Satellite Communication & the Indian Subcontinent

By Roshan Noorzai

Satellite signals can reach almost anywhere. They can be used both for point-to-point or point-to-multipoint transmission. Satellites can target audiences at local, national or global levels. They support both one-way and two-way communication, which can be broadband and narrowband.[1] The above mentioned qualities are some of the many reasons why satellite technology and communication are used by almost all the nations.

Satellite services are no longer limited to the affluent societies; they can serve and support the development process in the poorest of regions. This can be observed in the Indian Subcontinent, one of the less developed regions of the world. This paper examines the space-based assets of India and Pakistan and the ways those assets support the

[1] Don, Flournoy. "THE BROADBAND MILLENNIUM: COMMUNICATION TECHNOLOGIES AND MARKETS." Chicago: International Engineering Consortium, 2004.

development process in those countries. Examples cited include tele-education, tele-medicine, remote sensing and village connectivity.

The developing nations of the Indian subcontinent, the region with an estimated 23% of the world's population only on 3% of the world's land, can benefit from satellite sources because of their geographic location, language and cultural diversity, and the poor telecommunication infrastructure. Factors contributing to the role and importance of satellite communication in the region range from disaster recovery to poverty alleviation. Services provided by space assets are no longer limited to the affluent societies; they can serve and support the development process in the poorest of regions. This is true throughout the Subcontinent, one of the less developed regions of the world.

Satellite Assets: India is the largest country in the area with a population estimated at around 1.1 billion people. India uses satellite communication for multiple purposes in relevant sectors. India is one of the few nations of the world hosting its own domestic satellite systems. The country owns eight satellites in the geostationary orbit: INSAT-2E, INSAT-3A, INSAT-3B, INSAT-3C, INSAT-3E, KALPANA-1, GSAT-2 and EDUSAT.[2] India supports eight Intelsat earth stations and one for Inmarsat in the Indian Ocean region.

With the recent deregulation and liberalization of telecommunication laws, India has witnessed a great change throughout its telecommunication industry. Satellites, complemented by fiber optic and other communication infrastructures on the ground,

[2] "Geostationary Satellite System." Annual Report 2003-2004: ISRO. Accessed 2 February 2005. <http://www.isro.org/rep2004/Geostationary.htm>.

provide significant increases in bandwidth and coverage for voice and data as well as video.[3]

Adjacent Pakistan with a population of 160 million has a communication satellite of its own, Paksat-1, in geostationary orbit and an LEO earth imagining satellite called Badar B. Pakistan hosts three Intelsat earth stations, one sensing Atlantic Ocean and two Indian Ocean.[4] Pakistan has experienced rapid growth in its telecommunication sector as well. A good example is its cellular phone market that reaches 7 million consumers.[5] This sector showed of 172.7% in the year from 2003 to 2004. The growth was witnessed after deregulation and liberalization of laws and policies in the country.[6]

There are two Intelsat earth satellite stations sensing the Indian Ocean region in Bangladesh,[7] and Nepal has one as well. [8] Sri Lank hosts two Intelsat earth stations for communication purposes and Maldives has three Intelsat earth stations. Other international players such as Eutelsat, Asiasat, Inmarsat and New Skies are also operating in the region. These companies provide satellite services to governments, non-governmental organizations, corporation, small businesses and individuals.

This paper will focus principally on the national programs of India and Pakistan, as both of these countries are building their space capabilities and have developed their

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[3] Ibid., pp 11 of 13.
[4] CIA – The World Factbook – Pakistan. pp 10 of 13., Accessed 14 February 2005. < http://www.cia.gov/cia/publications/factbook/geos/pk.html>.
[5] "7 Million Consumers Using Cellular Phone in Pak." Pakistan Press International. 16 December 2004. Accessed 1 February 2005. < http://web.lexis-nexis.com/universe/document?_m=8704e08e8aef35ab8a4dcdbcbef134ff&_docnum=1&wchp=dGLbVzz-zSkVb&_md5=beb36ee76339618771c5378ec75ddabf>.
[6] "Deregulation of Telecom Sector and Its Results." Financial Times Information. 30 October 2004. pp 2 of 3. Accessed 1 February 2005. http://web.lexis-nexis.com/universe/document?_m=01212de28940944f4df522325a468791&_docnum=8&wchp=dGLbVzz-zSkVb&_md5=8a2f650e90698545ec933f015da89d37 pp 2 of 3.
[7] CIA – The World Factbok – Bangladesh. pp 10 of 13. Accessed 14 February 2005. < http://www.cia.gov/cia/publications/factbook/geos/bg.html>.
[8] CIA – The World Factbook – Nepal. pp 11 of 13. Accessed 14 February 2005. < http://www.cia.gov/cia/publications/factbook/geos/np.html>.

own domestic space programs. The paper also focuses on some of the satellite applications in India initiated to support the development process in the country.

