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The Rise and Fall of Iridium[1]

"Rune Gjeldnes and Torry Larsen had been skiing towards the North Pole for twenty-six days when they heard the bad news. On a Monday in early March 2000 their expedition coordinator called from Norway to tell them that the Iridium global phone on which they were speaking—the only satellite phone which could work in the Arctic and on which they were entirely reliant for communications—was about to be de-activated. Permanently."[2] With another sip of aquavit burning a line of fire down their throats, the explorers tried their handset one last time and listened for the reply. It never came. Just the hiss of static, increasingly lost in the howling winds of the Arctic. Iridium was dying.

Chapter One: The Freedom to Communicate. Anytime. Anywhere

"But we can't go on vacation now, I'm just getting close to making this deal work. How can I close it from Green Turtle Cay—it's one of the most remote islands in the Bahamas! They won't even have a phone." Karen Bertiger, a real estate broker in Arizona, complained to her husband Bary in the winter of 1987. Bary Bertiger had worked at Bell Labs, had designed radars, and had helped develop the Safeguard anitballistic missile system. As a chief engineer in Motorola's strategic electronics division, Karen wanted to know, why couldn't he devise something simple and useful, like a global telephone system that worked? So goes the legend of the beginning of Iridium.

Back at Motorola, Bertiger raised the possibility of a global phone network with two fellow engineers, Ray Leopold and Ken Peterson. Bertiger, Leopold and Peterson worked in Motorola's Space and Systems Technology Group, located at the company's satellite facility in Chandler,

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[1] Much of this case's historical data on Iridium draws on company documents filed with the SEC; David Bennahum, "The United Nations of Iridium," *Wired*, 6.10 (October 1998): 134-138, 194-201; and Joe Flower, "Iridium," *Wired*, 1.05, November 1993 <http://www.wired.com/wired/archive/1.05/iridium.html> (27 March 2000).

[2] Heather Hodson, "The Phone That Fell to Earth," *Electronic Telegraph*, 8 July 2000 <www.telegraph.co.uk/> (22 August 2000). Gjeldnes and Larsen were real people affected by the Iridium collapse. Other real people included: French yachtsman Philippe Monet, who was attempting to beat the westabout round-the-world solo record, and faced three months without contact; the crew of Viracocha, an 18m reed sailboat halfway into a 3500 mile Pacific voyage from northern Chile to Easter Island; Jo LeGuen, a Frenchman attempting to row across the Pacific solo; and, a couple of Swedes walking unsupported across the Arctic.

Research Associate Kerry Herman prepared this case under the supervision of Professor Alan MacCormack. This case was developed from published sources. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

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Arizona. All three had cut their teeth on the race to the moon and other adventures in space. Leopold, a former Air Force pilot, had worked on secure communications for the military with the Milstar satellite system in the 1980s. Peterson created the algorithms that tracked and controlled military satellites. They had been brought together, along with twelve other engineers, in the late 1980s by Durrell Hillis, the group's general manager, who was charged with diversifying and commercializing Motorola's government-dependent space business as the end of the Cold War began to dawn on the horizon.

At the time, cellular phone technology was just breaking the airwaves. This rapidly proliferating new communications technology relied on ubiquitous radio towers that provided coverage for a limited geographic area (called a "cell"). As the caller moved out of the range of the first tower, her call signal was transmitted on to the tower in the next cell. While the global cellular market in 1985 totaled only 250,000 subscribers, it was expected to reach 4 million by 1990. Indeed, AT&T was forecasting up to 30 million cellular subscribers in the United States alone by the year 2000.[3] The problem with cellular however, was that there was no reception in areas where towers had not yet been built; at the end of the 1980s, reception was therefore limited to a few high-density, urban areas. In addition, physical obstacles—like mountains or tunnels—tended to interfere with reception, resulting in a poor quality experience for the user.

The three engineers played with a number of ideas for creating a global communications network which could overcome the limitations of cellular, including a network of high altitude airships, and a web of remotely-operated airplanes that could serve as transmission links.[4] Finally however, Bertiger went back to the cellular analogy; "Why not flip the whole thing over so it hangs overhead?" he thought, putting towers—or, in this case, satellites—into the sky.[5] As they orbit the Earth "whizzing by at 17,000 miles an hour," the satellites, or "cells," would move over the caller while she stayed stationary; the call signal would be relayed to the next satellite in succession, as each bird disappeared over the horizon. In this way, reception would not be limited by geographic inconveniences like lack of towers, mountain ranges, polar ice, or oceans.

The engineers' ambitious ideas captured Durrell Hillis' attention. As the general manager of the Space and Technology Group, Hillis faced the challenge of reinventing Motorola's space division in the face of fewer and fewer lucrative cold-war era, government-funded projects. Hillis saw the commercial arenas of satellites and mobile communications as ideal means for Motorola to make the transition from its current status as a component-supplier to, eventually, a builder of entire systems. Hillis encouraged the trio to work out the kinks in their plan, funding the project out of Motorola's Research and Development resources, but keeping it under wraps to protect it from intra-company R&D competition. As he recalled, "I created a bootleg project with secrecy so no one in the company would know about it."[6]

By August 1988, after 14 months of research and rewrites on the business plan, Hillis felt the team was ready to present the idea to Bob Galvin, Motorola's chairman. Galvin's response was immediate and enthusiastic, advising Motorola CEO John Mitchell to throw Motorola's full support behind the

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[3] Judith Bird, "Cellular Technology in Telephones," *data processing*, vol. 27, no. 8 (October 1985): 37.

[4] Bennahum (1998): 194; and Charles F. Mason, "Iridium forges ahead with its grand PCN plan," *Telephony*, 1, vol. 25, no. 18 (November 1993).

[5] Bennahum (1998): 194.

[6] Hillis, as cited in Bennahum (1998): 195. Bennahum cites "ferociously competitive" research projects at Motorola, all jockeying for R&D dollars.

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project. As Galvin said, "If you don't write a check for this John, I will."[7] Finally, in November 1989, Mitchell approved $6 million for another year of development, bringing the skunk-works project into the open.

Defining the System Architecture

In the late 1980s, communications networks relied upon both cable- and satellite-based links. Underground cables blanketed the globe; those that were underwater were laid by submarine, a costly and sometimes unreliable process.[8] Communications satellites tended to orbit the earth at fixed points above the equator, about 22,300 miles out, in what is known as a geo-synchronous orbit (or GEO—see **Exhibit 1**). GEO satellites match the earth's rotation, making them appear stationary to a ground-based observer. Transmitting/receiving stations (called "gateways") can therefore send and receive signals without having to rotate to track them. Given the high orbits of GEO satellites, they "see" a large part of the earth's surface. As a result, only three to five of them are required to provide global coverage, each with an associated gateway to route outgoing signals up to the satellite and received signals back into the land-based telecommunication network.

Unfortunately, Bertiger, Leopold and Peterson knew GEO satellites would not work for their system. While they were highly reliable, they sat too far out in orbit for the weak one-watt signals transmitted by a mobile phone. Using a higher wattage signal to overcome these problems would damage human tissue. The team would need a new kind of communications satellite, placed in a low earth orbit (LEO). Orbiting the earth between 450-1000 miles out, LEO satellites could provide a higher quality service, while requiring far less power—anywhere from 200 to 2000 times less—than a GEO system.[9] While some competitors felt that the energy a GEO system required could be solved with larger antennas in space rather than more powerful phones, Leopold disagreed. These antennas were not a proven solution in 1989, and would be extremely costly. Nor did they address other quality issues, such as the time lag associated with signal transmission. The transit time to GEO was a quarter of a second each way. A signal to LEO more closely matched the service provided by land-based phones, taking only two to eight milliseconds.[10]

The advantages of a LEO-based system however, did not come for free. While a lower orbit would mean smaller satellites, which were easier and less expensive to launch, it also resulted in a diminished field of vision on the earth's surface, requiring more satellites for global coverage. And given each satellite remained in view of the caller for only a brief period of time, calls had to be switched from satellite to satellite very frequently as they passed overhead and disappeared over the horizon. A low orbit also made satellites more susceptible to "shadowing" (the blockage of signals by buildings or hills that similarly disrupts cellular service). Finally, since they orbited the earth more

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[7] Bennahum (1998): 195.

