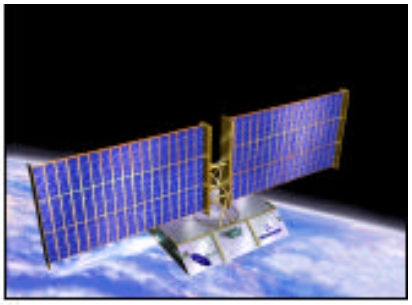
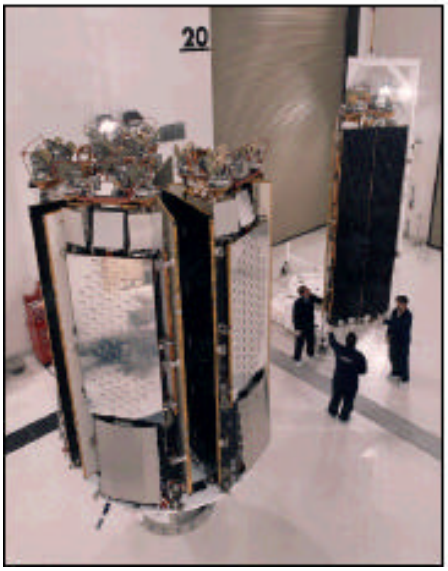
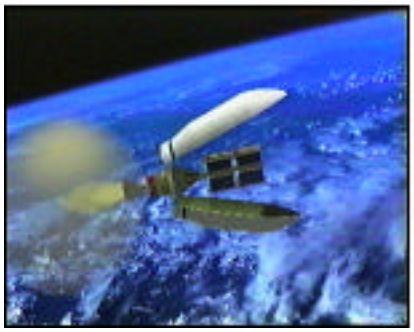




1998 LEO COMMERCIAL MARKET PROJECTIONS

Associate Administrator for
Commercial Space Transportation (AST)

May 1998



ABOUT THE ASSOCIATE ADMINISTRATOR FOR COMMERCIAL SPACE TRANSPORTATION (AST)

The Federal Aviation Administration's Associate Administrator for Commercial Space Transportation (AST) licenses and regulates U.S. commercial space launch activity as authorized by Executive Order 12465 and *Commercial Expendable Launch Vehicle Activities*, Title 49 of the United States Code, Subtitle IX, Chapter 701 (formerly the *Commercial Space Launch Act of 1984*). AST's mission is to regulate the U.S. commercial launch industry and license commercial launch operations and sites to protect public health and safety, the safety of property, and the national security and foreign policy interests of the United States during commercial launch operations. In addition, the statute and the *1996 National Space Policy* direct the Federal Aviation Administration to encourage, facilitate, and promote the U.S. commercial space transportation industry.

Cover Photo Credits (clockwise, from top left)

ORBCOMM Global LP (1997). Stack of eight ORBCOMM satellites in final production. The satellites were successfully launched on December 23, 1997 from Vandenberg Air Force Base.

Teledesic LLC (1997). Computer-rendered drawing of a Teledesic satellite in low Earth orbit.

The Boeing Company (1998). Second Globalstar launch on a Delta II 7420. The successful launch took place on April 24, 1998 from Cape Canaveral Air Station.

Orbital Sciences Corporation (1997). Eight ORBCOMM satellites mated to a Pegasus XL, which successfully launched from Vandenberg Air Force Base, CA on December 23, 1997.

Globalstar LP (1998). Video image showing four Globalstar satellites being deployed in low Earth orbit. The first such launch took place February 14, 1998 from Cape Canaveral Air Station.

Iridium LLC (1997). Iridium satellites being mated to a Delta upper stage at Vandenberg Air Force Base, CA, in early April 1997. The satellites were successfully launched May 5, 1997.

EXECUTIVE SUMMARY

The Federal Aviation Administration's Associate Administrator for Commercial Space Transportation (AST) has prepared a projection of the low Earth orbit (LEO) commercial satellite launch market for the period 1998 to 2010. The *1998 LEO Commercial Market Projections* is the fifth annual assessment of launch demand for all commercial space systems in orbits other than geosynchronous orbit (GEO), and addresses launches to LEO, medium Earth orbit (MEO), and elliptical orbits (ELI). Launch demand was assessed for Big, Little, and Broadband LEO telecommunications systems, remote sensing satellites, and foreign scientific payloads.

The most significant change between the *1998 LEO Commercial Market Projections* and last year's forecast is the inclusion of two Broadband LEO systems in the "baseline" scenario, compared with only one broadband system in last year's "high growth" scenario. Over the past year, there has been significant progress toward the development of Broadband LEO systems, as well as applications to the Federal Communications Commission (FCC) for at least 10 additional Broadband LEO systems.

The past year was also noteworthy for the first deployment launches of Big LEO systems—those for Iridium and Globalstar. A large number of applications were also submitted to the FCC for Big LEO follow-on and expansion systems. In addition, Little LEO operators reached a spectrum sharing agreement and the remaining Little LEO applicants received FCC licenses.

For the *1998 LEO Commercial Market Projections*, AST has developed two scenarios assessing LEO satellite and launch services demand through 2010—a "baseline" scenario and a "robust market" scenario. The "baseline" scenario assesses launch demand for those systems whose development and deployment currently appears likely during the forecast period, as assessed by AST. The "robust market" scenario assumes that market demand for LEO satellite services is sufficient to support expanded follow-on systems, as well as the entrance of new service providers. Both scenarios include commercial remote sensing and foreign scientific payloads.

Based on the information provided in this report, AST projects the following scenarios:

- **Baseline Scenario**: deployment and replenishment of four Big LEO, three Little LEO, and two Broadband LEO systems.

- **Robust Market Scenario**: deployment and replenishment of five Big LEO, four Little LEO, and three Broadband LEO systems.

The baseline scenario projects that 1,202 payloads will be deployed between 1998-2010. Looking at only the 10-year period, 1998-2007, the baseline scenario projects 1,044 payloads will be deployed, compared with 980 in last year's high growth scenario over a similar 10-year period. The robust market scenario projects that 1,540 payloads will be deployed over the forecast period 1998-2010, with 1,265 from 1998-2007.

The demand for commercial launches to LEO for the baseline scenario is projected to average 19 launches annually of medium-to-heavy launch vehicles, plus 12 launches annually of small launch vehicles. The number of launches per year is expected to fluctuate widely from the average, peaking with the deployment of Broadband LEO systems in 2002 and 2003, and again with the deployment of Big LEO follow-on systems in 2005 and 2006. Launch demand for the robust market scenario is projected to average 24 launches of medium-to-heavy launch vehicles and 14 launches of small vehicles annually.

