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## 和平利用外层空间委员会

# 卫星通信和信息网络使用新技术

## 秘书处的说明

1. 评价第二次联合国探索及和平利用外层空间会议（82年外空会议）各项建议执行情况全体工作组第十届会议（A/AC.105/637，附件二，第11段）建议，应进行若干项关于空间应用的研究，以表明空间技术的潜能，重点是解决发展中国家的需要。全体工作组查明这些研究的一些可能主题，其中包括卫星通信和信息网络使用新技术。

2. 科学和技术小组委员会第三十三届会议通过了全体工作组的报告（A/AC.105/637，第25段），报告中所载的建议获得大会第51/123号决议赞同。

3. 根据全体工作组的请求，秘书处编写了一份关于卫星通信和信息网络使用新技术的研究报告。研究报告仅有英文本，载于本说明附件。研究报告的目的是介绍审查静止和低地球轨道卫星及平流层高空长久平台所载宽带通信设备用于主要造福尚未使用这一技术但对其潜在利益感兴趣的国家的情况。在编写研究报告时，使用了各种国际和国家来源的资料，这些来源列于书目选编（见附件）。现将研究报告概要介绍如下，报告只有英文本，列于本说明的附件。

## 研究报告概要

4. 信息正变得日益重要，与显示人们生活质量的经济机会、教育、卫生保

健和公共服务等各方面息息相关；但世界上大多数人民和地方目前还缺乏基本电话服务．即使可得到电话服务，绝大多数也是通过老技术——摸拟式铜线电话网．一些专家认为，大多数这种电话网根本不会改为或升级为先进的数字式操作．

5. 由于电信技术获得了巨大进步，一个新的全球社会正在出现．美利坚合众国的国家信息基础结构计划（ NII ），进而全球信息基础结构（ GII ），预计将使现代的通信发生革命性变化．在美国， NII 被用于描述未来的国家“信息高速公路”，目前这一信息高速公路正处于规划阶段，可能将包含互联网络和正在讨论中的广泛的一系列其他网络和媒体． GII 指扩大到全世界范围的这种信息高速公路． NII 和 GII 都包括进一步使用计算机、电话、广播和电视把消费者相互联接起来，并把消费者与世界各地的服务联接起来．

6. 电信市场分析家预测，无线通信将成为本世纪末发展最快的领域．随着移动通信的数字化，广播和电信业正在进入数据传输市场，造就出来的数据产业本身到 2000 年时价值即可达到 100 亿美元．这是估计为 3 万亿美元的全世界电信设备服务市场的一部分；无线通信部分预计达 6,000 亿美元．如今发展最快的两种电信服务是个人移动通信和互联网络，美国巨大的需求量正在推动无线通信行业激增．世界个人移动通信市场 1995 年增长到 5,000 万个用户，大多数专家估计，到 2000 年时，无线电话用户将达到 2 亿个，2005 年时将增加到 3 亿个．长期预测表明，美国目前的有线电信用户最终将有一半会成为无线电信用户．虽然在当今世界的 5,000 万个移动电话用户中，有一半以上在美国，但预测表明， 2000 年后移动电话用户的增长将主要在发达国家之外．

7. 虽然这些发展中的技术有不少优越性，但对于这些技术是否将为发展中世界带来实际利益，有截然不同的两种观点．一种看法认为，电信和信息技术可使不太发达的国家大步飞跃前进，有助于这些国家促进经济发展，吸引外国投资，增加出口，改进公共服务和扩大教育机会．在 1996 年 5 月 13 日至 15 日于南非 Midrand 举行的信息社会和发展会议上，与会者指出，全球信息社会是一个极为重要的问题，与所有发展中国家紧密相关，无论这些国家的发展阶段如何．

8. 相反的意见认为，电话、计算机和电视网络只会带入外国文化，抹杀发展中国家本身的特性．

9. 最近的研究表明，在每平方公里用户密度不足200个的许多地区，无线通信系统是发展或升级电信网络成本效益最高的方法．固定的无线通信系统的安装速度比有线网络快5 – 10倍，起始费用相对较低，而后者则需要对基础设施大量投资．这是许多发展中国家在决定投资于哪种电信系统时需要考虑的一个重要因素．即使世界上已有许多光导纤维网络，而且其数量正在与日俱增，但这些网络主要用于使各国和电话公司总部接入高密度通信业务的干线．将纤维电缆与各办公室和各家各户接通占整个网络费用的80%．许多专家认为，在世界上大部分地区，光缆不能完全解决问题。

10. 农村地区基础设施欠发达，正在迫使人们移居到日益拥挤的城市地区去寻找机会；世界的城市人口每天增加17万．这种大规模人口迁移会带来不利的后果，造成经济和环境恶化．如果只有先进的城市地区有数字式新技术，农村人口就可能继续向这些地区迁移，去寻找经济机会和满足其他需要。

11. 但是，实施这些技术费用巨大．要实现GII，世界银行估计每年将需要600亿美元的投资．消除发展中国家的电信差距，估计总耗资将达3万亿美元。

12. 但是，信息社会和发展会议宣布，主要国际电信公司已商定建立一个连接北美、欧洲和日本的高速地面网络，这是朝向建立GII迈出的重要一步。全球通信的这一突破是七大工业国集团达成协议，促进GII的应用示范试点项目的结果，是用于支持远距离医疗、远距离学习、环境研究、远距离参观博物馆和高能物理等领域的国际合作。

13. 卫星和无线通信技术对于今后实施GII将具有重要意义，可提供其他电信技术无法做到的关键环节． GII将不是一个“统一的”网络，而是将由采用不同技术的许多部分组成，随着使用程度的不同而增减．

14. 除成本与距离无关，稀路由通信成本效益高，覆盖面广，地形复杂的地区易于联接和能够使群岛实现一体化等特点之外，卫星技术中出现的新趋势产生于即将装载在卫星上的新的宽带技术．这些技术可以做到以良好的成本效益从空间直接将互联网络和电视会议等交互式服务提供给定点的和活动的终端用户．

15. 目前实施GII的国家或区域性努力，在范围、目标、工业政策或计划服务等方面各不相同．另外，对于支持这一设想的基本技术也难以达成一致，其中部分原因是这一计划的许多重要组成部分尚处于当前技术的最前沿．

16. 本研究报告仅扼要阐明一个概念:卫星和高空长久平台技术可有助于实施 GII，特别重点是其对发展中国家的作用.