[8] Satellites provided almost 10 times the telecommunications capacity of submarine telephone cables for almost 1/10th the price. This price differential was maintained into the late 1980s, when TAT-8 cables (the first fiber-optic cables) were laid across the Atlantic. In the early 1990s, satellites still maintained two advantages over cable: first, reliability (despite protective coating, submarine-laid cable were frequently damaged by trawling gear from fishing vessels, significantly impacting international telecommunications) and second, they could be used for point-to-multi-point broadcasting. David J. Whalen, "Communications Satellites: Making the Global Village Possible," 18 February 1997 <www.hq.nasa.gov/office/pao/History/satcomhistory.html> (14 September 2000).

[9] Brian Moskal, "Iridium Inc.," *Industry Week,* vol. 243, no. 23 (19 December 1994): 50-52.

[10] Moskal (1994).

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rapidly, moving frequently through damaging temperature transitions—from the heat of the sun to the cold shadow of earth[11]— LEO satellites would need to be replaced every five years.

One of the biggest obstacles to a LEO system was that communications satellites typically did not relay signals from satellite to satellite; they only sent/received signals to/from gateways.[12] In order to provide global coverage, a LEO system would therefore require a large number of gateways, substantially increasing the cost of the system.[13] To overcome this problem, Bertiger, Peterson and Leopold proposed a radically new concept: a cross-linked network of satellites, flying in low-earth orbit, which communicated *directly* with each other. With this ability, only one gateway would be required on the ground to act as a central control, switching all mobile-to-landline calls into the existing telephone system. Mobile-to-mobile calls would be relayed around the satellite network until they reached their target without using *any* gateways. The key to such a system was moving the call-routing information up from the gateways and into the sky, with switching decisions made by a computer on-board each satellite. It would be the world's first true satellite-based mobile communications system. The three engineers began to converge on a design with 77 satellites in seven orbital planes of 11 satellites each. With an array of 77 satellites, Iridium—the 77th element of the periodic table—seemed the perfect name.

Iridium was not alone in targeting the skies for the next installment of the communication revolution. By 1990, several other firms had also proposed satellite ventures, using GEO, LEO and MEO (middle earth orbit) systems (see **Exhibit 2**). For example, Globalstar, had proposed a LEO system similar to Iridium's, but with only 48 satellites, each placed in a higher orbit.[14] As a result, the system would have significant black-out areas over the poles and oceans. In addition, Globalstar's system did not use satellite-to-satellite call routing like Iridium, and would therefore require between 50-70 ground-based gateways to transfer signals to/from each satellite. Another company, Ellipsat, planned to use satellites placed in elliptical orbits, skewing coverage to more populated areas. As CEO David Castiel pointed out, "Frankly, my business plan can do without the people on Easter Island."[15]

By comparison with other satellite ventures, the Motorola system was by far the most sophisticated. Satellites with on-board call routing were complex: They needed computers, and therefore consumed greater power; they needed to talk to each other, and therefore required additional antennae with more precise positioning abilities.[16] Yet while the system was complex, it was the best answer to the problem; it could handle the greatest number of calls, had the widest coverage, promised the highest quality of service, and delivered the best level of overall system reliability. Iridium would be orders of magnitude more effective than the emerging technology of cellular with its patchy network. And with only one gateway, it would minimize the earth-bound infrastructure required for global coverage.

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[11] Bruce Gerding, "Personal Communications via Satellite: An Overview," *Telecommunications*, vol. 30, no. 2 (February 1996): 35, 77.

[12] This kind of satellite communications technology is referred to as "bent-pipe architecture," since the signal is sent up from the caller to the satellite, and is then bent back down to the gateway in an upside down U.

[13] Estimates of gateway costs were around $25 million per location. Marc Crossman and Lior Bregmen, "Satellite Communications. Iridium World Communications," *CIBC Oppenheimer* (10 December 1997); Casewriter estimates.

[14] Globalstar planned to locate its satellites in an orbit 900 miles out, in contrast to Iridium's 450 mile orbit.

[15] Flowers (1993).

[16] Iridium's satellites would have to send signals to one of four adjacent birds, and "would thus need four separate transmitting antennas, each pointed to one of the companion satellites. For receiving calls, a satellite would also have 48 spot beams pointed at Earth, each beam covering an area 375 miles in diameter. One satellite would therefore cover around 3 million of Earth's 197 million square miles." Bennahum (1998): 195.

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Chapter Two: Launching the Venture

On June 26, 1990, Hillis and his team formally announced the Iridium project to the public at simultaneous press conferences around the world: in Beijing, London, Melbourne and New York City. Iridium's system was primarily targeted at voice customers, but would provide paging services and some data transmission capability (see **Exhibit 3** for Iridium's planned service offerings). The project, ambitious at every level, was estimated to cost $3.5 billion to build, with the 77-satellite constellation expected to be fully deployed by 1996. Motorola, which had privately funded the project up to this date, insisted that while they would remain involved and carry a great deal of the risk, the project should stand independently and raise funds from public markets and private investors.[17] In 1991 Iridium LLC was therefore incorporated by Motorola as a separate limited liability company, in order to develop and deploy the network.

With the announcement, skeptical public reaction was unleashed. The press noted in particular the high cost of service projected, and the significant funds Iridium still needed to raise before any service could be offered.[18] Skepticism ranged across a spectrum of concerns, including unproven technology, frequency spectrum licenses yet to be granted from various governing bodies, target markets, revenue models, and competitive pricing factors between Iridium and existing cellular services. Even Iridium's competitors felt that while a mobile satellite service (MSS) was the way to go, an effective system could be deployed with fewer birds at a fraction of the cost. For example, Ellipsat's proposed 12-24 satellite system would charge callers only 50¢ a minute, versus Iridium's planned $3 a minute charge.

Iridium executives were undeterred. With its technical solution in place, and 30 employees already aboard, Iridium's architects hit the road.[19] They conducted extensive research to assess the market, service needs, and rates; Iridium had to be able to compete with every phone service offered. The management team built a model documenting telephone-call fees between 239 countries, and came up with close to 60,000 rate variations with which Iridium could potentially compete. They researched the patterns of their target market—people on the move—screening 200,000 people, interviewing 25,000 individuals in 54 cities, across 42 countries, and 3,000 corporations with remote operations. Their research concluded that most calls made while traveling were made to a caller's home city or country. Long distance calling from overseas to home remained one of the last frontiers of high-margin telephony at the end of the 1980s; this would be a lucrative market for Iridium.

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[17] By 1998, according to analysts, Motorola and its industrial partners would spend more than $150 million on research and development for Iridium. Steve Franck, "Iridum World Communications (IRIDF): A New Shoe for Get Smart," *U.S. Investment Research,* Morgan Stanley Dean Witter (18 March 1998): 30.

[18] Initial estimates were that each phone would cost $3000, and per minute calling costs would be $3 and up. See Green, "Cash triggers Iridium countdown—Motorola's satellite project has taken the lead," *Financial Times* (4 August 1993): 20; and Kerry Fehr, "Iridium Phone Project Rests With Money," *The Phoenix Gazette* (11 June 1993): E1.

[19] As Bennahum noted, "In 24 months . . . Bertiger made at least 50 visits to potential service partners and investors in 24 countries, gaining 30 pounds on airline food. Leopold essentially lived on airplanes…Mitchell logged over a million miles in the air while suffering from extreme arthritis, which gnarled his hands. Hillis, while traveling to Guyana, was bitten so badly by mosquitoes that two weeks later his right leg had swollen, covered with red dots; the malady remains undiagnosed, and he now takes Dapsone, a leprosy drug, daily." Bennahum (1998): 199.

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Forecasting the market however, was a tricky issue. There were often as many forecasts as there were forecasters. In 1991, industry analysts estimated that MSS subscribers would exceed 1.8 million by 2001, and 2.3 million by 2006.[20] Iridium itself however, projected a user-base of 1.4 million subscribers in 1996, its first year of operation. Furthermore, while the Iridium system could support up to 10 million subscribers, the company calculated it would be profitable with merely 700,000.[21]

With such a rosy scenario, Iridium thought it would have little trouble getting financed. They planned to raise approximately $800 million by partnering with a small number of big, blue-chip telecommunications companies like AT&T, and NTT—the Japanese phone monopoly. But Iridium's satellites also functioned as switching stations, relaying calls from satellite to satellite, switching over into landline services only for the last mile. The venture looked very much like a service provider in this light, and could be seen as a direct competitor to these companies. Not surprisingly, the big telcos declined the offer. Iridium would have to rethink its financing strategy.