INTRODUCTION

Commercial launch demand is driven by the telecommunications services market, which provides telephony, television broadcasting, and data communications worldwide using satellites in geosynchronous orbit (GEO) and, more recently, low Earth orbit (LEO), medium Earth orbit (MEO), and elliptical orbits (ELI).

In order to assess the demand for commercial launch services resulting from the deployment of LEO satellite systems, the Federal Aviation Administration's Associate Administrator for Commercial Space Transportation (AST) compiles the *LEO Commercial Market Projections* on an annual basis. This report was developed based on AST research and discussions with industry, including satellite service providers, satellite manufacturers, launch service providers, and independent analysts.

LEO Commercial Market Sectors

To assess demand for commercial launches to LEO, it is first necessary to understand the range of proposed LEO satellite systems. Multi-satellite systems—dedicated to serving the telecommunications markets—will produce the highest level of demand for LEO launch services during the forecast period. Multi-satellite systems are being developed in three categories:

- "Big LEO" systems providing voice and data communications and operating in the 1-2 GHz frequency range. Target markets include mobile business users and fixed-site users in rural areas not served by conventional communications systems.

- "Little LEO" systems providing narrowband data communications such as e-mail, two-way paging, and messaging using frequencies below 1 GHz. Target markets include automated meter reading and fleet tracking.

- "Broadband LEO" systems providing high-bandwidth data communications, including Internet, videoconferencing, and high-speed data services using Ku-band (12-17 GHz), Ka-band (17-30 GHz), V-band (36-45 GHz), and Q-band (46-56 GHz) frequencies.

Each of the three LEO telecommunications market segments has a different effect on demand for commercial launch services because they are orders of magnitude apart in size (i.e. total mass of the constellation). This is demonstrated in Figure 1, which shows mass to orbit versus frequency (both uplink and downlink) for systems currently licensed by the FCC.

Since publication of the *1997 LEO Projections*, applications for a large number of new Big and Broadband LEO satellite systems have been filed with the FCC by both current and new LEO satellite proponents. If developed, these proposed systems would significantly increase demand for commercial launch services.

While communications satellites are expected to be the primary driver of demand for commercial launch services to LEO, a number of commercial remote sensing systems are also

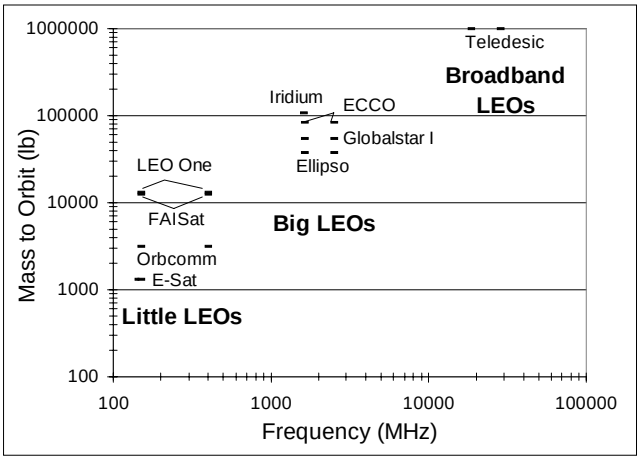


Figure 1 Proposed LEO Telecom Systems (Mass to Orbit vs. Frequency)

expected to be deployed over the next decade. These remote sensing systems, encompassing a range of passive and active space-based techniques for observing the Earth, will contribute to demand for commercial launches, particularly for small launch vehicles.

In addition, foreign governments and research organizations generate a low but steady level of demand for commercial launches of payloads to LEO to conduct scientific research, including communications, microgravity experiments, and life sciences investigations.

Market Scenarios

For each publicly announced system, AST assessed progress in system design maturity, licensing, financing, contracting, target market development, and deployment plans, inter alia. Based on this information—and underlying assumptions about the LEO satellite services markets themselves—AST developed two market scenarios assessing LEO satellite and launch demand through 2010: a "baseline" scenario and a "robust market" scenario.

The "baseline" scenario assesses launch demand for those systems likely to be developed and deployed within the forecast period. The baseline scenario represents AST's assessment of how many systems will actually be launched, not how many will attract enough business to prosper after deployment. The baseline scenario assumes that once deployed, failed satellites will be replaced as needed, and that entire constellations will be replaced at the end of their useful life by systems of the same size and number, unless otherwise specified by the system proponent.

The "robust market" scenario assesses launch demand in the event that market demand for low Earth orbit satellite services is sufficiently great to support expanded follow-on systems, as well as the entrance of new service providers.

The baseline scenario reflects current development plans by the LEO satellite providers, and therefore represents the "baseline" expected to unfold over the forecast period. The robust market scenario reflects more optimistic—but reasonable—assumptions about greater than expected demand for LEO satellite services, representing a more "robust market" than the baseline.

The terminology "baseline" and "robust market" differ from those used in previous *LEO Commercial Market Projections,* which referred to "modest growth" and "high growth" scenarios. The term "growth" was deemed no longer applicable now that deployment of these systems has begun. While dramatic growth may continue over the next few years, there will also be years in which the number of launches will be less than in the previous year because of the cyclical nature of LEO satellite system deployment. The terms "modest" and "high" were also changed because both scenarios represent significantly larger numbers of LEO launches as there were no LEO constellation launches prior to 1997.

Payload and Launch Projections

For each scenario, satellite projections were converted to launch projections based on an understanding of individual system deployment plans, satellite mass, and orbital configuration. Demand for commercial launches to LEO was assessed for two launch vehicle sizes—small launch vehicles (<5,000 lb to LEO, at 100 nm altitude and 28.5^{o} inclination), and medium-to-heavy launch vehicles (>5,000 lb, 100 nm, 28.5^{o}).

The study results do not indicate FAA support or preference for any particular proposal or system. Rather, the information provided reflects an AST assessment of overall trends in the LEO commercial satellite markets, with the ultimate purpose of projecting future space transportation demand.

PROPOSED LEO SYSTEMS

As discussed above, there are five categories of users of commercial launch services. Four of these are proposed commercial LEO systems, each planned to meet demand in separate market segments. Of these four commercial categories, three—Big LEO, Little LEO, and Broadband LEO—are for telecommunications applications and the fourth is for remote sensing. Foreign scientific payloads represent the fifth category of commercial launch services user.

