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Teledesic (Abridged)

Teledesic LLC proposed to use hundreds of satellites to provide broadband data communications service to subscribers anywhere in the world. Teledesic was conceived by Craig McCaw, who previously had built McCaw Cellular Communications—which was sold to AT&T for $12.6 billion in 1993—into the largest U.S. mobile phone company. McCaw believed that Teledesic could help bridge a growing "digital divide" between world's rich and poor. He said, "The cost to bring modern communications to poor and remote areas is so high that many of the world's people cannot participate in our global community."[1]

Teledesic (pronounced Tel-e-DEH-sic, not Tel-e-DEE-sic) was funded in 1994 with equal personal investments by McCaw and Microsoft's Bill Gates.[2] Additionally, Teledesic had partnered with Motorola and other manufacturers who provided equipment and engineering expertise in exchange for equity (see **Exhibit 1**). Major regulatory hurdles were cleared in 1997 when Teledesic gained approval from the U.S. Federal Communications Commission (FCC) and was allocated 500 MHz of **Ka-band spectrum** by the World Radio Communication Conference, the international body governing satellite communications (see glossary for definitions of terms in bold type).

As of 2000, Teledesic's success depended on many factors, some of which were beyond the company's control. Most notably, there was great uncertainty about the demand for its service. Which potential customer segments were most promising: businesses, residences, or governments? In developed or developing countries? Would competing access technologies like fiber, cable modems, or DSL preempt broadband satellite services, or could they conceivably complement Teledesic's offer? Would SkyBridge, Teledesic's chief rival, try to compete on the basis of price? Teledesic's service was not expected to be operational until 2004, well after SkyBridge's planned launch. Finally, Teledesic was expected to require at least $7.5 billion in additional capital, beyond the $1.5 million committed to date. In the wake of the recent failures of Iridium and other narrowband satellite services and sharp stock price declines across the entire telecommunications sector, would investors provide this capital?

Technology

Teledesic planned to use a constellation of 288 **Low-Earth-Orbit (LEO)** satellites to provide data communications service throughout the world at speeds rivaling those of fiber optic lines and with

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1999 MBA Doug Rogers and High-Tech Fellow Dan Green prepared this case under the supervision of Professor Thomas Eisenmann. This case is based on published materials and on interviews the casewriters conducted with Teledesic executives. Teledesic does not verify the accuracy, validity, or relevance of the material provided by Harvard or third-party sources.

superior service quality. The Teledesic network was comprised of space and ground segments (see **Exhibit 2**).

Space Segment Teledesic planned to place its satellites in near-polar orbits at an altitude of about 700 miles. Satellites would be distributed between twelve orbital planes, each containing 24 satellites (**Exhibit 3**). As the satellites orbited and the Earth rotated below, the constellation would provide coverage to the Earth's entire surface. Three or four satellites would be within range of every user at any given time. From a ground perspective, the satellites would require about 30 minutes to traverse the sky from the southern to northern horizons.[3] Much as a cellular phone user traveling by car was passed from cell site to cell site, a user would be "handed off" from one satellite to another as they passed overhead. The constellation ensured that the line of sight between a user's roof-mounted receiver and a satellite had an **elevation angle** of at least 40 degrees (note that a point directly overhead has a 90 degree angle). This high elevation angle helped to protect the signal from **rain fade**.[4]

Once in orbit, each satellite would become a node in Teledesic's network. Data communications signals would be transmitted from the ground into space (uplinked), then sent from satellite to satellite using **fast packet-switched intersatellite links (ISLs)**, and finally transmitted back to the ground (downlinked) by a satellite near their destination. Each of Teledesic's 288 satellites would be equipped with 1,200 Mbps of downlink capacity—the equivalent of 800 **T1** lines [5] The satellites had an expected life of up to ten years. They would be solar-powered, with rechargeable batteries for use on the "dark-side" of the Earth or when the signal needed to be boosted to get through rain storms. Batteries would be recharged when the satellites were on the Earth’s daylight side, passing over unpopulated areas with little up or downlink activity—for example, oceans, which covered 71% of the Earth’s surface.

Ground Segment Users would send uplinks and receive downlinks through a pair of roof-mounted, motorized dishes, each tracking a different satellite passing overhead. The dishes would be connected to terminals that processed signals and routed them over a local area network (LAN) to users' PCs or through a "gateway" to the Internet or Public Switched Telephone Network (PSTN). Access speeds would be determined by the end-user's choice of terminals. Standard terminals were expected to offer 64 Mbps (megabits per second) on the downlink and up to 2 Mbps on the uplink (see **Exhibit 4**). Teledesic's fully deployed system might have millions of user terminals scattered throughout the world. The positioning and operation of the satellites would be managed from nine ground stations, which would send and receive telemetry data needed to control intersatellite links and satellite-to-satellite hand-offs.[6]

Teledesic’s Technical Advantage

Teledesic's network offered two key advantages over a terrestrial fiber network. First, management believed that Teledesic could offer a major improvement in "quality of service" (QoS) This meant the uninterrupted ability to send and receive error-free signals with minimal and highly predictable transmission delays. High QoS was critical for many networked applications, e.g., military command and control; commodities trading; emergency management systems; credit card authorizations; and air traffic control. In terrestrial fiber networks, transmission delays were introduced by routers and opto-electronic equipment (which converted light signals carried over fiber into electronic signals that could be processed by semiconductors within routers). As data traffic was switched through the Internet, it often crossed network boundaries, moving from one network service provider's routers to another's. At each boundary some data packets might be dropped or delayed due to congestion. In 2000, there was no way to prioritize different data streams as they crossed network boundaries; the Internet was a network of networks, without a central authority to direct traffic. As a result, the loss of up to 40% of data traffic was common at certain **Network Access Points** (NAPs).[7] Lost data had to be resent, contributing to delays. For all these reasons, it was difficult to guarantee high QoS when networking multiple locations through the facilities of several telecommunications carriers, especially when service was required in distant countries with poorly developed infrastructure. Teledesic planned to avoid such problems by offering its customers end-to-end service and by actively managing its traffic, ensuring that the highest priority signals would reach their destinations without delay.

Second, Teledesic would be able to provide bandwidth on-demand. Teledesic could, for example, dedicate capacity equivalent to several dozen T1 lines to be shared by Boston-area customers, allocating varying portions of that capacity to individual customers only when they required it. This would be attractive for customers that had unpredictable bursts or cyclical peaks in their traffic. With terrestrial providers, such customers would have to lease, at a fixed monthly rate, sufficient capacity to handle their maximum traffic; thus, they would pay for idle capacity most of the time. Also, Teledesic's service could be attractive to customers who required "instant provisioning". In 2000, it was common for a business to wait several weeks for the local telephone company to provision T1 service.

Competition

Teledesic's most direct competition would come from other **Low Earth Orbit** satellites, described below. Teledesic also would compete with other types of communications satellites and with several terrestrial access technologies, including fiber, cable modems, DSL, microwave, and "HALO" (High Altitude Long-Operating) aircraft—blimps or unmanned planes flying in patterns high over cities (see **Appendix** describing broadband access technologies). These terrestrial technologies were likely to be deployed only in cities, because low user density made them prohibitively expensive in rural areas. In metropolitan markets, the terrestrial broadband technologies seemed likely to have a cost advantage satellite services, on a per-user basis. However, Teledesic's ability to guarantee high QoS might make it a preferred vendor for some urban customers, despite any cost differentials.

Communications Satellites

There were three types of communications satellites: **Geosynchronous Earth Orbit**, **Middle Earth Orbit**, and Low Earth Orbit (GEO, MEO, and LEO, respectively). GEO satellites orbited at 22,300 miles directly above the equator at a speed exactly matching the Earth's rotation, thereby maintaining a constant position over the Earth. LEO satellites orbited at altitudes of less than 1,000 miles. Most plans for MEO satellites called for orbits at an altitude of around 8,000 miles.