Further problems loomed in securing the valuable spectrum required to operate the service, given the team had announced Iridium before the FCC had allocated the desired frequencies. The company also had at least 170 countries to lobby in order to get a global spectrum allocation from the World Administrative Radio Conference (WARC). Unfortunately, some countries saw the project as an imperialist move by the Americans to monopolize the market for satellite communications. It represented a direct threat to their own Postal, Telephone and Telegraph (PTT) systems, which were predominantly state-owned at this time, and which generated significant revenues for the state. As one reporter noted, "It was a case of geekish can-do enthusiasm getting ahead of the plodding nuances of global lobbying and diplomacy."[22]

In response to these problems, Iridium promoted Leo Mondale to take over their international efforts, appointing him vice president of Iridium International in December of 1991. Mondale, a lawyer by training, had garnered technical and political acumen working for Fairchild Space and Defense Corporation and the French aerospace concern Matra Marconi. In order to get the regulatory approval Iridium needed to operate in 170 countries—many of whom depended heavily on revenues from their PTT authorities—Mondale realized that the technically elegant engineering plan had to be completely rethought in terms of geo-political realities. The crux of the problem was the single gateway that would circumvent crucial revenues for many countries over which Iridium hoped to provide service; the plan, as initially conceived, would never get support from these countries.

Evolving the Plan

Rather than looking for a few major investors, Mondale proposed that Iridium offer portions of the company to a broader range of international investors for about $40 million a piece. Instead of a single gateway, the satellite system would be redesigned to interface with many gateways—each representing an investment opportunity—that plugged into local PTT systems. These "regional" gateways, each independently managed by an investor and granted board membership, would perform uplink and downlink duties, as well as handling switching interfaces to the terrestrial phone network. Billing, location and routing information would also be monitored at these gateways. In

[20] Lloyd Covens, "Mobile Satellite Poised for Worldwide Growth," *Communications,* (February 1991): 25-30. This was further broken down: 42% business; 18% government and 40% private, including private aircraft, vacation boats, and rural and travel applications. By comparison, cellular subscribers were forecast to reach 38.7 million by 2000. S&P Industry Surveys, *Telecommunications* (15 November 1990).

[21] Covens (1991). See also Thomas F. Watts and Daniel P. Rheingold, "Comment, Iridium World Communications Ltd. Global Wireless Telephone System Poised For Take-Off," *Merrill Lynch* (15 July 1997).

[22] Bennahum (1998): 196.

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addition, Mondale reworked the investment offer to suit many developing countries: low cash demands up front, with guaranteed revenue from call traffic on the back end, and freedom to set rates for Iridium calls heading outside their borders. As Mondale put it; "We will give you the same money as AT&T, plus discounted shares in Iridium, discounted telephones, and free minutes for government use."[23]

By the time of the WARC conference in Spain in 1992, Iridium had gathered enough support from developing countries to counter the clout of the developed nations who saw Iridium as a threat. The first investor, United Communications Industry Co. of Thailand, signed on and acquired the rights to a gateway in Southeast Asia. One major investor made it easier to attract others to the plan. In 1992, Iridium signed a $3.37 billion contract with Motorola for system development, construction and delivery.[24] Motorola would be Iridium's prime contractor, supplying satellites, gateways, and communication products for the Iridium system.

By 1993, 160 countries had agreed to allocate part of the spectrum for LEO systems. As of July, Iridium had secured 14 investors, and raised $800 million in cash; 11 of these investors were to build and operate gateways. One unanticipated by-product of this new investment strategy was that the board of directors expanded exponentially. The first meeting of this board in 1993 was heralded by many as signifying the birth of the first truly multinational corporation, perhaps even the model of a 21st-century corporation. As *Wired* reporter David Bennahum described:

> Four times a year, 28 Iridium board members from 17 countries gathered to coordinate overall business decisions. They met around the world, shuttling between Moscow, London, Kyoto, Rio de Janeiro, and Rome…. Resembling a United Nations in miniature, board meetings were conducted with simultaneous translation in Russian, Japanese, Chinese, and English.[25]

In September 1994, a second round of equity financing to raise another $800 million was completed, bringing total funds raised to $1.6 billion. In 1995, the FCC granted Iridium an operational license. With the spectrum space finally allocated and the design of the system almost complete, the date for commercial activation of the system was set for 1998.

Building the Infrastructure

In the early 1990s there were six companies providing fixed satellite service to the U.S., operating 36 satellites with a net worth of over $4 billion dollars. Each year, ten to twenty more communications satellites were launched by international providers, including the U.S., Indonesia, Japan, India, Australia, Brazil, France, Germany, Mexico and others.[26] Although these numbers had been growing steadily since 1958, no single company had attempted to do what Iridium needed to

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[23] As cited in Bennahum (1998): 196. As Bennahum noted, the shares were especially appealing: Iridium offered governments and other large investors options for the purchase of up to 20,625 Iridium shares at $13.33 a piece. Developing countries could accrue dividends on the options, which could then be applied to acquire the stock. In other words, if the country waited a few years, the amassed dividends would essentially cover the cost of exercising the options—meaning they were, for all intents and purposes, free. This was not the only benefit for a developing nation; an Iridium system would leap-frog a technologically backwards nation straight into the twenty-first century, providing them with a quick and ready-built infrastructure for communications, media, etc.

[24] In addition to the contract to deliver the initial system, Iridium also signed an Operations and Maintenance Contract (OMC) with Motorola. This fixed-price contract was worth an additional $3.184 billion. It stipulated that if anything went wrong with the satellites that was Motorola's fault, Motorola would replace them at no cost. Crossman and Bregman (1997).

[25] Bennahum (1998): 136.

[26] Whalen (1997).

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do: deploy 66 satellites (plus 8 spares) into orbit over a two-year period.[27] As Iridium's prime contractor, Motorola faced an unprecedented technical challenge. Foremost among them, Motorola would have to significantly redesign its satellite manufacturing process.

Traditionally, satellite manufacturing involved clearing a spot on the factory floor, then building up the satellite by bringing everything to it—it was essentially custom built. Given the large number of satellites involved in Iridium however, Motorola would have to design an assembly line for building satellites. Hillis commented on how they began:

> We had a manufacturing team involved up-front…doing a lot of pathfinding things—like building mockup payloads, structures, and antennas, then assembling them. We've done dry runs of the entire satellite manufacturing process.[28]

Instead of the traditional vertical environment, where the satellite was built from the ground up, Motorola switched to a horizontal environment. The Iridium spacecraft and subsystems were designed as modules, to be assembled horizontally; the bus (the body of the satellite) moved from station-to-station through a 12,000 sq. ft. factory that could handle five satellites under construction simultaneously. A special wheeled dolly carried the Lockheed-built bus, which permitted rotisserie-like rotation for ease of access during assembly. From the start, parts and subassemblies were designed to simplify manufacturing, assembly and testing.[29] The assembly line relied on "just-in-time" deliveries from suppliers, eliminating the need for storerooms and "bonded" facilities in the factory. Motorola did not inspect incoming parts, instead requiring partners and subcontractors to deliver "perfect-quality material" (traditionally, 60% of satellite assembly time was devoted to testing materials before they went into the vehicle). As a result, what used to be an 18-36 month process was reduced to one in which a finished satellite rolled off the line every four and a half days.

Motorola delivered the first complete satellite in 1996. As part of continued funding efforts, $315 million in additional equity finance was secured, bringing total project support to $1.9 billion. In December, Iridium installed a new leader at the helm; *Business Week* called CEO Edward Staiano, former president of Motorola's General Systems Sector, a "big gun," ready to back the multi-billion dollar bet on satellite communications as Iridium headed into the final stages of deployment.[30] As the year closed, the first ground station was inaugurated in Japan and Iridium began a $140 million global advertising campaign, pitching its phones to businesspeople on company expense accounts.

On 5 May 1997, the first five Iridium satellites were successfully launched on a Delta II rocket from Vandenburg Air Force Base in California.[31] Fresh on the heels of this success, in June 1997, Iridium raised $240 million through an initial public offering on the NASDAQ (see **Exhibit 4** for investors as of the IPO).[32] At the time, analyst comments were extremely favorable, and many

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[27] As system development continued, the design team realized they could make do with 11 less satellites (one less orbital plane) than the 77 that had originally been planned. However, no one asked to change the name to that of element 66, Dysprosium, especially given its root meaning is "bad approach." Flowers (1993).

