's Skeptics, *Satellite News*, vol. 15, No. 37, Sept. 14, 1992.

systems has reportedly made them a ''hard sell" to the world's financial community. Time will eventually bring an economic recovery, and time could be used to improve the systems and services, but time is also the enemy of emerging systems. Existing (cellular) systems are expanding their coverage and improving their services at a rapid rate, and other new mobile technologies are also waiting in the regulatory wings.

OTHER U.S. ALLOCATION PROPOSALS TO WARC-92

Broadcasting-Satellite Service-HDTV

BACKGROUND

High-definition television refers to the next generation of television service that will have high resolution (nearly twice that of conventional television), better color, a wider screen, and compact disc-quality digital sound. It has been under intensive development in the United States, Japan, and Europe for several years.[167] Originally, HDTV developers planned to use an analog transmission format similar to that used by today's television sets. However, the superior picture and sound quality of HDTV would require much more bandwidth (and spectrum) to transmit the HDTV signal. Because these analog HDTV signals were expected to occupy so much spectrum, they would not fit into the channels that had previously been defined and planned for satellite television broadcasting in the 11.7-12.75 GHz band. As a result, new international allocations for satellite-delivered HDTV were believed to be necessary. The 1988 WARC on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It (ORB-88) attempted to allocate frequencies for these new wide-band television services, but no agreement was reached and the debate was carried over to WARC-92.

A desire to promote the development of one worldwide HDTV standard was one of the original forces pushing a worldwide allocation for BSS-HDTV. As countries developed different systems, however, and made choices about how HDTV would be delivered, standards began to diverge. Thus, at WARC-92 the rationale for a worldwide allocation, while still powerful, had lost some of its urgency.

U.S. PROPOSAL

The U.S. proposal for BSS-HDTV had two main components. First, the United States proposed that the existing allocations and associated plans for satellite television broadcasting around 12 GHz could serve as the basis for worldwide HDTV allocations.[168] This proposal was based on the expectation, discussed below, that developments in digital compression would allow HDTV signals to fit into the existing allocation plans. However, in order to accommodate future growth of the service and specific HDTV station assignments that could not be made according to those

167 HDTV was originally conceived more *than 20 Years* ago, but only recently have advances in microelectronics and digital signal processing brought the technology close to commercial applications, For discussion of the historical, technical, and economic implications of HDTV, see U.S. Congress, Office of Technology Assessment, *The Big Picture: HDTV and High-Resolution Systems,* OTA-BP-CIT-64 (Washington, DC: U.S. Government Printing Office, June 1990).

168 In the early 1980s, a separate (from HDTV) trend was developing that would directly affect the U.S. WARC-92 proposal. With advances in satellite technology and the shrinking of consumer electronics, entrepreneurs began to develop satellite systems they hoped would bring many channels of television programming directly into consumers homes via small (18 inches) receiving dishes. These services were dubbed DBS—direct broadcast satellite. In order to accommodate these new satellite services, the countries in Region 2 (essentially the Western Hemisphere) agreed in 1983 to allocate frequencies (12.2 -12.7 GHz) and developed a plan to implement DBS services. These allocations were formally adopted by the ITU at the 1985 WARC on the Use of the Geostationary-Satellite Orbit and the Planning of Space Services Utilizing It (ORB-85), Geneva, 1985. This conference also allocated spectrum to satellite broadcasting services in 11,7 -12.5 GHz in Region 1 and 12.2-12.5 GHz in Region 3. Thus, no common worldwide allocation was achieved. Although no DBS systems are yet operating in this country (Europe has operating DBS systems), several companies continue to pursue the idea of delivering television programming by satellite (see below).

plans, the United States also proposed to allocate the 24.65-25.25 GHz band for use by HDTV satellite broadcasting.

RESULTS

The U.S. proposals did not generate adequate support, and the United States eventually changed its position in order to support a common Region 2 allocation. In fact, WARC-92 delegates were unable to agree to a single worldwide allocation. Instead, the conference adopted two separate allocations, one (17.3 -17.8 GHz) for Region 2, including the United States, and another (21.4-22.0 GHz) for the rest of the world. These allocations cannot come into effect until April 1, 2007. In addition to the allocations for BSS-HDTV, allocations were made for frequencies to support BSS-HDTV systems. [169] WARC-92 also adopted Resolution 524, which calls for a future conference to consider modernizing the existing satellite broadcasting plans (originally set out in 1977) for Regions 1 and 3 in order to better accommodate digital HDTV technology.

DISCUSSION

HDTV was not one of the highest-priority concerns for the United States at WARC-92. In fact, the U.S. proposal for using the 12 GHz bands for HDTV was less a proposal than a position—it required no new allocations or regulatory changes.’ 70

Several factors underlie the U.S. position. First, there is little tradition of satellite delivery of television programming in the United States. Despite the 3 million backyard satellite dishes owned by American consumers, direct broadcasting by satellite (DBS) has not yet taken hold in this country. There are currently no DBS services in the United States, and the first is not expected to be operational until late 1993. Europe and Japan, by contrast, have operated DBS services in their countries for several years, and see HDTV as a natural extension to those systems. Japan, in addition, has been operating a satellite HDTV channel on a limited basis for several years. In the United States, by contrast, the primary focus for HDTV delivery has been on terrestrial broadcasting solutions—in large part a response to the historical importance and power of American broadcasters.[171] In addition, the U.S. position was based on the belief in this country that advances in digital signal processing would allow HDTV signals to be transmitted in the narrow channels that had previously been defined in the 12 GHz plans, thereby eliminating the need for extensive new allocations. This belief, in turn, was based on the continuing development of digital HDTV systems in the United States.[172] U.S. engineers expect these systems, which take advantage of advanced compression techniques, to be able to transmit full HDTV-quality programming in the 24 MHz television channels that are now used for conventional television broadcasting.