17. 有三种不同的宽带通信系统可以考虑:

(a) 空间途径:一些私营公司最近提出的若干种地球静止宽带卫星系统中的第一种，由 17 颗卫星组成;

(b) 遥测:一种低地球轨道系统，在 740 公里高空的太阳同步轨道上安放由 840 颗卫星组成的卫星群;

(c) 天空站:一种由高空长久平台构成的全球网络，包括 250 个安放在 23 公里高空平流层的平台.

18. 每个系统本身都相当于一个地面光导纤维系统，并具有各自的优点. 这些先进的数字式卫星和高空长久平台可真正与目前的光导纤维网络相媲美，更重要的是，可补充这些网络并与之相兼容.

19. 另外，遥测公司和国际天空站都宣布将免费向发展中国家提供一些电信能力，这即意味着若干区域和国家在保健和教育方面将可免费获得现有的一些最快速的通信服务.

*Annex*

# USE OF NEW TECHNOLOGIES IN SATELLITE COMMUNICATIONS

**Study by the Secretariat***

## INTRODUCTION

1. Because of the tremendous advances in telecommunications technology, a new global community is emerging. The National Information Infrastructure (NII) initiative of the United States of America, and by extension, the Global Information Infrastructure (GII), are expected to revolutionize modern-day communications. Both the NII and the GII embrace the increasing use of computers, telephones, radios and televisions to link consumers with each other and with services around the world.

2. But the absence of a sound, developed telecommunications infrastructure can effect a nation's entire economy. Since it is not cost-effective to deploy telecommunications in poor countries that might benefit most from it, it follows that economic investment most likely will not go to regions with inadequate telecommunications infrastructure.

3. This undeveloped infrastructure of rural regions is also forcing people to migrate into increasingly congested urban areas in search of opportunities; presently, the world's urban population is growing by 170,000 each day. This mass migration can bring in negative consequences and result in further economic and environmental deterioration.

4. According to the International Telecommunication Union (ITU), 4 billion of the world's 5.7 billion people still do not have basic telephone service. Fifty percent of the population has never made a phone call and lives two hours from the nearest phone. Rural customers now cost between 10 and 30 times as much to serve with wires as urban customers. Developing countries have only 1 to 3 percent of the telephones that industrialized countries have and only 10 percent of the television sets. By the year 2000, 40 percent of the world's population will be in India, Indonesia, and China, yet these nations currently have only 6 percent of the world's phone lines.

5. Many African governments have made considerable investments in telecommunications development. As a result, there has been an average 7 percent annual growth in main line density over the past decade. In spite of this impressive achievement, the overall effect on the goal of universal access to basic services remains quite modest; teledensity has risen in the same period only slightly in sub-Saharan Africa to 0.48 per 100 people, up from 0.33. There are still more phone lines in Manhattan than in all of Africa between the Sahara and South Africa.

6. The two fastest growing telecommunications services today are personal mobile communications and the Internet, with tremendous demand in the United States fuelling the explosive growth of the wireless industry. The personal mobile communications market worldwide has grown to 50 million subscribers in 1995 from its inception in 1986. Most experts estimate that by the year 2000 there will be 200 million wireless phones subscribers, and 300 million by 2005. Long-term forecasts indicate that as many as half of all wireline telecommunications users in the United States will eventually become wireless telecommunications subscribers. Although more than half of the world's 50 million cellular phone subscribers today are in the United States (in October 1996, there were 41.833 million, including pager users), forecasts indicate that most of the growth in cellular subscribers after the year 2000 will occur outside of the

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*The present study has not been edited.

developed countries. At present, more than 3 billion people in Asia have only 75 million telephone lines and in Africa, with 500 million people, there is on average only one telephone per 1000 people.

7. Cellular phones are increasingly popular in Asia. The number of cellular phones in Asia is predicted to rise by the year 2000 to 72 million from around 10 million now. Fuelling this boom is the region's dramatic economic growth, a preoccupation with high technology, and increased competition among cellular operators caused by market liberalization and the onset of new digital systems. Today in Hong Kong, approximately 113 out of every 1,000 residents carries mobile phones. That compares with 97 out of 1,000 in the United States. By the end of 1996, China will have more than 40 million pager subscribers, surpassing the United States as the biggest users of these devices in the world. Every two years, China adds a telephone network equal to France's national system.

8. As the GII will be built over the next decade, much of the activity will be in developing and transitional economies, and primarily in Asia. In just the next four years, Asia is predicted to account for half of the world's economic growth. Over the next 20 years the United States is going to generate about 25 million new jobs. In comparison, Asia will generate about 250 million new jobs. Those new financially sound customers will be able to buy all the state-of the-art electronic devices available on the market as well as the value-added telecommunications services.

9. For example, in the United States, the most developed country from an information technology viewpoint, telecommunications and information markets have become significant factors in economic growth. These industries account for almost US$ 1 out of every US$ 10 spent, an annual average of US$ 2,000 for each household. The information marketplace, broadly defined, now constitutes about 10 percent of the U.S. domestic economy, and is expected to grow to 20 percent in just a decade. These businesses now support more than 3.6 million jobs in the United States. The U.S. government's initiative in developing NII and GII further stimulates the creation of jobs. The converging industries of communications, computers and entertainment generated over 400,000 new jobs in 1995, about 20 percent of the total new jobs in the U.S. economy.