[28] William B. Scott, "Iridium On Track For First Launch in 1996," *Aviation Week & Space Technology* (3 April 1995): 57

[29] According to Larry Casey, Motorola's Iridium manufacturing manager "On a classic satellite, it might take three weeks to disassemble and replace a module in the center. The Iridium system is designed so [modules] can be replaced in 60 seconds." As cited in Scott (1995).

[30] Keith H. Hammonds, "A Powerful Boost for Iridium," *Business Week* (23 December 1996): 46. Staiano had been an independent director on Iridium's board prior to his appointment as CEO.

[31] Launch services were contracted to McDonnell Douglas, using Delta II rockets (five satellites per launch) and Russia's Khrunichev Enterprises, using Proton rockets (seven satellites per launch).

[32] The stock was issued under the name Iridium World Communications Ltd., which had been registered in Bermuda in December 1996 to serve as the public investment vehicle for the company.

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registered the company as a strong Buy. The reaction was not uniform, however (see **Exhibit 5**). One analyst's skepticism summed up the contrarian view: "Until commercial launch in September 1998, there is no quantitative data to defend either bullish or bearish fundamental analysis."[33] Despite this, the stock performed well (see **Exhibit 6**).

As the satellite launches increased in frequency, development also began to heat up on the subscriber equipment. The most significant development was a decision to redesign the phone. In addition to satellite calls, Iridium now planned to send and receive cellular signals through the use of removable cards that enabled the phones to work over nine of the major cellular standards. This would allow Iridium to sell a more flexible offering of services; using cellular where it existed, and switching to satellite where it didn't. As Staiano acknowledged "[We] underestimated the growth of cellular."[34] The design change also allowed Iridium to cover a weakness their engineers had discovered in the system during early tests: the phones did not work well in buildings, or on the streets of cities with tall buildings. The development team was less than excited about the redesign, since it meant changing millions of lines of software in the call-tracking and billing system. Randall Brouckman, director of software systems, recalled giving his developers a window of coping time: "I looked at my watch, and told them they had 10 seconds for fear and anguish. They shouted 'You're nuts!' I said, 'Nine.' 'I hate this.' 'Eight.' We counted down, then we went to work."[35]

By the end of 1997, Iridium had 47 satellites in orbit, allowing the first pager message to be received by Iridium board members. By mid-1998, as the system neared completion, the stock price hit a new high of $72. Finally, on September 9, the full constellation of Iridium satellites was in place.[36] To mark the occasion, Vice President Al Gore[37] placed a call from the White House to Alexander Graham Bell's great grandson in Virginia. Bell's immortal words—"Watson, come here, I need you," were relayed once again, this time being beamed through the earth's atmosphere. As one reporter wrote:

> For Bary Bertiger, Ken Peterson, and Ray Leopold, Iridium is their masterpiece, the most ambitious and complex commercial space venture of our time. Peterson, sitting at a golf course a mile and half from the Iridium launchpad at Vandenberg, has the look of a very contented man, sipping beer from a plastic cup while colleagues stop by to shake his hand and congratulate him. He recounts how he recently went out prairie hunting in Arizona with some friends: 'We were sitting around a campfire after a great dinner, and pretty soon I saw a LEO whiz by. And a little later came another. We saw five in one night.' Peterson smiles and looks towards the launchpad. 'After a millenia of people looking up at the same night sky, we're the first to put up a new constellation since God. It's never going to be the same again.'[38]

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[33] Crossman and Bregman (1997): 1.

[34] Staiano as cited in Quentin Hardy, "Iridium Creates New Plan for Globular Cellular Service—System Would Enable Phones to Work Over Most Transmission Standards," *The Asian Wall Street Journal* (19 August 1997): 18. As early as 1995, analysts' forecasts of U.S. cellular subscribers in the year 2000 began to exceed 100 million.

[35] Brouckman, as cited in Hardy (1997): B6.

[36] Note that the total cost of building the Iridium system far exceeded the roughly $2 billion of equity raised. The balance was funded through bank debt, lines of credit, and the issuance of notes bearing interest rates of between 10.8%-14.5%. For a complete discussion of Iridium funding and debt structure, see Ben Esty, *Iridium, LLC,* HBS Case N9-200-039, Rev. March 21, 2001.

[37] Also known for his role in the invention of the Internet, and the infamous "pregnant chad" scandal.

[38] Bennahum (1998): 201.

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Chapter Eleven: What Goes Up Must Come Down

Iridium had an impressive launch record with its satellites, while other MSS providers—most notably Globalstar—suffered several losses.[39] Unfortunately however, the much-hyped launch of commercial service, originally scheduled for September 23, 1998, had to be postponed, due to delays in handset deliveries and software glitches. Iridium had initially proposed a beta-testing period for the first seven weeks of operation, which was subsequently reduced to five in the haste to begin service. But as one analyst remarked, "We do not believe five weeks—or seven for that matter—is enough time for the company to learn anything meaningful from its Beta subscribers."[40] On November 1, 1998, service finally began.

Early reactions to the phones were mixed. Users reported blocked access, rampant interference, and dropped calls. The phone could not be used in buildings, and initially, could not be used in cities either. The handset listed at $3,000, with calls costing about $3 a minute, or $7-$8 for international calls. Some expressed surprise at the size of the phone—it was the size of a large brick, and was carried in a small suitcase. To ensure that a call could be made from anywhere, an array of additional paraphernalia was also needed. But others saw this size and attendant gear as a potential strength:

> The Iridium phone is a virility totem. Its hugeness is a sign of potency, of supremacy and exclusivity, the human equivalent of a silver stripe on a dominant male gorilla. Holding a prototype of the phone, which is about the size of a shoe, with a colossal antenna resembling a jumbo cigar tube, [John] Windolph [Iridium's executive marketing director] recounted the thrill of playing with it at a café in Geneva accompanied by Iridium chairman Robert Kinzie. 'I pulled out the prototype, and [everyone] wanted to talk to us. . . . It's so beautiful, that phone.'[41]

From a competitive standpoint, some of Iridium' advantages also appeared to have narrowed. Iridium had originally touted their service as the only truly global offering, but by 1998 cellular technology had expanded in unforeseen ways. (See **Exhibits 7** and **8**.) As one observer noted:

> Nineteen-nineties technologies are changing so fast that it is hard to keep up. Iridium [was] designed from a 1980s perspective of a global cellular system. Since then, the Internet has grown and cellular telephony is much more pervasive. There are many more opportunities for roaming than were assumed in 1989. So there are fewer businesspeople who need to look for an alternative to a cell phone while they are on the road.[42]

Of course, for those who needed to make that crucial call while travelling in the jungles of the Amazon, nothing could beat Iridium. As service began, CFO Roy Strong confidently announced that

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[39] Cynthia M. Motz and Robert J. Hordon "Iridium—Up, Up, and Away!" *Credit Suisse First Boston Analyst Report* (18 December 1998): 6, 17. By December 1997, Iridium had lost only 2 satellites, at a cost of $90 million to Motorola. Projecting forward, analysts at CIBC Oppenheimer concluded "Iridium paid an extra $2.5 billion for peace of mind…[for the operations and maintenance contract]…for the same amount or less, Iridium could have bought an entire second system, which would be needed should the first system truly require $3 billion worth of replacements." Crossman and Bregman (1997): 1.

[40] Marc Crossman, Lior Bregman, and Ahn Nuyen-Steininger, "Iridium World Communications Delays Highly Promoted Commercial Launch," *CIBC Oppenheimer Equity Research* (10 September 1998): 1.

[41] As cited in Bennahum (1998): 200.

[42] Professor Heather Hudson, director of the telecommunications program at the University of San Francisco, as cited in Bennahum (1998): 200.

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by the end of 1999, 600,000 subscribers would be signed, meaning Iridium would be operating at breakeven and could begin to start paying down its debt.[43]

As the hype of initiating commercial activation faded, subscriber numbers failed to rise in line with forecasts, and critics began to voice concern. Analyst reports cited "leads" of between 400,000 and 850,000 potential customers that Iridium had received in response to its marketing efforts in 1998, with 40,000 "intentions to purchase,"[44] but these leads and intentions did not appear to translate into paying customers. By the end of 1998, Iridium had only 3,000 subscribers.[45]

As the numbers fell short, Iridium tried to revamp its marketing strategy. Initially, the phone had been aimed primarily for individuals—a horizontal market. Perhaps the real market was vertical—governments and organizations working in remote areas such as oil fields and war zones. So Iridium refocused on a new set of targets identified by a well-known consulting firm—the "corporate/industrial user"—encompassing industries such as the media, energy, electrical utilities, construction, oil and gas exploration, mining, forestry, shipping and fishing.[46] Some successes were made—for example, CNN was an exemplary client, with much of their coverage of the Balkan War made possible by Iridium phones. Despite these changes, however, the figures continued to disappoint.