Engineers in other countries and the CCIR report on the technical bases for WARC-92 were less optimistic about the prospects of digital compression and of fitting all HDTV channels into existing plans, and the United States had a difficult time convincing other countries that such technologies could actually produce the high level of quality they believe HDTV viewers will

169 These ‘‘feeder link’’ operations were allocated frequencies at 18.1 -18.4 GHz (footnote 870A), 24.75-25.25 GHz (the original U.S. proposal for BSS-HDTV, footnote 882Z), and 27.5-30.0 GHz (footnote 882 W).

170 Tacit recognition and acceptance were given t. use of the existing plans in Resolution 524, in which WARC-92 delegates called for a reworking of existing plans in Regions 1 and 3 to better utilize modern HDTV technology.

171 This is an oversimplification. The delivery of HDTV signals t. the home consumer has been an intense struggle between local broadcasters, cable companies, and DBS service proponents. Each is actively testing HDTV transmission systems, and the FCC *is* expected to define a standard for HDTV sometime in 1994.

172 Originally, all of the proposals for U.S. systems were analog. The Conversion to digital began with the announcement by General Instruments that they would develop an all-digital HDTV system. All the other remaining proponents quickly followed suit, with the exception of Japan’s Muse system, which eventually withdrew its system from consideration.

demand.[173] As a result, the primary focus of the HDTV debate at WARC-92 centered on where to put the additional bands that countries perceived would be needed for HDTV service.

There were initially three proposals for new HDTV frequencies. The United States, supported initially by Japan, proposed to allocate the 24,65-25.25 GHz band to BSS-HDTV. Many of the countries in Region 2 supported an allocation at 17.3 -17.8 GHz, and CEPT, supported by Australia and the Russian Federation, proposed an allocation at 21.4 -22.0 GHz.

Each of the various proposals had specific advantages and drawbacks. The U.S. proposal was unsuccessful largely because other countries believed that the extremely high frequencies proposed by the United States would take more power to deliver and consequently systems would cost more to build and operate.[174] Despite U.S. technical papers showing that the costs of these systems would not be substantially higher than those that would operate in the other proposed bands, by the third week of the conference, the U.S. position had garnered little support internationally, and U.S. delegation leaders decided to pursue an alliance with other Region 2 countries, who advocated BSS-HDTV allocations in the 17.3 -17.8 GHz band. The 17.3 -17.8 GHz proposal suffered primarily from its impacts on existing services and on plans to use the band in support of other services in Regions 1 and 3. The 21.4-22.0 GHz proposal, by contrast, enjoyed substantial international support-CEPT was able to line up as many as 55 countries to support its proposal-but was unacceptable to the United States because those frequencies are used in this country for microwave telephone links. U.S. and other delegates from Region 2 were successful in preventing the 21.4-22.0 GHz band from being allocated to BSS-HDTV in the region. If that had happened, many U.S. microwave communication users would have been forced to relocate to other bands, costing the industry a great deal of money and causing disruptions in domestic point-to-point communications.

ISSUES AND IMPLICATIONS

WARC-92 established relatively long lead times (the year 2007) before BSS-HDTV could be implemented in order to allow existing users of the band adequate time to shift their operations to other bands, but perhaps more importantly to allow the technology to more fully develop. A long lead time will allow standards to be developed for HDTV transmission around the world, and will allow engineers and spectrum managers to become more familiar with the operational characteristics of satellite HDTV systems only now being designed. Long lead times are not expected to constrain new HDTV services, since existing BSS bands will likely be used at frost, and it will be some time before demand for HDTV will require the additional spectrum.

Satellite-delivered HDTV services in the United States are expected, at least initially, to be provided using the frequencies outlined in the existing 12 GHz plans for DBS. As a result, the future of satellite HDTV is closely tied to the relative success or failure of current DBS efforts. If the systems now being planned to deliver (standard analog) television programming directly to home consumers from satellites do not come to fruition, or if the services fail to attract a sufficient number of subscribers, future plans to deliver HDTV programming by satellite may be reevaluated.

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173 International Telecommunication Union, International Radio Consultative Committee, *CCIR* Report: *Technical and Operational Bases for the World Administrative Radio Conference 1992 (WARC-92)*, March 1991, p. 7-1.

174 Interestingly, Some of the European countries reportedly had originally wanted to propose these same frequencies. However, because Of a compromise agreed to in the CEPT, they decided to support allocations in the 21.4-22.0 GHz band instead. So, despite sympathy for the U.S. position, CEPT unity prevailed on this issue.

On the other hand, if DBS services "take off," the delivery of HDTV by satellite becomes much more likely. Hughes Communications' DBS system, DirecTv, for example, is moving ahead with its plans to deliver television direct to homes.[175] The system is expected to begin delivery by early 1994, and will use two satellites to carry up to 150 channels of programming on 32 transponders.[176] Its first satellite is scheduled to launch in December 1993, and co-owner United States Satellite Broadcasting (Hubbard Broadcasting) has already purchased 5 of the satellite's 16 transponders, with 5 more dedicated to cable programming for rural areas. The remaining 6 transponders will be used by Hughes for DirecTv entertainment programming.[177] Depending on the success of these services, other providers may decide to enter the DBS/HDTV arena.[178] If DBS and initial HDTV services are successful, it is likely that the additional frequencies allocated by WARC-92 for BSS-HDTV will be used to accommodate (new) providers that cannot be accommodated in the lower bands.[179]

However, even if DBS does not succeed and direct-to-home HDTV satellite services never come into operation, viewers may still have the opportunity to get such services. Satellites will continue to carry video traffic for the major broadcast and cable networks, and consumers who wish to purchase their own ''backyard dishes" (and any descramblers needed) will be able to receive HDTV services just as they receive television service today.