10. Strong competition in this area lowers consumer costs. A three-minute long-distance call within Germany, where a telecommunications monopoly still exists, costs two to four times more than in the United States and the United Kingdom of Great Britain and Northern Ireland, where this type of service is provided by competing private companies. Similarly, equipment prices in the United States for the direct broadcast satellites dropped from US$ 700 in January 1996 for the digital satellite system hardware to as low as US$ 150 just 10 months later.

11. The Internet, developed as the electronic communications media of scientists and computer experts, has tremendously transformed and absorbed new technologies and users, creating new applications. More than 40 million people were using the Internet in 1995, and it is continuing its dramatic growth, consistently doubling in size every year since 1980.

12. With the Internet, Asia again is demonstrating tremendous growth. In 1995, the number of host computers doubled in Thailand, tripled in Malaysia and Japan, quadrupled in China, increased by a factor of six in the Philippines and Singapore, and increased by a factor of 12 in Indonesia. Market research predicts that by 1999 the annual pace of on-line business will be US$ 10 billion.

13. Some 35 million computer users worldwide are currently estimated to exchange more than one billion e-mail messages each month. In 1995, in the United States, for the first time more mail was delivered electronically than was delivered by the United States Postal Service. The World Wide Web was created only four years ago, and as of June 1996, Web sales reached US$ 130 million. But the appearance of this so-called "cyberspace" raises many questions which have to be resolved if the GII is to serve a meaningful and positive role in human affairs.

## I. DEFINITIONS

14. It should be noted that there are some ambiguities in the terms "cyberspace," "National Information Infrastructure (NII)," and "Global Information Infrastructure (GII)." Many use these terms, as well as "the Internet," more or less interchangeably. However, more precise usage of these terms is important.

15. "The Internet" refers to the existing set of interconnected communications networks commonly known by that designation. Compared to 650 million telephone subscribers, 1.2 billion television sets or more than 2 billion transistor radios the world over, the Internet - with an estimated 40 million users - is just a small part of the telecommunications world. Moreover, the Internet is not really the infrastructure but rather a massive public transmission network.

16. The "NII" is used to describe the future U.S. national "information superhighway" that might incorporate the Internet as well as a wide range of other networks and media that are currently under discussion. The "GII" refers to the worldwide extension of this information superhighway; the term GII was defined at a February 1995 meeting of the G-7 nations, not by what it is (or will be), but by what it will enable: "The GII will allow ready access to relevant information, at reasonable cost, by anyone, anywhere, at any time." Lastly, "cyberspace" is used in its more general sense as the "virtual location" where computer-mediated communication occurs.

17. There are several visions of what the GII might be, as seen by the many segments of the information and communication industry. One vision is that of a high-performance computer network that will facilitate high-speed data access and retrieval. In this model, the Internet is sometimes seen as the precursor to the GII. If the Internet can be successfully extended from the academic and research communities it traditionally served to a broader commercial marketplace without losing the openness and innovation that have been a critical part of its success, then perhaps it could form the basis for a new model of network development. However, the Internet suffers from the problems often found in resources that are in common ownership: potential misuse, security problems and lack of structure. It is also currently a narrowband rather than a broadband or high-capacity network. The reason that much of the Internet is narrowband is because of the limitations in the current underlying telecommunications infrastructure. The Internet may, therefore, be more useful as a testbed for network evolution rather than being the network itself.

18. A second vision is that of a multimedia network for which the primary use will be conveying video datastreams in conjunction with data, text and voice. According to this vision, many of the potential applications will be in entertainment, education, health care and the business market. In public policy statements, it is often this vision of providing access to schools, universities, hospitals and public libraries that predominates. It is understood that residential and business users will be the major market, but the emphasis is on achieving universal service goals, with the public sector participating alongside the private sector.

19. A third vision is that it will serve as a medium for interactive television, in which it is the intelligent television set, rather than the home computer or the videophone, that is the main communication channel. Entertainment would be the key service, but many other education and business services could come as a supplement.

20. Hopefully, with the advantage of modern technology, a single network of networks could accommodate each of these different views. The issue on which all experts agree is that this single network will be digital. The process of digitalization began in the computer industry and has already penetrated both the telecommunication and the broadcast industries. As these three sectors converge, it will become increasingly difficult, and unnecessary, to distinguish between the different parts of the information media. Information should, in theory, be able to flow from any source to any destination providing the network is digital, and providing the addressing scheme is universal.

21. Network routing functions might also be considered part of the infrastructure. The common network infrastructure that can accommodate the different applications, including computer internetworking, is - and will have to continue to be - built according to underlying standards that meet broad needs. The infrastructure standards will have to reflect the requirements of the diverse applications. The GII itself will be a "network of networks" that will evolve out of existing technologies and services, just as communications has always done.

22. The three visions above of the GII reflect the different parts of the information industry as it currently exists: the computer industry, the telecommunications industry and the entertainment industry.

23. This document will concentrate on a concept for the implementation of the GII, with a special emphasis on its impact on developing countries: the contribution of new broadband communications technologies by systems deployed both on geostationary orbits and low-Earth orbits (LEO), and high-altitude long-endurance (HALE) platforms deployed in the stratosphere. The concepts that are being developed by three companies are presented only to illustrate the possible communications systems that may someday become a reality. This illustration does not imply an endorsement by the United Nations of any commercial or technical aspect.

## II. DIFFERENT ASPECTS OF GII IMPLEMENTATION

24. To make the GII a reality, the World Bank estimates that US$ 60 billion for investment will be needed each year. The total cost of closing the telecommunications gap in developing countries has been estimated at US$ 3 trillion. Other estimates, however, are much higher. For example, PacTel, a U.S. local exchange carrier, has estimated the cost to upgrade the state of California's infrastructure to support broadband capabilities at US$ 15 billion, while telecommunications provider NTT has projected the cost of wiring all of Japan at over US$ 700 billion. In Australia, which has a strong public policy supporting universal access, providing broadband services to just the 30 percent of the population outside of cities would cost over US$ 20 billion. On the other hand, the Institute for International Economics estimates that the adoption of the agreement on telecommunications liberalization reached by the World Trade Organization's Negotiating Group on Basic Telecommunications could save, in general, consumers in both developed and developing countries more than US$ 1 trillion over the next 12 years in lower charges, better service and more advanced technology.