For each market segment, AST examined proposed systems to assess their progress toward development and launch. AST evaluated:

- System design maturity
- Licensing status and spectrum availability
- Business plan viability and/or maturity
- Spacecraft, ground services equipment, and launch services contracting status
- Financing status and partnerships secured
- Service provider agreement status

In addition, each market segment was examined to assess the number of systems it could sustain. AST assessed potential demand in each LEO market based on:

- Projected demand for target services (e.g. mobile telephony, data communications)
- Impact of competing technologies (e.g. cellular phones, GEO broadband systems)
- Government authorization and/or licensing processes, including spectrum availability
- Potential limitations on the availability of capital for space-based systems

Following examination of the data for each market segment, AST developed the baseline and robust market scenarios assessing LEO satellite and launch services demand through 2010.

"Big LEO" Telecommunications Systems

Planned Big LEO systems focus on providing mobile telephone services to two primary market segments—business users and fixed-site users. Two of the Big LEO systems—Iridium and Globalstar—have begun deployment of their constellations as of this writing, and one other is expected to begin deployment in late 1998. In addition, there have been proposals for at least 15 other Big LEO systems, including follow-on systems for Iridium and Globalstar. Proposed Big LEO constellations are detailed in Figure 2.

Proposed Systems In 1990, the FCC received applications from six companies for Big LEO systems, also known as Mobile Satellite Services (MSS) systems. Following a spectrum sharing plan developed in 1994, licenses were granted to Iridium, Globalstar, and Odyssey in January 1995. Later that year, AMSC withdrew its application. Licenses for both ECCO and Ellipso were granted in June 1997. Costs to develop and deploy Big LEO systems are estimated to be between $1.3 and $5 billion.

In September 1997, the FCC finished accepting applications for use of the 2 GHz band. As part of this filing, the current Big LEO licensees submitted applications for follow-on and expanded systems including Iridium Macrocell (now known as Salina), Globalstar GS-2, ECCO II, and Ellipso 2G. During this round of filings, Inmarsat spin-off ICO Global Communications filed a letter of intent with the FCC to operate in the United States. Following the application, TRW withdrew Odyssey in favor of a partnership with ICO. At the same time, Boeing proposed a 16-satellite MEO system to provide aeronautical support services to the commercial airline industry.

System	Operator	Manufacturer	# Satellites (Plus On-Orbit Spares)	Satellite Mass (lb)	Orbit	First Launch	Status
Under Development							
Iridium	Iridium LLC	Motorola	66 + 6	1,500	LEO	1997	FCC licensed, January 1995; launching
Globalstar	Globalstar LP	Alenia Spazio	48 + 8	985	LEO	1998	FCC licensed, January 1995; launching
ICO	ICO Global Communications	Hughes Space and Comm.	10 + 2	6,050	MEO	1998	FCC letter of intent filed, September 1997; launch & satellite contracts signed
ECCO	Constellation Communications, Inc. (CCI)	Orbital Sciences Corporation	46 + 8[1]	1,550	LEO	2000	FCC licensed, July 1997; Orbital selected satellite, launch contractor, May 1998
Ellipso	Mobile Comm. Holdings Inc. (MCHI)	Boeing	16 + 1	2,200	LEO & ELI	2000	FCC licensed, July 1997; Boeing selected satellite contractor, May 1998
Proposed							
Boeing 2 GHz	Boeing	TBD	16	6,400	MEO	TBD	FCC license applied for, September 1997; 2.0 GHz
ECCO II	Constellation Communications, Inc. (CCI)	TBD	46 + TBD	1,290	LEO	TBD	FCC license applied for, September 1997; 2.0 GHz
Ellipso 2G	Mobile Comm. Holdings Inc. (MCHI)	TBD	26 + TBD	2,900	LEO & ELI	TBD	FCC license applied for, September 1997; 2.0 GHz
Globalstar GS-2	Globalstar LP	TBD	64 + TBD	1,830	LEO[2]	TBD	FCC license applied for, September 1997; 2.0 GHz
Gonets-R	Smolsat (Russia)	NPO PM	48	2,100	LEO	TBD	Status unknown
Iridium II/Laredo	Iridium LLC	TBD	66 + 6	1,500	LEO	TBD	Iridium follow-on; to use original Iridium FCC license
Iridium Next Generation (INX)/Salina (aka Macrocell)	Iridium LLC	TBD	96 + TBD	3,775	LEO	TBD	FCC license applied for, September 1997; 2.0 GHz
Koskon	Koskon Consortium (Russia)	AKO Polyot	45	1,900	LEO	TBD	Status unknown; Koskon payload tested in 1991
Marathon/Mayak	Informkosmos (Russia)	NPO PM	10	5,533	ELI[3]	TBD	Status unknown
Rostelesat	Kompomash (Russia)	TBD	115	1,850	LEO & MEO	TBD	Concept definition complete; awaiting funding
Signal	KOSS Consortium (Russia)	NPO Energia	48	680	LEO	TBD	Status unknown
Tyulpan	NPO Lavotchkin (Russia)	TBD	6	TBD	MEO	TBD	Status unknown
Canceled Systems							
AMSC	American Mobile Satellite Co.	TBD	12	5,500	MEO	Canceled	FCC license application withdrawn, January 1997
Odyssey	TRW	TRW	12 + 0	4,880	MEO	Canceled	FCC licensed; system canceled by TRW in 1997

(1) ECCO to initially consist of 12 satellites in equatorial orbit; 42 satellites in inclined orbit to follow.
(2) Globalstar GS-2 also requested authority to operate four GEO satellites in conjunction with the LEO.
(3) Marathon is also proposed to include three Arcos GEO satellites.

Figure 2 Big LEO Satellite Systems

In the international arena, only Russia has proposed developing Big LEO systems (besides London-based ICO). The development of one or more of the proposed Russian systems will likely not affect U.S. commercial launch demand, as they will probably not use U.S. launch services.

Market Overview Planned Big LEO systems focus on providing mobile telephony and paging to two primary markets—international business travelers and rural fixed-site users. Big LEO systems can enable international travelers to connect to public switched telephone networks (PSTNs) from anywhere in the world via satellite. In addition, several Big LEOs propose the use of dual-mode handsets that permit users to use lower-cost cellular networks if available. Big LEOs can also provide telephone services to rural users in developing countries through fixed sites, or so-called "village phone booths." Installation of fixed-site satellite phones is expected to be more cost effective than building traditional terrestrial or cellular infrastructures.