By March 1999, Lehman Brothers' analysts reported that only 7,294 net additional subscribers were signed up for the first quarter, raising the number of subscribers to just above 10,000.[47] That same month, Iridium received a 60-day waiver from its bankers to meet certain terms of their $800 million line of credit, including—crucially—a covenant requiring 27,000 subscribers to be signed in the next quarter. Each successive month, the projected number of subscribers began to slip further and further below projections (and more importantly, debt covenants). Iridium's management was in turmoil.

In April 1999, CEO Edward Staiano resigned abruptly, and was replaced by John Richardson. Rumors abounded that Iridium's board sought to head the company with someone they believed could execute Iridium's business plan effectively and, more importantly, *quickly*, something they felt Staiano was not doing. Chairman Robert Kinzie said, "Ed has done a magnificent job in getting the system to where it is. Now as we move into an era of marketing and financing, basically the board felt that new blood was needed at the top."[48] But analysts couldn't agree whether the news was good

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[43] Roy Strong's comments were reported by Credit Suisse First Boston analysts. Motz and Hordon, "Iridium," *Credit Suisse First Boston Corporation* (15 January 1999): 3.

[44] In September 1998, analysts at ABN-AMRO Equities, an Australian firm, reported that Iridium's global advertising campaign of July-August attracted 400,000 queries and 40,000 "intentions to purchase." They acknowledged that subscriber targets were "far more optimistic," reaching 1 million by 2000, and 5 million by 2003. Ian Martin, Zara Lyons, and Radek Barnert, "Iridium LLC. Delay in mobile satellite service launch," *ABN-AMRO Flashnote* (10 September 1998): 1. In December 1998, analysts from Credit Suisse First Boston reported that "Iridium had received responses to its marketing efforts from over 850,000 prospective customers, with another 200,000 inquiries directed towards Iridium service providers." The analysts concluded "Our estimates for the company's subscriber growth are considerably lower than what Iridium is projecting throughout the model. For example, although Iridium believes it can reach five million customers by the end of 2002, we have shown total subscribers of only 2.87 million by that time." Motz and Hordon (1998).

[45] Rajiv Chandrasekaran, "CEO Steps Down At Troubled Iridium; Firm Having Difficulty Gaining Customers," *The Washington Post* (23 April 1999): E1.

[46] Booz-Allen projected more than 270,000 adopters in these vertical markets alone. Tom Watts, "Iridium World Communications Ltd. Full Speed Ahead," *Merrill Lynch Bulletin* (22 January 1999): 1.

[47] John M. Bensche and Robert S. Peck, "Iridium LLC," *Lehman Brothers Global Equity Research* (3 May 1999): 1. According to Lehman's analysts, "The company attributed the lower than expected numbers to delays in handset manufacturing and distribution problems."

[48] Kinzie, as cited in Chandrasekaran (1999).

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or bad; while Credit Suisse First Boston changed their rating from Buy to Hold in April, Lehman Brothers upgraded the stock from Outperform to Buy in May, and established a year-end target price of $80.[49] As one analyst commented:

> Is it the dealer, the cards that have been dealt, or is it the game itself that is the problem?…. This is an entirely new industry…. Iridium is the first one; there are no comparables up and running yet. Hence there is no such thing as more seasoned managers in this specific industry.… When we look at the cards Iridium as a company has in front of it, we are not certain if any player can pull in a winning hand (i.e. it may just simply be that the business model is too challenging).[50]

The confused reaction was in part due to mixed signals about Iridium's long-term viability. At the end of April 1999, Iridium announced that the United States Defense Department had signed a $219 million three-year contract with Motorola for Iridium equipment, which included the purchase of 28 million minutes a year.[51] By end of May, however, subscriber numbers had still not increased significantly. Contributing to Iridium's problems, Kyocera, the handset manufacturer and an Iridium consortium member, was several months late in delivering equipment; without handsets, it made little sense to try to sell a service, especially when service providers had several other options to sell. In addition, while several service providers had inked distribution agreements, not even Sprint, an Iridium consortium partner, had trained its sales force in time for the launch of Iridium's service.[52]

In June, Iridium slashed its prices, selling handsets for $1,000, down from the original price of $3,000. Richardson also announced that the company had simplified its pricing structure on airtime charges; international calls were reduced to $3 a minute, national calls to between $1.60 and $2.50 a minute, and Iridium-to-Iridium calls to $1.50 a minute.[53] Richardson exuded confidence: "With our announcement today, we've positioned ourselves to be a competitor with anyone in the industrial markets. I'm confident we'll be successful."[54]

With its heavy cash burn rate, and overwhelming debt responsibilities, however, Iridium continued to sink fast. On August 17, 1999, Iridium filed notification that the company's reported net loss would be "significantly more" than the losses projected in March. The notification also reported that on August 13, 1999, less than a year after activation, Iridium had voluntarily filed Chapter 11, and was pursuing a comprehensive financial restructuring. Richardson reiterated his confidence in the company, "There is no doubt there is a market for this product. Once we get this financial restructuring out of the way, we are a very competitive element in the marketplace."[55]

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[49] Bensche, "Notes from the Sell Side," *Red Herring* (August 1998).

[50] Motz and Hordon, "Iridium. Changing our Rating from Buy to Hold," *Credit Suisse First Boston Equity Research* (23 April 1999): 2.

[51] Bensche and Peck (1999): 2. As the analysts noted: "This is just one of many contracts Iridium expects will be announced over the next several quarters." Analysts expected a typical user to consume 50-70 minutes a month.

[52] Brian Taptich, "Earthbound," *Red Herring* August 1999 <http://www.redherring.com/mag/issue69/news-iridium.html> (22 August 2000). Taptich reported that Globalstar and ICO learned from Iridium's problems: their handsets were easier to design; they had manufacturing agreements with several handset makers; and they had signed agreements with service providers that guaranteed a minimum number of sales representatives dedicated to delivering a minimum number of subscribers committed to using a minimum number of minutes of service.

[53] Anonymous, "Iridium Slashes Prices, Wall Street Remains Skeptical," *Mobile Satellite News* (24 June 1999).

[54] Richardson, as cited in *Mobile Satellite News* (1999).

[55] Richardson, as cited in Joseph C. Anselmo, "Iridium's Future is Up in the Air," *Aviation Week & Space Technology* (23 August 1999): 40.

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By the end of 1999, Iridium had signed only 55,000 subscribers.[56] Revenues were reported at $1.54 million for the first month of 2000,[57] falling far short of covering operating expenses, much less the $100 million-plus per quarter Iridium owed creditors on its $3.4 billion debt. (See **Exhibit 9** for Iridium financials.) In March 2000, Iridium announced the end of commercial service. In June, the stock was suspended from trading at $0.81.[58] Finally, on August 31, 2000 at 4 p.m., the system was turned off. Permanently. Richardson commented, "We're a classic MBA case-study in how not to introduce a product. First, we created a marvelous technological achievement. Then, we asked the question of how to make money on it."[59]

Epilogue: We Are Attempting Re-Entry

Iridium faced one last challenge: How to safely decommission and de-orbit their constellation of satellites weighing more than 53 tons? U.S. policy required satellite makers to remove defunct objects from orbit within 25 years; in 2000 the U.S. Space Command tracked about 9,000 orbiting manufactured objects. For the most part, these objects were brought safely to ground (or ocean) by controlling their reentry and timing the final thruster firings properly. As experts noted, Iridium hardware was within government guidelines for acceptable risk—there was a less than one in 10,000 chance that falling debris would hit a person on the ground. Yet no one had decommissioned an orbiting system of such size and complexity.[60]

While Motorola was working out how to do this, offers to save Iridium were still being contemplated. As late as mid-September 2000, former CEO Edward Staiano and a group of investors were attempting to raise enough funds to buy the system. According to the *Chicago Tribune*, "The deal…includes a provision under which the U.S. Department of Defense would agree to pay an unspecified amount for Iridium phone service, thereby ensuring the system would have a certain level of revenues."[61] Other ideas for Iridium were also being contemplated: One federal agency even suggested that the Iridium system might make a good gift for the Neimann-Marcus Christmas catalogue.[62]

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[56] Eric Nee, "Iridium's Folly," *Fortune*, 20 March 2000 <www.fortune.com> (29 November 2000).

