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Federal Communications Commission
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Satellite Radio Bra

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D. C. 20554

In the Matter of the Application of	)	
	)	
SATELLITE CD RADIO, INC.	)	File Nos. 49/50-DSS-P/LA-90
	)	58/59-DSS-AMEND-90
for authority to construct, launch and operate a digital audio radio service satellite system	)	

Motorola Inc. is pleased to submit the attached comments in regard to the application captioned above.

Michael A. Menius

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November 30, 1990

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Federal Communications Commission
Office of the Secretary

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COMMENTS

1. Motorola Inc. opposes the grant of the above-captioned application as it is presently configured; that is, with signal downlinks to the individual receivers using the 1470-1530 MHz frequency band. This spectrum is urgently needed for development and expansion of other emerging land mobile services.

2. The 1429-1525 MHz band is not currently available for Broadcast Sound Satellite service. Instead, this band is designated in World Region II (including the United States) for co-primary use by fixed and mobile operations. The land mobile committee (Ad Hoc Group D, Interim Working Group 2) of the US Advisory Committee preparing for the 1992 Mobile World Administrative Radio Conference (WARC 92), has recommended that this designation be retained. Motorola supports this recommendation. It is essential that additional spectrum be allocated for expansion of land mobile services, for two reasons. First, the growth of land mobile services is closely linked to increases in national productivity, as well as to meeting the personal communications needs of the public. Secondly, additional land mobile spectrum must be made available if the nation is to maintain its technological leadership in the global arena of emerging telecommunications services. Other nations are moving forward to make substantial amounts of spectrum available in the 1 - 3 GHz band, because the importance of telecommunications to the overall economy is clearly understood. The United States cannot afford to lose its leadership position by failing to do the same.

3. Motorola further suggests that, in lieu of a grant of the instant application to operate as proposed in this band, the public interest would better be served by permitting mobile satellite service, such as IRIDIUM's low earth orbit satellite service. IRIDIUM is a unique technology, offering a highly spectrum efficient (voice and data) mobile satellite service to users around the world. A discussion of this exciting technology is contained in the comments which Motorola filed in the Commission's digital audio rule making (FCC General Docket No. 90-357). A copy of these comments is attached as Appendix I.

4. In its broad inquiry on the digital audio radio service, the Commission has called for comment on several different bands, including the possible accommodation of digital audio radio service in the bands generally allocated for mobile satellite service.[1] Additionally, in the Second Notice of Inquiry in preparation for the 1992 WARC, the Commission has proposed use

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1 The comments filed by the American Mobile Satellite Corporation (AMSC) have confirmed that such an accommodation is feasible.

of the 728-788 MHz terrestrial broadcasting bands on a shared basis, and the 2390-2420 MHz band. Motorola strongly urges that, in lieu of granting the instant application for use of the 1470-1530 MHz band, the Commission should fully explore the other various options. This particular band is not appropriate for BSS.

5. In conclusion, Motorola opposes the grant of the instant application. The Commission should instead proceed to conduct the digital audio rule making, conclude its preparations for WARC 92, retain the co-primary designation of this spectrum for fixed/mobile use, and consider making the band available for use by mobile satellite applications such as the IRIDIUM low earth orbit satellite service.

APPENDIX I

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

Nov 13 '90

In the Matter of

Amendment of the Commission's Rules with regard to the Establishment and Regulation of New Digital Audio Radio Services	))))	GEN Docket No. 90-357

COMMENTS

Motorola Inc. is pleased to submit the attached comments in the Commission's digital audio radio inquiry.

Respectfully submitted:

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November 13, 1990

COMMENTS
FCC General Docket No. 90-357

SUMMARY

1. The Commission's inquiry into digital audio radio services seeks to focus public attention on this new medium in order to take appropriate and timely regulatory action "to facilitate the emergence of digital radio as appropriate."[1] The Notice further highlights the important regulatory issue of the impact on existing audio services of regulatory alternatives relating to digital audio. The 1460-1530 MHz band which was discussed in the Notice of Inquiry is not appropriate for such an allocation. It is urgently needed for other services and technologies which are even more crucial to the nation's technological leadership. In Region II this band is currently designated as co-primary fixed/mobile use. This band should not be reallocated for digital audio radio service, as petitioned by Satellite CD Radio. The public interest would better be served by permitting the additional use of this band for low earth orbit satellite service, as exemplified by IRIDIUM. As has been described in other filings with the Commission, the exciting IRIDIUM technology carries the promise of maintaining the nation's technological leadership in mobile satellite communications as well as efficiently meeting the telecommunications needs of many users around the entire world. Since this band is already designated for co-primary fixed/mobile use, an alternative would be to allow compatible sharing with existing users and land mobile services.

