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REPORT OF THE UNITED NATIONS WORKSHOP ON SPACE COMMUNICATIONS TECHNOLOGY FOR CAPACITY BUILDING, ORGANIZED IN COOPERATION WITH AND HOSTED BY THE GOVERNMENT OF ISRAEL

(**Haifa, Israel, 21-25 September 1997**)

CONTENTS

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INTRODUCTION

A. Background and objectives

1. On 10 December 1982, the General Assembly adopted resolution 37/90, in which it endorsed the recommendations[1] of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space. In that resolution, the Assembly decided, among other things, that the United Nations Programme on Space Applications should disseminate, through panel meetings and seminars, information on new and advanced technology and applications, with emphasis on their relevance and implications for developing countries.

2. The United Nations Workshop on Space Communications Technology for Capacity Building was one of the activities of the Programme for 1997 that was endorsed by the General Assembly in its resolution 51/123. The Workshop was organized in cooperation with the Government of Israel, and was hosted on that Government's behalf by the S. Neaman Institute. It took place from 21 to 25 September 1997, the participants coming from both developed and developing countries.

3. The objectives of the Workshop were to give the participants, particularly the managers of telecommunication institutions, the opportunity to explore ways of using space communication technology to further the development of their respective telecommunication infrastructure, and to consider ways in which developing countries could use satellite communications and broadcasting to become a part of the global information society.

4. Presentations were made at the Workshop on the use of global satellite broadband communications systems, stratospheric high-altitude long endurance platforms, direct-to-home (DTH) satellite broadcasting, very small aperture terminal (VSAT) systems, low Earth orbit (LEO) non-voice messaging systems, frequency spectrum regulations and usage, optical satellite communications, satellite-based disaster warning broadcasting and spacecraft on-board technology, and how they could be used, separately or collectively, to improve existing telecommunication infrastructures and provide both basic telephony in rural regions and value-added services in areas with a high-density population.

5. The present report, which covers the background, objectives and organization of the Workshop, the observations and recommendations made by the participants, as well as a summary of the lectures presented, has been prepared for the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee. The participants will report to the appropriate authorities in their own countries.

B. Organization and programme of the Workshop

6. The Workshop was attended by 72 participants from 19 States Members of the United Nations, including the following: Belarus, Cameroon, Czech Republic, Cyprus, Estonia, Hungary, Latvia, Lithuania, Nigeria, Poland, Romania, South Africa, Viet Nam and Ukraine. Speakers at the Workshop came from France, Israel, Italy, Russian Federation and the United States of America. The Office for Outer Space Affairs of the United Nations Secretariat, the International Telecommunication Union (ITU) and the International System and Organization of Space Communication (Intersputnik) were also represented.

7. The participants were professionals with several years of experience in managerial positions with national telecommunications institutions and companies.

8. Funds allocated by the United Nations were used to defray the cost of air travel and an allowance for incidental expenses of 13 participants from 13 countries. The Government of Israel, through the S. Neaman Institute, provided room and board for those participants.

9. The programme for the Workshop was developed jointly by the Office for Outer Space Affairs and the S. Neaman Institute. The Workshop was conducted through a number of plenary and working group meetings. At

the latter, the participants discussed issues related to the use of space communications technologies to improve telecommunication infrastructures and concluded the meetings with the observations and recommendations presented below.

I. OBSERVATIONS AND RECOMMENDATIONS OF THE WORKSHOP

A. Observations of the Workshop

10. Participants observed that in areas with an undeveloped telecommunication infrastructure, wireless local loop (WLL) technologies were making a forceful entry as a low-cost solution to the “last mile” problem. Such areas currently had a population of more than 3 billion people. The only reasonable way to penetrate that market was to exploit land wireless and satellite wireless technologies together.

11. It was increasingly unrealistic to expect developing countries with large, sparsely populated areas to build an infrastructure with wireline technologies. Instead, it was more likely that the isolated high-density population areas of the country would be connected via wireless and satellite links.

12. There was considerable interest in creating new global satellite systems to offer communication services to parts of the world that were currently underserved, and to exploit the anticipated growth in demand for data distribution arising from the computer-to-computer distribution of multimedia. The cost of building all of those systems probably exceeded the amount of risk capital, so that only a few were likely to be built.

13. By the end of 1996, nearly 2,200 space networks, notified by 62 administrations (including international satellite organizations), had been in one of the phases of processing by ITU.

14. The satellite fraction of telecommunication revenues, as commonly estimated, was less than 3 per cent of the current market in global telecommunication infrastructures; that figure was likely to amount to somewhere between 5 and 10 per cent in the future. Associated with wireless technologies, satellite communications could play a major role in global communication infrastructures.

15. The most important development in satellite communication mission design within the last decade had been the use of new orbital configurations to create improved look angles, increase irradiated power densities, achieve different coverage patterns, reduce signal transmission latency, and allow operation with hand-held terminals.

16. In addition to the financing of new communication systems, there were technical challenges to be overcome. They included the building of satellites, which for the first time employed large, complicated on-board processors, and reduction of the cost of the earth terminals to affordable levels. The Ka-band rain fade problem would be severe in some parts of the world, and might limit the types of service that would be acceptable to users. Already some proponents were known to be rethinking mission scenario designs of their communication systems with a view to achieving a lower-cost entry into the market. It was also likely that some of the project proposals would merge as an additional way of reducing the business risk.

17. Several key satellite technologies were still being developed. There was no on-board processor that could handle all of the switching and routing of the thousands of calls in milliseconds. There was currently no reasonably priced active-phased antenna system with electronic beam forming and tracking. Finally, there were no flight-proven and reliable automatic satellites or high-altitude long-endurance platforms that could cost-effectively support those operations.

18. Conservative estimates suggested that mobile satellite systems with projected communication rates of $1.00-$3.00 per minute would capture no more than 3 per cent of the total wireless mobile revenues. The most optimistic

projections estimated penetration rates that were from three to five times greater. Since those systems would not be largely deployed until the turn of the century, the actual market results would not be known for some time. The key issue was the degree to which consumers other than a small group of international business people would be willing to pay a high premium for global connectivity from any remote location.