It is too soon to tell how successful DBS and any future HDTV services will be. Some analysts are still skeptical that DBS services (HDTV or not) will be able to compete against the existing cable television industry. The DBS industry has been trying to get off the ground (figuratively and literally) for more than a decade now, and DBS efforts in the early and mid- 1980s ended in failure. The success of DBS and, in the longer term, satellite-delivered HDTV, will depend in part on the strength of competition from other video delivery systems in this country--cable, local broadcasters, multichannel multipoint distribution service (often known as "wireless cable"), and perhaps new fiber-to-the-home systems supplied by the telephone companies. With so many choices available to consumers, DBS and HDTV systems may have difficulty gaining enough customers to be viable.

In some cases, these technologies/systems are already gearing up to provide HDTV services. Cable systems, for example, have been aggressively laying fiber optic cables in order to increase their capacities—an increase that could be used to carry HDTV programming. Satellites will, however, have some advantages in the transition from regular television to HDTV. Compared with local broadcasters, there will be far fewer equipment changes in one or two satellites compared with hundreds of local broadcasting stations.

The regional, as opposed to global, allocations agreed to by WARC-92 are not expected to convey any relative advantages or disadvantages

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175 Hughes recently signed a $250 million-deal with the National Rural Telecommunications Cooperative (NRTC), formed in 1986 by rural telephone and electric companies, who will retail the DirecTv programming and sell/lease the receiving equipment. The target market is the 12 million households served by NRTC members.

176 ''IS DirecTv Coming Alive at Last?' *Telcom Highlights International,* May 6, 1992.

177 Debra Polsky, ''Hughes DirecTv Deal to Bring Satellite Service to Rural Areas, *Space News, vol.* 3, No. 16, April 27-May 3, 1992, p. 4.

178 There are no licensing restrictions that would prevent DBS providers from offering HDTV programming.

179 It could take Until 2007 for this size demand to be built, so the lead time agreed to at WARC-92 may not be all that limiting.

in terms of global competitiveness.[180] In fact, the regional allocations of WARC-92 may serve to confirm and reinforce the trend toward divergent HDTV standards already being developed around the world. Originally, international spectrum managers hoped that the establishment of a single worldwide spectrum allocation for HDTV would facilitate the global deployment of HDTV and promote the development of one international standard for the production and transmission of HDTV programming. The establishment of a single standard, in turn, would have reduced the potential for interference between systems, and would mean that only one type of HDTV equipment would have to be manufactured, and no complicated conversion would be needed to show HDTV programming in different parts of the world.[181] However, technological developments in various countries and different choices on how to deliver HDTV programming to consumers have made it almost a certainty that standards will again be divided, making the establishment of a single BSS-HDTV frequency band less important.

Terrestrial Aeronautical Public Correspondence

BACKGROUND

Aeronautical public correspondence (APC) services allow airline passengers to place telephone calls while in flight (phone calls cannot yet be received by passengers). The systems use transmitters in aircraft to communicate with receiving stations at various locations on the ground. These ground stations then relay the telephone calls through the public telephone network to their final destination.

APC services were frost proposed on a global basis at the 1987 Mobile WARC (MOB-87). That WARC allocated frequencies in the 1.5-1.6 GHz band for APC experiments. However, in the United States and many other countries, these frequencies are heavily used for other services and could not be used for APC. As a result, the United States decided to operate APC services in the 849-851 MHz and 894-896 MHz bands. A number of companies in the United States currently provide such services, and several other countries, including Canada and Mexico, use these frequencies as well. The North American system is fully operational, and hundreds of aircraft have been equipped with equipment using these frequencies.

U.S. PROPOSAL

The United States proposed that the 849-851 MHz (ground-to-air) and 894-896 (air-to-ground) MHz bands be allocated for APC use on a worldwide basis. This proposal was based on the extensive use of these frequencies for APC in North America.

RESULTS

The U.S. proposal was not adopted, but the United States was successful in protecting its existing APC system. A primary worldwide allocation was made to APC at 1670-1675 MHz for transmissions from ground stations and in 1800-1805 MHz for transmissions from aircraft to the ground. The United States, along with Canada and Mexico, inserted footnote 700A specifying that they would continue to provide APC in the 849-851 MHz and 894-896 MHz bands.

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180 Likewise, any competitive advantage that would normally convey to the company or country that develops a standard first, has also been lost. The world has already been effectively divided into three standards areas by policy decisions in the United States, Japan, and Europe, that each would have their own standard. Thus, the markets have already been predefine to a large extent, and the competitive race now has shifted to individual companies within regions, or in the case of the United States, a country.

181 Television programming is currently produced and transmitted in one of three incompatible formats: National Television Standards Committee (NTSC), Phase Alternation Line (PAL), and Systeme Electronique Couleur avec Memoire (SECAM), each of which are used by different groups of countries. The U.S. standard is NTSC.

DISCUSSION

The APC debate again pitted the United States against the CEPT countries, which proposed that the 1670-1675 MHz and 1800-1805 MHz bands be allocated for APC service worldwide. The choices facing WARC-92 delegates on this issue were clear-support either the United States or Europe. No other bands were seriously considered. Although there was important support for the U.S. position in Region 2—the Western Hemisphere--other countries around the world did not back the United States, and the U.S. proposal was ultimately rejected. The CEPT countries were again able to muster strong internal and external support, and were uncompromising. Their strong position made the U.S. proposal difficult for other countries to accept.