GEO, MEO, and LEO satellite orbits were characterized by different **latencies**. Critics of satellite systems often cited latency, or transmission delay, as their primary drawback for broadband communications. Round-trip latency was defined as the time it took for a signal to travel from the earth to a satellite and back to the ground. Latency became a problem for both voice and data applications when it exceeded 100 to 200 milliseconds (msec). GEO satellites, due to their distance from Earth, had a minimum round-trip latency of about 500 msec. The delay was often higher for Internet and other data communications. Client/server protocols and Domain Name System (DNS) queries required numerous low-bandwidth requests and responses between the client and server; DNS transactions accounted for one-quarter of all Internet traffic.[8] There might be 25 or more "challenge-response" transactions following a single "click" on a web page element, depending on how the network was set up. Consequently, using a GEO satellite system to access the Web could introduce a delay of up to 12.5 seconds (25 transactions x 500 msec delay per transaction). By contrast, due to their low orbits, Teledesic's LEO satellites were expected to have an average round trip latency of less than 100 msec, which was not detectable by the human ear for voice applications.

Besides lower latency, LEOs offered two other advantages over GEOs. First, with enough satellites in a constellation, LEO satellites would pass overhead at a high elevation angle and thus could offer service in cities and at high latitudes. By contrast, at latitudes far north and far south in the northern and southern hemispheres,[9] respectively, GEO users required a clear line of sight to a point in the sky just above the horizon (e.g., 20 degrees in St. Petersburg or Oslo). Satellite transmissions could not travel through trees or buildings, so reception was impossible when the line of sight was obstructed.[10] Second, the sheer number of satellites launched in a LEO system served as a hedge against failure. According to Teledesic's Russell Daggatt, "When you are putting up a single geostationary satellite, a loss or malfunction can be catastrophic. With a network like Teledesic's, you can factor into your plans a certain statistical percentage of failures both on launch and in orbit."[11]

Skybridge

Besides Teledesic, one other company had announced plans to use LEOs to offer broadband data communications services: SkyBridge, a joint effort between the telecommunications equipment manufacturer Alcatel and Loral, a satellite manufacturer. By 1999, Skybridge had attracted numerous equity partners, including Mitsubishi, Sharp, Toshiba, Thomson, and Boeing. Boeing, which previously had launched the Iridium and GlobalStar narrowband LEO constellations, agreed to launch half of SkyBridge's satellites in a contract valued at $500 million.[12]

SkyBridge planned to employ a constellation of 80 LEO satellites orbiting at 913 miles. Many aspects of the SkyBridge system were similar to Teledesic's design, with one major exception. Unlike Teledesic, SkyBridge would not utilize intersatellite links (ISLs), and therefore had a simpler design for its satellites but a more complicated ground segment. Since Skybridge's satellites could not switch traffic to each other, all traffic had to be uplinked and then downlinked through a gateway—a point of access to a terrestrial network within range of a single satellite. If the traffic's destination was outside the range of that satellite, it would have to travel over terrestrial networks to a second gateway near the destination, where it would again be uplinked then downlinked through a second satellite closer to the recipient. This **"bent-pipe"** architecture required many dozens of gateways. According to Teledesic's co-CEO Bill Owens, "Gateways are expensive. And each place where you locate one has a businessman—sometimes not a real partner and always demanding—who wants a big piece of your revenues." SkyBridge's greater reliance on terrestrial networks also implied a degradation in QoS as well as higher transit costs paid to third-party carriers. However, by avoiding the R&D required to manage intersatellite links, SkyBridge was likely to beat Teledesic to the marketplace. Skybridge anticipated a 2001 launch date, but the company was still obtaining regulatory approvals required to offer service.

Beyond Skybridge, it was unclear whether Teledesic would face other broadband LEO rivals. Regulation posed a big entry barrier, as did the enormous capital cost of a LEO project. Notwithstanding these barriers, critics argued that since Teledesic could only upgrade its satellites upon their replacement, competitors might be able to leapfrog Teledesic's technological abilities. Daggatt discounted this argument: "They'd be contending with a company that has an established customer base. They would have to split the existing market, and Teledesic could leapfrog them with its second generation."[13]

Customers

Many observers surmised that Teledesic would fill in the gaps where other high speed access methods were cost-prohibitive, most notably for rural customers in developed countries and unserved customers in developing ones. But there were some doubts about this, such as those voiced by Peter Bernstein, president of Infonautics Consulting. Bernstein believed that Teledesic would pursue urban markets, driven by the same logic as Willie Sutton, who said he robbed banks "because that's where the money is."[14]

Residential Users in Developed Nations At least 90% of residential users in developed markets lived in metropolitan areas where cable modems and DSL were expected to emerge as the dominant technologies for providing broadband Internet access. Satellite services only seemed likely to attract residential users in rural areas.

Telephony and Internet Access in Developing Nations China and India had 8.2 and 1.2 telephones per 100 people, respectively, whereas the U.S. had 68 phones per 100 people.[15] One reason for low phone penetration in these nations was the enormous cost of deploying communications networks over vast geographic areas. Governments might choose to leverage Teledesic's network to provide their populations with access to telephone networks and the Internet.

Maritime and Aviation Markets Teledesic hoped to sell its services to many of the 14,000 large transport ships (800+ ton cargo capacity), each of which spent an average of $75,000 per year for narrowband communications services.[16] Likewise, offering high-speed Internet access to passengers on commercial airplanes was a huge potential market.

Multinational Businesses While terrestrial networks would suffice for many organizations, Teledesic could offer high-quality data communications service to multinational businesses with remote manufacturing and distribution facilities, customers, and suppliers. The energy exploration and distribution industry, for example, transferred huge amounts of information (such as sensor data from offshore drilling rigs, where real-time analysis could prevent expensive equipment failure), and spent about $2 billion per year on communications.[17] Reflecting on the need for rapid, reliable communications, an executive of an auto parts supplier noted, "We have 15 minutes to inform a partner once a truck leaves our shipping dock. If we miss the notification window, the purchasing department erupts about paying penalties."[18] Many companies also required low-latency broadband communications links to geographically-dispersed locations as they upgraded their Enterprise Resource Planning (ERP) systems. Likewise, more companies were relying on Application Service Providers (ASPs) for access to software applications hosted on remote servers. Through ASPs, companies could avoid the delays and costs associated with installing new software releases on all their workers' PCs, and could provide telecommuters and traveling employees with access to software.

The most important selection criteria for the purchase of wide-area network (WAN) services, according to Forrester Research, were global coverage (cited by 46% of companies surveyed) and price (cited by 44%).[19] These criteria ranked ahead of performance, reliability, and the existence of an ongoing carrier relationship.[20] Among early adopters, the value of coverage was even more pronounced: 57% cited limited coverage and 33% cited network performance (including access speed) as their biggest problems with their WANs.