19. Developing countries were concerned that the majority of their citizens might not be able to afford mobile satellite services. On the other hand, those services should be an essential element in early warning, preparedness and disaster relief activities and should provide communication links during emergencies. Mobile satellite services would seem to be the most effective in disaster relief, since they were the most resistant to the effects of disasters.

20. Currently, nations could monitor or intercept telephone transmissions within their countries. A major concern of national regulators was whether satellite mobile services could allow law enforcement personnel to continue to monitor calls.

21. In accordance with the ITU Radio Regulations, the advance publication procedure was the obligatory first phase of the relevant regulatory process. It did not give the notifying administration any rights or priorities. The coordination procedure was a formal regulatory obligation both for an administration seeking coordination and for an administration whose existing or planned services might be affected by new assignments. Coordination must be completed before the frequency assignments in question were brought into use or notified to the Radiocommunication Bureau.

B. Recommendations of the Workshop

22. Participants recommended that, because of the ever-increasing use of the orbit/spectrum resources and the resulting likelihood of satellite congestion in the geostationary orbit, more serious consideration should be given at the World Radio Conference 1997 to the question of equitable access to and efficient use of the orbit/spectrum resources.

23. In order to facilitate the implementation of global satellite communication systems, international cooperation, both between industrialized and developing countries and among developing countries, needed to be improved.

24. Satellite communication pricing policies were also in need of improvement. Both local service providers in the countries themselves and ITU on a world scale should be encouraged to seek more liberal approaches to setting up pricing structures.

25. Developing countries should give high priority to telemedicine and distance education applications (with special emphasis on their use in remote and rural areas of these countries), which could be provided at affordable prices by forthcoming broadband satellite communication systems.

26. Participants noted that WorldSpace Inc. was developing, specifically for the developing countries, the first world satellite-based digital audio broadcasting system. Probably, however, most people in developing countries would not be able to afford the quoted price of $200 for a digital radio (“Starman”) receiver. It was therefore recommended that every effort should be made to reduce the cost of the Starman radio set. It was also noted that the radio could apparently be modified at a reasonable cost so as to add a built-in disaster warning feature, and a recommendation along those lines was made to a representative of WorldSpace Inc.

II. SUMMARY OF THE PRESENTATIONS

A. Satellite communications and broadcasting for development

27. Over the next decade, the worldwide telecommunication industry and the information industry in general would undergo massive changes. Privatization of the governmental telecommunication sector and legislation deregulation were a driving force in the development and restructuring of the industry's infrastructure.

28. The information industry had traditionally been defined in terms of the "form" of information involved and the underlying technologies for handling each form, including images, text, voice, data, audio and video. Each must perform a series of functions, including creation, distribution, process, storage and display, in order to serve its markets.

29. The primary impetus for the convergence of those different forms of information was clearly technological change, and the key technological change had been the rapid diffusion of digital technology into an ever-wider array of information businesses. Beyond digitization, dramatic changes in the computing and telecommunication industries were also a force behind such convergence.

30. Digital technology also promised to bring even greater changes, which would be continuous, and which would open up virtually every household to interactive multimedia and video information: through the air from satellites and terrestrial wireless systems, through fibre-optic cables and cable television, and even through telephone company coaxial cables.

31. The growth rate of communication infrastructure and services had been exponential, fed by the commercial economic forces that had followed the deregulation process in many countries. Such activity, however, threatened to widen the gap between the industrialized and underdeveloped countries, a development that was undesirable for either side.

32. Access to a cheap bandwidth would be an essential factor in economic development in the next century, just as inexpensive power was for the Industrial Revolution. Developing countries must be assured of ample, low-cost access to high-density broadband telecommunication links.

33. It was estimated that it would take about 25 years to implement that challenging task by terrestrial means and that it would cost at least $1 trillion to connect the world with fibre optics. Other estimates indicated that the total cost of just closing the telecommunication gap in developing countries would be $3 trillion. Less than one fifth of the world's land surface was currently wired for communication services. Even though there were many fibre-optic networks in the world, and their numbers were growing by the day, they were used primarily to connect countries and the central offices of telephone companies with high-density traffic through trunk lines. Connecting fibre cables to individual offices and households accounted for 80 per cent of the cost of a network.

34. New satellite communication technology could intervene in those cases in rural, low-density traffic areas. Rural customers currently cost between 10 and 30 times as much to serve with wire-based telephone service as urban customers. Developing countries had only 1-3 per cent of the world's telephones and 10 per cent of the television sets. Some 3 billion people, about half of the world's population, lived in countries with less than one telephone line per 100 inhabitants. Recent research had indicated that wireless systems were the most cost-effective way in which to develop or upgrade telecommunication networks in areas where density was lower than 200 subscribers per square kilometre. Fixed wireless systems could be installed from five to ten times faster than wireline networks, which required considerable investment in infrastructure.

35. Satellites had demonstrated the ability to provide communication services to the less developed part of the globe with astounding ease. They were ideally suited for disaster emergency, relief and development work because they operated independently of the local telecommunication infrastructure. Disasters such as drought and insect infestations currently resulted in annual losses of over $50 billion. The known costs of satellite systems were only a fraction of that figure.

36. Satellite communication was the key technology in the developing countries' participation in the build-up of a global information infrastructure (GII). While developing countries did not constitute a viable market for most of the large-scale satellite communication projects, they benefited from lucrative markets in the industrialized countries that lured international commercial programmes, and might be able to take advantage of the excess capacity of those programmes to satisfy their own communication needs.

37. Satellite communication services and the telecommunication industry were entering a new era, driven by a combination of market growth, liberalization and deregulation of laws that had unleashed commercial economic forces and technological advances, many of which were spin-offs from military developments. The development of the industry still required due care: the large footprints of the satellites limited the density of communications that could be supported without interference. They were liable to mask scientific observations that were just as important to the world economy (weather observations, for example) and research (radio astronomy). A careful balance of interests—communications for everybody, economy, national interests and scientific needs, had to be developed and preserved throughout the process, to guarantee true progress.