ISSUES AND IMPLICATIONS

As a result of the two sets of frequencies allocated by WARC-92, aircraft may have to carry two different kinds of equipment to provide APC services in different parts of the world. Alternatively, aircraft may have to be outfitted with new transceivers that operate in both bands and that presumably would be more expensive. This issue could be revisited at a future world radiocommunication conference if a dual system proves technically unworkable or economically undesirable.

In the long term, terrestrial APC systems may be augmented or even superseded by satellite technology. For example, Comsat, GTE Airfone, and Northwest Airlines have successfully demonstrated a satellite-based communications system for both cockpit and cabin telecommunications services.[182] The system, linked through Inmarsat satellites and Comsat's Earth stations, will provide global telephone and other communications services when aircraft are out of range of GTE's terrestrial network.

For the United States, the WARC-92 APC allocation could undermine the U.S. advantage in terrestrially-based airline communication systems. The United States is currently the world leader in developing APC services and providing communications services for airline passengers. Japan has focused its efforts on delivering such services via (Inmarsat) satellite. Until now, Europe has been unable to match the systems operating in North America because common frequencies to carry such services did not exist.[183] The WARC-92 decision essentially levels the APC playing field-erasing the previous U.S. advantage and starting development of and competition for such systems and services back at square one. The decision clearly benefits European APC interests by allowing them to "catch up" to American developers.

The longer-term implications of the decision are unclear. U.S. manufacturers of APC equipment will either be shut out of world markets altogether, or will have to retune production lines to manufacture radios compatible with the new world frequencies. This could mean producing to two different frequencies and sets of standards.[184] U.S. equipment makers will have to work hard to maintain their technical and market lead in APC in the face of divided markets and production inefficiencies.

▮ Fixed-Satellite Service at 14.5-14.8 GHz

BACKGROUND

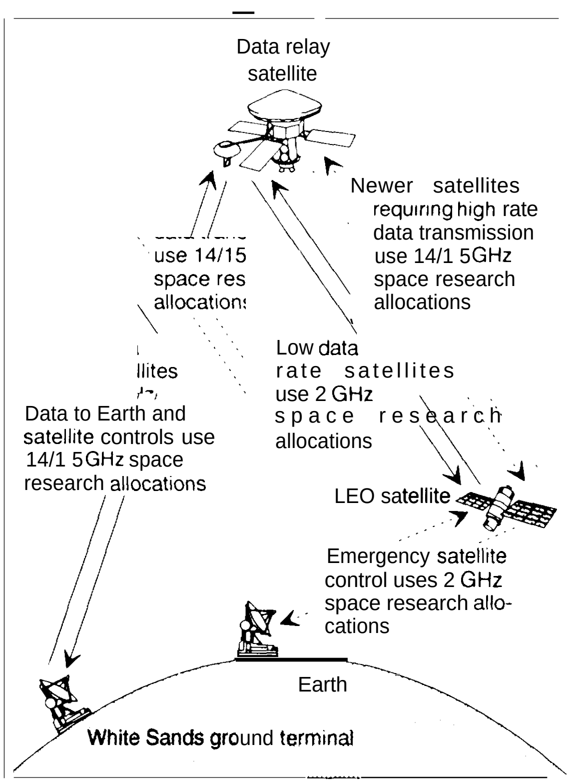
Fixed-satellite service (FSS) refers to communications systems that use satellites to link

182 "CCJIMSAT, GTE Airfone and Northwest Airlines Successfully Test satellite Communications," *Telcom Highlights International,* April 29,1992, *p. 17.*

183 'The Executive Office Arrives on Airliners,' *Telcom Highlights International,* vol. 14, No. 20/21, May 20, 1992, p. 23.

184 A draft CEPT recommendation proposes that only those phones that comply with Eurpean Telecommunications Standards Institute (ETSI) standards be allowed to operate in Europe. Evagora, op. cit., footnote 156.

Figure 2-1 l-Data Relay Satellite System



SOURCE: National Aeronautics and Space Administration, 1993.

stationary (fixed) satellite antennas on Earth.[185] The FSS is used around the world to provide long-distance communications links for telephone conversations, data files, and video programming. Currently, international use of the 14.5 -14.8 MHz band is limited to transmission of video programming for BSS, and is used extensively by Intelsat. In the United States, however, these frequencies are allocated solely for government use, and are used primarily to support Department of Defense operations. NASA also uses the band (on a secondary basis) to support its Tracking and Data Relay Satellites (TDRS), which relay data from remote sensing satellites to Earth (see figure 2-11). WARC-92 considered reallocating these frequencies in order to correct shortages in the amount of spectrum available for FSS uplinks relative to downlinks. The shortage was 500 MHz in Region 2 and 250 MHz in Regions 1 and 3.

U.S. PROPOSAL

Because of existing uses in the band 14.5 -14.8 GHz, the United States strongly opposed reallocating these frequencies for FSS. The United States said it would not agree to any licensing of freed-satellite operations in the band, nor to protect such operations from interference from other users. As a result, the United States proposed that the allocation at 14.5 -14,8 GHz remain unchanged.

RESULTS

The United States was successful in preventing WARC-92 from reallocating the band. Instead, the conference allocated 250 MHz to FSS uplinks at 13.75 -14.0 GHz. The allocation is coprimary with radiolocation services, and standard frequency and time signal-satellite and space research services are secondary. Two footnotes were added to the allocation. Footnote 855A specifies power levels and antenna sizes for Earth stations, and footnote 855B lays out a phase-in schedule for making FSS primary in the band. In addition, WARC-92 adopted Resolution 112, which calls on the CCIR to conduct sharing studies between FSS and the existing services in the band, and evaluate the impact of the FSS on these other services.