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1 <u>See</u> "Notice of Inquiry," ("Notice") GEN Docket No. 90-357, released August 21, 1990, par. 7.

BACKGROUND

2. The Commission's Notice seeks to initiate an initial inquiry at this time into the development and implementation of a new digital audio radio service, in order to enable the Commission, if appropriate, to act in an expeditious and reasoned manner to facilitate the emergence of digital radio. The Commission emphasizes the United States' current efforts to formulate frequency allocation proposals for the 1992 World Administrative Radio Conference (1992 WARC).[2] As the Notice of Inquiry points out, a number of filings have already been received by proponents of several variations, both satellite-based and terrestrial, of digital audio radio services. One way or another, each such petitioner/applicant seeks a license (and thus a spectrum "home") somewhere within frequency bands which are currently used or are being sought by other spectrum users. Whatever decisions the Commission may ultimately reach concerning digital audio radio services will extend beyond the specific requests of these individual petitioners, so an inquiry proceeding is appropriate at the outset.

3. Motorola suggests that, if the Commission concludes in this proceeding that digital audio radio service allocation(s) are in the public interest, it should at the same time explore fully the possibility of utilizing spread spectrum technology in whatever band(s) may be allocated. This technology offers sharing opportunities with existing

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2 See Notice, par. 7.

users as well as protection against intentional and unintentional interference.

4. While the Inquiry makes no specific proposals to allocate spectrum, it calls for comment on the filings previously submitted concerning terrestrial or satellite digital audio services. One petition, that of Satellite CD Radio, requests that the 1460 - 1530 MHz band be reallocated for a hybrid version, 10 MHz for terrestrial and the remainder for Broadcast Sound Satellite service (BSS). Without taking any position on the technical merits of the Satellite CD Radio proposal, Motorola opposes the allocation of this particular band to digital audio radio service; this frequency band is more urgently needed for development and expansion of other emerging land mobile services.

5. Alternative frequency bands have been proposed for the broadcast sound satellite service. In the Second Notice of Inquiry in preparation for the 1992 WARC, the Commission has proposed use of the 728-788 MHz terrestrial broadcasting bands on a shared basis, and the 2390-2420 MHz band, with a complementary terrestrial broadcast service.[3] Additionally, in the instant proceeding, the Commission called for comment on the possibility of accommodating DAR service in the bands generally allocated for mobile satellite service.[4] Motorola urges that

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3 See Second Notice of Inquiry ("Second WARC Inquiry"), FCC Gen. Docket No. 89-554, released Oct. 1, 1990, pars. 97 - 104.

4 See Notice, par. 12.

these alternative options be explored fully, and that the 1460 - 1530 MHz band not be allocated for DAR.

6. The frequency band 1429 - 1525 MHz is presently designated in Region II (including the United States) for co-primary fixed/mobile use. The land mobile committee (Ad Hoc Group D, Interim Working Group 2) of the US Advisory Committee preparing for the 1992 Mobile World Advisory Radio Conference (WARC 92), has recommended that this designation be retained. Motorola supports this recommendation. It is essential that additional spectrum be allocated for expansion of land mobile services, for two reasons. First, the growth of land mobile services are closely linked to increases in national productivity, as well as meeting the personal communications needs of the public. Secondly, additional land mobile spectrum must be made available if the nation is to maintain its technological leadership in the global arena of emerging telecommunications services. Other nations are moving forward to make substantial amounts of spectrum available in the 1 - 3 GHz band, because the importance of telecommunications to the overall economy is clearly understood. The United States cannot afford to lose its leadership position by failing to do the same.

7. Motorola further suggests that, instead of an allocation to broadcast sound satellite service, the public interest would better be served by the operation of low earth orbit satellite service (as exemplified by IRIDIUM) in the 1460 - 1530 MHz band. IRIDIUM is a unique technology, offering a highly spectrum efficient (voice and data) mobile satellite service to users around the world. A discussion of this exciting

technology is contained in the appendix.[5] IRIDIUM holds the promise of maintaining the nation's technological leadership in mobile satellite communications as well as efficiently meeting the telecommunications needs of many users around the entire world. An allocation which provides adequate spectrum for IRIDIUM-type low earth orbit mobile satellite service is urgently needed.[6] This particular spectrum is adjacent to spectrum which is being considered for generic mobile satellite service and is ideally suited for implementation of Iridium. These important possibilities should not be precluded by an allocation in this particular frequency band to broadcast sound satellite services.