Demand projections for Teledesic's services were difficult to develop. Some research suggested that multinational companies might be reluctant to adopt satellite-based WANs based on their bad experiences with previous networks. The Forrester study indicated that only 31% of Fortune 1000 companies had a WAN in place or planned, while 21% had evaluated and rejected WAN plans. The remaining 48% had no plans whatsoever for development. On the other hand, Lucent researchers noted that for each 1% decrease in the price of bandwidth, there was a corresponding 1.5% increase in demand. The Lucent heuristic suggested that as bandwidth became available, new applications would emerge to fill it.[21]

Government Users Several emerging WAN applications promised to attract the interest of not just businesses, but also health, human service, education, and other governmental agencies around the globe:

- ***Tele-medicine*** By linking digital cameras through Teledesic's network, a heart specialist in India would be able to assist in surgery being performed in Bolivia. An X-ray that might take an hour to send from a dial-up location could be sent in seconds.
- ***Distance Learning*** Interactive learning would be improved with broadband access. Companies would be able to run a single training session involving all of their offices at once. Governments could use the system to run educational programs on crop rotation.
- ***Military Applications and Peacekeeping*** A U.N. inspection team would be able to transfer data from a facility in a remote part of the world. The U.S military was a huge consumer of bandwidth, and represented a $1 billion potential market for Teledesic and other LEO satellite services.[22]

Despite this long list of potential applications, some industry observers were skeptical of the market for LEO data communications. For example, Andrew Cole, head of the wireless practice for Renaissance Worldwide, said, "In the areas where the money is, the market is taken away. You have broadband to the desert, or to rural areas, and there isn't a lot of money there."[23] Owens countered, "We aren't analyzing an established business in a fixed market. The potential market is vastly larger than the current one, and the future uses won't strike you as traditional applications. There are increasing returns to scale at work here. The system will create its own demand." Owens predicted that the worldwide market for broadband data communications would be much greater than $100 billion.[24]

Business Model

Revenue

Teledesic would probably provide connectivity directly for large, multi-site organizations and wholesale capacity to other Internet Service Providers (ISPs) who would resell Teledesic's services to consumers and small/midsize businesses.[25] Small and midsize businesses usually bought connectivity from ISPs in bandwidth increments; for example, 1.54 Mbps T1 services. Larger business often bought **T3** service, the equivalent of 28 T1 lines. Growth rates for ISPs targeting business users were expected to be strong (see **Exhibit 5**, which also includes growth forecasts for consumer Internet access markets and pricing trends for access services).

Due to its wide geographic reach and high QoS, Teledesic might command a price premium over terrestrial ISPs, which averaged about $1,000 per month for a T1 line (see **Exhibit 5c**). Teledesic's total network capacity was difficult to calculate. Each satellite could carry traffic equivalent to about 800 T1 lines, although at any point in time a sizable fraction of the satellites would either be: 1) over water or totally uninhabited regions; or 2) on the dark side of the Earth, where demand for uplink and downlink services was likely to be low. If demand exceeded capacity, Teledesic could always add more satellites. It was also likely that Teledesic would substantially "oversell" its network capacity. Typically, buyers of connectivity services did not send continuous streams of data; hence, they rarely used the full capacity available to them and an ISP could sell the unused capacity to other customers. In the consumer dialup ISP business, for example, a user-to-modem ratio of eight or ten was common.

Capital Costs

Teledesic faced a capital outlay of at least $9 billion before it could begin service. $5.8 billion would be spent for satellites, assuming that Teledesic and its suppliers could exploit efficiencies from high-volume production and bring the cost per satellite down to $20 million. Teledesic would also have to pay an estimated $2.5 billion to launch its satellites. Launches could only occur at a few overscheduled locations around the world. Teledesic could economize by launching several satellites on the same rocket, but this would make launch failures more expensive. Payloads were destroyed in about 6% of commercial satellite launches. Finally, Teledesic would also have to build nine ground stations for telemetry, which had averaged $10 million each for Iridium and GlobalStar (which were less complex than Teledesic) and had run as high as $150 million each for some satellite projects.

Although Teledesic's ground equipment was still under design, Jupiter speculated that Teledesic's terminals would each cost approximately $1,000.[26] As Bill Owens noted, "Whether they cost $500 or $1,000 or $5,000 is a huge deal, because if we are successful there will be millions of them." It was not yet clear whether users would purchase their terminals or whether Teledesic and its reseller partners would subsidize the terminals, then seek to recover their cost through ongoing service fees.

Operating Costs

Marketing and Customer Service To provide marketing and customer service functions—including installation, field repairs, and billing—Teledesic could use either resellers or in-house staff, or it could rely on both. In existing telecommunications markets (e.g., long distance telephone and cable modem services), wholesale rates averaged about 20-50% below the retail prices charged by resellers.[27]

Teledesic's target customer base would influence its choice of distribution partners. According to former Co-CEO Steve Hooper, Teledesic planned to "use systems integrators such as IBM and EDS and regional telcos to market to the telecom managers of mid-size to large organizations."[28] To sign up smaller businesses and residential users, Teledesic might choose to rely on ISPs or Competitive Local Exchange Carriers (CLECs, i.e., competitors to incumbent regional telcos).

Transit and Access Costs When both the sender and receiver of a transmission were Teledesic subscribers, traffic could be carried end-to-end within the Teledesic constellation, without interconnection to terrestrial networks. However, Teledesic would need to interconnect to the public Internet to provide its subscribers with the ability to access parties who were not Teledesic customers. Likewise, if Teledesic terminated phone traffic, it would have to pay access fees to the telephone company completing the call.

Teledesic’s interconnection costs would depend on its scale. If the company did not have a large subscriber base, it would need to buy “transit” from wholesale ISPs (i.e., “backbone” network service providers like MCI’s UUNET). Retail dialup ISPs spent about 5% to 10% of revenues on transit in 1999. With a large customer base, Teledesic might be able to negotiate peering agreements with other wholesale ISPs. In bilateral peering agreements, two ISPs agreed not to charge each other when one ISP’s customers accessed sites through the other's network.

Challenges

Bill Owens emphasized that Teledesic was not like most other businesses: "You won't earn your first dollar of revenue until the network is built, and all those billions of dollars are out the door." He cited four requirements for success:

- **Distribution** Ground segment hardware had to be sold through channels that would differ in each country. The sale would be consultative. Teledesic needed to specify the scope of activities and commissions for local partners—and determine whether and how to avoid working with powerful but sometimes less-than-honest parties in some politically unstable third-world countries. Finally, Teledesic had to extend front-office functions like billing and customer service to a customer base that spoke dozens of languages and used dozens of currencies.

- **Regulation** Teledesic's use of radio spectrum was licensed by numerous national and international regulatory bodies, including the International Telecommunications Union, the World Radio Conference, and nearly 200 national agencies, such as the U.S. FCC. Teledesic had secured critical regulatory approvals, but regulations were constantly evolving and much additional work remained to be done to gain permission to interconnect with local telecommunications providers in smaller countries around the world.

- **Finance** Teledesic had to raise billions of dollars. This was a daunting task, even before the recent bankruptcies of Iridium and ICO, a MEO service. "Those failures," Owens remarked, "dramatically changed the mood of traditional capital providers. There are perceptions of reality and then there is reality. Due to perceptions, we're not now able to go to the high-yield debt markets like Iridium did. We've got to keep planning through that, looking for less traditional investors who see our reality, and who have different risk-return preferences and investment horizons than traditional capital providers. Who understand that it's the undoable that we are about to do."

- **Technical and engineering** Teledesic had to find a way to mass-produce satellites at low cost and keep enough aloft to maintain a viable network. It was also important to develop telemetry and switching applications that yielded end-to-end QoS that met or exceeded customers' expectations.

Owens thought that at Iridium, management's perception of the relative importance of these four issues probably had not been correct. In his view, Iridium had focused perhaps too much attention on engineering and finance and not enough on how to provide services that customers valued and distribute phones at a low cost. He said, "Reflecting Craig McCaw's heritage, Teledesic is more entrepreneurial, more focused on the customers, service, and the opportunity."