DISCUSSION

The U.S. Government had put an absolute block on these frequencies in order to protect Department of Defense systems supporting national security interests. Intelsat, with the backing of many developing countries, strongly supported the reallocation, while some European countries sided with the United States in opposition.

185 These satellite antennas are the large dishes familiar to most people.

ISSUES AND IMPLICATIONS

The FSS allocation at 13.75-14.00 GHz has mixed implications for the United States. On the positive side, government operations at 14.5 -14.8 GHz were successfully protected. On the other hand, the United States must now share 250 (out of 600) MHz of spectrum that had been devoted to active sensors, such as radar altimeters. The impacts of this sharing on the existing services in the band, especially the space services, are not known, and will be studied as noted above. Some protections are given to the existing services in the footnotes adopted by WARC-92. The United States may revisit this issue at a future conference in order to allocate additional frequencies for sensor applications or further protect existing services.

■ Space Services

SPACE RESEARCH AND OPERATIONS SERVICES BELOW 2 GHz

Background —The need for communications to support space activities by the nations of the world has grown significantly in recent years. Radio frequencies are used in space to communicate with manned spacecraft, to command and control satellites, to relay data from remote sensing satellites to Earth, and to communicate with astronauts working outside their spacecraft. The United States, for example, uses these frequencies during shuttle missions, for support of the Hubble Space Telescope, and may need them for future operations of Space Station Freedom.

The frequencies allocated to these communications and support services, like frequencies in many other bands, have grown increasingly congested over the years.[186] The 2 GHz bands, which were used for both the Apollo and Soyuz space missions, are becoming especially prone to interference because of their favorable transmission characteristics and high reliability. In 1979, there were just over 70 assignments for space uses of these frequencies. By 1992, this number had risen to over 300 assignments around the world.[187] The most recent and dramatic example of the congestion now plaguing space communications was demonstrated during the rescue of the Intelsat VI satellite by U.S. shuttle astronauts—interference was evident in conversations between the astronauts and their colleagues in the shuttle and on the ground.

U.S. Proposals-The United States had several proposals for Space Research and Space Operations Services in the 400-420 MHz and 2 GHz bands. In the band 400.15-401 MHz, the United States proposed that a footnote be added to the Space Research Service specifically allow space-to-space communication between manned vehicles in space-in support of docking maneuvers, for example. In the band 410-420 MHz, the United States proposed to add a coprimary allocation for the Space Research Service to allow communications in support of extra-vehicular activities (EVA)—work performed by astronauts while they are outside their spacecraft. These activities include such things as maintenance on both the shuttle and Space Station Freedom and future satellite rescues.

The United States proposed to upgrade allocations to the space services to primary status in various frequencies between 2025 and 2290 MHz. Previously, these bands had only been allocated to the space services through footnotes (747, 748, 750), and were subject to difficult coordination requirements under Article 14 of the international Radio Regulations. The proposed

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186 WARC-ORB-88, for example, noted in Recommendation 716 the increasing use of these bands by the space research and space operation services, leading to increased coordination difficulties. Recommendation 716 further notes that this congestion may slow the development of such services. Both W= C-ORB-88 and WARC MOB-87 requested that a conference be convened to address these issues.

187 Robert Taylor, Spectrum Management Specialist, National Aeronautics and Space Administration, personal communication, July 10, 1992.

upgraded allocations (which would eliminate Article 14 coordination requirements) included[188]:

- 2025-2110 MHz to space research, space operation, and Earth exploration-satellite (uplink and space-to-space) services;
- 2110-2120 MHz to space research service (uplink for deep space activities-defined as distances greater than 2 million kilometers from the Earth); and
- 2200-2290 MHz to space research, space operation, and Earth exploration-satellite (downlinks and space-to-space) services.

Results-U.S. proposals were generally successful. In the band 400.15-401 MHz, the requested footnote was added to the primary space research allocation enabling these frequencies to be used for space-to-space communications. These frequencies will be shared among a number of services, including downlinks for little LEOS services. Spectrum was also allocated to the Space Research Service at 410-420 MHz, but on a secondary basis. It is likely that the United States will seek to have this allocation upgraded at a future conference, once interference and sharing concerns with terrestrial users are resolved.

In the 2 GHz bands, all U.S. proposals were accepted by the conference. However, a footnote was added to the bands 2025-2110 MHz and 2200-2290 MHz to protect communications between geostationary and non-geostationary satellites. WARC-92 also adopted Resolution 211, which calls for additional study of sharing between the space services and mobile services (see below) and Resolution 710, which calls for a future conference to consider upgrading the status of the Meteorological-Satellite and Earth Exploration-Satellite Services (401-403 MHz) to coprimary status.

Discussion and Implications-In years past, some ITU members had opposed the upgrading of the space services, primarily because of the possible interference they could cause to existing freed and mobile systems. Observers note several reasons for the change at WARC-92. First, the space services had been operating in these bands under their footnote allocations for many years. Experience had shown that sharing with the freed and mobile services could be accomplished, at least for some mobile services (see below). Second, the various space agencies of the world had been working on these issues before the agenda for WARC-92 was even set, and had already reached a tacit agreement in the Space Frequency Coordination Group (SFCG), composed of space agencies from around the world. That agreement was translated back to member governments and was used to build support for U.S. space proposals at WARC-92. As a result, a high degree of coordination and cooperation existed between SFCG members prior to WARC-92, making the negotiations for space services allocations at the conference relatively easy. Interestingly, CEPT was an important element of this process, since Germany, France, and the European Space Agency are all members of the SFCG.[189] The successful negotiation and resolution of the space issues serves as a counterpoint to the difficulties the United States had with the CEPT bloc in other areas, and indicates that the United States and Europe may be able to work together in the future.