38. Currently, international, regional, and domestic satellite systems were predominately "fixed services" (that is, non-mobile earth stations). Those satellites accounted for 90 per cent of the commercial systems in operation, and almost all of them operated in the C-band (6/4 GHz) and the Ku-band (14/12 GHz). The 30-year trend in fixed satellite service (FSS) had been one in which communication satellites were becoming more powerful, were three-axis stabilized, and were using higher-gain and larger-aperture antennas operating with multi-beams to achieve multiple frequency re-use. Those trends not only let satellites increase capacities and lifetimes but also made operation possible with much smaller and cheaper ground stations. The remarkably rapid growth in FSS satellite technology had been paced by competition from fibre-optic cables and the rapidly growing demand for international telecommunication traffic and all forms of television relay. The desire to decentralize Earth-station facilities and reduce their costs had also been a key force in the market place.

39. The world market for satellite communications was distributed among the space segment (satellites, launchers, insurance, control stations), ground segment (end-user terminals and networks), and the services provided. With the expansion of direct-to-home (DTH) television and digital audio broadcasting (DAB) services, and the introduction of personal communication and multimedia services, the ground segment would grow by many millions of users per year, and its worldwide market would amount to nearly twice that of the space segment. But the service segment would account for by far the largest gain. The total market for the coming 10-year period could be estimated at $60-80 billion for the space segment, $120-150 billion for the ground segment and over $400 billion for services. That would amount to a global market for satellite communications of over $600 billion.

40. More satellites were expected to be launched in the next 10 years than all of those put into orbit the past 30 years. Nearly 800 of the projected 1,138 satellites over the next 10 years would be for mobile systems. During the past five years, the worldwide growth rates for mobile telephony had hovered around an astonishing 50 per cent per annum, and some countries were actually doubling their mobile subscriber base every year.

41. Systems using constellations of LEO or medium Earth orbit (MEO) satellites would soon provide personal communication services (PCS). LEO constellations, as well as constellations of geostationary satellites, would provide multimedia services, with fast Internet access, in the very early years of the next decade.

42. There was indeed a very big market for DTH and direct broadcasting services (DBS), very small aperture terminals (VSAT), personal computer (PC), multimedia and other services; but whether all planned systems would prove successful, and the current expansion would continue remained an open question. Serious consideration had also been given to the use of DBS not only for entertainment services but also as a broadband telecommunication interface into the home to support Internet mosaic video services, as well as other broadband services.

43. Satellite communication systems had evolved rapidly from a purely network-oriented approach, interconnecting gateways of different terrestrial networks, to increasingly user-oriented ones, providing services directly to terminals

installed on the user's premises. That inevitable evolution resulted from the rapid expansion of fibre-optic cables, which were more appropriate than satellites for trunk telephony and point-to-point communications. The satellites' specific features, namely large coverage areas and instant access to them from any site within those areas, led services to concentrate on taking advantage of those features.

44. The current expansion of satellite systems affected both those based on geostationary satellites and those based on constellations of LEO and MEO satellites. The expansion was supported by many factors: (a) the worldwide growth of the economy, in particular in the Asia and Pacific region; (b) increased demand for direct services to end-users; (c) worldwide expansion of terrestrial cellular services, but with limited coverage; (d) poor terrestrial infrastructures in many areas, both in developing and industrialized countries; (e) worldwide deregulation and privatization of domestic, regional and global telecommunications; (f) intense competition inside the space and the telecommunication industries: many satellite manufacturers had also become systems promoters and operators; and (g) access to considerable private funds for new satellite systems.

45. The expansion of satellite communication systems implied continuous and rapid progress in space technologies and shorter production cycles of satellites and launchers, but the significantly increased difficulties in frequency coordination had to be solved. Many satellite systems required considerable amounts of private investment in the space and Earth segments.

46. That evolution was also accelerated by the rapid progress in satellite technologies (and launch vehicle performances), allowing marked increases in spacecraft mass and power consumption, leading to higher effective isotropic irradiated power for on-board antennas and reduced overall dimensions and cost of earth terminals. Large numbers of those terminals did increase considerably with the expansion of DTH Ku-band television services, which became the major users of satellite capacity. The growing expansion of DTH services and the coming introduction of satellite-provided PC and multimedia services would significantly increase those quantities.

47. Digitization of satellite transmissions followed that of the terrestrial ones. Coordination difficulties and system economy compelled satellite systems to use more spectrum-efficient transmission techniques, multiple frequency re-use, more sophisticated antennas, new frequency bands and, if possible, more interference- resistant transmissions. Increased spectrum efficiency was achieved by using digital transmissions with sophisticated coding techniques. For example, in telephony, the 500-700 voice channels (half duplex) capacity of a 36 MHz transponder when using analogue transmissions, increased to 3,600-4,000 channels when using digital ones, and the amount would probably double in the next decade. In television, a 27-36 MHz transponder transmitting one analogue television programme was capable of transmitting from 4 to 12 television programmes when using digital compression. Again, significantly higher compression rates for television signals would probably be introduced in the next decade.

B. New global satellite and stratospheric communication systems

48. It had become extremely difficult to secure an orbital location along the geostationary arc and operate in the C-band or Ku-band without interfering with traffic on adjacent satellites. While additional frequency assignments for commercial satellite use had existed in the Ka-band (roughly wavelengths in the 1.5 to 1 cm range), they had not hitherto been considered because rain absorbed those wavelengths, and little in the way of earth terminal equipment was available for that band.

49. The new proposed satellite (operating in the Ka-band) and stratospheric (operating in the V-band) systems would accelerate the realization of both national and global information infrastructures (NII/GII), particularly in regions of the world where terrestrial telecommunication infrastructures were non-existent or inadequate for high-speed communications. The term "Ka-band satellite" had become generally recognized as a shorthand term for a new generation of communications satellites that would use on-board processing and switching to provide full two-way services to and from small Earth stations comparable in size to the current satellite television dish. Such Ka-band satellite systems had also been described in other terms, such as "multimedia satellites", "Asynchronous Transfer Mode (ATM) satellites", "broadband switched satellites", and "broadband interactive satellites".