Long-term demand for mobile telephony is likely to be extremely robust. Worldwide, there are more than 100 million subscribers to analog and digital mobile telephone services, with growth rates consistently in double digits. According to the International Telecommunications Union (ITU), demand for conventional wireline telephone services in developing countries is growing at an annual rate of 11 percent, suggesting a growing market for service to fixed-site users in remote locations.

Estimates of the number of subscribers Big LEO operators will attract ranges from several million to as high as 42 million subscribers worldwide. Typical business plans for the Big LEO providers project a more modest three million subscribers per provider by 2002.

Competition Global mobile satellite telephony will face competition from the expansion of terrestrial and cellular networks as well as GEO satellite service providers offering regional telephony services. In general, satellite systems cannot compete directly with terrestrial wireless and wireline infrastructure in areas of high population density, either in terms of price or in terms of service quality. However, satellite service providers may be more effective in competing for international business travelers accustomed to paying high per-minute rates for telephone services. In addition, satellite systems can acquire fixed-site customers where terrestrial infrastructure does not exist, or is not practical due to low population density or terrain.

Competition will also come from GEO satellites providing regional mobile telephony, which have competitive advantages and disadvantages compared to LEO systems. While proposed GEO systems provide regional rather than global services, they will likely offer mobile and fixed-site telephony for lower cost than LEO systems. However, it is likely that both types of systems will be deployed, with each developing market niches based on price and service offered.

Market Demand Scenarios It is AST's assessment that under the baseline scenario, four Big LEO systems will be deployed and replenished through 2010. Two systems are already being deployed (Iridium and Globalstar) and construction of a third, ICO, is well under way with launches to begin in late 1998. AST projects deployment of a fourth Big LEO system in late 2000. AST projects that each Big LEO operator will deploy follow-on systems with similar characteristics at the end of each initial system's lifetime.

It is AST's assessment that under the robust market scenario, five Big LEO systems will be deployed and replenished. At the end of its on-orbit lifetime, each system would be replaced by higher capacity follow-on, or expansion, systems to meet growing market demand.

"Little LEO" Telecommunications Systems

Planned Little LEO systems will provide narrowband data services such as e-mail, two-way paging, messaging, remote data monitoring, and asset tracking to fixed and mobile users using frequencies below 1 GHz. Over the last year, ORBCOMM began full-scale deployment and three additional systems received licenses—LEO One USA, FAISat, and E-Sat. Proposed Little LEO systems are shown in Figure 3.

Proposed Systems Little LEOs have been proposed by a wide variety of commercial and quasi-commercial organizations using store-and-forward capabilities (storing received messages until in view of a ground center) or functioning as relay systems. Users will employ hand-held or vehicle-mounted transmitter/receivers, using low-power omni-directional antennas. Proposed Little LEO systems are expected to cost between $50 and $300 million.

In 1990, Orbital Sciences Corporation, Starsys, and Volunteers in Technical Assistance (VITA) requested FCC licenses for Little LEO systems. Licenses were issued to all three in 1995 following spectrum allocation by the ITU and agreement on spectrum sharing. A second round of filings in 1995 attracted five new applicants—E-Sat, CTA, LEO One USA, Final Analysis, and GE Americom. CTA's GEMNet, GE Americom, and Starsys are no longer being pursued. In late 1997, a spectrum sharing agreement was reached among the remaining applicants—ORBCOMM, E-Sat, FAISat, LEO One, and VITA. In February 1998, the FCC licensed LEO One. In March 1998, FAISat and E-Sat were licensed and ORBCOMM and VITA received authority for modest system expansions.

In addition, a number of proposed "constellations" of mini- and micro-satellites and communications payloads exist to serve narrowband data markets, shown in Figure 4. These systems are expected to be deployed as secondary payloads or as piggybacks on other satellites. As such, they do not represent drivers of demand for commercial launch services.

Market Overview Business plans for Little LEO providers indicate that a major expected market is automated meter reading, where data are collected from fixed assets on the ground. Another important market is expected to be mobile asset tracking (such as monitoring trucking fleets) using both positioning and messaging. Several Little LEO providers plan to offer paging, text messaging, and e-mail using low-cost ground receivers. According to an ITU study, the satellite addressable messaging market could be as large as 43 million subscribers, of which 18 million are in North America.

Competition Little LEO service providers will face competition from both terrestrial and satellite service providers. Because of the relatively low system and ground terminal costs, as well as their global nature, Little LEO systems are expected to be competitive with conventional wireless technology.

Many proposed Big LEO systems also plan to offer position location, tracking, messaging, and e-mail as part of their core services, and may be competitive with Little LEOs on price in selected markets. However, the success of Little LEOs will depend on tailoring equipment to specific market niches, which Big LEO providers may not find economically viable.

Market Demand Scenarios It is AST's assessment that under the baseline scenario, three Little LEO systems will be deployed and replenished over the forecast period. One system, ORBCOMM, has already begun deployment and a second, FAISat, has experimental satellites in orbit. Under the robust market scenario, AST projects deployment of four Little LEO systems.

System	Operator	Manufacturer	# Satellites (Plus On-Orbit Spares)	Satellite Mass (lb)	Orbit	First Launch	Status
Under Development							
ORBCOMM	ORBCOMM Global LP	Orbital Sciences Corporation	48[1]	95	LEO	1997[2]	FCC licensed, October 1994; launching
FAISat	Final Analysis Communications	Final Analysis, Inc.	38	332	LEO	2000[3]	FCC licensed, March 1998
E-Sat	E-Sat, Inc.	TBD	6	250	LEO	2000	FCC licensed, March 1998
LEO One USA	LEO One USA	TBD	40 + 8	275	LEO	2001[4]	FCC licensed, February 1998
Gonets-D	Smolsat (Russia)	NPO PM	36	510	LEO	TBD	Based on military system; 3 experimental sats on-orbit
KITComm	KITComm (Australia)	AeroAstro LLC	21	220	LEO	TBD	Licensed by Australia
Not Yet Under Development							
Courier/Convert	ELAS Courier Complex (Russia)	Moscow Institute Thermotechnics	8 to 12	1,107	LEO	TBD	Status unknown
LEO One Panamericana	LEO One Panam. (Mexico)	TBD	12	330	LEO	TBD	Licensed for operations by the Mexican government
LEOPACK	Space Agency of Ukraine	TBD	28	TBD	LEO	TBD	Unfunded
Canceled Systems							
Starsys	GE/Starsys	Alcatel	24 + TBD	165	LEO	canceled	FCC licensed, 1995; system canceled 1997
GE Americom	GE Americom	TBD	24	33	LEO	canceled	Merged with Starsys in 1996
GEMNet	CTA Space Systems	CTA Space Systems	38 + TBD	100	LEO	canceled	CTA purchased by OSC; GEMNet canceled

(1) In March 1998, ORBCOMM received authority to expand the basic 28-satellite constellation to 48.
(2) ORBCOMM launched two experimental satellites in 1995; full constellation deployment began in 1997.
(3) FAISat is currently operating two experimental satellites under an experimental license.
(4) LEO One USA plans to launch two test satellites in 2000.