Sharing between mobile services and the newly upgraded space services will be a subject of continuing study and experience. Sharing difficulties may limit the number and/or kinds of mobile services that can operate in the bands. Proponents of the mobile services point out that sharing has been demonstrated over time. However, this sharing has generally only been with

188 All these allocations would be on a coprimary basis and would share with terrestrial freed and mobile services.

189 As of November 1992, the members of the SFCG included: Argentina, Australia, Austria, Belgium, Brazil, Canada, China, European Space Agency, France, Germany, India, Italy, Japan, Netherlands, Russia, Spain, Sweden, United Kingdom, and the United States.

"low-density mobile systems, " such as electronic newsgathering (ENG) services. Resolution 211 notes that the introduction of conventional landmobile systems, such as cellular/PCS/FPLMTS-type services, would cause "unacceptable interference to the space services," and calls for the CCIR to continue its studies of protection for the space services from mobile services.[190] It also suggests that future limits on mobile systems may be needed to permit the services to continue to share the bands. This would clearly constrain the types of mobile services that could use the band, Until the CCIR finishes its studies, the resolution recommends that only "low-density mobile systems," be permitted-no conventional land mobile services such as cellular phone service or PCS/FPLMTS.[191] Resolution 211 also calls for a future conference to define the conditions for sharing between mobile and space services.

U.S. space service proponents won what they perceive to be an important battle against the increasing number of mobile services in the 1-3 GHz band. With their new status, and the new limits proposed in Resolution 211, the space services seem well-positioned to continue and expand their use of these 2 GHz bands. The limits proposed on mobile services, on the other hand, should not greatly affect future U.S. interests since the FCC's emerging technologies proceeding does not include these bands. The impacts are likely to be greater in Europe, with their increasing push for terrestrial mobile systems (although this will not affect FPLMTS, since it is not identified for use in 2025-2110 MHz or 2200-2290 MHz). The new allocations may also help to solidify the status ENG operators, of which the United States has many, since they apparently can share with the space services, and future competition from other mobile systems will be limited.

SPACE SERVICES ABOVE 20 GHz

Background—As the bands around 2 GHz become increasingly crowded, space operations and services have had to look for additional spectrum at higher frequencies. Congestion in the 2 GHz bands is exacerbated by the ever-increasing bandwidth requirements of NASA's space operations, especially data collection from remote sensing satellites. For example, although NASA currently uses the 14 GHz bands for data relays, it is already considering higher bands (around 23/26 GHz) to serve future generations of satellites.

U.S. Proposals and Results--The United States had a number of proposals regarding various satellite-related and space services above 20 GHz. These are summarized below.

Inter-Satellite Links: The United States proposed to allocate the 21.7-22 GHz band to support links between satellites of the various mobile satellite services. These frequencies, for example, could be used to provide communications between satellites as envisioned in Motorola's Iridium system. The United States also proposed a primary allocation in the 25.25-27.50 GHz band for wideband space-to-space links to support space research and Earth exploration-satellite applications. These links would be used to transmit data, including high-resolution video, from low orbiting spacecraft such as the United States space shuttle or Space Station Freedom to geostationary data relay satellites, including the U.S. TDRS.[192] The existing intersatellite service allocation would be used for TDRS-to-user links in the 22.55-23.55 GHz band based on the availability of bandwidth and the feasibility of

190 ITU, *Final Acts,* Resolution COM4/2, op. cit., footnote 27, p. 81.

191 PCS and FPLMTS, however, are not currently proposed for use in these bands.

192 Four TDRS systems are now being developed-by the United States, the European Space Agency, Japan, and the Commonwealth Of Independent States. The United States system is the only one operational at this time, serving approximately 100 satellites.

sharing, See figure 2-11.193 In addition, these wideband space-to-space links could be used to provide communications between Space Station Freedom and a variety of space vehicles flying near it.[194]

The U.S. proposal for 21.7 -22.0 GHz was not accepted. However, an equivalent amount of spectrum (300 MHz) was allocated at 24.45-24.75 GHz for intersatellite service. For the wideband satellite links at 22.55-23.00, the BSS allocation was deleted to make more room for future intersatellite links. The U.S. proposal for a primary allocation at 25.25-27.50 GHz was accepted.

Space Research Service Requirements: To support domestic and international space research efforts, the United States proposed two new allocations. The first proposal was for coprimary allocations at 37-38 GHz (downlink) that would support space research activities such as Very Long Baseline Interferometry (VLBI) by satellite,[195] which requires wide bandwidths to send data. In addition, the 37-37.5 GHz (downlink) would also be used in conjunction with 39.5 -40.5 GHz (uplink) to provide communications with a planned station on the Moon and the mission to Mars in the 21st century. Because of the intense use of data communication these efforts will require, wideband radio links will be needed.

> There are no frequency bands allocated in the Radio Regulations that could be used for wide bandwidth links between the Earth and the Moon and between the Earth and Mars. Use of the same band for both sets of links is desirable because it would permit use of common equipment, ..196

The United States also proposed a worldwide upgrade for the Space Research Service (for deep space research-such as the Voyager and Viking interplanetary missions) to coprimary status at 31.8 -32.3 GHz (downlink) and 34.2-34.7 (uplink) to support increasing space activities in these bands. Currently, these bands are allocated to the Space Research Service worldwide, but only on a secondary basis, and not for deep space research. The United States, however, and 10 other countries had different allocations.[197] This disparity created a situation that the United States believed threatens future deep space research missions at a time when the trend toward international cooperative missions for deep space exploration creates the need for increasing unity and cooperation.