25. The G-7 Ministerial Conference on the Information Society and Developing Countries (ISAD) (May 1996, South Africa) mentioned that the Global Information Society is an extremely important issue and highly relevant to all developing countries, irrespective of their stage of development. It is important that all developing countries become part of the Global Information Society. This calls for a massive, predominantly private, investment effort, which should be supported by a substantial regulatory framework. This requires regulatory reforms in many countries in order to create a stable and flexible environment attractive to investors. In order to become part of the global information society, the efforts of the developing countries themselves are key. Industrialised countries and the more advanced developing countries should be ready to assist developing countries in supporting this integration process. Traditional development instruments should be mobilized and redirected for this purpose.

26. With the build-up of the GII, many developing countries would be able to leapfrog the telecommunications gap with wireless and mobile telephone systems. Recent research has indicated that wireless systems are the most cost-effective manner to develop or upgrade telecommunications networks in many areas where density is lower than 200 subscribers per square kilometre. Fixed wireless systems can be installed five to 10 times faster than wireline networks, which require considerable investment in infrastructure, and initial costs are comparatively small. This is an important factor for many developing economies to consider very seriously when making a decision in which type of telecommunications to invest

capital. Fibre optic cable is an excellent solution for high-density population areas, but its cost-effectiveness drops very quickly when it goes to rural and hard-to-access remote places.

27. At the ISAD Conference it was announced that major international telecommunications carriers have agreed to create a high-speed terrestrial network linking North America, Europe and Japan, an important step toward the creation of a Global Information Infrastructure. This breakthrough in global communications is the result of an agreement of the G-7 countries to promote "pilot projects" that demonstrate applications of the GII. The network will be used to support international cooperation in areas such as telemedicine, distance learning, environmental research, remote access to museums and high-energy physics. It also will help ensure that the high-speed networks developed by different countries will work together. This fibre-optic network will operate at 155 megabytes per second, 100 times faster than most current international networks. That speed is enough to transmit all 33 volumes of the Encyclopaedia Britannica in just 20 seconds.

28. Indeed, the advent of fibre optics has made an astonishing impact on the further development of telecommunications in general and influenced satellite communications in the developed part of the world. Current state-of-the-art fibre optic systems can transmit the equivalent of 80,000 simultaneous telephone conversations over a single optical fibre and will soon be able to carry 320,000 conversations over a fibre pair. With the widespread use of fibre optics, satellite communications in the developed part of the world have become more concentrated on rural communications; point-to-multipoint distribution networks, such as cable distribution, DBS and VSAT networks; and mobile and transportable communications.

29. It was also successfully shown at the ISAD Conference that satellite technology available today could contribute to GII implementation. The International Telecommunications Satellite Organization (INTELSAT) indicated that its 24-satellite fleet is able to provide global access to the Internet, showing how different countries can use INTELSAT to extend ISDN networks worldwide, even to the most remote areas of the world where communications infrastructures have not yet been developed to support these advanced networks locally. Besides Internet access, desktop videoconferencing, electronic mail, and other new applications are all possible in every corner of the world today via this global international satellite operator.

## III. CONTRIBUTION OF COMMUNICATIONS SATELLITES TO GII

30. Satellite systems have important features that fibre optics lacks: (i) mobility - mobile users cannot be connected to the fibre network directly; (ii) flexibility - once a terrestrial infrastructure is built it is extremely expensive to restructure it; and (iii) rural and remote connections - it is still not cost-effective to deploy high-capacity fibre networks in areas with low-density traffic and difficult topography.

31. Thus, satellites and wireless technologies will be important in the future implementation of GII, providing the missing link that no other telecommunications technology can supply. The GII will not be a "uniform" network but will consist of many parts using different technologies, growing or shrinking with differing levels of usage.

32. With few recent exceptions, both communications and broadcasting satellites were not designed to be compatible with the Internet, which requires individual, bi-directional and, increasingly, high-speed ("broadband") communications.

33. Recently, satellite designers have been preparing to extend cellular telephony to space. There are now several projects, so-called "Big LEOs" (A/AC.105/564), in various stages of implementation to deploy satellite networks providing global telephone services, but they are "narrowband" rather than "broadband" systems. Most individual connections would be able to carry data at only 2.4 kbits per second (kbps).

34. Broadcasting satellites (A/AC.105/591), like those used for digital television, have sufficient bandwidth, but they are one-way systems distributing the same stream of information to an enormous community of users. Nevertheless, because of consumer demand, some satellite systems were modified to accommodate a small degree of a two-way interactivity for personal Internet connection. Users of the Direct PC system by Hughes Network Systems in the United States send data requests over their regular telephone lines to download an Internet file. The company routes the requested files to its control centre, which codes them so that a subscriber's personal computer (PC) can recognize them as its own, and then sends them up to a satellite for broadcasting. But broadcasting data to an entire country in response to a single user will apparently never be the cost-effective solution. Hence, for a full two-way connection with Internet, a different type of satellite network has to be deployed.

35. A new satellite industry based on drastic progress in computer and microchip technology is currently emerging in response to this consumer market demand. The total communications satellite market will account for some 67.5 percent of the space missions planned for the next 10 year and the market for communications satellites for the same period has been estimated in the range of US$ 8 billion to US$ 15 billion.

36. Virtually all communications traffic today - video, voice and data - is being converted to the digital format, and the remaining analogue traffic will undoubtedly undergo conversion in the next few years. The general trend in these different services, and particularly the mobile service, has always been toward the simplification of the ground equipment.