8. As noted previously, the 1460-1530 MHz band is designated in World Region II as co-primary fixed/mobile use. Use of this band for broadcast sound satellite services has been strongly opposed by aeronautical telemetry users who contend sharing is not feasible. There are preliminary indications, however, that it may be possible for an IRIDIUM-type system to share operations with the same users. A number of different sharing options are currently being actively pursued with the aeronautical telemetry community.

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5 IRIDIUM can operate in a single frequency band; i. e., it is capable of bidirectionally transmitting and receiving in a single band.

6 Motorola has previously urged the Commission to make the 1530-1544 /1626.5-1645.5 MHz band available for Iridium and LEO service. This band has been proposed to be made available for generic mobile satellite service. See "Notice of Proposed Rule Making," ("generic mobile satellite rule making") FCC GEN Docket No. 90-56, released March 5, 1990.

9. In conclusion, the Commission should continue to study the comments received in the DAR rule making. If it is determined that an allocation is in the public interest, the Commission should also explore the benefits of utilizing spread spectrum in digital audio radio service. Among the various alternative bands on which the Commission requested comments, the 1460-1530 MHz band is clearly not appropriate and should be rejected. The public interest is far better served by allowing this band to be made available for mobile satellite service, including in particular low earth orbit, IRIDIUM-type service. Such a regulatory decision will help maintain national productivity while also permitting technical leadership in the arena of future and emerging mobile satellite service.

LOW-EARTH ORBIT GLOBAL CELLULAR COMMUNICATIONS NETWORK

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Abstract

The technical parameters which led to Motorola's newly announced Iridium system are discussed. Iridium is a worldwide, digital, satellite-based, cellular, personal communications system primarily intended to provide commercial, low-density, mobile service via portable, mobile, or transportable user units, employing low-profile antennas, to millions of users throughout the world. Calls can be made and received anywhere in the world with a personal, portable unit. Seventy-seven small (320 Kg), smart satellites are internetted to form the network's backbone. Small, battery-powered, cellular-telephone-like user units communicate directly to the satellites. Gateways (earth stations) interface from the satellites to the individual Postal, Telephone and Telegraph Authorities (PTTs). The system is intended to complement the terrestrial cellular telephone systems installed, or being installed, in densely populated areas by providing a similar service everywhere else in the world. Iridium is much more than the technology that allows it to be built -- Iridium is a vision, a realizable vision, for a worldwide portable, personal communications system -- a vision whose greatest realization, like the telephone of a century ago, are beyond today's imagination.

Introduction

Iridium was named by a cellular telephone system engineer, Jim Williams, who works in a Motorola facility in a suburb of Chicago -- the 77-satellite constellation reminded him of the electrons encircling Bohr's atom, so Mr. Williams looked to see what element has 77 electrons. The instant he suggested the name, Iridium, a twinkle flashed in the eyes of the rest of the Iridium team -- they knew their system had been named. It was some 15 months later, just prior to the public announcement of Iridium that the Iridium team learned that the high concentration of Iridium in a large meteor which struck the earth is "credited" with providing the final blow to the earth's dinosaur population -- the team could only wonder what conjecture would follow -- it was too late, the name was not going to be changed, the announcement was imminent.

Iridium is truly an amalgamation of technologies that were creatively interwoven by a small team of engineers with dissimilar backgrounds inside a company with diverse areas of expertise. The key technologies include wireless communications in two realms: space communications systems and cellular telephone systems. Important supporting technologies include small satellites, phased-array antenna systems, functionally-dense radiation-tolerant semiconductors, advanced baseband processing architectures, and distributed network architectures.

The global international economic industrial process providing the momentum for Iridium is man's apparently unquenchable desire for mobile communications. The demand for terrestrial cellular

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closely to local demographic considerations. Currently, the highest demands for service are during the "rush hour" commuter periods in Los Angeles, where the car telephone both extends the business day and eases the drivers' tension. The number of cellular telephones now exceed 7 million--the number anticipated in 1983 to be achieved by the year 2000. More recent projections now are as high as 100 million, worldwide, by 2000. Iridium does not replace or substitute for cellular telephone service, but rather extends the radio-telephone coverage area to the entire world. Iridium, by its very nature, is a lower-density, higher-priced service than cellular. For a given amount of spectrum, a common modulation/multiplexing technique, and reuse pattern, the system capacity is driven by the number of cells that are created. Cellular telephone systems employ cells that have diameters as small as 1 mile, whereas Iridium's cells are about 400 miles wide, and, Iridium's per minute cost for service is estimated to be 3 to 10 times that of cellular. So where is the advantage?

Where an area is covered with a terrestrial-based cellular system, Iridium is a backup or emergency service. In areas of the world where no mobile service is readily available, Iridium is the mobile system. In areas of the world where mobile service is only provided with geostationary satellites, Iridium provides more channels, shorter delays, and worldwide networking. And, in areas of the world where there is no telephone service, Iridium can provide telephone service.