Figure 3 Little LEO Satellite Systems

System	Operator	Manufacturer	# Satellites (Plus On-Orbit Spares)	Satellite Mass (lb)	Orbit	First Launch	Status
VITASat	Volunteers in Technical Assistance	Final Analysis, Inc.	2	198	LEO	1999	FCC licensed, 1995; may piggyback communications package on other satellites
SAFIR	OHB Teledata (Germany)	OHB Systems	6	132	LEO	1998	In development; launch as secondary Ariane payload
IRIS	SAIT Systems (Belgium)	OHB Systems	2	144	LEO	1998	In development
Temisat	Telespazio (Italy)	Kayser Threde	7	88	LEO	1998	In development
Elekon	NPO PM/ Elbe Space (Russia/German)	NPO PM	7	TBD	LEO	TBD	Status unknown; comm package piggybacks on Tsikada navigation sats

Figure 4 "Micro" LEO Satellite and Payload Proposals

"Broadband LEO" Systems

Planned Broadband LEO systems will provide high bandwidth data transmission for such applications as video-teleconferencing, Internet access, and high-speed corporate data communications. Since release of the *1997 LEO Projections*, progress has been made toward the development of several Broadband LEO systems, and a large number of new and follow-on systems have been proposed. Broadband LEO systems are summarized in Figure 5.

Proposed Systems A range of companies has submitted license applications to the FCC to build and operate broadband satellite data networks. In 1997, the FCC issued licenses to several applicants for the use of Ka-band frequencies for broadband data applications. While the majority of these licenses are for GEO satellites, one LEO system, Teledesic, was licensed in 1997. Several additional Ka-band applicants are currently under consideration, including Motorola's Celestri and Hughes' Spaceway NGSO (non-geosynchronous orbit). Alcatel Espace has filed license applications for Skybridge, a Ku-band constellation, and Skybridge II, a Ka-band follow-on system. Broadband LEO systems are estimated to cost between $5 and $15 billion.

In September 1997, the FCC finished accepting applications for the use of frequency bands between 30 and 60 GHz, commonly referred to as V-band (36-45 GHz) and Q-band (46-56 GHz). The FCC received 13 applications, including seven proposals for constellations using LEO and MEO orbits. Several applicants proposed hybrid constellations that pair LEO or MEO satellites with GEO satellites.

Market Overview Proposed broadband data communication satellite systems plan to provide instant, worldwide high-speed data transmission. Target markets for broadband satellite systems include multinational corporate data transmission and Internet service providers. Global demand for future broadband communication services is expected to be robust; market estimates are in the range of $100 billion by 2006, with satellites able to address much of that market demand.

Competition Broadband LEO systems will face competition from planned terrestrial networks and GEO satellite systems capable of offering similar high-bandwidth data communications. The degree to which satellites can capture this market primarily depends on whether terrestrial systems will be able to cost-effectively serve the market. Satellites will be most competitive where there is no existing terrestrial infrastructure due to the high cost of installing wirelines, either fiber optic or copper. Satellites are less likely to be able to compete directly with terrestrial infrastructure that provides broadband services to consumer and business users; terrestrial systems are likely to be less expensive on a per-minute basis, and terrestrial wireline systems do not have to contend with spectrum limitations or rain attenuation.

Satellite systems have the potential competitive advantage of providing "bandwidth on demand," allowing users to pay only for what they use, not for open-ended access to the network, enabling users to better manage costs. Satellites are also likely to be used to provide data trunking for terrestrial networks, both as back-up and surge capacity, similar to satellite usage for trans-oceanic phone cables today.

LEO and MEO systems providing broadband services will also compete with planned GEO broadband systems. AST anticipates that neither type of system will have sufficient competitive advantages to outperform the other; the service quality of LEO systems will attract some users while the likely lower prices of GEO services will attract others. As a result, both types of systems are likely to be deployed.

System	Operator	Manufacturer	# Satellites (Plus On-Orbit Spares)	Satellite Mass (lb)	Orbit	First Launch	Status
Under Development							
Teledesic	Teledesic LLC	Boeing	288 + 12	3,300	LEO	2001[1]	FCC licensed, March 1997; Ka-band
Celestri LEO	Motorola	Matra Marconi	63 + 7	7,000	LEO[2]	2002	FCC license applied for, June 1997; Ka-band
Skybridge	Alcatel Espace	TBD	64 + 4	1,770	LEO	2002	FCC license applied for, February 1997; Ku-band
Proposed Systems							
@Contact	@Contact LLC	TBD	16 + 4	7,500	MEO	TBD	FCC license applied for, December 1997; Ka-band
GSN (Global EHF Satellite Network)	TRW	TRW	15	13,150	MEO[3]	2005	FCC license applied for, September 1997; V-band
Globalstar GS-40	Globalstar LP	TBD	80 + TBD	2,700	LEO	TBD	FCC license applied for, September 1997; V-band
LM-MEO	Lockheed Martin	Lockheed Martin	32	4,800	MEO	TBD	FCC license applied for, December 1997; Ka-band and V-band
M-Star	Motorola	TBD	72 + 12	4,400	LEO	TBD	FCC license applied for, September 1996; V/Q-band
Orblink	Orbital Sciences Corporation	Orbital Sciences Corporation	7 + TBD	4,450	MEO	TBD	FCC license applied for, September 1997; V-band
Pentriad	Denali Telecom	TBD	9 + 3	4,400	ELI	TBD	FCC license applied for, September 1997; V-band
Skybridge II	Alcatel Espace	TBD	96	5,850	LEO	TBD	FCC license applied for, December 1997; Ka-band
Spaceway NGSO	Hughes Comm.	Hughes Space and Comm.	20	6,300	MEO[4]	TBD	FCC license applied for, December 1997; Ka-band
Starlynx	Hughes Comm.	Hughes Space and Comm.	20	7,700	MEO[5]	TBD	FCC license applied for, September 1997; V-band
Teledesic V-Band Supplement (VBS)	Teledesic LLC	TBD	72 + 36	TBD	LEO	TBD	FCC license applied for, September 1997; V-band
WEST	Matra Marconi	Matra Marconi	9	8,800	MEO[6]	TBD	Status unknown; Ka-band