> There is a serious potential for interference to national and international deep space missions because the current allocations allow uplinks and downlinks for space research conducted by Earth orbiters to use the same bands as deep space links. These links are not compatible because of the widely different transmission [power] and received signal strengths, [198]

The U.S. proposal for space research (VLBI) and communication downlinks (for a lunar colony) at 37-38 GHz was accepted, but WARC-92 allocated only half the proposed amount for the uplink frequencies--4O-4O.5 GHz. Although this creates an imbalance in the frequencies available

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193 Current TDRS satellites use 13.4-14.0 GHz for sending the&@ from the TDRS satellite to the ground station at white Sands, New Mexico. These space research frequencies, however, are only secondary (to radiolocation services). The next generation of satellites, however, will use government frequencies in the 20.2 -21.2 GHz band.

194 Portions of these frequencies may also be used to co remand and control remote robots working on the space station, and retrieving remote scientific modules that would be in orbit near the space station.

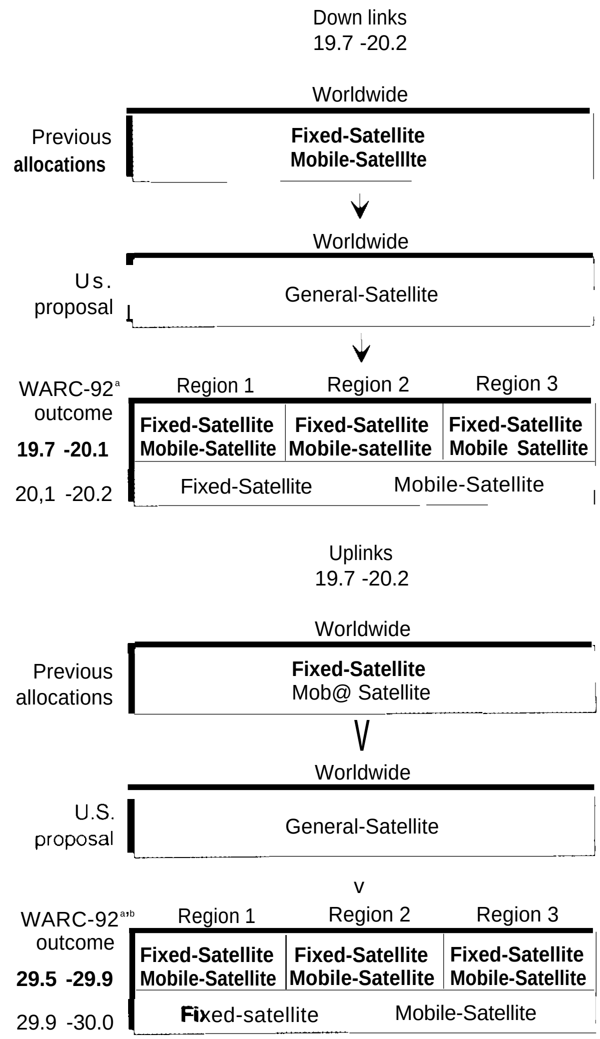
195 VLBI refers to measurements made using satellites that enable scientists to track geodetic movements on Earth and provide information on the changes caused by earthquakes.

196 U.S. Department of State, *u.S. Proposals,* op. Cit., footnote 5.

197 See footnotes 890 and 891 of the ITU, *Radio Regulations,* op. cit., footnote 19.

198 U.S. Department of State, *U.S. Proposals,* Op. Cit., footnote 5.

Figure 2-12—U.S. Proposal for General-Satellite Service



a A number of footnotes further define the uses of these bands.
b This band is also allocated to the Earth Exploration-satellite Service on a secondary basis.

NOTE: Radio services in all capital letters are allocated on a primary basis. All others are secondary.

SOURCE: Office of Technology Assessment, 1993.

for uplinks and downlinks, the needs outlined above should be satisfied.

The U.S. proposal for deep space downlinks at 31.8 -32.3 GHz was accepted, but an existing footnote (893) designed to protect the navigation systems in the band could limit some uses. Sharing and interference criteria will have to be worked out on a case-by-case basis. The U.S. proposal for deep space uplinks at 34.2 -34.7 GHz was accepted. Additional allocations were made to the space research service (downlinks) on a secondary basis in the band 74-84 GHz.

General-Satellite Service: The United States proposed a new service, the General-Satellite Service (GSS) that would have operated at 19.7 -20,2 GHz (downlinks) and 29.5 -30.0 GHz (uplinks), and would have replaced current primary fixed-satellite and secondary mobile-satellite service allocations in those frequency bands. This proposal was based on efforts now underway in the United States to develop and implement communications satellites integrating a wide variety of capabilities on a single, flexible-use satellite. These include fixed, mobile, and point-to-multipoint applications. The U.S. (Government and industry) position is that such flexibility is needed in order to better match future satellite capacity with future satellite communication needs.

The concept of a General-Satellite Service was not adopted by WARC-92. The United States did win a minor victory by having MSS upgraded to coprimary status in 19.7 -20.1 GHz, but only in Region 2 (see figure 2-12). MSS was also made coprimary worldwide at 20.1 -20.2 GHz. Similarly, MSS was upgraded to primary status in 29.5 -29.9 in Region 2 and worldwide only at 29.9-20.0. However, a number of footnotes will affect the use of these bands. First, existing footnote 873 allocates these same bands to the terrestrial fixed and mobile services on a primary basis for large sections of Africa, the Middle East and Asia. Five new footnotes describe various limitations and conditions that MSS networks must meet to operate in the bands, including coordination requirements relating to the countries in footnote 873. WARC-92 also adopted Recommendation 719 that calls for studies to be conducted on the technical and sharing characteristics of 'multiservice' satellite networks.