[57] Iridium LLC 8-K "Current Report," filed 29 February 2000, 7 <www.FreeEdgar.com> (30 October 2000).

[58] The stock was delisted by NASDAQ 19 November 1999 and traded on the "pink sheets" until June 2000. Iridium LLC 8-K "Current Report," 29 February 2000, 10.

[59] Mark Leibovich, "A Dream Come Back to Earth; Missteps, Shortfalls, Glitches Have Iridium Scaling Back Expectations for Its Satellite Phone Service," *The Washington Post* (24 May 1999): F12.

[60] Kathy Sawyer, "Hanging up on a Network of Satellites," *The Washington Post*, 29 August 2000: A3 <www.washingtonpost.com.cgi-bin/gx> (15 September 2000). In August 2000, there were 88 satellites total in the Iridium constellation: 66 plus 8 backups, and 14 that stopped functioning after reaching orbit. Sawyer reported that the latter are expected to make uncontrolled entries into the atmosphere over the next 100 years.

[61] Robert Kaiser, "Ex-CEO of Iridium May Help Buy System," *Chicago Tribune*, 15 September 2000, <www.chicagotribune.com> (20 September 2000).

[62] Sawyer (2000).

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Exhibit 1 Alternative Satellite Communication Systems

GEO

GEO (geo-stationary orbit) satellites orbit the earth 22,300 miles out. Their orbit takes 24 hours, hence they move with the earth, appearing stationary to a ground-based observer. A GEO system requires only three to five satellites and a small number of ground stations to provide full global coverage. The satellites themselves however, are much larger and more complex than LEO or MEO satellites, in order to handle the higher level of power required to transmit and receive signals at this distance. They are highly reliable, and suffer less from the rapid decay that lower orbit satellites experience; they therefore last longer (about 7-15 years), making a system less expensive to build and maintain over time. Disadvantages include that they are large, expensive to construct, and expensive to launch; they impose high power requirements on ground units; and they require large cumbersome antenna of some 30′ in diameter. GEO signals travel a great distance, creating a noticeable time lag (of up to 0.5 seconds), meaning that voice quality is not on a par with landline systems.

MEO

MEO (middle-earth orbit) satellites orbit the earth between 6200 to 9400 miles out. They complete their orbit in about six hours, so are typically "in view" of a caller for around 90 minutes. A MEO system can provide coverage over every inhabited area of the Earth with a small number of satellites—as few as 10-12—with associated ground stations. Fewer satellites mean fewer launches. Compared to LEO satellites, MEO satellites orbit the earth more slowly, lessening the damaging effects of frequent transitions from the sun's heat to the earth's cold shadow. They do not therefore need to be replaced as often. Their orbit is close enough to avoid the significant time delays associated with a GEO system, although still noticeable at 0.1 second. MEO satellites fly high enough to reduce the "shadowing" effect of hills and tall buildings experienced by LEO satellites.

LEO

LEO (low-earth orbit) satellites orbit the earth between 450-1000 miles out, traveling at approximately 17,000 miles an hour to offset the pull of gravity. They complete an orbit of the earth in about 90 minutes, remaining in view of a caller for only a brief period of time—around 15 minutes. Hence call signals have to be switched between satellites frequently. The footprint, or coverage area of each satellite, is comparatively small. It therefore takes many LEO satellites to cover the globe; at least 50 for complete coverage. If call-switching technology is not carried on the satellites, many ground stations are required in order to send/receive signals to/from each satellite. LEO systems have low transmitting power requirements for both satellite and user's transceiver. Each satellite requires an antenna of only 6′ diameter. LEO satellites have an average life span of only 5-8 years, primarily due to damage from radiation and frequent temperature transitions. Because they orbit earth so closely, LEO satellites are susceptible to "shadowing" (signal blockage from hills or buildings). A LEO system will continue to operate with the malfunction of one, or even several, satellites. The time delay for voice or data signals is negligible in a LEO system.

Source: S&P's Industry Surveys, *Telecommunications: Wireless*; (June 2000); Richard Dreher, Lawrence Harte, Steven Kellogg, and Tom Schaffnit, *The Comprehensive Guide to Wireless Technologies*, (Fuquay-Varina, North Carolina: APDG Publishing, 1999) ; Bennahum (1998); casewriter estimates.

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Exhibit 2 Some Proposed Mobile Satellite Service (MSS) Systems

System (Owner)	Application	System	Satellites (spares)	Gateways	Targeted Launch	Actual/Projected Launch	System Cost	Subscriber Unit Cost (phone)	Per Minute Cost of Service
Orbcomm (Orbital Sciences Corp., Teleglobe)	Remote sensoring, industrial control	Little LEO[a]	35	4	1996	1996 partial service 1998 full service	$190 M	$500	$.25 per message
Comsat Planet 1 (Inmarsat)	Mobile voice, data	GEO	2		1996	1997	$750 M	$3,000	$3
AMSC Skycell (Now called Motient)	Mobile voice, data	GEO	4	40	1995	1997	$5.5 B	$2,000	$1-$1.45
VITA (NFP)	Messaging and High-speed data	Little LEO	2[b]	25	1996	1997	$150 M	$500	N/A
Iridium (Motorola, others)	Mobile voice, data	Big LEO[c]	66 (+6)	11	1996	1998	$4.9 B[d]	$3,000	$3
Globalstar (Loral, Qualcomm)	Mobile voice, data	Big LEO	48 (+8)	38[e]	1997	2000	$3.26B	$750-$1,000	$.35
Ellipso (Boeing, Lockheed Martin, Harris, L-3Com, others.)	Mobile voice, high-speed data	MEO	14-20		1999	2002	$1.5B	$1000	$35 per month $.50 per minute
Skybridge (Alcatel, Loral)	High-speed data	Big LEO	80	Thousands	2001	2002	$4.1B	$700	$40 per month
Spaceway (Hughes, DirecTV, PanAmSat)	High-speed data, video, bandwidth-on-demand	GEO	2 (First Phase)	Personal satellite dish	1999	2002 (N. America)	$3.2 B	N/A	$1 per 10mb
Leo One (dBX)	Messaging, Hi-speed data, Vehicle tracking, etc	Little LEO	48	3 (U.S.)		2003	$250 M	$75-$400	
Teledesic (McCaw, Gates, Boeing, others)	High-speed data, video	Big LEO	288		1998	2005	$9-$15B	$1,000-64 Kbps, $6,000-2Mbps	$.04
New ICO (Inmarsat Consortium, McCaw, others.)	Mobile voice, data, fax	MEO	10 (+2)			2003	$4.6 B	$2,000	$1-$2
Astrolink (Lockheed Martin, TRW, Telespazio, Liberty Media Group)	Video/Broadband	GEO	4-9	4	1999	2003	$1.3B		
M-Star (Motorola)	High-speed data	Little LEO	72		1999	Absorbed by Teledesic	$6.1 M	N/A	N/A
GE Starsys (GE)	High-speed data	Little LEO	24		1998	Cancelled. License Returned in 1997.	$170 M	$500	N/A
Celestri (Motorola)	High-speed data, video	Big LEO/ GEO	63		2001	Absorbed by Teledesic in 1998	$12.9 B	N/A	N/A
Odyssey (TRW and Teleglobe)	Fixed wireless telephony, celiular extension	MEO	12	7	1997	Cancelled. License Returned in 2000.	$3.2 B	$500-$700	$.65

Source: Emmett (1997); Harte, Dreher, Kellogg and Schaffnit (1999); Lo, "Space Jam," *Wired*, 6.10 (October 1998); <http://www.comlinks.com/satcom/satmenu.htm> (17 October 2000); casewriter research.

[a]Little LEO systems have fewer smaller satellites, and are designed to provide voice and data service at lower baud rates.

[b]VITA (Volunteers in Technical Assistance) operates a LEO system with 2 satellites

[c]Big LEO systems have numerous larger satellites, and are planned to provide high-speed data and Internet access services (or broadband) to consumers.

[d]Although Iridium was initially projected to cost $3.5 billion, by 1997 its cost was anticipated to be $4.9 billion. Emmett (1997).

[e]This did not provide full global coverage: 50-75 gateways would be needed to achieve this.