(1) Teledesic launched the T-1 experimental satellite in February 1998.
(2) Celestri application includes integration with Motorola's Millenium GEO broadband system.
(3) TRW intends to operate four GEO satellites in conjunction with the 15 GSN MEO satellites.
(4) Spaceway NGSO to be operated with 16 Hughes Spaceway GEO satellites.
(5) Starlynx application also requests authority to operate four GEO satellites in conjunction with MEO system.
(6) Matra Marconi intends to operate one or two GEO satellites in conjunction with the nine WEST MEO satellites.

Figure 5 Broadband LEO Satellite Systems

Market Demand Scenarios It is AST's assessment that under the baseline scenario, two Broadband LEO systems will be deployed and maintained through 2010. Two of the three systems currently under development have made significant progress toward realization over the past year and their deployment appears likely. However, it is also likely that the actual timing and configuration of Broadband LEOs could change over the next few years, impacting launch demand. This report reflects configuration and deployment plans as they are known today.

Under the robust market scenario, AST projects that three Broadband LEO systems will be deployed and maintained through 2010.

Remote Sensing Systems

In addition to telecommunications-oriented applications, a number of companies are developing commercial remote sensing systems for LEO which will use commercial launch services. Proposed commercial remote sensing satellite programs are summarized in Figure 6.

Over the past year, two companies—ORBIMAGE and EarthWatch—have launched commercial remote sensing spacecraft. In August 1997, ORBIMAGE launched OrbView-2 which provides one-kilometer resolution ocean color data under contract to NASA. In December 1997, EarthWatch launched the first high-resolution commercial remote sensing spacecraft, EarlyBird-1, which failed to operate shortly after launch.

Despite the EarlyBird-1 failure, it appears that a number of commercial remote sensing systems will be deployed over the forecast period. Like the LEO telecommunications systems, the deployment of additional satellites beyond the initial deployments will depend on the development of a viable market for commercial imagery which does not exist today.

Because commercial remote sensing satellites are few in number and are not part of large constellations, they do not represent a significant demand for commercial launch services. However, if a viable market for commercial remote sensing imagery appears, there will be a low but steady demand for launches of small launch vehicles for remote sensing satellites. Commercial launch services may also be used to launch military remote sensing spacecraft for countries without launch capabilities.

Foreign Scientific Payloads

In addition to communications and remote sensing systems, demand for commercial launch services comes from foreign governments and research organizations. Typically, foreign research organizations launch small spacecraft to conduct scientific research in LEO, including microgravity, life sciences, and communications experiments using commercially available small launch vehicles. Demand for such launches is expected to steadily increase over the forecast period and has been incorporated into the projections in this report. Projections of demand for launches of U.S. government-sponsored scientific payloads are not included in this report.

System	Operator	Manufacturer	First Launch	Mass (lb)	Satellites	Highest Resolution	Status
OrbView	ORBIMAGE	Orbital Sciences Corporation	1995	607	4		First 2 sats launched under NASA cooperative program
					OrbView-1	10 km	Launched 1995; weather info
					OrbView-2	1 km	Launched 1997; ocean imagery
					OrbView-3	1 m	Launch 1999; high resolution
					OrbView-4	1 m	Launch 2002; high resolution
IKONOS	Space Imaging EOSAT	Lockheed Martin	1998	1,800	2		Satellite construction underway
					IKONOS-1	1 m	Launch summer 1998
					IKONOS-2	1 m	Launch late 1998/early 1999
EarlyBird	EarthWatch	Orbital Sciences Corporation (formerly CTA)	1997	686	3		EarlyBird program canceled in favor of QuickBird due to failure of EarlyBird-1 in Dec. 1997
					EarlyBird-1	3 m	
QuickBird	EarthWatch	Ball Aerospace	1998	2,000	2		Satellite development underway
					QuickBird-1	1 m	Launch planned 1999
Resource-21	Resource-21	Boeing	2001	TBD	4	10 m	Satellite development underway

Figure 6 Commercial Remote Sensing Satellites

PAYLOAD AND LAUNCH PROJECTIONS

Following the assessment of proposed LEO commercial satellite systems, AST developed the baseline and robust market scenarios projecting LEO satellite and launch demand through 2010. The baseline scenario includes those systems whose deployment currently appears likely. The robust market scenario assumes that high demand for LEO satellite services will allow the deployment of follow-on and expanded systems.

Launch demand is assessed for two launch vehicle sizes—small launch vehicles (<5,000 lb, 100 nm, 28.5^{o}) and medium-to-heavy launch vehicles (>5,000 lb). If launch vehicle selection had already been made by the system operator, it was incorporated directly into the assessment. If vehicle selection was not known, assumptions were made based on the number of spacecraft, mass, orbit, and number of satellites per plane.

Launch vehicle selection for deployment of the initial Big LEOs is well understood, typically involving vehicles with performance of 6,000-11,000 lb to high inclination orbits, such as Delta II and Proton. For deployment of Broadband LEOs, a mix of medium-to-heavy vehicles with average performance of 16,000-19,000 lb to high inclination orbit was assumed. This higher average performance reflects current plans of Broadband LEO providers to use heavy vehicles which are not currently available. Ariane-5 performance to high inclination orbit is around 26,000 lb; for the EELV-Heavy variants, it is closer to 50,000 lb. Deployment of Little LEOs is expected to use only small launch vehicles.

Baseline Scenario

The baseline scenario reflects the deployment of four Big LEO, three Little LEO, and two Broadband LEO systems. It includes operations and maintenance, and anticipates deployment of follow-on systems with similar characteristics at each constellation's end of life. In addition, it includes a low but steady demand for commercial launches to deploy remote sensing and foreign scientific payloads.

The baseline scenario projects that 1,202 payloads will be deployed between 1998 and 2010, as shown in Figures 7 and 8. Looking at the next 10 years, the baseline scenario projects 1,044 payloads will be deployed, compared with 512 over 10 years in last year's modest growth scenario. The large increase is due to the inclusion of two Broadband LEO systems in the baseline scenario, compared with no Broadband LEOs in last year's modest growth scenario.