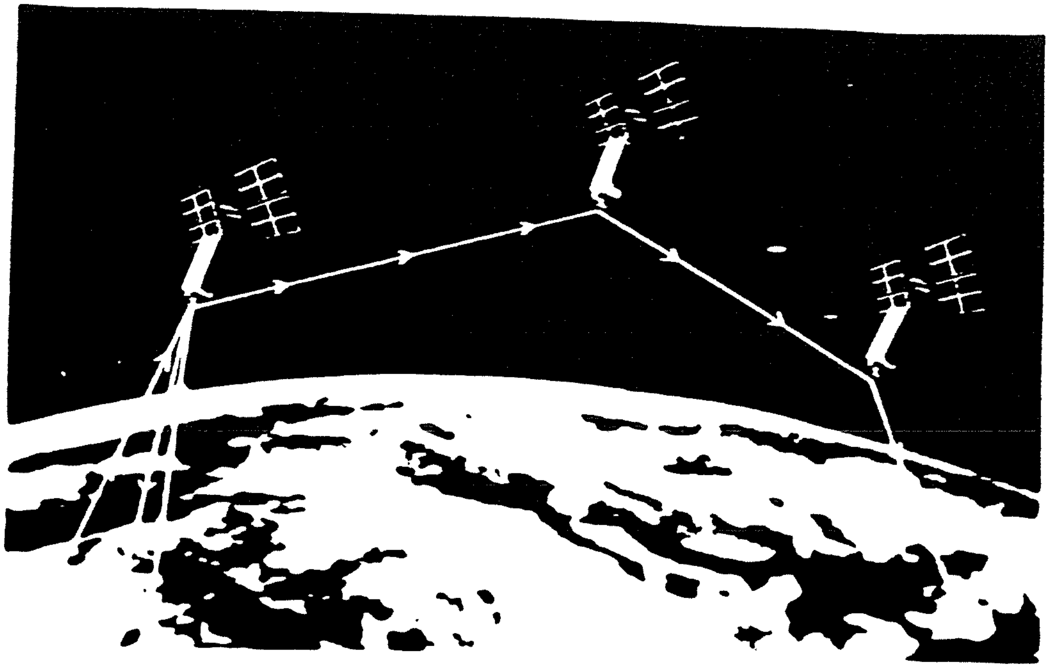
Iridium customers will be widespread and varied. An international business person with a portable unit in his coat pocket can have easy access to the home office, and the head of a large multinational corporation can quickly call any of his general managers, whether they are at home or traveling, on the earth's surface or in the air, anywhere in the world. The mountain climber, skier, or recreational sailor can continue to communicate with his brokerage business. Third world countries without a telephone infrastructure can have subsidized, solar-powered, centrally-located telephone "booths" in every village. Land and sea mining operations can have continuous worldwide service. And, areas experiencing natural disasters can maintain a reliable communications linkage to the rest of the world.

Some of the primary technical parameters of Iridium are described here, but quite obviously, Iridium's foremost challenges are not in the technology -- the regulatory and licensing aspects of a truly-worldwide, portable radiotelephone service are clearly the dominant issue areas. The technology is at hand, the authority to provide this service to all mankind is to be debated.