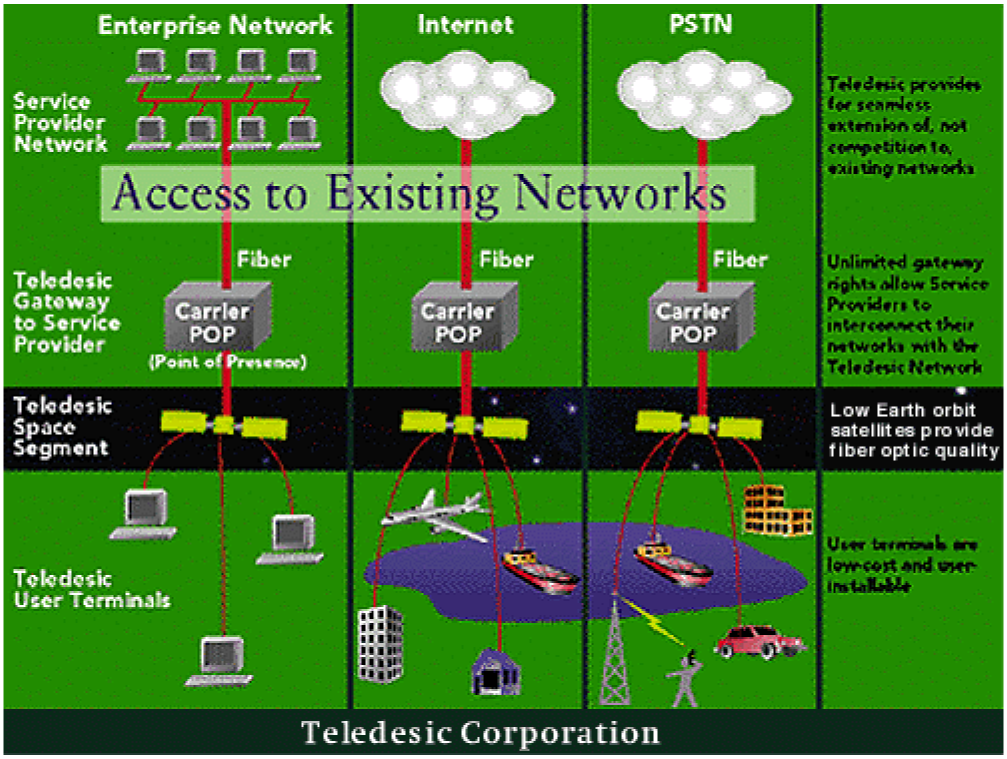
Owens was optimistic that Teledesic would succeed. The company was poised to provide the most reliable, highest quality, most far-reaching, lowest latency broadband communications solution of the twenty-first century. Owens said, “We have money in the bank. We have the time necessary to evaluate opportunities created by the unfortunate difficulties of others. We have investors with long-term vision. And, above all, we have the hands-on commitment and proven track record of Craig McCaw."[55]

Exhibit 1 Teledesic Ownership Structure

Investor	Investment ($mm)	Date	Ownership Stake
Motorola	$750	5/98	26%
Boeing	$100	4/97	4%
Saudi Prince Alwaleed	$200	4/96	11%
Craig McCaw	n/a	1994	21%
Bill Gates	n/a	1994	21%
Hyundai, AT&T's McCaw Cellular Unit, Kinship Ventures, others	n/a	n/a	
Total	**$1.5 billion as of 9/99**		**100%**

Sources: Marco Caceres, The Teal Group, personal conversation, 27 September 1999; Teledesic press releases, 14 April 1998 and 21 May 1998; *Aerospace Daily* 13 July 1999; *Space News*, 20 April 1998, 19 July 1999; *Puget Sound Business Journal*, 29 May 1998.

Exhibit 2 Teledesic's Network Architecture



Source: Teledesic web page: http://www.teledesic.com. Accessed 11/23/99

Exhibit 3 Teledesic Constellation

Source: Patrick Worfolk, The Geometry Center at the Univ. of Minnesota, accessed14 Jan. 2000 at Teledesic website.

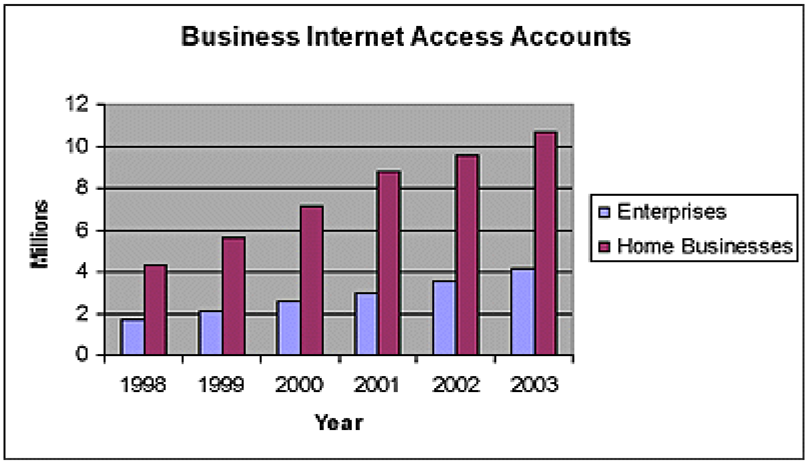
Exhibit 4 Comparison of Broadband Data Rules

Technology	Upstream Access Speed	Downstream Access Speed
Dialup Modems	33 kbps (up to 56 kbps with digitally-provisioned line)	33 kbps (up to 56 kbps with digitally-provisioned line)
Cable Modems	300 kbps maximum, comparable to dialup modems when many users were logged in	Up to 40 mbps in theory, but bandwidth was shared by multiple users
ADSL	Up to 160 kbps within 18,000 feet of the phone company central office. Up to 1.5 mbps within 6,000 feet of the phone company central office.	Up to 1.5 mbps within 18,000 feet of the phone company central office. Up to 12 mbps within 6,000 feet of the phone company central office.
Teledesic	2 mbps (standard terminal) 64 mbps (broadband terminal)	64 mbps

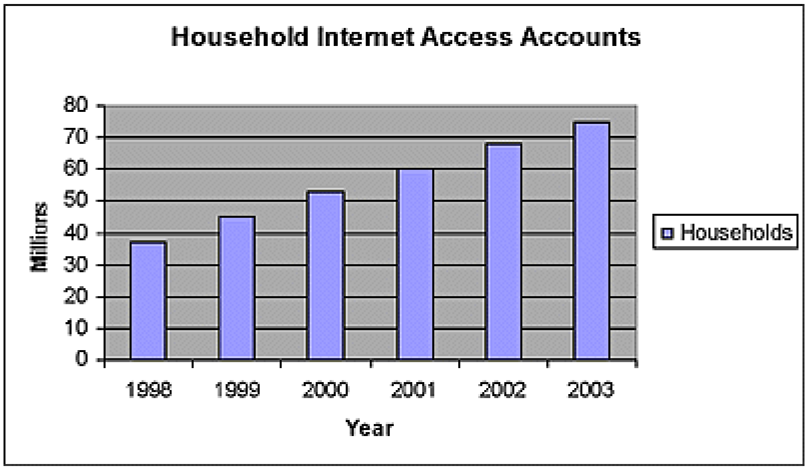
Source: Dan Green, "The Last Mile of Broadband Access," HBS Case No. 800-076, 14 September 1999

Exhibit 5 The U.S. Business and Consumer Internet Access Markets (excludes private data networks)

5a The U.S. Business and Consumer Internet Access Markets (excludes private data networks).