Launch demand for the baseline scenario is projected to be 7 to 43 medium-to-heavy launches per year (average 19) and 6 to 16 small launches per year (average 12) from 1998-2010. Demand for medium-to-heavy launch vehicles peaks with the deployment of Broadband LEO systems in 2002 and 2003 and again with the deployment of Big LEO follow-on systems in 2005 and 2006. Launch demand is shown in Figures 7 and 9.

Robust Market Scenario

The robust market scenario reflects deployment and maintenance of five Big LEO, four Little LEO, and three Broadband LEO systems, and anticipates deployment of a mix of follow-on and expansion systems to meet robust market demand for LEO services. In addition, the scenario includes a low but steady demand for commercial launches to deploy remote sensing and foreign scientific payloads.

The robust market scenario projects that 1,540 payloads will be deployed over the forecast period 1998-2010, as seen in Figures 10 and 11.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
Payloads														
Big LEO	85	21	17	18	13	9	9	70	78	13	9	9	10	361
Little LEO	18	8	10	32	38	14	4	26	38	34	8	14	16	260
Broadband LEO	0	0	0	64	168	138	17	17	17	17	22	22	22	504
Remote Sensing/Foreign Science	4	3	3	4	6	4	7	7	6	7	8	10	8	77
Total Payloads	**107**	**32**	**30**	**118**	**225**	**165**	**37**	**120**	**139**	**71**	**47**	**55**	**56**	**1,202**
Launch Demand														
Medium-to-Heavy (>5,000 lb LEO)	10	7	7	15	43	34	13	25	27	15	17	18	17	248
Small (<5,000 lb LEO)	9	6	7	13	16	11	12	11	13	15	13	15	14	155
Total Launches	**19**	**13**	**14**	**28**	**59**	**45**	**25**	**36**	**40**	**30**	**30**	**33**	**31**	**403**

Figure 7 Baseline Scenario Payload and Launch Projections

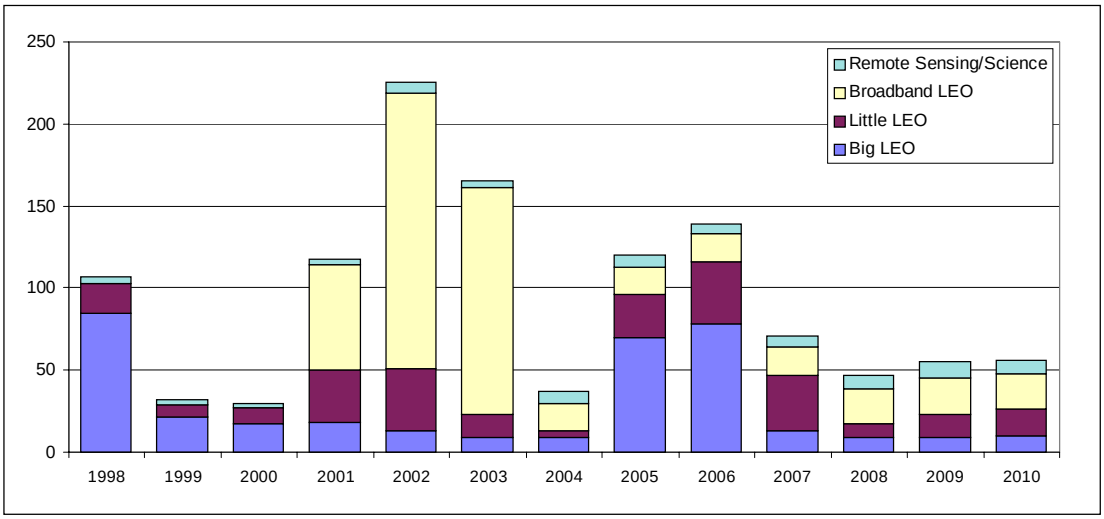


Figure 8 Baseline Scenario Payload Projection

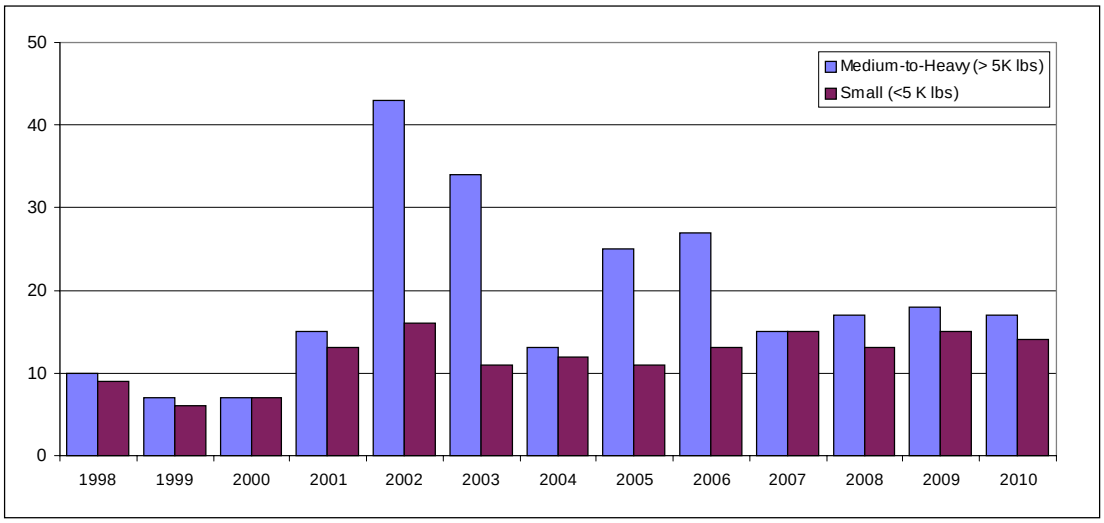


Figure 9 Baseline Scenario Launch Demand Projection

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL
Payloads														
Big LEO	85	21	17	30	13	39	41	90	89	16	28	24	50	543
Little LEO	18	8	28	32	38	14	4	26	50	40	8	14	16	296
Broadband LEO	0	0	0	64	186	172	33	20	20	20	25	25	59	624
Remote Sensing/Foreign Science	4	3	3	4	6	4	7	7	6	7	8	10	8	77
Total Payloads	**107**	**32**	**48**	**130**	**243**	**229**	**85**	**143**	**165**	**83**	**69**	**73**	**133**	**1,540**
Launch Demand														
Medium-to-Heavy (>5,000 lb LEO)	10	7	7	18	45	43	22	36	38	15	21	20	28	310
Small (<5,000 lb LEO)	9	6	11	13	16	11	12	15	19	21	17	19	19	188
Total Launches	**19**	**13**	**18**	**31**	**61**	**54**	**34**	**51**	**57**	**36**	**38**	**39**	**47**	**498**