In line with the decisions of WARC-92, the FCC has adopted an NPRM to upgrade MSS to coprimary status in the 19.7 -20.2 GHz and 29.5 -30.0 GHz bands. The notice responds to a July 1990 proposal by Norris Satellite Communications to establish a general satellite service to provide fixed, broadcast, mobile, and personal communications services in the Ka-band. While the upgrade to MSS will enable Norris to operate many services, broadcast services are still not allowed. The FCC hopes that broadcasting experiments in the 20/30 GHz range as part of NASA's Advanced Communications Technology Satellite (ACTS—scheduled for a 1993 launch) will answer sharing and interference questions regarding shared use of the band by broadcasting and other satellite services. Depending on the success or failure of the ACTS experiments and Norris' efforts, the United States may pursue a GSS definition and allocation at future world radiocommunication conferences.

Earth Exploration-Satellite; Earth Exploration-Satellite Services (EESS) are being increasingly used by the United States to obtain higher quality data about the Earth and regions of the atmosphere that are not available through the use of other frequencies. To avoid the potential of future interference to these activities, the United States proposed a primary allocation for EESS (passive) allocations at 60.7 -60.8 GHz and 156-158 GHz.[199] However, because of domestic coordination and preparation problems, the 60 GHz proposal was withdrawn.

The 156-158 GHz proposal was accepted. Other EESS allocations made at WARC-92 include secondary allocations at 25.5-27 GHz (downlink-to be shared with the **intersatellite links** noted above), 28.5 -30.0 GHz (uplink-limited to data transfer), and 37.5 -40.5 GHz (downlink-shared with a variety of services).[200] A number of footnotes, however, which relate to the operation of the FSS in the 28.5 -30.0 GHz band will affect EESS operations, and may constrain future development of EESS services in that band.[201] Sharing and coordination arrangements will have to be developed for all these allocations.

Radiolocation-Satellite Service: The United States proposed to define a new space service, the Radiolocation-Satellite Service, and to provide a primary allocation for this service in the band 24.55-24.65 GHz. This new definition and allocation will provide for satellite-based location services to a variety of users.

The U.S. definition was adopted, but the proposed allocation was made in a slightly higher band-24.65-24.75 GHz, and only for Region 2.

Discussion—The U.S. proposals for space services were the most successful proposals the United States made at WARC-92. Much of the success of these proposals has been attributed to the work done prior to WARC-92 in the SFCG. As noted, this group provides a forum within which the space agencies of the world can discuss their spectrum needs and identify future spectrum requirements. This mechanism makes it much easier to precoordinate frequency allocations for space services and applications at international conferences such as WARC-92. The group also provides a mechanism for space agencies to build support for their proposals and generate cross-support among different nations.

199 The use of these bands for this type of data collection is "passive," meaning that radio waves being received by the satellite are merely measured and recorded for analysis. "Active" data collection on the other hand, is accomplished by a satellite sending out signals (such as radar) to a particular target (layers of the atmosphere, the Earth itself) and analyzing the signal when it returns.

200 A primary allocation was also made to EESS at 40-40.5 GHz.

201 Some of these footnotes were proposed by the United States to provide uplink power control systems that will be required to enhance FSS performance. Currently, the 27.5-29.5 GHz band is allocated to the FSS for uplink use only. A downlink signal is required to provide adequate information to control system performance. To accommodate a downlink transmission to support these power control systems, the United States proposed to add a footnote to permit the use of downlink beacon operations within the 27.5 -29.5 GHz band. This proposal was accepted, but was further refined and divided into footnotes 882A and 882B.

The problems with GSS were slightly different and more political in nature. The Europeans saw no need for the new service, maintaining that existing allocations provide adequate flexibility.[202] This view is similar to the European views on and opposition to the generic MSS allocation proposed by the United States. This recurring split may indicate either a deeper philosophical opposition to more generic, vague service allocations, or it may simply indicate a fear of, generic-type services on the part of the Europeans.[203]

Depending on the actual reason for this opposition, two factors may influence the success of future U.S. GSS (and generic MSS) proposals. First, the European preference for more stratified allocations may come from a stronger belief in planning and/or that more specific allocations are easier to use. The United States, on the other hand, generally has rejected *a priori spectrum* planning, preferring to let market forces dictate spectrum uses. Second, and perhaps more likely, economic advantage may be the driving force behind European opposition. It appears the United States has a slight technological lead in MSS and advanced space applications, and the Europeans may believe that GSS systems will give the United States a greater advantage in building systems and providing services in these new, and as yet undefined, allocations.[204]

Implications—The space communications allocations made at WARC-92 represent some of the United States' more clear-cut successes at WARC-92. The United States got most of the allocations it wanted in this area (with the exception of GSS), and seems well-positioned to move ahead with plans for future space missions and activities.

The implications for future GSS-type services are less clear. Proponents maintain that the allocations made will allow services very similar to what a GSS would have allowed-permitting *de facto GSS* systems to operate. This belief is probably overoptimistic. The various footnotes and political opposition associated with the so-called GSS bands will make establishment of a GSS-type service complex. The successful development of such systems by the United States or others will depend on how much the political opposition fades and the manner in which sharing arrangements are resolved. Systems will develop as negotiations allow.

202 Reportedly, an agreement to support some type of multiuse satellite concept was worked Out between representatives of the United States and CEPT. EC observers, however, apparently feeling that Europe had been too willing to compromise on other issues, decreed that no compromise on GSS would be acceptable. Consequently, the Heads of the European Delegations opposed the U.S. proposal.

203 It is interesting t. note, however, that the Europeans did support FPLMTS, a concept that is as poorly defined as GSS or generic mobile.

204 On the other hand, when the Europeans have the perceived advantage, as they do in terrestrial mobile systems, for example, the tables turn--the vagueness and flexibility (of FPLMTS) become acceptable to them, but not to the United States.