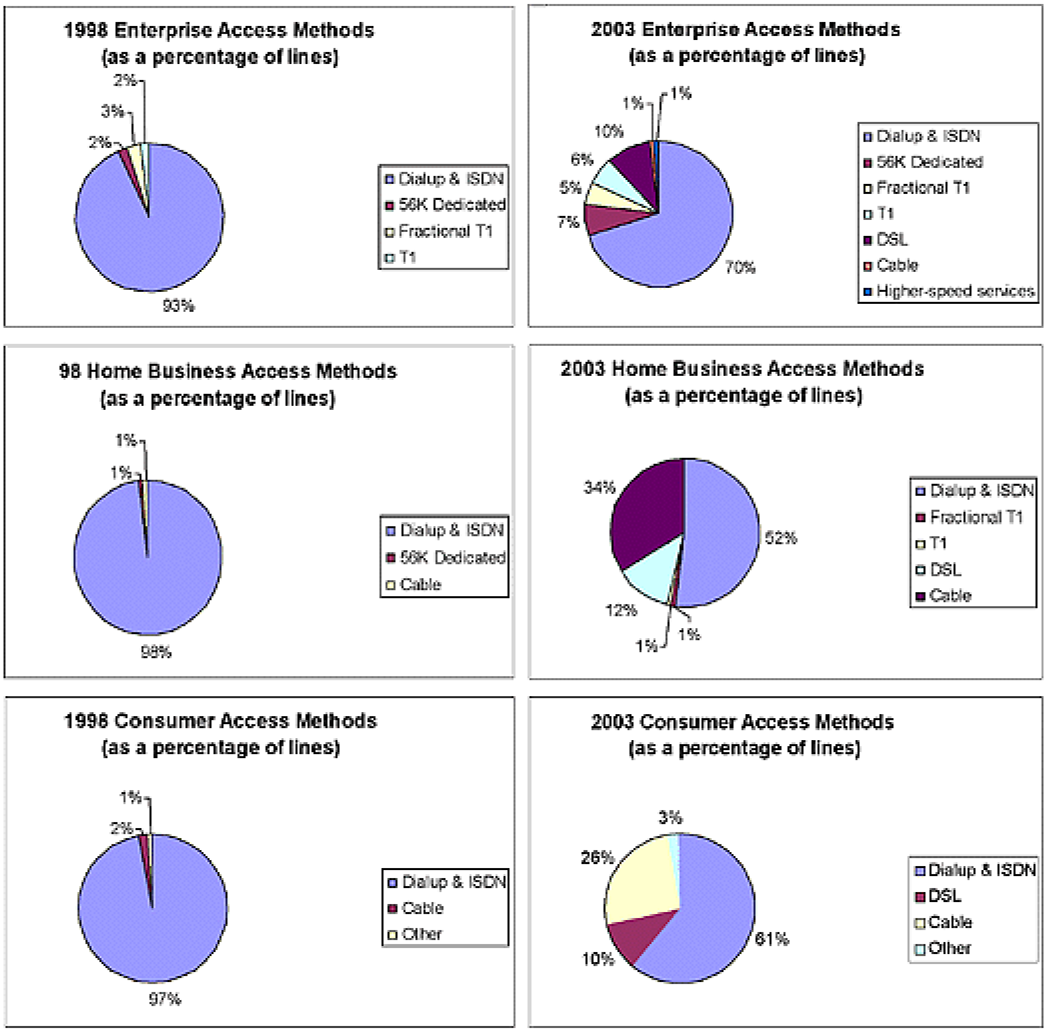


Source: James Lindsay Freeze, "Internet Services Hypergrowth," Forrester Research, February 1999.



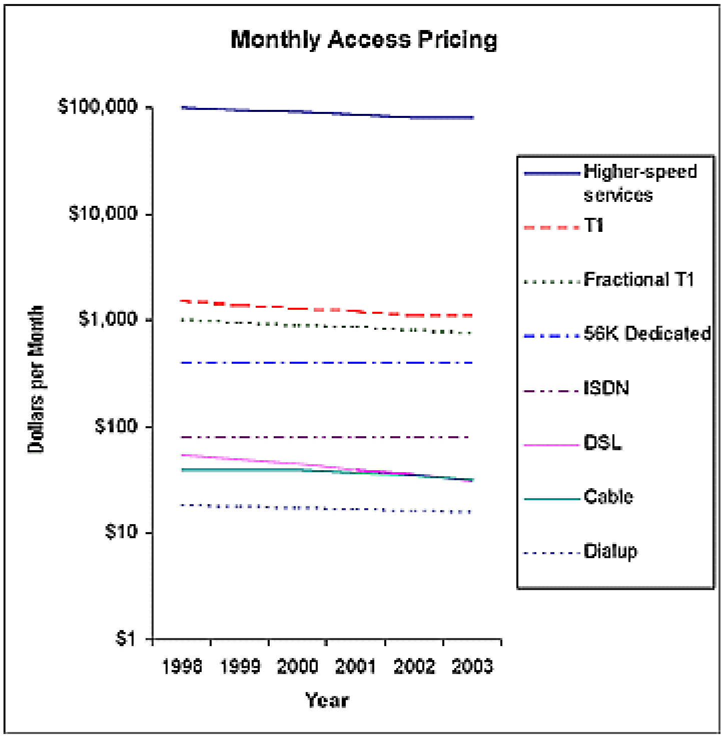
Source: Bruce Kasrel, "From Dialup to Broadband," Forrester Research, April 1999.

5b U.S. Internet Access Methods (excludes private data networks).



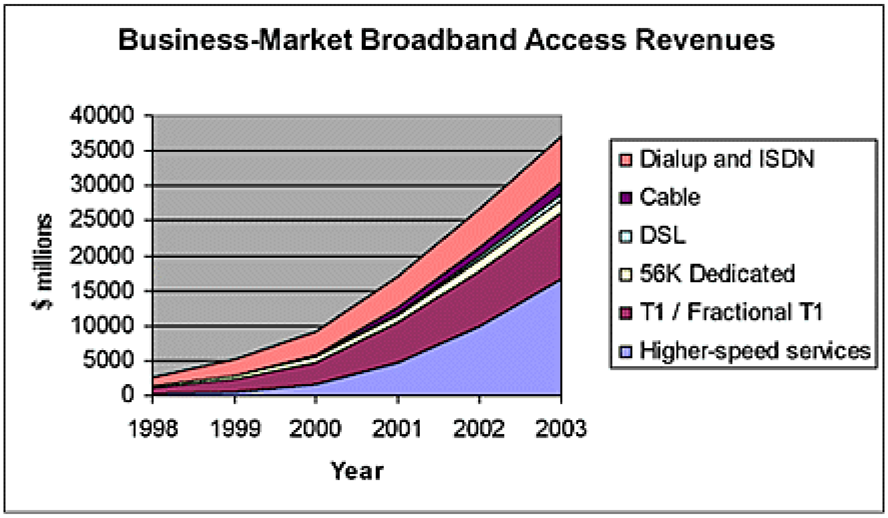
Sources: James Lindsay Freeze, "Internet Services Hypergrowth," Forrester Research, February 1999; Bruce Kasrel, "From Dialup to Broadband," Forrester Research, April 1999.

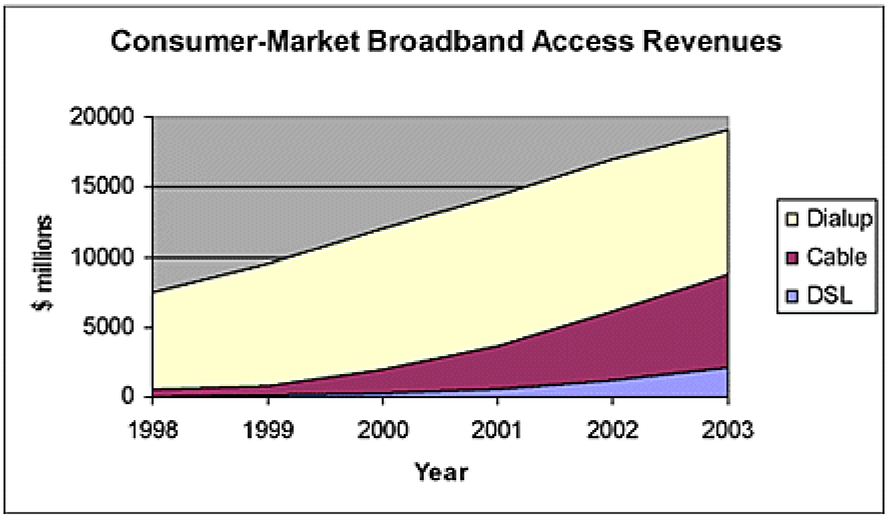
5c U.S. Internet Access Pricing



Sources: James Lindsay Freeze, "Internet Services Hypergrowth," Forrester Research, February 1999; Bruce Kasrel, "From Dialup to Broadband," Forrester Research, April 1999.