50. Proposed services included voice, data, video, imaging, video teleconferencing, interactive video, television broadcast, multimedia, global Internet, messaging and trunking. A wide range of applications were planned through those services, including distance learning, corporate training, collaborative work-groups, telecommuting, telemedicine, wireless backbone interconnection (that is, wireless Local Area Network-Wide Area Network), video distribution, DTH video and satellite newsgathering, as well as the distribution of software, music, scientific data and global financial and weather information. Satellite-based systems were also indispensable for emergency communication services.

51. According to ITU recommendations, those services had been classified into five categories: (a) messaging (electronic mailbox, paging); (b) retrieval (videotext, document retrieval, high-resolution image retrieval, data retrieval); (c) conversational (broadband person-to-person telephony, broadband multipoint videoconference, video surveillance, multiple-sound program signals, high-speed unrestricted digital information transmission, file transfer, high-speed tele-action, telefax, high-resolution image retrieval, document communication, digital telephony etc); (d) user-controlled distribution (restricted digital information transmission, videography); and (e) interactive diffusion (message diffusion, voice and sound diffusion, document diffusion, unrestricted digital information transmission).

52. The Ka-band concept offered the equivalent of a local telephone circuit, where the user paid for temporary lease of time. The Ka-band environment also made it feasible to offer the alternative of charging per bit of information moved. Such services required a lot of bandwidth, however, because each link would usually be operating on a point-to-point basis. The prime method of efficiently using the available spectrum efficiently was to use multiple “pencil” spot beams, each covering only a small area of Earth. That allowed frequency re-use in much the same way as a cellular phone network re-used the spectrum.

53. The use of multiple spot beams in itself demanded the use of on-board processing and switching to direct each transmission path between the different spot beams used for uplinking and downlinking. Similarly, intersatellite links with similar Ka-band satellites would demand switching capabilities. In effect, the on-board processing and switching capability was a network management facility and Ka-band satellite operators would each become like telephone companies but with their telephone exchanges in the sky.

54. The proposed Ka-band systems featured user data rates ranging from 16 Kbps to as high as 1 Gbps, support for ATM, regional and global coverage through intersatellite links (ISLs), a large number of small spot beams, and the use of on-board baseband processing and switching for beam interconnection. Some of the proposed systems were aimed at providing complete or nearly complete global coverage.

55. The Ka-band available to satellite operators involved a massive 2.5-3.5 GHz of spectrum, some four-seven times that available to some C-band satellite operators. In 1997 some 59 Ka-band projects had emerged worldwide, alongside an intensified research and development (R&D) effort to refine Ka-band satellite and associated technologies.

56. The development of those systems was contingent upon overcoming significant challenges in terms of frequency coordination, technology readiness and financing. That meant that only a few of the proposed systems could be expected to be deployed by 2000 or 2005.

57. The proposed Ka-band systems used a large number of small beams (approximately 1 degree) to deliver a high satellite effective isotropic radiated power (EIRP) of 50 dBW to user terminals. Beam types and their quantities varied widely from one system to another. Hopping beams (proposed by some systems) provided efficient satellite resource utilization by assigning each beam to a number of dwell areas (beam spots) consisting of one major traffic area and several thin-traffic areas. Dwell time could be adjusted dynamically on the basis of response to the traffic demand of each beam area.

58. Fixed-beam satellites were generally simpler in design than hopping-beam satellites. For an efficient use of resources, however, coverage areas needed to be adjusted to place roughly equal amounts of traffic into each beam. The number of fixed beams per satellite could be anything from 10 upwards.

59. Most of the systems proposed would employ on-board baseband processing and switching. The on-board processing subsystems would use fast packet switching, which was also referred to as “cell switching”, “packet switching”, “ATM switching”, and “packet-by-packet routing”. On-board baseband processing made it possible to switch and multiplex user traffic according to destination into high-speed downlink carriers. That permitted the downlinks to operate with a single carrier per power amplifier, which, when operating near saturation, afforded the most efficient use of available transmitter power. Downlink transmission would be Time Division Multiple Access (TDMA) for hopping beams and Time Division Multiplex for fixed beams. The proposed transmission rate in most of the GEO systems was about 100 Mbps. For most on-board-processing Ka-band systems it was planned to use ISLs to provide direct user-to-user connection without the assistance of intermediate ground stations.

60. Several user terminals had been proposed for the Ka-band systems. A typical user terminal, operating at an uplink bit rate of between 128 and 768 Kbps, would employ a small-aperture antenna with a diameter of 66 cm and a solid-state power amplifier (SSPA) of 1-3 W. All radio frequency components (SSPA, low noise amplifier, and up/down-converters) would be integrated into a small outdoor unit mounted on the reflector. Gateway terminals would employ a larger antenna with a diameter of 2.4-5 metres and a high-power amplifier of 50-200 W.

61. For the Ka-band systems to be deployed in LEO, users might be able to employ smaller antennas. Their terminals must, however, be capable of tracking the satellites and performing a handover once every few minutes. Satellite handover in those systems also required precise timing coordination between satellite traffic routing and user terminal processing, as well as traffic-shaping at the user interfaces.

62. VSATs were available for operation in the C-band or Ku-band, but currently cost from $5,000 to $15,000, depending on their application. To be financially viable, the proposed Ka-band systems would need to be accessible by terminals costing considerably less (for example $1,000). To achieve such low prices required mass production, which in turn required a commitment on the part of a system operator to a very large order (for example 1 million or more terminals), further increasing financial exposure.

1. Examples of proposed systems

63. EuroSkyWay was a multiregional network of interconnected Ka-band satellites being developed by Alenia Aerospazio to provide innovative and affordable services to business and consumer end-users. Low-cost and ultra-small-aperture user terminals were adopted to manage packet- and circuit-switched data traffic, with a flexible allocation of resources at the user’s request.

