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Comment

The extraterrestrials are coming

A Michael Noll

A number of systems using communications satellites to provide telephone and data services are reviewed and compared in terms of their features and orbital characteristics. Analyses are performed of their technological, financial, market and regulatory aspects. The conclusion is that the many low Earth-orbit systems have a very doubtful future.

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This paper was presented at the conference 'The Future of Wireless Communications' held by the Columbia Institute for Tele-Information at Columbia University (New York) on 5 May 1995. The paper is from a chapter of Noll's manuscript for a new book, tentatively entitled *Highway of Dreams: A Critical Appraisal of the Information Superhighway*.

Wireless communication

Cellular telephone service has been a great success. The average length of a cellular call is 2.4 minutes, and the average monthly bill is $61. Cellular is only one example of wireless communication; the cordless telephone used within the home is another. Some people believe the wireless market has much room for future growth from new technologies. Personal communication service (PCS) is a form of wireless that works outside the home or office, but does not have all the sophisticated features of cellular and thus would be less costly. However, the price of cellular phones and service continues to decrease, and I am uncertain whether a new technology that looks so similar would have much of a chance in the marketplace. Cellular and cordless are terrestrial-based wireless communication services.

Cellular is based on the concept of frequency reuse within a large metropolitan area, along with frequency switching as a user moves from one cell to another. An alternative approach is to place many communication satellites in orbit and to switch users from satellite to satellite. The aerospace and defense industries have been strong advocates of communication satellites and, not surprisingly, are promoting these extraterrestrial forms of mobile communication.

LEOS, GEOS, MEOS

The basic idea of using an artificial Earth-orbiting satellite for communication was first proposed by the renowned author Arthur C Clarke in 1945. It was not until 1962 that the first communication satellite, *Telstar I*, was launched. Today, the Earth's equator is ringed by communication satellites 22 300 miles above the surface of the Earth. This specific orbit is such that the satellite takes exactly 24 hours for each circular orbit, thereby matching perfectly the rotation of the Earth below and appearing stationary with respect to the Earth's surface, a so-called geosynchronous orbit. Satellites at lower orbits will orbit the Earth at faster rates and will not be geosynchronous, thereby requiring a series of orbiting satellites so that at least one is always above the specific area requiring communication service. Low Earth-orbiting satellites are called LEOS, geosynchronous Earth-orbiting satellites GEOS, medium Earth-orbiting satellites MEOS, and elliptical Earth-orbiting satellites EEOS. The extraterrestrial GEOS, LEOS, MEOS and EEOS are coming, according to their proponents and hopeful investors. But are they?

One the earliest proposed LEOS was Motorola's Iridium® employing 66 operational satellites in six polar orbits about 500 miles above the Earth's surface. Iridium is projected to cost $3.4 billion with full operational service scheduled for 1998 and 1.8 million subscribers projected for 2001. The handheld telephones, providing voice telephony at a reduced bit rate of 4800 bps, would cost $1000 in large quantities, and service would cost $3 per minute. Telephone calls from the ground could be relayed from satellite to satellite to reach the final destination. By mid 1994, only $0.8 billion had been raised, and Iridium has attracted competing systems before itself even becoming close to commercial service. Globalstar, owned by Loral, Qualcomm and others, proposes 48 satellites in orbits about 750 miles above the Earth at a cost of $1.6 billion. Odyssey, owned by TRW, proposes 12 MEOS at a cost of $2.5 billion. But the system that has attracted the most recent attention and big-name investors is Teledesic.

Not to be outdone by Iridium, the Teledesic system proposes to launch 840 satellites in 21 polar orbits 440 miles above the Earth's surface at a cost of $9 billion. Each refrigerator-sized satellite will use sophisticated ATM packet switching and will offer variable bandwidth to meet different user needs. The industrialists Bill Gates and Craig McCaw are frequently mentioned as two prominent investors in Teledesic. I was once asked to give my private views on the system and concluded that there were 'serious uncertainties' and 'astronomical' funding requirements and that the system was not practical for the foreseeable future. My future comments about the Teledesic system are applicable though to most similar LEO systems. The following analysis of LEOS draws upon a framework developed in my recent manuscript for a book and forms the basis for my conclusion that LEOS are inherently unsustainable.

Analysis

Technology

We first ask whether the technology is available at hand today for LEO telecommunication. It is not, and there are still many unresolved uncertainties. Each satellite might need to handle tens of thousands of simultaneous users, and this degree of switching is comparable to packing 10 central-office switching machines into each satellite. The high-frequency signals used to communicate to the satellite are highly directional and would be blocked by buildings and absorbed by rain. The microwave safety issue is also not well understood. At low altitude orbits, air friction is encountered and each satellite is projected to have a life of about seven years before falling back to Earth. I guess we will all need to wear hard-hats as protection! But, keeping hundreds of satellites in precise orbits, switching signals from one satellite to another as each rapidly passes over the horizon, and keeping track of thousands of simultaneous users for each satellite are serious technical challenges, perhaps resolved only on paper but not yet in orbit. LEOS do minimize greatly the round-trip delay encountered with GEOS and LEOS and require much less power since they are so close to the Earth. However, these advantages are few and are outweighed by serious technical problems.