5d U.S. Internet Access Revunues (excludes private line and other non-Internet data services).





Source: Bruce Kasrel, "From Dialup to Broadband," Forrester Research, April 1999.

Appendix: Broadband Access Technologies

Satellites

Geosynchronous Earth Orbit (GEO) Satellites

GEO satellites had large coverage areas, or **footprints**. The signals from a GEO satellite could reach most of the facing surface of the Earth, only breaking down when the signal's path through the atmosphere was oblique. Because of the large footprint, only three satellites were required to provide global coverage. Because of latency problems, however, GEO satellites were used more frequently for broadcast applications such as the transmission of television signals, rather than point-to-point voice or data communications.

As of late 1999, **Direct Broadcast Satellite (DBS)** systems such as EchoStar and Hughes Electronics' DirecPC system used GEO satellites to provide Internet access. In these systems, the satellites broadcast downstream signals to the Earth, employing a roof-mounted dish and a specialized terminal to receive the signal, descramble it, and isolate the data intended for the subscriber. The maximum downlink transfer rate was 400 Kbps. Users sent upstream data (e.g., outgoing email or webpage requests) through the PSTN via a dialup modem. Hence, compared to traditional ISP architectures in which the end user employed narrowband phone lines in both directions, DBS users sent upstream data at the same speed (i.e., a maximum of 56 Kbps), but received downstream data at rates that were up to seven times faster. This increase in downlink transmission rates implied an improvement in overall performance, because upstream data sent from a user to a host server comprised only 2% of the total data exchanged in typical Internet applications. The balance, 98%, was downstream data transmitted from the host server to the user. Because much of the Internet's traffic was composed of queries between the user and host server, however, latency often slowed GEO Internet access services to dialup speeds.[29]

GEO satellite systems were especially attractive for point-to-multipoint (i.e., "broadcast") applications. Beyond transmitting the signals of television networks, they could be used for broadcasting corporate training and communication programs to multiple facilities.[30] Hughes' "Direc" line of offerings and Loral's CyberStar service both exploited these corporate markets using GEO satellites with downlink speeds of up to 30Mbps per user.[31] While uplink transmissions for these projects initially would be provided through independent ISPs using telephone lines, within a few years CyberStar planned to offer direct ground-to-satellite uplink capabilities of 500Kbps.

The first GEO system to offer broadband rates for both uplink and downlink transmissions was expected to be AstroLink, founded by a consortium of investors including Lockheed-Martin, TRW, and Telecom Italia. AstroLink planned to launch service in 2001 with a constellation of nine Ka-band satellites occupying five orbital slots, providing users anywhere in the world a choice of data rates ranging from 416 Kbps to 20 Mbps. Because of the constellation's distance from the earth, latency was likely to pose a problem for voice and many other interactive applications.

Mid-Earth Orbit (MEO) Satellites

Mid-Earth Orbit satellites, or MEOs, orbited the Earth at an altitude between 1,500 and 13,000 miles. Occupying the middle ground between GEOs and LEOs, they offered some of the desirable and undesirable properties of each. The chief advantage that MEOs held over GEOs was a reduction in latency, which could be as little as a tenth of a second for round trip transmissions, or one-fifth that of GEO satellites. Since they operated much lower than geosynchronous orbit, MEO satellites typically remained within range of a given point on the Earth's surface for only a few hours. Consequently, a constellation of up to 20 satellites was required to provide global coverage.

ICO Global's MEO system had been targeted for launch in the year 2000 with 10 MEO satellites to provide global mobile phone service. ICO planned to link its customers to existing terrestrial cellular towers whenever they were within range, then pass them to satellites whenever they were out of range of terrestrial towers. However, ICO had declared bankruptcy soon after Iridium in 1999. Its future, like Iridium's, remained uncertain, although ICO's prospects improved in October 1999 when Craig McCaw announced a plan to rescue the service by leading a group of investors with a $1.4 billion financing round.

The other significant MEO satellite company was Hughes Electronics, long a leader in GEO satellite-based services, which planned to supplement its GEO broadcasts with the interactivity allowed by MEOs through a system known as "Spaceway." Set to begin operation in 2002, a constellation of eight GEOs and up to 20 MEOs would together offer uplink and downlink speeds of up to 6 Mbps, depending upon the level of service selected by the customer.[32]

High-Altitude, Long-Operating Aircraft (HALOs)

The HALO[33] category included dirigibles (also known as blimps or zeppelins), unmanned "drone" airplanes, and manned airplanes that flew in patterns at a 50,000 to 70,000-foot altitude. HALO backers believed that the inherent disadvantages of satellites called for a low-latency, low-capital, staged-deployment solution.

Aircraft

Some plans called for lightweight jets to operate at altitudes above 52,000 feet, high above the flight paths of commercial aircraft. Each aircraft would serve as a hub, handling point-to-point data exchange within its coverage area. Information addressed to non-subscribers or to points outside the coverage area would require the use of terrestrial transmission lines. To provide continuous service, several aircraft would be assigned to a single area and would fly overlapping shifts, allowing for refueling, maintenance, and equipment upgrades.

The best developed of these systems was Angel Technologies' HALO Network. Angel, which planned to deploy its first aircraft above Los Angeles in 2000, proposed to offer access to video, data, and the Internet at rates ranging from 1 to 5 Mbps and higher.

Dirigible Systems

Dirigible systems would use lighter-than-air platforms hovering at approximately 70,000 feet above major cities. The only dirigible system planned was Sky Station International, pioneered by former U.S. Secretary of State Alexander Haig. Beginning in 2002, Sky Station planned to deploy blimps above 250 of the world's largest cities. The structures would each be as wide as a football field and 70% longer, and would have 5-10 year life spans. Users would have broadband Internet access at speeds ranging from 2 to 10 Mbps.

HALO Advantages and Disadvantages

HALO systems offered several advantages. First, their proximity to Earth eliminated latency concerns. Second, it would be straightforward to bring HALO equipment back to Earth for maintenance and upgrades. By contrast, once launched, satellite hardware could not be modified economically. Third, compared to both satellite and terrestrial wireless systems, HALOs were less likely to suffer from line-of-sight problems. Fourth, unlike traditional satellite systems, HALO costs were relatively scalable--platforms could be introduced and financed on a city-by-city basis instead of on the "all or nothing" basis associated with satellite systems.

Disadvantages associated with HALO systems included their reliance on terrestrial systems to provide links between metropolitan areas and their lack of coverage in less densely populated areas. Additionally, HALO systems either would need to compete for spectrum in the regulatory arena with terrestrial wireless systems. Much of the available spectrum had already been allocated to competing wireless services such as **LMDS**. Alternatively, HALO operators would need to purchase capacity from carriers with spectrum licenses. Furthermore, HALO operators needed numerous regulatory clearances from federal and state agencies in the U.S. before they could operate above major cities.

Fiber Optics

Fiber optic lines were capable of providing symmetrical transmission speeds measured in gigabits per second (Gbps). Most fiber lines were used by telecommunications carriers as "backbone" links between large population centers. A group of companies (e.g., Level 3, Qwest, and Global Crossing) founded during the second half of the 1990s was aggressively deploying backbone network fiber, and planned to wholesale their capacity to CLECs that provided access to retail customers (e.g., Teleport and Craig McCaw’s XO Communications). Because of the industry's rapid pace of fiber deployment, backbone network capacity in 2002 was expected to balloon to 200 times its 1997 capacity.[34] Most of this fiber, however, served major metropolitan areas in developed economies.