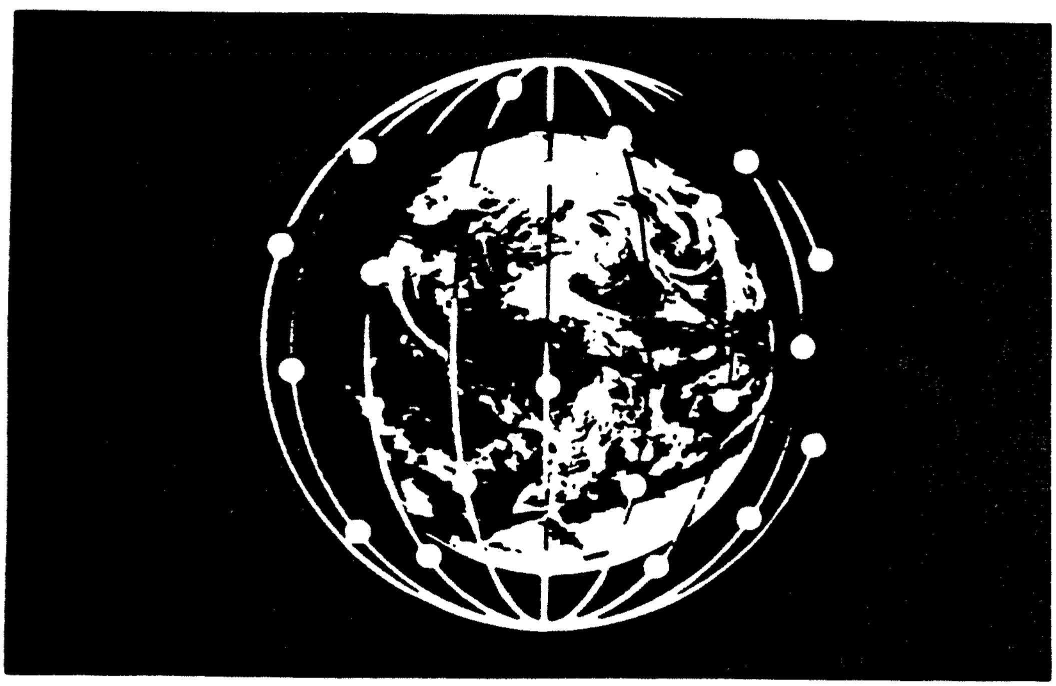
Scope

Prior to describing Iridium further, it is useful to state what Iridium is not. It is not a substitute for existing telephone or cellular telephone systems, which by their nature have much more capacity and lower rates. It is not a system that guarantees building penetration from a portable unit, yet its low-data-rate "ringer" will function at a much higher link margin. It is not a service which will categorically bypass local, national, or international excise taxes.

Iridium does provide direct line-of-sight communications to and from portable subscriber units on or above the earth's surface. Iridium is a digital communications system that operates in a cellular communications architecture. The constellation of satellites covers the earth with cells that allow channels to be reused many times. The individual cells are turned on/off as needed to cover the world.



When placing a call on the Motorola Iridium system, the signal is transmitted from the caller's portable cellular phone directly to the nearest overhead satellite which in turn sends the signal to an earth "gateway" station that verifies the caller as an authorized user. The call is then routed through the constellation of satellites to its destination anywhere on earth.



The heart of Motorola's Iridium system is a "constellation" of 77 satellites arranged in seven polar orbital planes. Each plane contains 11 satellites.

Iridium is a system that is in development, and though a complete, integrated baseline design exists, tradeoff analyses continue, and the final design for the satellites will not be frozen until early 1992. The system is to become operational by the end of 1996.

The Constellation

The constellation was chosen from among a family of constellations described by Adams and Rider (1), which provide full-earth coverage with a minimum number of satellites. The constellation employs optimally-phased polar orbits in which the satellites in the odd-numbered planes are in phase with one another but halfway out of phase with those in the even-numbered planes. The satellites essentially travel, in co-rotating planes, up one side of the earth, cross over at the pole and come down the other side of the earth. (The earth, of course, continues to rotate beneath them.) There is an area between the first and last planes where the satellites are essentially counter-rotating. Since the counter-rotating "seam" in the constellation does not cover the earth's surface with the efficiency of the optimally-phased co-rotating planes, Adams and Rider separate the first and last planes less than the co-rotating planes. Alternative constellations (e.g., those at other inclinations) would either require more satellites, higher altitudes, or a combination of both.

As an aside, nevertheless an important aside, it should be noted that for a cellular system that employs fixed geometry beams (keeping the satellites' antennas less complex than electronically scanned beams), it is important to keep each of the cells projected on the earth as equal in area as possible. This allows the system capacity to be set at a nominal level, and not limited to the largest (least dense) cell. Therefore, the circular orbits are very desirable.

The Iridium engineers chose a constellation, from among the family of constellations defined by Adams and Rider, with the configuration of seven planes, eleven satellites per plane for the reasons described below. This constellation employs co-rotating planes separated by slightly more than 27°, leaving about 17-1/2° separation for the "counter-rotating" planes 1 and 7. They set an orbital elevation of 413 nautical miles to guarantee grazing angles to the subscriber units are always 10° or more. (Consideration of higher altitudes, e.g. 490 n.mi. which yields grazing angles of 13° minimum, are still under consideration.)

The engineers' choice of constellation primarily balanced the overall cost of the constellation with the system capacity (i.e. the number of subscriber units which can be provided service). In general, the capacity varies directly with the overall number of satellites -- a 6-by-8 constellation (six planes, eight satellites per plane) would offer about 62% the capacity of Iridium's 7-by-11 constellation, while an 8-by-12 constellation would offer about 25% more than Iridium. The cost of the constellation is driven by the number of satellites, together with the size and complexity of the satellites.

In addition to balancing the system's cost and the system's capacity, several other considerations led to the 7-by-11 constellation. The engineers did not want a constellation higher than 600 nautical miles because the radiation environment would drive up the hardware costs. The engineers did not want to go lower than 200 nautical miles because the station keeping, and fuel, requirements would become excessive due to the increase drag.