64. The EuroSkyWay system represented a solution to providing multimedia services to users located within Europe, Africa and the Middle East with the possibility of integration with GII, as well as with other satellite or terrestrial wide-area networks.

65. The deployment of the EuroSkyWay system would be based on two different phases: the first operational phase envisaged two co-located satellites, providing coverage of Europe and nearby countries (in the Middle East and Mediterranean Africa and in some countries of the Commonwealth of Independent States); the second operational phase envisaged three additional satellites, to be integrated with the first-phase component, to increase capacity and to provide coverage of Africa (two satellites) and of the western part of Asia (one satellite).

66. The EuroSkyWay network was different from other proposed global satellite networks in that its geostationary orbit location, the selected link design and the novel traffic management scheme allowed for improved satellite resource utilization and overall service profitability. The cumulative high system throughput capacity (46 Gbps)

obtained through a single cluster on five satellites, required smaller initial capital investments and satellite airtime from both service providers and end-users. The adopted digital transmission link design delivered an exceptional quality of service.

67. The Celestri system by Motorola was designed to provide near-global coverage with both geosynchronous orbit (GSO) and LEO satellites to provide the lowest-cost optimized broadband service for DTH small business and corporate terminals. The Celestri system would comprise the Celestri LEO system and two other systems also developed by Motorola: the Millennium and the M-Star systems. Celestri GSO used nine satellites to provide global coverage. By networking LEO with GEO satellites, the system would provide regional broadcast capabilities with real-time interactivity.

68. The Celestri Multimedia LEO was a constellation of 63 satellites in seven inclined orbital planes interconnected to nearly all of the populated land masses in the world. The planes were circular at a 1,400 kilometre altitude, inclined at 48 degrees with respect to the equator, which would enable operation to relatively low-power and low-cost Earth terminals with delays equivalent to those experienced with terrestrial systems. Each satellite contained all the hardware necessary to route communications traffic through the network, including Earth-to-space, space-to-Earth and space-to-space connections. Satellite-to-satellite interconnections used laser links, while Earth-to-space was in the 30 GHz band and space-to-Earth was in the 20 GHz band. Multi-beam phased arrays would provide fixed beams to give ubiquitous coverage through the satellite footprint. Data rates were from 64 Kbps to 155.52 Mbps.

69. The Celestri LEO system was designed to enable frequency sharing of the Ka-band spectrum with GSO and other LEO systems by using satellite diversity. The antennas formed a large number of narrow antenna beams. Beams that would cause interference with GSO or other LEO satellites operating at the same frequencies were turned off (blanked) and the communication was switched to another satellite with a different position. Switching was predictive, on the basis of known satellite positions. Ground terminals, as well as satellite equipment, were commanded to provide beam blanking to avoid interfering geometries. No cooperation from the other system was required other than satellite positional data. Frequency sharing by satellite diversity made it possible to achieve valuable increases in the functionality of the limited spectrum resource.

70. The M-Star system had 72 operational LEO satellites in 12 inclined orbital planes. Orbits were circular at 1,350 km altitude. LEO was selected to enable small low-power and low-cost ground terminals to be used and to ensure that the delays experienced by end-users are essentially equivalent to domestic transport systems. Each satellite contained multiple bent-pipe transponders with spot-beam antennas. Intersatellite links connected each with four adjacent satellites. That architecture enabled signals to be transponded directly back to Earth or relayed to other satellites and then routed to any location globally. Service links operated in the 40 GHz band while intersatellite links were in the 60 GHz band. The system would offer voice and data transport to service providers and business customers and interconnection service to enable terrestrial carriers to aggregate voice or data signals.

71. The Alcatel Corporation had proposed a new system called SkyBridge, which would operate in Ku-band in order to reduce the rain fade problem, and was also designed to avoid interfering with existing geostationary Ku-band satellites. SkyBridge employed two constellations, each of 32 LEO satellites at 1,457 km altitude. Both constellations comprised four satellites equally spaced in each of eight orbital planes that were inclined at 55 degrees, and spaced 45 degrees apart at the equator. The two constellations were arranged to be offset from one another so that pairs of satellites crossed the sky. It was then possible to avoid interfering with geostationary satellites by commanding all Earth stations to cease using a SkyBridge satellite when it was within ±10 degrees of the geostationary arc, and to switch to the alternate satellite of the pair. While 387 gateway Earth stations would be needed to cover all the land areas between ±68 degrees latitude, only 253 would be needed to serve 90 per cent of the world’s population.

72. SkyBridge would deliver an asymmetrical broadband connection to the fixed network, with up to 60 Mbps (in increments of 16 Kbps) to residential terminals and up to 2 Mbps (in increments of 16 Kbps) on the return link via

a gateway. Higher bit rates would be accommodated by professional terminals. In addition, the small size of the increments would provide the user with bandwidth on demand.

73. The SkyBridge system was an ATM-based access network, providing the "last mile" connection between users and a local exchange. The traffic generated by terminals was transmitted transparently by the satellite (in other words without any processing other than amplification and frequency transposition) to the gateway and vice versa. In the case of terminal-to-terminal communications, the connectivity was established by the gateway switch, with a double hop. Each gateway collected, through the space segment, the terminal traffic within a 700 kilometre diameter cell. SkyBridge cells were permanently illuminated by at least one satellite spot beam. In most cases in temperate latitudes, at least two satellites were permanently visible.

74. Under the SkyBridge system all users were required to employ at least two tracking antennas, which represented a cost penalty and might confine the use of the system to larger enterprises that could afford expensive terminals; it did, however, hold out a promise of higher service availability.

2. Stratospheric platforms

75. There were four general telecommunication architectures that could be used to deliver broadband WLL service to consumers. Two of those architectures were space-based: geostationary satellites and non-geostationary satellites. The other two were considered terrestrial: rooftop cellular-type millimetre wave repeaters and stratospheric relay platforms.