By the late 1990s, direct connections to fiber lines were available for large business customers within many major metropolitan areas. The biggest constraint in deploying fiber to end users was cost. For example, Nippon Telegraph and Telephone estimated that it would cost approximately $900 billion to provide fiber access to everyone in Japan.[35] Laying fiber lines in rural areas cost $20,000 - $35,000 per mile, versus $100,000 per mile or more in urban areas.[36] Deployment involved obtaining right-of-way leases, digging up streets, and other labor-intensive tasks. Once the fiber was deployed, actually "lighting" it (i.e., installing all the equipment required to send and receive data)could increase costs substantially. The equipment included multimillion-dollar electronic switches, sophisticated lasers, and opto-electronic equipment designed to convert the light signals into electrical signals that could be interpreted by telephones and PCs. Given the high labor costs associated with laying fiber lines, most telecommunications carriers added significantly more "dark" fiber capacity than they needed over the near term. Carriers would light a few strands, then bring additional "dark" capacity online as it was needed.

The earliest entrants to the metro fiber market were companies like Metropolitan Fiber Systems (MFS), Brooks Fiber, and Teleport Communications Group (TCG) in the U.S., and NTL in the U.K. Gradually, many metropolitan fiber companies, which were laying fiber to their customers' buildings, were being acquired by long-distance telephone carriers seeking access to profitable metropolitan business customers. For example, MFS and Brooks had been acquired by Worldcom, and Teleport had been acquired by AT&T. Few companies had plans to deploy fiber to individual residences or within developing nations.

Cable Modems

By 2000, about 80% percent of the 60 million U.S. households subscribing to cable TV services were served by systems that had been upgraded to handle broadband Internet traffic via cable modems.[37] @Home, Road Runner and other cable modem services provided consumers with Internet access (and some unique broadband content) at speeds ranging from 1.5 to 3 Mbps for as low as $40 per month.

Cable modems had lower equipment and installation costs than competing systems for high-speed Internet access, including DSL, terrestrial wireless, and satellite-based systems. However, the "tree-and-branch" architecture employed in cable systems[38] meant that all the users on a single coaxial cable "branch" shared its transmission capacity. This could compromise privacy if customers failed to disable their computers' file-sharing functions, and could slow data transmission rates when too many users shared the same coaxial line. However, cable operators pointed out that under conditions of strong demand, they could readily afford to extend fiber optic lines deeper into any neighborhood facing capacity constraints, subdividing existing coaxial cable branches so that each was shared by fewer households.

DSL

Digital Subscriber Line, or DSL, made use of the "twisted-pair" copper lines already extending into hundreds of millions of businesses and residences around the world. DSL used modems at a phone company's Central Offices (COs) to modulate and encode signals from the data provider into a DSL signal. The modem then combined voice traffic with the data traffic and sent the combined signal to the customer over existing phone wires. The customer's modem separated the voice and data signals, then routed them to the appropriate device (PC, telephone, or fax).[39] As of late 1999, the high costs of customer premise equipment (CPE) had limited DSL primarily to the business market. With typical price tags of $400 to $500 for a DSL modem (down from over $1,000 in 1998), $300 for installation, and $60 per month for access, DSL was still expensive for the average residential consumer.[40] The Bell Operating Companies (BOCs) and other LECs (local exchange carriers—providers of local as distinct from long distance phone service), were addressing high start-up costs through subsidization, reasoning that consumers would be unlikely to switch to cable modems once they installed DSL.

The quality of DSL service was dependent on the length of the copper line extending to the customer. For most DSL technologies, signals degraded when copper lengths approached 12,000 feet, or just over 2 miles. 40% to 50% of copper lines extended beyond 12,000 feet, and over 20% of copper lines extended more than 18,000 feet, beyond which DSL service was not yet technically viable.

The most common variant of DSL service was Asymmetric DSL, or ADSL. "Asymmetric" meant that the service operated at different speeds when sending and receiving data. Current ADSL technology received data at speeds of up to 6 Mbps and sent data at 640 Kbps, depending upon the distance from the CO. ADSL's rollout by Incumbent LECs (ILECs) had been slowed by their fear of cannibalizing existing high-margin services, such at T1 and T3 data communications lines. Commercial customers had been willing to pay as much as $1,000 per month for T1 service (which transmitted data at 1.544 Mbps). Notwithstanding this concern, International Data Corporation expected 5.9 million DSL lines to be in use by 2002, up from 100,000 in 1998.[41] In addition to the ILECs, DSL service was offered by CLECs such as Covad Communications and Northpoint Communications, who were "overbuilding" incumbent's networks with their own plant, and by ISPs such as Mindspring and Earthlink, who planned to lease DSL capacity from ILECs.[42]

LMDS

Local Multipoint Distribution Service, or LMDS, used microwave radio frequencies in the 28 GHz band for short-distance wireless broadband service. LMDS providers placed base stations on top of tall buildings in a city. These base stations were connected via terrestrial fiber lines that provided high-speed access to the Internet and other networks. End users, equipped with Frisbee-sized antennas and a network interface card installed in their PCs, were able to transmit data to and receive data from the base stations at speeds up to 155 Mbps.

LMDS offered many unique benefits: it was extremely low-cost (a base station could be established for about $200,000 and additional buildings could be linked for approximately $6,500 each); could be deployed to a customer site in a matter of days; was extremely scalable; and was profitable even with low penetration.[43] WinStar Communications, an LMDS provider, estimated that breakeven profitability could be achieved with a network serving only ten buildings.[44] However, high transmission frequencies limited the range, or "footprint," of LMDS systems, and the requirement for a clear line-of-sight between end users and the base station was problematic in the urban environments where the technology was most likely to be economically deployed.[45] Furthermore, roof rights for antenna placement had been historically costly and difficult to negotiate.

Several other companies, most notably AT&T, Teligent (backed by AT&T's Liberty Media unit), NEXTLINK (backed by Craig McCaw), and NTL, planned LMDS systems that would offer synchronous high-speed transmission rates for Internet access, videoconferencing, and other applications. These services would be initially targeted at high-volume business users.

As of 1999, New York City-based SpeedUS.com (formerly CellularVison) used LMDS technology to provide multichannel TV service ("wireless cable") and Internet access to residential users throughout Manhattan, Brooklyn, and Queens. Through its SpeedUS Internet Access, users were able to achieve downlink speeds of 48 Mbps. However, users still used traditional phone connections for the uplink (similar to Hughes' DirectPC system). By only offering high-speed downlink capabilities (which account for about 98% of data transfer), SpeedUS.com eliminated the need for a transmit-capable antenna, which would have put upward pressure on the already pricey $60 per month fee and $500 startup cost.[46]

GLOSSARY

Definitions adapted from Harry Newton. Newton's Telecom Dictionary. (New York: Telecom Books, 1999).