In order to change the current paradigm of mobile satellite telecommunications, which today is dominated by relatively-large, geostationary satellites, each currently costing hundreds of millions of dollars, it was decided that for Iridium to be viable in the commercial realm, it would truly need to offer a new paradigm for mobile communications. The worldwide internetting of portable, handheld subscriber units is very visible and noteworthy, but there is more. Motorola, a distinctively successful worldwide manufacturer of high quality wireless communications equipment, drew from its strength: high quality manufacturing. The heart of Iridium, a system on which a profitable commercial endeavor can be based, includes a warm production line of small satellites, in stark contrast to large, generally one-of-a-kind, satellites intended for a geostationary orbit. Yes, space systems are different, but not so different that time-proven manufacturing principles cannot be applied to both reduce costs and to increase quality simultaneously. Motorola will achieve this in conjunction with a yet-to-be-named experienced satellite manufacturer -- several manufacturers from around the world are competing for this long-term production line.

The essence of a small, relatively simple, high quality design led to the decision to constrain the size, weight, and power limits to that of a Pegasus-like launch vehicle. Though a Pegasus, or a Pegasus-like launch vehicle has not been chosen for Iridium, and though an Ariane, Delta, Proton, Long March, or similar vehicles can be used to launch several Iridium space vehicles simultaneously, and though on-orbit sparing is a possibility, a Pegasus-like launch vehicle for the scheduled, as well as the unscheduled replacement of satellites, offers some advantages worth highlighting:

1) A "warm" well-exercised launch capability could lead to a more reliable and a less expensive capability, even if a dedicated aircraft were required;

2) Unscheduled replacement launches can be quickly scheduled, without today's concern for the availability of a polar-orbit launch site; and,

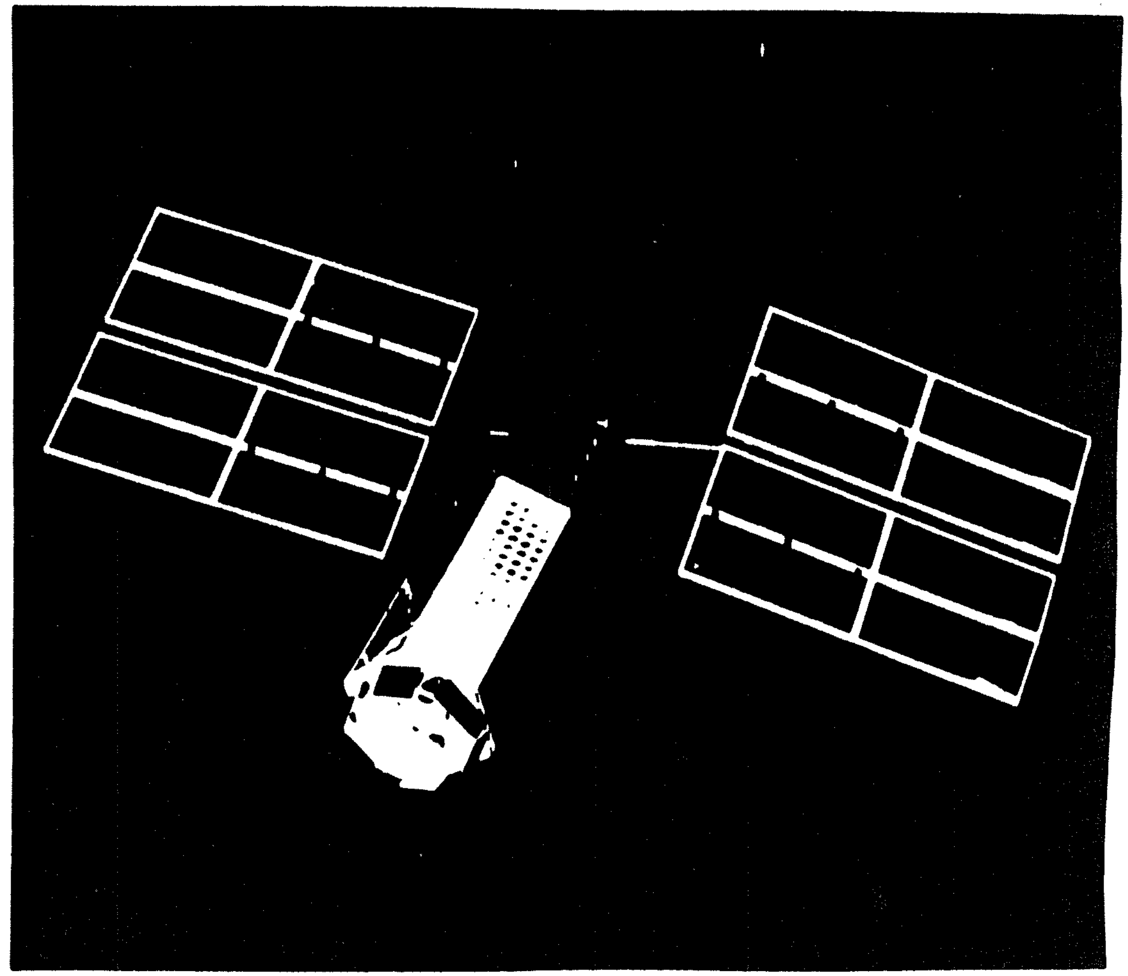
3) The Pegasus-like form-fit helps to enforce design, as well as cost, discipline into Iridium's developmental process.