76. Intrinsic reasons relating to geometry and hardware engineering inevitably led to a technical conclusion that the greatest amount of communication capacity over global metropolitan areas, for an equivalent investment in equipment and bandwidth, would come from the stratospheric architecture. Accordingly, the greatest amount of broadband Internet capacity for the lowest cost would be provided to consumers via stratospheric telecommunications.

77. If bandwidth, antenna aperture, power and other technical factors were kept constant, the metropolitan capacity of a telecommunications system was equal to the number of spot beams that the system provided. The number of metropolitan area spot beams that a system could generate varied directly with the distance between the radio repeater and the coverage area until the line of sight approached the outer boundary of the metropolitan area, and inversely thereafter. For example, because of the constraints imposed by antenna size, for all practical purposes a single-building top repeater could generate at most six spot beams using a 60 degree sectorial antenna. At the other end of the continuum, a geostationary satellite could generate more than one spot beam per metropolitan area using typical state-of-the-art antenna apertures of 5 metres at 20/30 GHz.

78. A single stratospheric telecommunications platform at 21 kilometres altitude could, however, generate approximately 700-1,000 spot beams within a single metropolitan area, whereas a non-geostationary satellite at 500 km altitude would generate only 4 to 16 spot beams out to 100 kilometres from the centre of a metropolitan area. The stratospheric architecture thus yielded approximately 100 times greater metropolitan area capacity than the non-geostationary satellite orbit architecture, assuming the same bandwidth allocation.

79. Stratospheric and other broadband systems could be differentiated as high-density and low-density market segments. All space systems (geostationary and networked non-geostationary) were low-density architectures. They did an excellent job of providing some bandwidth everywhere, but could not compete with terrestrial architectures in providing maximum capacity in metropolitan areas. Stratospheric and ground-based millimetre wave systems were high-density architectures. Those designs excelled at delivering to metropolitan consumers the greatest value in terms of cost-per-unit bandwidth, but were not very cost-effective when it came to rural service.

80. It was therefore vitally important for developing countries to include stratospheric platforms, such as the Sky Station stratospheric platform, in their national telecommunications plans. If developing countries relied solely on satellites for their broadband links, they would find themselves in the situation of having only low-density broadband capability to meet high-density broadband demand. That would lock developing countries into an inferior information infrastructure, which would be inconsistent with the ITU mandate for global information development. Stratospheric telecommunications platform technology was currently available for global deployment, subject to frequency allocation approvals and national business arrangements.

3. Little LEO

81. ORBCOMM was deploying a constellation of 28 small communication satellites in orbit 775 kilometres above Earth. With help from a ground infrastructure of Gateway Earth Stations (GES), the satellites connected the ORBCOMM users to the worldwide telecommunication network. Partial service was already available and the system would be fully operational in 1998.

82. A message could be sent by a user to a remote subscriber communicator through any personal computer using standard communication protocols. The user would simply connect to the Gateway and send a message using his computer. The Gateway would relay the message to the appropriate satellite and on to the remote subscriber communicator. Inbound messages from remote subscribers would follow the same route, but in reverse. Those messages could be delivered via an active circuit, or be stored in memory at the Gateway for retrieval at the customer's convenience.

83. The ORBCOMM system also had the unique capability of determining and reporting the position of remote communicators to users. ORBCOMM communicators were designed to measure the Doppler shift on the signals downlinked from the satellite. Each satellite determined its own position using the Global Positioning System (GPS). By combining the Doppler measurements with satellite GPS data, a communicator was able to determine its own position, generally with an accuracy of better than 1,000 metres.

4. Broadcasting satellite systems

84. Radio was the most ubiquitous communication device in the world. There were over 2 billion radio sets in the world and over a 100 million sets were sold every year. In developing countries, for example, on average there was one radio station for every 2 million people; in industrialized nations, the ratio was one station for every 30,000 people.

85. The goal of WorldSpace was to bring cheap but high quality digital radio broadcasting to 3.5 billion people; it relied on a DAB system that worked by routing a radio signal through a VSAT up to a geostationary satellite. The satellite transmitted down the signal, which was picked up by millions of portable radio receivers. The new global infrastructure that WorldSpace was creating would enable broadcasters and advertisers to reach underserved emerging markets, including the Middle East, Africa, Asia, the Caribbean and Latin America. People in those areas would be able to receive digital sound broadcasting of unprecedented quality and diversity on a new type of radio needed to receive programmes from WorldSpace satellites.

86. There were three satellites, AmeriStar, AfriStar and AsiaStar, each weighing around 3,000 kilograms. All three would be in geostationary orbit. All three satellites had three spot beams, each representing a coverage area of approximately 14 million square kilometres for a single channel. It would be possible to broadcast up to 288 channels for talk radio, 144 for monophonic music, or 72 for high-fidelity sound.

87. Expected to be priced at $200, the portable WorldSpace receiver used several technologies to achieve the company's objectives of cost, size and reliability. The receiver consisted of the antenna, Starman chipset, audio amplifier, speakers, monitor and serial interface.

88. The radios would receive high-quality monophonic and near CD-standard stereo radio programmes transmitted in L-band (1,467 to 1,492 MHz) via WorldSpace's three communication satellites. The use of digital transmission technology allowed other services to be offered, including text, fax, e-mail and message-paging services. An antenna the size of a business card inside the receiver would receive the satellite signals. In addition, the receivers would be equipped for standard AM, FM and short-wave broadcasts. The main remaining unknown factor on the financial and technical side was the price of the portable radios. The initial price was estimated at about $200, beyond the reach of all but the region's middle class layer but still low enough to attract from 5 to 10 million listeners, the number needed to be financially viable.

C. Regional and national satellite systems

1. Lockheed Martin Intersputnik

89. With 22 member nations, Intersputnik had been providing international, regional and satellite communications for more than 25 years. With its recently established joint venture with Lockheed Martin, known as Lockheed Martin Intersputnik (LMI), both organizations would greatly enhance their capabilities. The satellites deployed by LMI would be flight-proven, high-performance A2100 spacecraft, built by Lockheed Martin Missiles & Space. The A2100 platforms, with a 15- year lifetime, would replace Russian-built satellites and offer a large increase in capacity, with 44 high-powered transponders operating both in C-band and Ku-band. LMI would offer unique capabilities and expertise in providing state-of-the-art solutions that met user requirements with flexible tariffs and direct access to the space segment.