37. Significantly for mobile services, users are beginning to talk of terminals, rather than earth stations, making it possible to design high-capacity systems aimed at a mass market. This represents a major departure from the present situation, where mobile communications by satellite is supported by geostationary satellites offering global coverage.

38. Because of this digitalization process, satellite designers are no longer limited by the constraints of analogue technology and resulted in the development of regenerative communications payloads instead of the traditional, transparent ("bent pipe") transponders with fixed bandwidth in the range of 27-36 MHz. These payloads include sophisticated all-digital processors that demodulate and decode the uplinked packetized traffic, and then route the traffic to the appropriate downlink or intersatellite crosslink beam according to the packet header address for recording, remodulating and further transmission. The bit stream obtained from demodulation of a given uplink carrier is then used to modulate a new carrier at downlink frequency. This carrier is noise-free and this regenerative payload does not retransmit the uplink noise on the downlink, improving the overall link quality. To greatly increase the overall system efficiency, the traffic switch should be installed on the satellite, not in the ground station.

39. Contrary to widespread opinion, the altitude of the satellite is not a determining factor in the link budget for a given earth coverage. The propagation attenuation varies as the inverse square of the distance and this favours a satellite in a LEO because of its low altitude. However, this disregards the fact that the area to be covered is then seen through a larger solid angle, resulting in a reduction in the gain of the satellite antenna and offsetting the distance advantage.

40. One of the keys to the problem of the simplification of the terminal lies in the size of the cells forming the coverage area of the satellite: the narrower the elementary beam that produces these cells, the lower the power required at the terminal. Various solutions may be attempted, including the use of constellations of low-Earth orbit (LEO) satellites (in the altitude range between 400 and 1,500 km) or medium-Earth orbit (MEO) satellites (altitude around 10,000 km).

41. LEO and MEO systems have the advantage of being able to form small beams on the ground (on the order of a few kilometres in radius) with on-board antennas of acceptable size. Moreover, as the cell area to

be covered by each satellite is much smaller than the area visible from a geostationary satellite (roughly 10 times smaller for a LEO and three times smaller for a MEO), the number of beams to be produced by each satellite is correspondingly much smaller, and interconnecting all the beams is a much less complex matter. By being 50 times closer to the earth's surface than geostationary satellites, transmission power requirements for LEO satellites are drastically reduced - up to 2,500 times less. Subsequently, LEOs allow much more throughput capacity, and cheaper and smaller antennas.

42. The evolution from geostationary to low-Earth-orbit (LEO) satellites has resulted in a number of proposed global satellite systems that can be grouped into three distinct types: "Little" LEOs, "Big" LEOs and "broadband" LEOs and can best be distinguished by reference to their terrestrial counterparts. Little LEOs are the equivalent of paging systems, Big LEOs provide the equivalent of cellular telephone services and broadband LEOs are similar to fibre optic networks.

43. Crossing the skies at a speed of approximately 25,000 kilometres per hour in the range of altitudes between 500 and 1,400 kilometres, LEO spacecraft constellations will drastically expand the volume of outer space available for satellite-based communications systems because of congestion on the unique geostationary orbit. On the other hand, as LEO or MEO satellites are in motion with respect to the Earth, several satellites are needed to ensure continuous service over a given area (the pass-time of a satellite is a few minutes for LEOs and a few hours for MEOs). The constellation may then be optimized to make more than one satellite visible to the user at once, thereby improving the system's quality of service and capacity. This affects terminal design, because the terminal may have to track multiple satellites simultaneously.

44. These systems also require a large number of satellites to be manufactured and launched within a fairly short timespan, entailing the development of new, less expensive production and assembly concepts (assembly-line production, fewer and simpler tests, etc.), constituting a challenge for both the satellite and launcher industries.

45. At the same time, systems in non-geostationary orbit have to be served by a large number of feeder stations, owing to the small coverage areas of the satellites and their movement. One remedy is the use of intersatellite links, although this makes the satellite more complex to produce.

46. The allocation of the system's internal resources and frequency coordination with other systems also constitute a more complex task for LEO and MEO systems because of the continuous movement of the satellites compared with conventional geostationary systems. For efficient operation, dynamic allocation is the only real option, and this increases considerably the complexity of resource management.

47. Control and management of the LEO constellation is much more complex than that of the geostationary system, in which satellites have stationary coverage, because of the global coverage capability of each individual LEO satellite.

48. The demand for wireless communications, either terrestrial or by satellite, has increased the problem of a shortage of the telecommunications frequency spectrum, which will become even more acute as less developed areas of the world increase the demand for information services. Ka-band is the only band allocated internationally that is capable of accommodating global broadband systems. It has the advantages of increasing the number of satellites that can be injected into the geostationary orbit because of the narrow beamwidth that results from the use of the higher frequency, and of reducing the size of the satellite and ground antennas required for any given gain.

49. One disadvantage of Ka-band is its susceptibility to signal loss due to rain, which dictates that suitable measures be taken to compensate for the loss of signal in order to provide reliable, high availability communications channels. The use of Ka-band allows implementation of very high bandwidth channels.

50. The economics of telecommunications also depend on how far the user is from a fibre optic head-end and how intense their usage is. If a user is in an urban area and has fibre optic cable coming into the office or home and uses it continuously for a large percentage of the day, then fibre optics will be more cost-effective. But if a user needs broadband access for a few seconds at a time, then it makes sense to pay for bandwidth on-demand rather than for a dedicated line. Broadband satellite and stratospheric systems would provide service at rates comparable to urban wireline service. That would constitute a few cents a minute for the equivalent of a basic voice channel, when a user wants it.