One further point needs to be made regarding the satellites. To maintain the satellites' cost control, the design philosophy has always focused on simplicity over complexity -- this implies avoiding deployment of anything on the satellites other than the solar arrays. The satellites' antenna systems went through several iterations and some of the candidates included deployables. Without deploying the antennas, the dimensions are quite restrictive. The baseline design includes multiple-beam, fixed phased arrays (refer to the photograph of the model) that do not need to be deployed. Alternative non-deployable designs are continuing to be evaluated, but the implications are clear: the $25 million per satellite (on orbit) goal in a quantity of 77 is realistic, and the low-cost design implies little flexibility in the subscriber unit to/from satellite spectrum requirement (the system must be designed for a small piece of spectrum between 1 GHz and 3GHz).

The Communication Network

Iridium employs communication links in two portions of the spectrum. The up/down links between the satellites and the subscriber units are designed for L-Band operations. The satellites' crosslinks, as well as the up/down links to the gateways, are designed for Ka-Band operations. All links are circularly polarized.

Lightweight, portable subscriber units for the Iridium system communicate directly with satellites, using a small antenna.



Motorola's Iridium system is based on a costellation of 77 satellites in low earth orbit that use cellular technology to communicate with users on earth.

The L-Band links are dictated by the available technology that can provide link closure between the small satellites and the portable user units. The L-Band network employs a 37-hexagonal cell pattern from each satellite. The cells are designed for independent operation and each employs a different amount of power to close the links. The cell pattern is fixed relative to the space vehicle, but rapidly moving on the earth's surface. Handoffs occur from cell to cell as a subscriber unit is operated, similar to today's cellular telephones, but unlike those cellular telephones, the Iridium cells move through the users, rather than the users moving through the cells. Handoffs occur with the same frequency, about one per minute, as cellular telephones, but the handoffs in Iridium involve fewer handoff options and better information to choose from among the options than today's cellular telephone systems. In that sense Iridium is less complex. However, since Iridium's cell patterns overlap little in the low latitudes and very much in the high latitudes, Iridium has two problems to deal with that cellular telephones do not have:

1) Cells must be turned on/off depending upon their position in the orbit (when at the equator an individual cell will be on, and at some high latitude in each orbit it will be turned off for a period of time -- at any one time approximately 1,600 (56%) of Iridium's 2,849 cells are on). Of course, if operation were prohibited in some part of the world, more would be turned off.

2) The channel reuse pattern must be reset at different times during an orbital period -- a modified 7-cell reuse pattern is used.

The 7-cell reuse pattern was selected in a tradeoff analysis that considered the mainlobe and sidelobe interferences realized in alternative antenna designs. A theoretically, more-efficient 6-cell pattern is possible, but not within the antenna design constraints. The 7-cell reuse pattern basically provides a buffer of two cells between any two cells using the same channel. Within any individual satellite, this separation is strictly maintained; between two adjacent satellites more than one, but less than two, buffer cells are maintained for the cells at the boundary line. This reuse pattern offers part of the spectral efficiency realized with Iridium -- worldwide, the same channel can be reused over 200 times. The modulation form is QPSK and the L-Band multiplexing scheme is a combination of TDMA and FDMA. Over an area the size of the United States' 48 contiguous states, forty cells are formed with an average of 2 KHz of spectrum needed per usable channel. The reuse assignments employs a combination of fixed and dynamically assigned channels, so that both the entire world as a whole, as well as the possibly higher concentration of users in isolated localities, can be handheld with a balanced efficiency. For the current baseline point design for the initial constellation, the typical 360 n.mi. diameter cell can service up to approximately 150 simultaneous users, while isolated individual cells can handle 2 to 3 times that many.