Figure 10 Robust Market Scenario Payload and Launch Projections

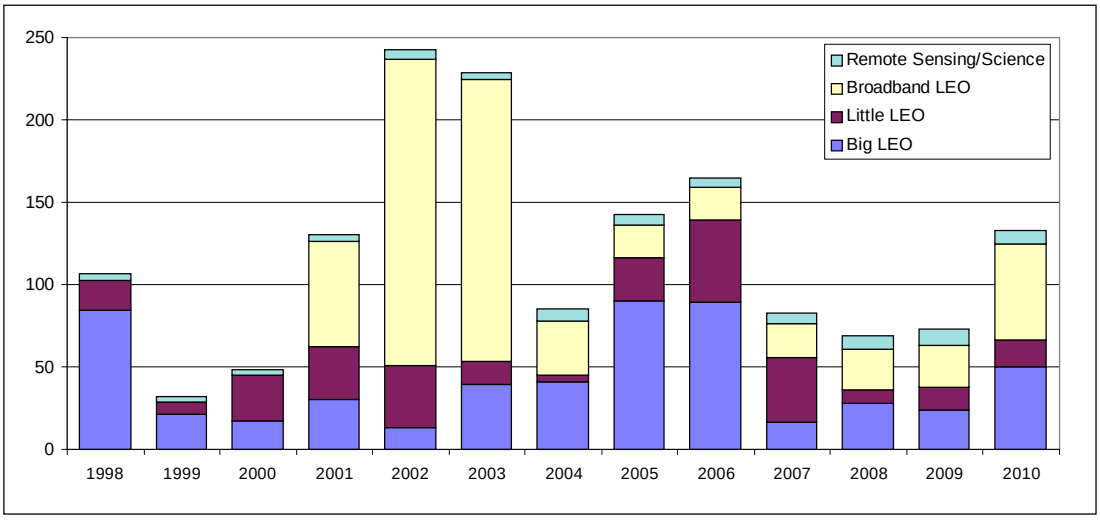


Figure 11 Robust Market Scenario Payload Projection

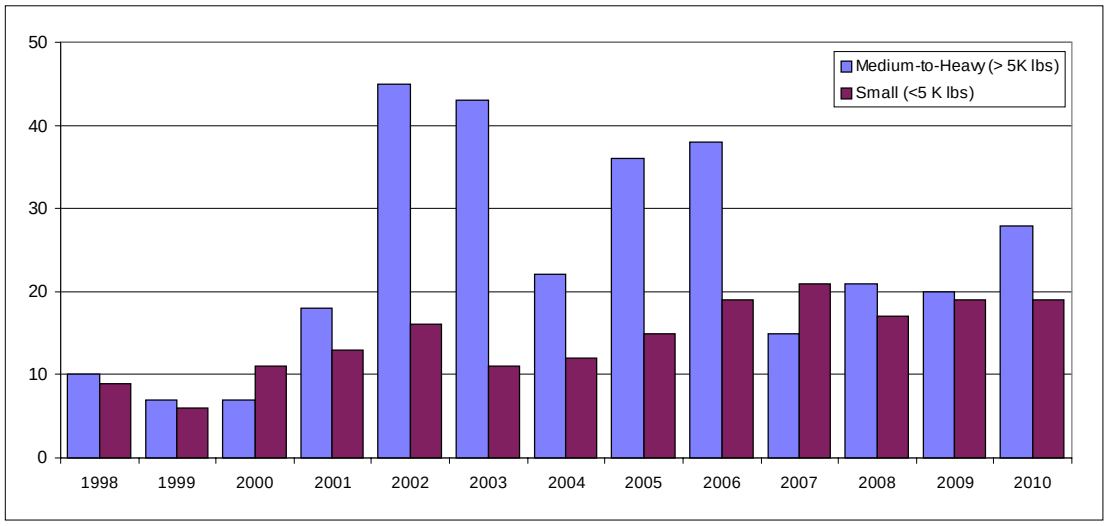


Figure 12 Robust Market Scenario Launch Demand Projection

Looking at only the 10-year period, 1998-2007, the robust market scenario projects 1,265 payloads will be deployed, compared with 980 satellites projected for a 10-year period in last year's high growth scenario. As with the baseline scenario, the large increase is due primarily to the inclusion of more Broadband LEO systems. The robust market scenario reflects deployment of three broadband systems, compared with only one in last year's high growth scenario.

Based on these payload projections, launch demand for the robust market scenario is projected to be 7 to 45 medium-to-heavy launches per year (average 24) and 6 to 21 small launches per year (average 14) over the forecast period. As with the baseline scenario, demand for medium-to-heavy launch vehicles peaks with the deployment of Broadband LEO systems in 2002 and 2003 and again with the deployment of Big LEO follow-on systems in 2005 and 2006. However, peak demand is slightly higher and a higher sustained level of demand exists throughout the latter part of the forecast period. Launch demand is shown in Figures 10 and 12.

For both scenarios, the projected satellite and launch demand reflects system configuration and deployment timing as provided to AST by the system operators. For systems included in each scenario, actual system data as known at the time of writing was used without providing any subjective filtering of the data. It is highly likely that actual deployment configuration and timing for many of these systems will change as their development progresses.

Historical LEO Market Assessments

Since publication of the first *LEO Commercial Market Projections* in 1994, there has been tremendous growth in the number of proposed systems, as well as substantial progress toward deployment of many of these systems. At the same time, AST's forecast of systems likely to be deployed has also increased. Figure 13 summarizes AST's commercial LEO market projections for the past five years revealing significant growth in the number of systems expected to be deployed in all three LEO telecommunications market segments.

	1994	1995	1996	1997	1998
Systems Projected *					
Big LEO	1-2	2-3	3-4	4-5	4-5
Little LEO	1-1	1-2	2-3	2-3	3-4
Broadband LEO	0	0	0	0-1	2-3

* The lower limit reflects the Baseline scenario and the upper reflects the Robust Market scenario (previously Modest and High Growth).

Figure 13 Past LEO Systems Projections