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Exhibit 3 Iridium's Planned Services (as of 1991)

Type of Service	
Geo-positioning and two-way messaging	An RDSS-type unit to be used for automatic location reporting and two-way messaging.
Digital voice transmissions	Two-way, high-quality, 4800-bps voice communication using handheld, portable, and vehicle-mounted terminals. Iridium phones should be available in combination with terrestrial cellular phones with a GPS unit.
Facsimile	Two types of mobile facsimile units: a stand-alone and one designed to be used with an Iridium phone.
Data transmission	A modem that works with the Iridium voice terminal to provide data transmission at a 2400-bps rate.
Global paging	An alphanumeric pager for instantaneous global paging. It is similar in size and performance to present-day terrestrial pagers and capable of receiving messages inside buildings.

Source: Jim Foley, "Iridium: Key to Worldwide Cellular Communications," *Telecommunications*, (October 1991): 23-27. (NB: At that time, Foley was manager of business development at Motorola, Inc.'s Satellite Communications Division).

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Exhibit 4 Iridium Investor and Gateway Structure

Strategic Investor	% Owned	Regions Served	Description
Motorola, Inc.	19	North America, Mexico, Central America, South America, Caribbean	Primary contractor to Iridium and gateway operators
Nippon Iridium (Bermuda) Limited	11.3	Japan	Subsidiary of Nippon Iridium Corporation, consortium consisting of DDI, Kyocera (supplier of Iridium subscriber equipment) and other investors
Vebacom Holdings, Inc.	8.9	Europe, including Austria, Bulgaria, Czech Republic, Finland, Germany, Hungary, Ireland, Israel, Norway, Poland, Portugal, Romania, Spain, Sweden, Slovakia, Ukraine, United Kingdom	Indirectly owned by VEBA AG (Germany)
Iridium World Communications	8.5	N/A	Public investment vehicle, traded on NASDAQ.
South Pacific Iridium Holdings, Ltd.	5.4	South Pacific region, including Australia and New Zealand	Subsidiary of P.T. Bakrie & Brothers
Krunichev State Research and Production Center	4.4	Russia and eight other republics of the Commonwealth of Independent States	Russian federation (state-owned) aerospace engineering and manufacturing company (provided launch services)
Iridium Middle East Corporation	4.3	Middle East, Morocco, Egypt, and Central Asia	One-half owned by Mawarid and one-half owned by Trinford Investments, SA (affiliated with Binladin Group of Saudi Arabia)
Iridium Italia S.p.A.	4.0	Europe (including Belgium, Denmark, France, Greece, Italy, the Netherlands, Switzerland)	Affiliate of STET, Italian integrated telecommunications group (provides various engineering service to Motorola for Iridium system)
Iridium Canada, Inc.	3.8	North America	One-third owned by Motorola, two-thirds by subsidiaries of Bell Canada
Iridium China (Hong Kong) Ltd.	3.8	China, Mongolia, Hong Kong and Macau	Owned by China Aerospace (subsidiary China Great Wall Industries provided launch services)
Iridium India Telecom Limited	3.8	Indian Subcontinent	Owned by consortium of Indian financial institutions and Motorola subsidiary
Korea Mobile Telecommunications Corp.	3.8	North Korea and South Korea	Subsidiary of Sunkyong Business Group
Pacific Electric Wire & Cable Co., Ltd.	3.8	Indonesia, Brunei, Papua New Guinea, the Philippines and Taiwan	Diversified international corporation
Sprint Iridium	3.8	North America	Indirect wholly-owned subsidiary of Sprint Corp.
Thai Satellite Telecommunications Co., Ltd.	3.8	Southeast Asia	Owned by United Communications Industry Co., Ltd. of Thailand
Iridium Andes-Caribe	3.1	South America and Caribbean	Consortium of private Venezuelan investors
Iridium Africa Corporation	2.1	Africa, excluding Morocco and Egypt, and Turkey	Owned by Mawarid Overseas Company Limited
Iridium Brasil Ltda.	2.0	South America and Caribbean	Majority-owned by Inepar
Lockheed Martin Corporation	1.1	N/A	Principle subcontractor to Motorola in construction of satellites for Iridium
Raytheon	0.6	N/A	Principle subcontractor to Motorola in construction of main mission antennas for satellites

Source: Iridium S1/A Registration Statement (6 June 1997) 116-117.

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Exhibit 5 Selected Analyst Ratings, Target Share Prices, and Subscriber Projections

	Credit Suisse First Boston	Lehman Brothers	Merrill Lynch	Morgan Stanley Dean Witter	CIBC Oppenheimer
1997	No coverage.	Nov: Initiate at OUTPERFORM. 1998 target share price of $52. Project 825K subscribers by 1999. Project 3.85M subscribers by 2002.	Jul: Initiate at ACCUMULATE. 1998 target share price of $54. Project 4.1M subscribers by 2002.	No coverage.	Oct: Initiate at HOLD. No target share price Project 20,000 (low-end) to 180,000 (high-end) subscribers in first 12 months of service.
1998	Dec: Initiate at BUY. 1999 Target share price $57. Project 4,000 subscribers in 1998. Project 735K subscribers by 2000.	Jul: Changed to BUY. 1999 Target share price $80. Project 9,000 subscribers in 1998. Project 1M+ subscribers by 2000.	Jul: Changed to NEUTRAL. Oct: Changed to ACCUMULATE. 1999 Target share price $82. Project 40,000 subscribers in 1998.	Mar: Initiate at NEUTRAL. No target share price. Project 95,000 subscribers in 1998. Project 1.7M subscribers by 2000.	Continue at HOLD. No target share price. Project 17,000 subscribers in 1998.
1999	Apr: Changed to HOLD. Jul: Changed to SELL. Project 91,000 subscribers in 1999.	Aug: Changed to NEUTRAL. Apr: 1999 Target share price $74. May: 1999 Target share price $30. Project 478K subscribers in 1999.	Mar: Changed to NEUTRAL. Aug: Changed to Under Review. 1999 Target share price $64. Project 600K subscribers by 2000.	Continue at NEUTRAL. No target share price. Project 230K subscribers in 1999. Project 860K subscribers by 2000.	No coverage.

Source: Selected analyst reports; casewriter estimates.

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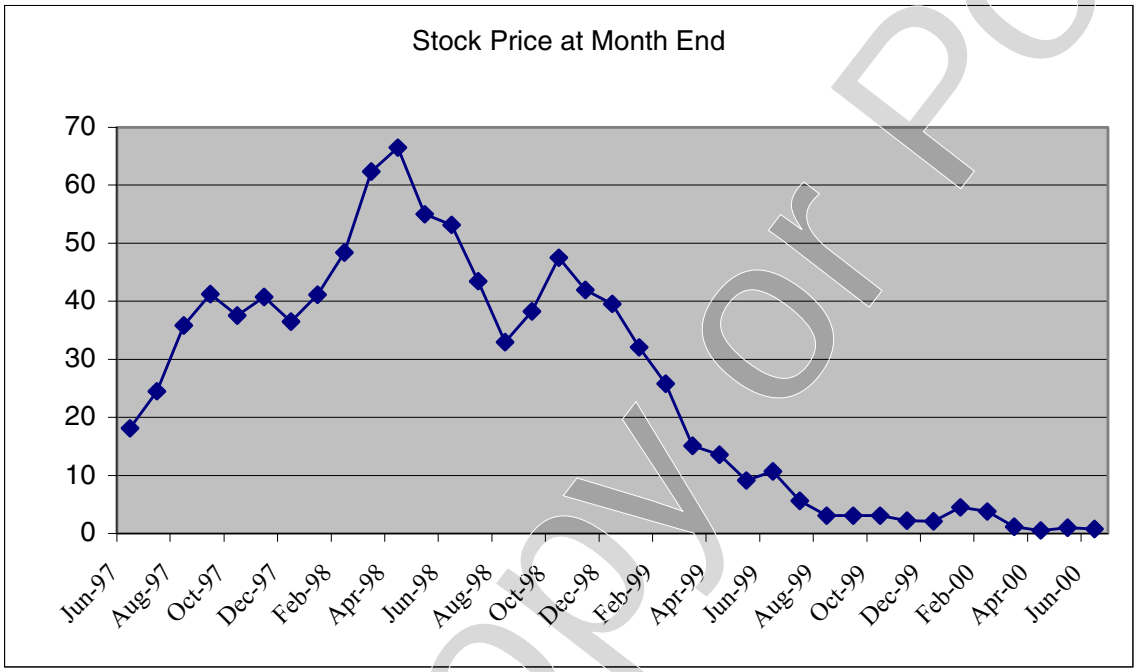
Exhibit 6 Iridium Stock Performance



Source: Adapted from OneSource data.