Since no one can truly estimate the number of subscribers Iridium will generate or the usage patterns of those subscribers, it is difficult to put an exact number on the subscriber units the system can accommodate -- nevertheless by most accounts, the 2% average user rate experienced by cellular telephones is thought to be high; but, even if Iridium were used at this 2% rate with the baselined point design, several million users in reasonable locations in the temperate latitudes can be serviced (virtually all the others, in less likely subscriber areas, can also be serviced).

Iridium would break even financially with the baseline design at about 500,000 users worldwide, while 870,000 users represents a very lucrative business. The baselined architecture does allow for growth, and of course the initial constellation's capacity could be adjusted slightly higher or lower to accommodate costs, spectrum allocations, schedule adjustments or other non-technical considerations.

The Ka-Band network employs up to six crosslinks per satellite and up to two independent gateways per satellite. The crosslink and gateway architecture is designed for growth and each link is initially baselined at 3,000 user channels. The System Control Facilities will also use this network, employing 128 encrypted channels. Two control facilities, each located at relatively high latitudes, are included in the baseline point design. Though nominal locations for these facilities, as well as that for the minimum of 20 gateways (earth stations) are carried in the point design, for the initial system, the final locations will be determined by the consortium which will operate the system. In a mature system that has grown over time, hundreds of gateways are possible.

The gateways employ a minimum of two 3.3 meter tracking dish antennas that are separated by up to 20 miles -- in areas of reasonably frequent thundershower activity a third, and perhaps a fourth, geometrically-separated antenna will be employed. The antenna separation also assures that no sun orientation will incapacitate the gateway linkage from the constellation.

The gateways also include the interface electronics to reconfigure Iridium's 4.8 KBPS voice capability to the Postal, Telephone and Telegraph Authorities (PTTs) through the world's public switched telephone networks (PSTNs). (The gateway includes the local switch.) Though some people question the quality of 4.8 KBPS vocoders, it is important to recognize that the capacity and the spectral efficiency is directly related to the vocoder selected, and since all the vocoders are ground-based (the satellites are nothing more than transmitters, receivers, and digital switches, i.e. baseband processors), the system is baselined at what is practical for the mid-1990's -- some "critic's" have actually advocated the more efficient 2.4 KBPS vocoder. Iridium does include "version numbers" in its protocol, so as time goes on, if a high-quality 2.4 KBPS vocoder is available, future satellites can handle both versions.

Though a variety of voice and/or data subscriber units are feasible, the initial development focuses on the individual portable/handheld unit, the mobile unit which can be installed in an automobile or boat, and the transportable unit that can be moved between remote fixed locations.

The mobile and transportable units anticipate the availability of power sources and antenna orientations better suited to wireless communications than the portable/handheld unit.

The portable/handheld unit can operate for 24 hours on a single recharge -- 23 hours of standby (able to receive a "ring" indicating an incoming call) plus 1 hour of operation. The antenna "stub" can provide -1dB or more gain. The biological RF safety margin of approximately 1 watt can be maintained -- the system can be operated with 600 mW user units (comparable to cellular telephones). The subscriber unit has an optional Global Positioning System (GPS) capability which can enhance the unit's timing, positioning, and warm-up capabilities, but Iridium is not dependent upon GPS for operation. Without GPS a user unit starting from a "cold start" from a new location anywhere in the world can become functional within Iridium in less than 1 minute. The small functional design of the subscriber unit is possible due to the efficient distribution of functionality among user units, satellites, gateways, and the system control facilities. And, though the hardware is minimized, the subscriber unit is capable additionally of monitoring signals in channels other than its own assigned channel to assist in the execution of handoff operations.

Summary

A low-earth global cellular communication was described as were many of the key system-level considerations which have driven the design. Many specific details were omitted, both because of the limitations imposed by this forum and because of the competitive nature of the mobile telecommunications business.

Iridium represents a bold step into the future in terms of portable radiotelephone capability and its worldwide networking capability. Not to be slighted is the pioneer effort in manufacturing that is embodied in a warm commercial production line of satellites supporting a dynamic constellation frequently maintained with new satellite launches and old satellite decommissionings.

The Iridium team is a team of professionals, well educated and each with considerable experience. They have no illusions concerning what has been done, what is yet to be done, and what alliances are essential for success. They are highly motivated and eager to join with others from around the globe to bring Iridium into reality on cost, on schedule, and within specification.

The technical know-how for a revolutionary global mobile telecommunications system is at hand; what remains is the collective will to surpass the regulatory and licensing barriers. The door is open for both technical and non-technical local noble content. The rest of the story remains to be written.

(1) Adams, W.S. and L. Rider, "Circular Polar Constellations Providing Continuous Single or Multiple Coverage Above a Specified Latitude," The Journal of the Astronautical Sciences, Vol. 35, No. 2, Apr-Jun 1987.