90. The first launch by the Proton launch vehicle was scheduled for late 1998 to place an LM-1 satellite in the 75 degree east longitude orbital slot. Three more would follow before the end of 2000. Intersputnik had 15 highly valuable orbital slots. Initially, LMI would provide broadcast, fixed telecommunications and VSAT services to customers in Eastern Europe, South Asia, Africa and the Commonwealth of Independent States. Later, LMI services would include DTH video and audio, and mobile services to customers worldwide. Annual revenue was expected to reach $300 million-$500 million by 2001 and to keep growing as more services were added.

2. Kupon satellite

91. In Russia, economic progress depended on efficient financial network services. Telecommunication was an essential part of banking technology. The Central Bank of Russia had developed the BANKIR Satellite Communication Network (SCN), which provided a powerful means of meeting today's essential telecommunication needs and the flexibility needed to develop future networks.

92. A new generation of Kupon satellites had been specially designed for VSAT applications with new VSAT technology developed in Russia. The first phase of network deployment had begun in 1997. The first Kupon satellite had been launched on 12 November 1997 to a 55 degrees east longitude orbital slot to support BANKIR SCN of the Central Bank of Russia. But it would also be able to serve Europe, Africa, the Middle East and most of Asia and the Pacific Rim. The three planned satellites would provide virtually global coverage.

93. Kupon satellites would use the latest technologies, previously only available for military and governmental communications. They included multi-beam receive-and-transmit antennas, electronically steerable beams, in-orbit footprint size and shape control, dynamic power distribution between the beams and on-board traffic switching between the transponders. Those advanced features provided for extended built-in flexibility in network services and a wide range of applications.

94. The use of active on-board phased-array antennas provided for very high flexibility and system reliability. Each Kupon satellite had 24 (expandable to 32) Ku-band medium power transponders and 16 pairs of independent receive-

and-transmit spot beams. Kupon transponders and footprints could be instantly reconfigured to meet a wide range of the ever-changing needs of customers.

4. AMOS satellite

95. The AMOS satellite communications system had been initiated as a commercial venture in January 1992. The AMOS-1 satellite had been launched successfully in May 1996 and communication services begun on 1 July 1996. The AMOS satellite was a new lightweight geostationary communication satellite with a launch weight of less than 1,000 kilograms and a three-axis attitude control subsystem. It carried a communication payload in the Ku-band, with seven active transponders (out of nine), of 72 bandwidths each.

96. Communication services were provided to the two main service areas: the Middle East (centred over Israel) and Central Europe (centred over Hungary). The allocation of the active transponders between the two service areas was provided by a ground command. There was a possibility for cross-connection between the two service areas: to uplink from one and downlink to the other. The AMOS satellite had a 750,000 square kilometre footprint. The technical features of AMOS, such as high, effective isotropic irradiated power at 55 dBW at the centre of the footprint allowed for numerous video, voice, and data communication services, as well as traditional broadcasting.

D. Advanced communication technology

97. Gilat Satellite Networks Ltd. designed, developed, manufactured, marketed and supported VSAT satellite Earth stations and related hub equipment and software. The company had more than 37 per cent of the world market share in 1996. The company’s products were incorporated into telecommunication networks that provided satellite-based communications between a central location and a large number of geographically dispersed sites.

98. The company offered a range of products: Skystar Advantage, which made interactive, transaction-oriented applications possible; FaraWay VSAT offered multi-channel, toll-quality telephone service; DialAway VSAT offered single-channel, near toll-quality telephone service; SkySurfer VSAT delivered satellite-based Internet access; and OneWay VSAT provided unidirectional data broadcasts. The company’s equipment was used for numerous applications, including credit card authorization, lottery transactions, pipeline monitoring, distance education, corporate telephony applications and paging. Next generation VSAT products were being designed to provide from 10 to 100 times the current throughput capacity to transmit text, voice and video signal in real time.

99. Gilat VSAT telephone products were an excellent solution to the problem of providing basic telephone services in remote locations. Potential users of VSAT rural telephony were rural communities served by public call offices, business users, local authorities and tourists at remote sites.

100. Techsat - I spacecraft had been developed by the Technion Institute. It was light (50 kg), inexpensive, with low power consumption (10 W) and three-axis stabilized. All those features made the platform well-suited for various applications. Currently two types of application-oriented satellites were being developed: SensTech microsatellite for high-resolution remote sensing and ComTech for communications. Two platforms were already at the manufacturing stage, and one of them was expected to be launched by the end of 1997.

101. The ISL in the global satellite projects used microwave radiation as the carrier. Free space optical communication between satellites networked together could make high-speed communication possible between different places on Earth. The advantages of an optical communication system instead of a microwave communication system in free space were: (a) smaller size and weight; (b) less transmitter power; (c) larger bandwidth; and (d) higher immunity to interference. The pointing from one satellite to another was a complicated problem owing to the great distance between the satellites, the narrow laser beam divergence angle and vibration of the pointing system. Vibration of the transmitted beam in the receiver plane decreased the average received signal, thus increasing the bit error rate.

102. Recent advances in the development of directly pumped solar lasers provided new opportunities for the increasing demand for both bandwidth and power for space communication. Using a unique technique for concentrating the solar light, splitting the spectrum to various spectral bands, and using each band for direct optical pumping of different lasers near their emission band resulted in an overall efficiency of 20 per cent. The lasers used in the experiments were Alexandrite, tunable in the range between 750 and 900 nanometres and various crystals doped with neodymium active in the region of between 1.054 and 1.064 microns. The bandwidth could be further extended by frequency doubling and optical multichannel oscillators. A collecting mirror with a 2 m diameter could provide total laser power of more than 500 W. That power was sufficient for communication between low-orbit and high-orbit satellites and provided better conditions for penetrating the atmosphere. Another application of that technology was power transmission between satellites.