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Exhibit 7 U.S. Wireless Industry Historical Development (Cellular and PCS)

	1991	1992	1993	1994	1995	1996	1997	1998	1999	F2000	F2001
Market penetration (%)[a]	N/A	2.5	6.2	9.2	12.9	16.6	20.0	25.0	29.0	33.0	36.0
Subscribers (in thousands)	N/A	10,000+	16,009	24,134	33,786	44,043	55,132	69,200	86,047	107,100	134,500
Annual growth in subscribers	N/A	N/A	45.1	50.8	40.0	30.4	25.6	25.1	24.3	24.5	25.6
Monthly $ per subscriber	N/A	N/A	61.48	56.21	51.00	47.70	42.78	39.43	41.24	42.00	43.00
Industry revenues ($M)	N/A	N/A	10,892	14,230	19,072	23,635	27,486	33,133	40,018	48,025	57,630
Annual growth in revenues	N/A	N/A	39.2	30.6	34.0	23.9	16.3	20.5	20.8	20.0	20.0

Source: Cellular Telecommunications Industry Association, Standard & Poor Industry Surveys, *Telecommunications: Wireless* (1990, 1991, 1992, 2000).

Notes:

[a]Calculated by S&P based on Census Bureau data. F=Forecasts by S&P. PCS=Personal communications service.

Exhibit 8 Key Indicators for the World Telecommunications Service Sector

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000e
Mobile cellular subscribers (millions)	11	16	23	34	55	91	145	214	319	472	650
Main telephone lines (millions)	520	546	574	606	644	691	740	792	844	905	970
Intl. telephone traffic minutes (billions)	33	38	43	48	56	62	71	80	90	100	110
Revenue[a] for Services $B (excluding International)	396	419	461	491	530	615	673	702	744	792	840
Revenue for Equipment $B	112	119	132	138	161	182	213	237	260	290	320
Total Revenue	508	539	593	630	691	797	885	939	1004	1082	1,160
Revenue for Services $B: Detailed Breakdown											
Telephone[b]	356	373	394	410	444	497	508	500	500	480	460
–International[c]	33	37	43	46	47	53	53	54	56	58	60
Mobile	11	15	23	33	47	75	104	129	154	192	230
Other[d]	29	31	44	48	39	43	61	73	90	120	150

Source: International Telecommunication Union, 2000.

Notes:

[a]Current (2000) prices and exchange rates.

[b]Revenue from installation, subscription and local, trunk and international call charges for fixed telephone service.

[c]Retail revenue.

[d]Including leased circuits, data communications, telex, telegraph and other telecom-related revenue.

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Exhibit 9 Iridium Consolidated Statements of Loss (thousands)

	1996	1997	1998	1999Q1[a]	Q2[b]	Q3[b]	Sep 1999[a] (14th-30th)	October 1999[a]	November 1999[a]	December 1999[a]	January 2000[a]
Total Revenues	--	--	186	1,451	N/A	N/A	591	1,225	1,277	1,490	1,548
Operating Expenses:											
Sales, general and administrative	70,730	177,474	435,861	181,810			9,908	10,841	10,754	10,166	8,009
Depreciation and amortization	674	119,124	551,912	205,901			39,147	7,519	69,144	69,218	68,739
Operations & maintenance expense							14,285	25,209	25,209	25,209	25,209
Pension expense adjustment							(380)	(1,770)			
Total operating expenses	71,404	296,598	987,773	387,711	N/A	N/A					
Operating loss	**71,404**	**296,598**	**987,587**	**386,260**	**N/A**	**N/A**	**63,551**	**41,799**	**106,384**	**106,083**	**103,505**
Other income and expenses:											
Interest (income) expense, net	(2,395)	(3,045)	265,214	119,141			3,567	7,519	7,391	7,981	8,574
Loss before income tax provision	69,009	293,553	1,252,801	505,401							
Provision for income taxes	4,589	--	--	--							
Loss before reorganization items	**73,598**	**293,553**	**1,252,801**	**505,401**	**N/A**	**N/A**	**65,936**	**109,872**	**111,221**	**114,064**	**108,983**
Reorganization Expense Items:											
Professional fees							1,104	2,847	1,212	1,810	2,241
Employee retention costs[c]									2,374	2,474	2,176
Workforce reduction costs[d]							1,140	(19)	(6)		
Interest income							(445)[e]	(1,031)[e]	(587)[e]	(862)	(812)
Net Loss	**73,598**	**293,553**	**1,252,801**	**505,401**	**N/A**	**N/A**	**67,7335**	**111,669**	**114,214**	**114,506**	**112,588**

Source: Iridium LLC Annual and Quarterly Reports, casewriter estimates.

Notes:

[a]1999 and 2000 figures are unaudited.

[b]Q2 and Q3 reports were not filed.

[c]Employee retention figures not available for October 1999.

[d]Workforce reduction costs not available for December 1999.

[e]Interest earned on accumulated cash resulting from Chapter 11 proceedings.

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Exhibit 10 Iridium Time Line

1987	Motorola engineers Ray Leopold, Bary Bertiger and Ken Peterson conceive Iridium system and begin research and development.
1988	Iridium gateway concept is developed; satellite constellation system will interface with existing terrestrial telephone systems around the world through ground station gateway.
1990	Iridium system announced at simultaneous press conferences around the world.
1991	Iridium, Inc. is incorporated. The U.S. government reserves radio frequencies for Iridium LEOs.
1992	The World Administrative Radio Conference (WARC) and the global regulatory body (the International Telecommunications Union, or ITU) allocates spectrum for Global Mobile Satellite Service (MSS) providers. The FCC grants experimental licenses to Iridium. Iridium signs a $3.47 billion contract with Motorola for system development, construction, and delivery. Motorola, Lockheed, and Raytheon commence full-scale research and development. Motorola becomes prime contractor supplying satellites, gateways, and communication products for the Iridium system.
1993	Iridium completes the first round of financing, securing $800 million in equity. Space System and Operations and Maintenance Contracts with Motorola are effective.
1994	Iridium, Inc. completes second round of equity financing; $1.6 billion total capital raised. Preliminary design reviews of Iridium system are completed. Gateway Authorization Agreements executed.
1995	FCC grants Space Segment license, essentially an operating license for the Iridium system. Date for commercial activation set for 1998. Registration statement with the U.S. Securities and Exchange Commission is filed. Board of directors adopts Iridium Global Ownership program. Critical design reviews for the Iridium system completed. Terrestrial Network Development Contract with Motorola executed. Eleven Gateway contracts signed with investor organizations. Prototype phones become available for lab testing.
1996	Iridium secures an additional $315 million in funding, and obtains $700 million bank facility. Full-scale manufacture of Iridium satellites begins. First ground station inaugurated in Japan. Kyocera begins development of Iridium subscriber equipment. Iridium agrees with other MSS providers to a frequency-use plan, allowing them to cooperate in efforts to secure global authorizations for radio-frequency spectrum use.
1997	First Iridium satellite launched May 5; 47 satellites successfully placed in orbit. Offers a total of $240 million in stock through an IPO, and completes debt financing of $800 million, representing full funding through the beginning of commercial operation. Receives authorization from national governments to proceed with construction and testing of nine ground station gateways. Master control facility substantially completed. System testing begins with prototype phones. First pager message delivered by orbiting satellites, received by Iridium board members. Company obtains additional service providers, roaming agreements and operating licenses worldwide.
1998	Iridium completes deployment of 66-satellite constellation on May 17. Agreements negotiated with some 165 service providers and 155 roaming partners. All 12 Gateway stations become fully operational. Commercial voice operations begin November 1; commercial paging operations begin November 17. Iridium donates telephones and airtime to Central American relief efforts in the aftermath of Hurricane Mitch.
1999	Relief organizations in the Balkans receive free Iridium telephones and airtime in Kosovo refugee crisis. Iridium LLC announced comprehensive financial restructuring through a voluntary Chapter 11 filing.
2000	Iridium ended commercial service 17 March. Iridium system shut down on 31 August.

Source: Company information; Motz and Hordon (1998); casewriter research.

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