Bent-Pipe	A satellite system which did not use Intersatellite Links (ISLs). In a typical data session or call, a user established an uplink to a satellite, which promptly "bent" the signal back down to earth where it ran over a terrestrial network, often to another ground station, where it was uplinked and downlinked again to the user at the other end. Compared to systems that used ISLs, bent-pipe systems generally had more latency because of the extra terrestrial routing, uncertain interconnection quality on the ground, and the additional satellite round trip. They also had more complicated and expensive ground segments than systems that used ISLs. However, bent-pipe systems had simpler and less expensive satellites.
Central Office (CO)	A telephone company facility in which subscribers lines are joined to switching equipment for connecting subscribers to each other, locally and long distance.
Circuit-Switched	On a circuit-switched network, you pick up the phone and dial another party. When you finish dialing, the various telephone company switches along the way pick a path for your call. When the other party answers, you and she have the exclusive and full use of the circuit that was set up between you until you (or she) hang up, at which time it is idle until the system of switches grabs it for another call. That call might include voice, data, or video. Because you get exclusive access to the full circuit, the phone company cannot use it for anything else; you pay for the privilege of tying up that circuit.
Direct Broadcast Satellite (DBS)	A digital satellite system for transmitting TV programs. TV signals were received by small and inexpensive dish antennae typically mounted on either the roofs or sides of houses.
Digital Subscriber Line (DSL)	A generic name for a family of high-speed digital communications services provided over existing twisted-pair copper phone lines by local telephone companies to their local subscribers.
Elevation Angle	The angle between the line-of-sight to a satellite and the horizon. If the angle was too low, buildings or trees could obstruct the line-of-sight required for reliable communication. Similarly, at low angles, the signal degraded rapidly because it had to travel through more of the atmosphere. Low elevation angles also amplified the effects of **rain fade**.
Fast-Packet Switching	Fast-Packet switching was designed to meld the best qualities of circuit-switched and packet-switched networks. It had three principal features: First, data and voice were transmitted in packets, much as they were in packet-switched networks. Second, each "channel" or circuit available between two points was divided into different time slots, as they were in circuit-switched networks. As in a railroad train, each "conversation" or stream of data traffic was allocated a different position Conversation 1 was given boxcar 1 (time slot 1), conversation 2 was given boxcar 2 (time slot 2), etc. Third, switches in the network had additional "intelligence". This intelligence allowed switches to begin sending a packet before it had been fully received, to assign packet priority, and to interrupt the delivery of low-priority packets (usually data traffic) in order to deliver a high-priority packet (usually video or voice traffic).

Footprint	The geographic area to which a satellite directed its downlink transmissions, and from which it could receive uplink transmissions. While a typical LEO had a footprint about 1,000 km in diameter, a typical GEO had a footprint that covered about a third of the surface of the Earth.
Fractional T1	A level of service offered by telecommunications carriers that enabled data transmission rates of less than 1.544 Mbps, but more than the 56 Kbps allowed by dialup lines.
Geosynchronous Earth Orbit (GEO)	An equatorial orbit at an altitude of 22,300 miles. GEO satellites orbited at a speed that matched the Earth's rotation, and appeared to hover over a single point at the equator.
High-Altitude, Long Operating (HALO)	A term used to describe a special category of aircraft designed to fly more than 50,000 feet above the earth and provide telecommunications services. HALOs included manned aircraft, drones, and blimps.
Intersatellite Links (ISLs)	A system by which a satellite carrier avoided interconnection with terrestrial carriers for traffic on its network. Signals travel from one user, through the satellite constellation, directly to another user. Only one uplink and downlink is required, because the routing of the signal happens in the satellite field. See **Bent-Pipe**.
Ka-Band	The portion of the electromagnetic spectrum in the range from 33 - 36 Gigahertz (GHz). Ka Band was used in satellites that operated at 30GHz for uplink and at 20GHz for downlink.
Ku-Band	The portion of the electromagnetic spectrum in the range from 12 - 14 Gigahertz (GHz). Ku Band was used in satellites that operated at 14 GHz for uplink and 11 GHz for downlink. The Ku Band was used for broadcast TV "on the scene" interviews and other applications that required a small, portable dish. Hughes Electronics used the Ku Band for its DirecTV and DirecPC services.
Latency Delay	The time it took to get information through a network. Latency was caused by a number of factors, including an absolute limit on the velocity at which information could travel (the speed of light), differences in the physical properties of the medium (i.e. glass fiber, copper, deep space, or through the atmosphere) through which transmissions were sent, and the amount of time required by a switch or router to perform its tasks.
Local Multipoint Distribution System (LMDS)	A method of using microwave technology to deliver data services to numerous buildings in a neighborhood. A transmitter/receiver on top of a local building broadcast television, voice, or data services to dishes on other buildings in the neighborhood and then received return signals from the households. In the U.S., LMDS systems operated at 28 GHz, and therefore encountered rain fade and line-of-sight problems. In certain other countries such as Brazil, LMDS operators shared the lower-frequency FM band with radio. FM radio waves could bounce off buildings and were relatively unaffected by the weather, significantly expanding the range of LMDS service.
Low Earth Orbit (LEO)	An orbit that is typically within 1,000 miles of the earth. LEO satellite communications functioned like cellular systems; to establish a connection, a user gained access to one of these satellites much as he would gain access to a cell site in proximity. When the satellite moved out of range, the transmission was handed off to another satellite that had come into view. Handoffs could occur several times during a transmission. Whereas in cellular networks, the towers were stationary and the users were mobile, in a LEO network, the "towers" moved and the users were relatively stationary. The underlying algorithm for switching calls was

	the same for both types of networks. LEOs were grouped into two categories. "Little" LEOs were used in narrowband data applications such as **VSAT**, worldwide paging, or cargo tracking. "Big" LEOs were granted separate spectrum and were used for both data and voice. The Iridium, GlobalStar, and Teledesic constellations were Big LEO systems.
Middle Earth Orbit (MEO)	An orbit that fell anywhere between LEO and GEO orbits. In principle, MEO satellite systems worked on the same principles as LEO satellite systems.
Near-Earth Orbit (NEO)	See HALO.
Network Access Point (NAP)	An exchange point for Internet traffic, where Internet Service Providers connected their networks to those of other Internet Service Providers for the purposes of exchanging traffic. A NAP allowed small regional ISPs to connect to the network backbone. A NAP was also called a peering point.
Packet-Switched	Data to be sent over a packet-switched network was sliced into packets, each of which could be routed independently through different paths in the network. Packet-switching had one big advantage. It made very efficient use of network, especially with traffic that came in bursts, as data typically did. Packet-switching had one big disadvantage, however. Because packets could travel over different routes through the network, they could experience varying levels of delay and arrive in a different order than they were sent or not arrive at all. If any server along a packets route was too full to receive more packets, packets were simply discarded. When the receiving server detected that it had not received all the packets in a transmission, or when it detected an error in the packets it received, it requested that the originating server resend the transmission.
PCS	Personal Communications Service (PCS) A digital version of cellular telephony that used higher frequency radio signals, digital signals, and towers that were spaced more closely. PCS phones were smaller, had shorter range, and used less power than conventional analog cellular phones.
Rain Fade	The temporary loss of a wireless signal due to the inability of the signal to penetrate dense rain clouds or rainfall. In general, the higher the frequency of the transmission, the greater the susceptibility to rain fade.
T1	A level of service offered by telecommunications carriers that enabled data communications rates of up to 1.544 Mbps.
T3	A level of service offered by telecommunications carriers that was the equivalent of 28 **T1** lines.
Very Small Aperture Terminal (VSAT)	A relatively small satellite antenna, typically fewer than 3 meters in diameter, used for satellite-based data communications. VSATs were employed widely at places like retail stores and gas stations, which used them to transmit the day's receipts or inventory levels. At gas stations, credit card readers on pumps often used a VSAT terminal to approve transactions. VSATs had traditionally supported data rates of up to 56 Kbps, although recent systems were enabling services up to T1 speeds.

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[10] Iridium's constellation, although LEO, had so few satellites (77 altogether) that it often required users to have clear line-of-sight to a satellite just seven degrees above the horizon. At such a shallow elevation angle, line-of-sight was difficult to establish even in an open city park.

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[29] Carmen Nobel, "Despite Hiccups, Satellite Access Looms," *PC Week* http://www.zdnet.com/zdnn/content/pcwk/1515/305862.html. Accessed December 21, 1999.

[30] GEO satellite systems also were used in Very Small Aperture Terminal, or VSAT, applications. VSATs were small low-power antennae used by businesses to transmit and receive narrowband and data, enabling business applications such as inventory tracking and credit card authorization. VSAT terminals were not generally useful for broadband applications because their low power limited the uplink capacity.

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