51. Advanced digital satellites and high-altitude long-endurance (HALE) platforms can truly compete with and, more important, complement and be compatible with current fibre optic networks. However, for such a broadband platform, a highly efficient cellular antenna system with over 100-fold frequency re-use must be installed, and intensive onboard bit-by-bit total signal regeneration, as well as LEO satellite constellation, have to be reoptimized. If all this is implemented, such a satellite would have "fibre-like latency," provide full ISDN quality and system availability, and still offer up to 325 Gbps of throughput capacity. This kind of capacity would allow the delivery of all the 7 Terabits that could contain all the information in the United States Library of Congress in just 20 seconds.

52. The evolution of satellite/HALE systems technologies can move ahead quickly, as demonstrated by the new generation of geostationary systems (using as an example the Spaceway system design) and by the low-Earth orbit concept of the broadband LEO Teledesic and Sky Station stratospheric systems. These new systems, for the first time, show the potential that satellites/HALE platforms have to compete with fibre optics networks.

## IV. EXAMPLES OF NEW BROADBAND SATELLITE AND HALE-BASED SYSTEMS FOR GII

53. There are three different broadband communication systems to be considered, each the equivalent of a terrestrial fibre optics system. Spaceway was selected out of several geostationary broadband system proposals as it was the first of its kind.

### A. Spaceway

54. Spaceway is a network of regional systems utilizing satellites in the geostationary satellite orbit to provide cost-effective, two-way voice, data, image, video and video telephony communications to business and individual users. Direct access to the satellites will be available on demand via inexpensive ultra-small aperture terminals (USATs). A two-satellite regional configuration could enable more than 250,000 simultaneous telephone calls at 16 kbit/s. The all-digital 16 kbit/s circuits utilized for telephony will ensure consistent high-quality voice channels.

55. This global broadband communications system costs US$ 6 billion. It is based on using up to 17 Hughes-built satellites to create four interlinked regional networks covering North America, Central and South America, Europe and Africa, and Asia and the Pacific.

56. In developing countries, the Spaceway system will offer essential domestic and international telephone and facsimile services seamlessly integrated into the public switched telephone network (PSTN). This service will be competitively priced with basic terrestrial telephone services and available in rural or remote areas where basic telephone services are neither economically feasible nor available. The system will offer both next-generation very small aperture terminal (VSAT) applications, and high-bandwidth services for a variety of consumer and business applications, both in countries with existing telecommunication infrastructures and those with emerging needs for advanced services. The availability of teleconferencing facilities that interface

with existing services and are provided at a low cost should help under-served countries improve the delivery of vital services such as health care and education.

57. Each regional system will begin with two of the four satellites per region. By 2001, Spaceway will provide global communication services using intersatellite links and satellite beams. The system uses on-board signal processing and switching, small, easily installed ground terminals and digital transmissions at a variety of bit rates.

58. Each satellite will utilize an on-board switch/processor to provide individual end users with immediate access to the space segment and to route transmissions within and between appropriate destination spot beams, as well as to interconnect with other satellites in the network. This will be accomplished without the use of the traditional VSAT hubs.

59. A key component of the system architecture is the Ka-band spot beam network. Each spot beam normally will use 125 MHz bandwidths. Narrow spot beams (about one degree) with a footprint approximately 650 km in diameter will cover most of the land mass of the populated world. The satellite design will permit reuse of frequencies up to 12 times. Thus, the 500 MHz of spectrum utilized by each satellite will result in an effective 6 GHz of useful bandwidth per satellite. The system allows symmetric and asymmetric data communications with an antenna 66 cm in diameter at transmission rates from 16 Kbps to 1.544 Mbps, depending upon user requirements. Multi mega-bit per second applications can be accommodated with a system-specific optional broadband uplink terminal. All these system-specific terminals will receive data at 92 Mbps.

60. This technology allows the use of ultra-small aperture terminals (USAT) and provides a high degree of spectrum efficiency. The USATs used by the system will be functionally advanced and more affordable compared to today's VSATs. The system will be less expensive to businesses, both because of the terminal price and maintenance cost, and because it offers complete mesh connectivity without the need for an expensive hub station. Smaller businesses that cannot afford present VSATs can take advantage of satellite networking.

61. This system will accommodate conventional VSAT applications and will offer a variety of broadband services, including video telephony and conferencing, telecommuting, medical and technical tele-imaging. Because of the terminals small size and low cost, the system will be available to individual consumers for basic telephony and data communications, personal video telephony, and high-speed personal computer access to on-line services.

62. The system allows for faster data transmissions than those provided by a terrestrial system. For many applications, like sending medical images such as x-rays, short transmission time is critical. The Spaceway network can provide transmission rates more than 150 times faster than conventional telephone lines.

**B. Teledesic**

63. Teledesic Corporation is planning to construct and operate a global telecommunications network based on a constellation of 840 LEO satellites. Total cost of the project is estimated at US$ 9 billion. The network will deliver a wide array of affordable, yet advanced, interactive information services to people in remote parts of the world. The company intends to establish a global partnership of service providers, manufacturers, governments and international agencies to create a "Global Internet" that will provide people with videoconferencing, interactive multimedia and real-time two-way digital data flow.

64. The Teledesic system will use Ka-band (30/20 GHz) to send and receive signals from users. Each satellite will act as a node in a large-scale packet-switching network.

65. The service would allow a user to have two-way interactive conferences with any other user anywhere else in the world. Each participant would have the opportunity to "upload" broadband communications such as live video, as well as download them, rather than just responding to video signals. A rooftop antenna would be the size and price of a laptop computer. The interactive terminal could be a PC or a television set-top box.

66. The designers of "Big LEOs" were following the design concept of terrestrial cellular systems; Teledesic was using the Internet as a baseline. Teledesic estimates that when fully deployed, the system could support two million simultaneous basic rate (16 kbps) connections, corresponding roughly to 20 million users. Satellite antenna footprints will be 53 km in diameter, small enough to keep the number of users in each cell to a manageable level. The network is designed to provide 18 simultaneous Internet links each with throughput capacity of 1.5 Mbps in each cell, or 20,000 worldwide.