103. Participants were shown tests of the DTX-360 digital circuit multiplication equipment. Each DTX-360 terminal accepted up to 360 trunk channels carrying 64 Kbps signals. The system provided for a high compression ratio of up to 10:1 for speech and of up to 6:1 for fax. System tests demonstrated its suitability for usage in operational satellite networks.

E. International regulations for the use of radio spectrum

104. The international regulatory regime governing the use of spectrum/orbit resources was contained in the Radio Regulations, which complemented the International Telecommunication Union Constitution/Convention.

105. The procedures laid down in the Radio Regulations allowed member States of ITU to meet their requirements in terms of orbit/spectrum resources, ensuring on the one hand equitable access to and on the other hand efficient use of those limited resources.

106. The explosive growth of the use of satellites by various services offered great benefits to mankind yet the current growth in their numbers posed a threat to the Radio Astronomy and Earth Exploration services. Downlink emissions could be particularly damaging and already the emissions of some satellite systems had severely curtailed radio astronomy observations. Some forthcoming satellites posed a similar threat. In building space vehicles, the highest engineering standards should not be sacrificed in favour of economic arguments. In particular, electro-magnetic environmental impact statements must be required before space-borne transmitter systems were launched.

F. Examples of applications of communication satellites in the telecommunication infrastructures of selected economies in transition

Belarus

107. Despite the fact that Belarus had long been a member of Intersputnik, the International Telecommunications Satellite Organization (INTELSAT) and the International Mobile Satellite Organization (Inmarsat), it had only recently become involved in specific communication satellite-related projects, with the commissioning on 1 November 1996 of Belarus Teleport, consisting of two INTELSAT standard B earth stations with 11 m diameter antennas. One of those operated via Intersputnik's Express-6 satellite to provide services in the Indian Ocean region with a throughput capacity of 512 Kbps. The second one operated via an INTELSAT satellite to provide services in the Atlantic Ocean region with a throughput capacity of 2,048 Kbps. Half of that capacity was intended for Internet access. There were plans to install two more earth stations at the Teleport premises, to provide services for the Middle Asia and Caucasus regions. Negotiations were in progress to establish a satellite-based link between Belarus and Israel.

Estonia

108. As terrestrial public mobile communication networks were highly developed, there would be no major need for satellite communications in Estonia. By August 1997 there were about 85,000 customers of public mobile telephone radio communication networks. Current penetration of mobile services in Estonia was 6.1 per cent for a population of 1.5 million. Currently, Estonia used satellite communication channels via the Inmarsat, mostly for maritime mobile communications. There were also a few cases of Inmarsat land-mobile terminals being used. There were also satellite earth stations for broadcasting and data communication.

Lithuania

109. At the beginning of 1996, there were 940,977 subscribers (751,725 in urban areas and 189,252 in rural areas) serviced by the Lithuanian telecommunication networks. The overall capacity of the automatic telephone exchanges was 1,058,454 numbers (77.6 per cent in urban areas and 22.4 per cent in rural areas). Seven powerful, 13 low-powered and two medium-wave State radio and television stations operated in Lithuania. They had 53 television and 61 radio transmitters, including 49 ultra-short-radio-wave transmitters. The State operated 1,147 km of radio relay lines. There were over 40 private radio transmitters and 16 private television transmitters. Forty-two licences had been granted to private enterprises to set up and operate cable television networks.

110. The Ministry of Communications and Informatics had signed cooperation agreements with Denmark, Finland, Germany, the Netherlands, Poland, Russia, Sweden and Ukraine. Contacts with Greece and Israel had been established. A target density of 35-40 telephones per 100 inhabitants was planned for Lithuania for 2000. For that purpose, new digital automatic telephone exchanges, with a capacity for 360,000-500,000 numbers, must be set up within five years. The main satellite systems used in the country were the European Organization of Telecommunications Satellites (EUTELSAT) and INTELSAT. The most powerful Earth station (2 Mbps) was still the most important bridge to Canada and the United States of America. There were more than 100 EUTELTRAC and about 40 Inmarsat terminals registered in Lithuania.

Poland

111. Poland had joined world and regional satellite organizations like INTELSAT, Inmarsat, Intersputnik and EUTELSAT. The Satellite Communication Centre had been created in Central Poland with satellite earth stations operating with the above-mentioned satellite organizations. Satellite communication in Poland was limited to fixed satellite service operating in the Ku-band and using the geostationary satellites of EUTELSAT, INTELSAT, Dividends from Space (DFS), Kopernikus and ORION F1. The C-band was not available for satellite service owing to high occupancy by fixed services.

112. The possibilities introduced by new legislation and the development of private business in the country had led to the submission of a considerable number of satellite licence applications. The country’s inadequate and obsolete telecommunication infrastructure had been replaced and completed by the dynamic development of domestic VSAT networks. There were currently VSAT networks belonging to seven independent private operators in the country, operating jointly about 1,000 VSAT terminals. The biggest network operated over 350 terminals.

Romania

113. Under the new legislation adopted by Romania in 1990 and with an undeveloped telecommunication infrastructure, many VSAT systems had been deployed. There were currently over 100 private VSAT system operators, in addition to a large number of private interactive star-shaped networks that were mainly transmitting data. VSAT networks for audio and video programmes were less widespread. The licensing procedures were simple and transparent, with very inexpensive licensing fees, and that had led to the existence of more than 850 operational VSAT terminals using the INTELSAT, EUTELSAT and ORION systems.

114. The use of mobile satellite services, in particular, through Inmarsat and plus EUTELSAT had started in Romania in 1990. In 1991 Romania had ratified the International Agreement on the Use of Ship Earth Stations within the Territorial Seas and Ports in order to free the way for the development of those services. There were no longer any restrictions on the use of the L-band frequency.

Notes

[1]See *Report of the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 9-21 August 1982* (A/CONF.101/10 and Corr.1 and 2), Part One, sect. III.F, para. 430.