Finance

About 70% of the time, each low Earth-orbit satellite will be over oceans and thus not much usable. The high cost of each satellite thus is not justified by its low average utilization. For the system to be operational, all the satellites must be in orbit, and there is no way to grow the system gradually as traffic develops, like terrestrial cellular. The financials proposed by the promoters of these systems are all overly optimistic and are far from the realism of the true costs of the technology and launch costs and disasters. The yearly profits needed to repay the $9 billion investment required for the Teledesic system in 10 years at a return of 15% are $1.8 billion. It is very difficult to believe that such profits could ever be generated given the competition from existing cellular systems and also the competition from other satellite systems.

Policy/regulation

Licenses would need to be obtained from many of the countries of the world, and some are not liberal re-

Table 1. Summary of systems.

Name	Owners	Type	Height	Number	Orbit	Cost	Services	Service date	Status	Misc
Iridium	Motorola	LEO	485 miles 780 km	66	6 polar planes	$3.4B	voice, data	1998	launch contract signed for 1/97 FCC license granted	$3/min satellite-to-satellite communication 1.8M users by 2001
Globalstar	Loral, Qualcomm and others	LEO	879 miles 1414 km	48	8 circular inclined planes	$1.6B		mid 1998	FCC license granted	CDMA access
Odyssey	TRW	MEO	6430 miles 10 350 km	12	3 polar planes	$2.5B		4Q/98	FCC license granted	
Teledesic	Gates, McCaw, Kinship Partners	LEO	440 miles 700 km	840	21 polar planes	$9B	voice, data, video			ATM switching variable BW
American Mobile Satellite	Hughes and others	GEO	22 300 miles 35 900 km	3	equatorial	$560M	voice, fax, data		first satellite launched in April 1995	'portable' terminals $1.50/min
Project 21 Inmarsat-P	Inmarsat	MEO	6431 miles 10 350 km	12 (10 + 2 spare)	2 circular inclined planes	$2.6B		1999	launch scheduled for 1998	handheld terminals
Spaceway	Hughes	GEO	22 300 miles 35 900 km	9 initially 17 complete	equatorial	$6.2B		2000 initially 2003 complete		
Aires	Constellation Communications	LEO	1200 miles 2000 km	48	8 planes	$1.7B		4Q/97	FCC license refused	
Elipso I and II	Mobile Communications Holdings	EEO		16	2 elliptical (5 sats) 1 equatorial (6 sats)	$800M		3Q/97	launch contract signed FCC license refused	domestic service only
OrbComm	Orbital Sciences	LEO	481 miles	26	inclined circular	$160M	digital messages, paging		2 satellites in orbit	
Global Positioning System	US Air Force	MEO	12 500 miles	24 (21 + 3 spares)	6 circular inclined planes	$10B ???	simple positioning signals			

garding competition, particularly from US firms.

Consumer/market

The terrestrial cellular systems are already installed, are growing rapidly, and are formidable competitors to LEOS. It would be inconceivable that LEOS could compete in large cities with existing cellular. Thus the only real market for LEOS would be in areas of the planet not served by conventional telephone or cellular service. Such areas are few and most certainly are poorer countries whose citizens could never afford such a luxurious service. This leads me to wonder whether the only markets for these systems are tourists on safari in equatorial Africa who are about to be charged by an enraged bull elephant and need to call international 9-1-1 for help, or shipwrecked survivors afloat in a raft in the middle of the Atlantic.

Conclusion

Although the preceding analysis is negative regarding LEOS, com-

Table 2. System analysis.

	GEO	MEO	LEO
Orbit	equatorial	polar and inclined	polar and inclined
Height	22 300 miles	5 000–12 000 miles	400–800 miles
Footprint	huge (thousands of square miles)	large	small (hundreds of square miles)
Power	much	medium	little
Delay	1/2 sec round trip	medium	very little
Interference	line of sight		blocked by buildings
Tracking	stationary	slow/required	fast/required
Utilization	very high	medium	very low (70% over ocean)
Cost	low	medium	high
Technology	proven		unproven
Price	$500/hr for 36 MHz		$3/min $1000 terminals

munication satellites do have their place. They are a great way to distribute network television programs around the Earth and domestically. They are also appropriate for reaching otherwise inaccessible portions of the planet. For these types of applications, GEOS have much to offer, as they are few and less costly since the satellite can be used nearly all the time. American Mobile Satellite Corporation, partially owned by Hughes Communications, will offer voice and fax using three GEOS at a development cost of $560 million. The first of the three satellites was launched in April 1995. Portable mobile units that need to be aimed at the satellites will be used. Simple digital messages are proposed to be carried by Orbital Sciences' OrbComm system using 26 satellites.

Satellites are also a good way to obtain precise positioning information. The Global Positioning System (GPS) is already in place with 24 satellites in medium earth orbit, broadcasting codes to enable users to position themselves accurately. Boaters and civilian aircraft are some of the users of GPS, and some people believe positioning receivers will soon be in automobiles to guide us along the auto highways of the world and handheld receivers will help hikers to find their way back to camp.