67. Unlike the other proposed "Little" and "Big" LEO systems, Teledesic is not focused on serving mobile customers. While a small degree of transportability will be accommodated, Teledesic is primarily designed to provide services to fixed locations.

68. Much of the capacity of the Teledesic system will reside over areas with little commercial demand for these advanced broadband capabilities but with compelling communications infrastructure needs. The Teledesic initiative would make that capacity, otherwise unused, available to developing nations. The company has agreed to set aside capacity for humanitarian causes on a non-profit basis. Also, the system is specifically designed the system to accommodate the regulatory requirements of local governing authorities.

69. Through this initiative, Teledesic hopes to play a part in helping to bring about universal access to a Global Information Infrastructure. The Company will work directly with country representatives to ensure that this capacity would create communications solutions that are appropriate to the needs of the developing nations. Teledesic has already initiated discussions with regional telecommunications development organizations.

70. The "earth-fixed" cells built in the system design respect both national boundaries and national sovereignty. The so-called phased array electronic antenna installed on the spacecraft can view a fixed cell on the earth surface without physically moving and shift the focus of its pattern instantaneously. Local authorities would have total physical control over the ground stations that serve as gateways for all traffic coming in and going out of a country.

71. The company plans to begin service in 2001 and does not intend to market services directly to users, but provide an open network for the delivery of services by local telephone exchanges and telecommunications authorities in host countries. Ground-based gateways will enable service providers to offer seamless links to other wireline and wireless networks. The Teledesic space segment could be used to supplement the services provided by a governmental PTT rather than compete with it.

72. The system alone will not have the capacity to carry all the world's high-speed traffic. It is counting on growing terrestrial fibre optic networks in the developed world to create and meet demand for high-speed services. The Teledesic system would fill in the gaps everywhere else.

73. The system has a so-called distributed type of architecture. It is a distributed network in space. The Teledesic constellation uses many satellites to make this system non-hierarchical and fault-tolerant so local congestion will not disrupt communications links. With a centralized type of network one would have to design and manufacture a central unit very close to 100 percent reliability, because the consequences of failure are catastrophic. The law of diminishing returns says that to provide reliability close to 100 percent, costs increase tremendously. With distributed networks, the reliability is in the configuration and design of network.

74. To better imagine Teledesic's constellation integrated scale, it can be characterized by the following figures:

- Some 500 million gallium arsenide microchips will generate microwaves from 180,000 phased-array antennas.

- The total electric power subsystem of an "integrated" space segment will consist of 12,000 batteries energized by thin film solar panels with total surface of 24.4 square km. Operating at only 4 percent efficiency, they still produce around 10 Megawatts, enough power to light a small town.

- To operate the sophisticated web of fast-packet communications among the satellites and ground terminals, the constellation would process some 282,000 million instructions per second inside radiation-hard microprocessors, and around one trillion bytes in random access memories.

75. Teledesic will manufacture and launch a large number of identical spacecraft, using off-the-shelf hardware as much as possible. This approach also provides economies of scale that could lower unit costs by a factor of 100 or more. In fact, this would constitute one of the world's largest and most expensive parallel computer systems to be launched into space.

76. To minimize the costs of constellation deployment, the spacecraft were designed as self-stacking. This means that on average, eight spacecraft can be launched on a single launch vehicle. It will require at least 116 separate launches to deploy the entire constellation. However, several launch vehicles currently available could carry 20 or more Teledesic spacecraft at a time, which would mean 40 or less launches over two years.

77. Each spacecraft carries over twice the propellant needed to insert itself into its orbital position, to overcome atmospheric drag for its design lifetime, to reposition itself when required and to perform a final deorbit manoeuvre and burn up during reentry before impact. A number of functionally redundant solutions have been mechanized into the spacecraft design to execute deorbiting manoeuvres. To avoid collisions at the polar regions, where all 21 planes of the constellation cross each other, each individual plane has a slightly different altitude. Thus, the entire constellation occupies a layer of space between 695 and 705 km.

## C. Sky station

78. Sky Station International, Inc., is a new company formed to implement a revolutionary new invention, a propulsion system called the Corona Ion Engine that allows a platform to remain stationary in the stratosphere for 10 or more years. The stationary platforms will be the backbone of a global Internet delivery system that offers variable broadband data rates (16 Kbps to 1.5 Mbps) to portable terminals.

79. According to the company's documentation and real test results, the Corona Ion Engine develops thrust that is more than 300 times stronger than the thrust of any other ion engine developed to date. It accomplishes this using a proprietary design that has been proven in scientific tests. The engine produces no pollution and has no moving parts. It uses ambient ions in the stratosphere as its fuel source, and is powered by solar energy. It can keep a multi-tonne platform supported by helium balloons stationary in azimuth and altitude with an extremely high degree of stability.

80. With virtually unimpeded access to the sun during the day, stratospheric platforms will collect sufficient solar energy to supply power to both the telecommunications payload and the housekeeping subsystems of the platform, including the Corona engines. Fuel cells will be utilized to provide power during solar eclipses and at night. The engines contain electrodes that are biased at a negative voltage of at least 3,000 volts to eject energetic electrons by means of field emission, forming a plasma of electrons and positive ions. Given the low drag force in the stratosphere, the engines will provide sufficient propulsion to transport the stratospheric platform to its on-station position and maintain it stationary for at least 10 years.

81. The stratospheric network will consists of at least 250 Sky Stations at an altitude of 30 km and positioned over areas of dense population. More Sky Stations can be added at any time. Stratospheric Internet Service will commence with the first Sky Station deployment in 1999. After that, one additional Sky Station will be launched per week in all parts of the world. Each Sky Station provides Stratospheric Internet Service to an area of approximately 7,500 square kilometres. Sky Stations could be custom-designed in accordance with user demand as requested expressed by relevant organizations in each country.

82. Designers of the system estimate that the Stratospheric Internet Service with a 64 kbps throughput capacity channel will cost about ten cents per minute, less than the least expensive mobile communications service. Unlike existing mobile communications services, the Stratospheric Internet Service will be broadband and have low latency and no hand-off problems.

83. The 47 GHz frequency band (47.2-47.5 GHz uplink and 47.9-48.2 GHz downlink) in which Sky Station operates was selected for several reasons. First, the International Telecommunication Union (ITU) has already defined those frequencies as being available for both Fixed Service (point-to-point communications) and Fixed Satellite Service (communications among many points and space stations). Because the Sky Station System provides both Fixed Service and Fixed Satellite Service, these are logical frequencies. Under ITU definitions, a stratospheric platform is a terrestrial service.

84. Second, these frequencies are currently unused and not part of an existing utilization plan. Thus, the Sky Station System will not displace any other frequency users. Third, the unique characteristics of stratospheric platforms, especially their high elevation angles and short path distances, make it feasible to use 47 GHz frequencies, whereas other kinds of communication systems cannot make effective use of such high frequencies. Hence, it is most appropriate for Sky Station to use these frequencies instead of lower frequencies that may only be usable by other technologies.

85. Sky Stations can be of variable size depending on market demand. Normally, a Sky Station will be approximately 30 metres by 30 metres and have a total mass of about seven tonnes. Each Sky Station will generate 75 kilowatts of power from solar panel arrays. After subtracting power needed for station-keeping and other functions, there are 15 kilowatts of radio frequency power for telecommunications. This is adequate to support 150,000 simultaneous 64 kbps transmissions.

86. Flight safety is a major consideration of the Sky Station development effort. Multiple safety features are being integrated into the entire system, the most important of which are the on-board monitoring systems installed in the Sky Station to report back a steady stream of system information to the ground control station. The use of zero pressure inner balloons also greatly reduces the probability of any catastrophic rupture of the main balloons since their envelopes are hardly stressed. The double envelope design also ensures that any rupture of the helium balloons will not cause the helium gas to stream out since it is still confined by the outer envelope. The thick-skinned structural balloons are more heavily stressed and are susceptible to rupture. But since they do not provide any lift, their rupture does not reduce buoyancy.

87. This way, by design, a sudden and complete loss of buoyancy is highly unlikely. In the event of such an occurrence, the envelopes will reach a terminal velocity of at most a few metres per second, and, owing to their extremely low area densities, cause insignificant damage to properties or lives. Since the envelopes weigh a total of five tonnes, this is an important consideration. The rest of the Sky Station consists of multiple, nearly independent, lightweight modules with little or no mechanical connections. These modules all weigh under one tonne and are designed to come apart as soon as they are subjected to unsafe force levels, which they will reach when they descend too rapidly. They are each equipped with emergency parachutes to slow their descent. Because of their long descent path, it would be possible to retrieve the impaired Sky Station with a suitably equipped helicopter. In the much more likely scenario of a slow helium gas leak, which can be detected by a combination of steady internal pressure drop and a persistent drop in altitude, on-board compressed helium containers will be commanded to compensate for the leakage and arrangements

will be made to bring the Sky Station down to a refurbishment site for repair after a replacement Sky Station takes its place.

88. By providing essential services at affordable prices this Global Stratospheric Telecommunications System (GSTS) will help preserve life and property by facilitating (i) medical diagnosis; (ii) emergency rescue and safety alerts; (iii) distribution of life-saving agricultural and health care information; (iv) disaster-proof communications; (v) crime monitoring; and (vi) environmental monitoring and analysis. Additionally, the system will deliver its advanced services to over 80 percent of the world's population, thus helping to bridge the disturbing and growing gap between information "haves" and "have nots." Indeed, the GSTS is a wireless telecommunications system to offer as much exchange line capacity as is available over wireline systems. GSTS also will increase global access to education by facilitating virtual universities, virtual hospitals, and other virtual education programmes. Finally, the GSTS network will not deplete the earth's fragile ozone layer or produce space debris, and its reusable platforms can return to the earth's surface for refurbishment.

89. The principal GSTS market will be that portion of the mobile communications market that wants broadband rather than narrowband mobile communications service. Another benefit would be seamless interconnectivity with the Internet's image-rich World Wide Web. The system will offer consumers worldwide wireless telecommunications service with built-in digital video capability for personal videophone or portable Internet services.

90. A second GSTS market will be that portion of the mobile communications market that wants supra-urban cellular coverage, but is unwilling or unable to pay the US$ 1 per minute and higher rates. The GSTS would provide continuous roaming communications capability throughout its coverage zone at a rate of ten cents per minute, and without the necessity for long-distance phone charges if the other communicator is also a GSTS user.

91. A third GSTS market consists of basic telephone service in parts of the world that are not covered by cellular or landline services and cannot afford satellite services. GSTS will provide the developing world with an instant nationwide broadband telephone service without the need to construct prohibitively expensive terrestrial systems.

92. GSTS services will be in demand by both high-end mobile communications users in developed countries as well as by initial users of telecommunications services in the developing world. The market focus of the GSTS will nevertheless be kept clear: broadband portable telephony that includes portable picturephone service and wireless Internet/World Wide Web connectivity. The GSTS has been designed with the capacity to serve up to 1.5 billion people.

93. In developing countries, there are two distinct markets for GSTS. The first market is for those persons who already use cellular phones but are frustrated by busy signals or lack of coverage outside major cities. They will become early users of the GSTS. The second market is for those persons who have no ready access to modern telecommunications due to either economic or infrastructure reasons. For these persons, a solar-powered fixed-site village GSTS communicator is a feasible way to join the telecommunications revolution. In addition, Sky Station International foresees providing, free of charge, GSTS access and equipment to educational, public health and environmental organizations in the developing world.

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