Space Agencies in the Region

Indian Space Research Organization:

Space Research was started in 1962 when the Indian National Committee for Space Research (INCOSPAR) was established to work on the Rocket Launching Station. The current Indian Space Research Organization (ISRO) was set up in 1969. It is now administered by the Space Commission and Department of Space (DOS) of the Indian Government.[9] ISRO has its headquarters in Bangalore, in the south of India , but operates through centers in different places in India. The objectives behind the establishment of ISRO program include satellite development, launch vehicles, sound rockets and associated ground systems. The present operational space systems can be divided into two categories: 1) Indian National Satellite (INSAT) used for telecommunication, TV broadcasting, meteorology and disaster warning, [10] and 2) Indian Remote Sensing Satellite (IRS) for resources monitoring and management. There are six IRS satellites in operation at present: IRS-1C, IRS-1D, IRS-P3, OCEANSAT-1, RESOURCESAT-1 and Technology Experiment Satellite (TES).[11]

ISRO trains personnel in the field of space for other countries. It has been participating in global scientific activities through its SROSS (Stretched Rohini Series

[9] "Department of Space: Indian Space Research Organization." About ISRO. Accessed 1 February 2005. < http://www.isro.org/about_isro.htm>.
[10] "Geostationary Satellite System." Annual Report 2003-2004: ISRO. Accessed 2 February 2005. <http://www.isro.org/rep2004/Geostationary.htm>.
[11] "Earth Observation System." Annual Report 2003-2004: ISRO. Accessed 2 February 2005. <http://www.isro.org/rep2004/Earth%20Observation.htm>.

Satellites) and IRS-P3 satellites. The main branch of the ISRO is its commercial sector called Antrix Corporation Limited. Antrix deals in space imaging data products and supplies IRS specific hardware, software and technical assistance. Data products of India's IRS are received by about ten ground stations worldwide, including in the USA. In terms of financial performance, its sales exceed Rs 3000 million (around $60 million). The activities are mainly export type, and more than 75% of the earnings are in foreign exchange.[12]

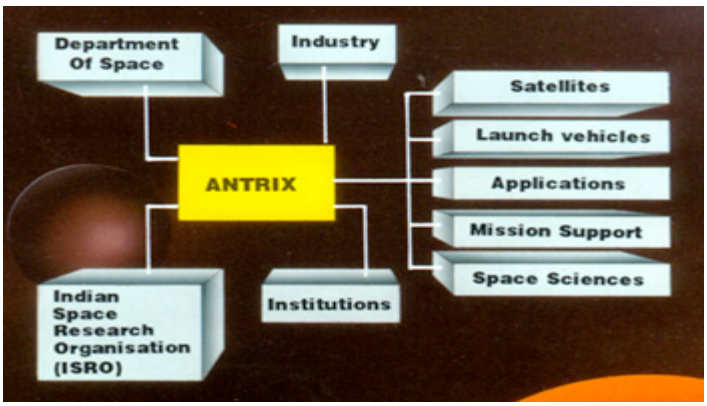

Figure 1 Antrix Corporation Limited

There are four Satellite Launch Vehicles. The SLV-3 (low orbit), Augmented Satellite Launch vehicle (ASLV) and Polar Satellite Launch Vehicle (PSLV) are used for launching IRS Satellites. The Geostationary Satellite Launch Vehicle (GSLV) is used for launching INSAT class satellites.[13] ISRO launching facilities are used not only for domestic purposes but to launch vehicles for other countries as well. Launch of the

[12] "Antrix Corporation Limited." Indian Space Research Organization. Accessed 1 February 2005. < http://www.isro.org/commercial.htm>.
[13] "ISRO Launch Vehicles." Indian Space Research Organization. Accessed 1 February 2005. < http://www.isro.org/launch.htm>.

Korean satellite KITSAT-3 and a German satellite using an Indian PSLV-C2, India's satellite vehicle, in May 1999 announced India's entry into the field of commercial launch services. Antrix also provides Telemetry, Tracking and Command (TTC) support services.[14]

ISRO annual budget is Rs. 27.3 billion ($600 million), a little under a 30th of NASA's yearly spending.[15] ISRO partners with a number of developed and developing countries. From the very beginning, India worked closely with the US, It worked with Russia for navigation satellites, and is currently working with the Europeans on the new GPS system Galileo. It cooperates as well with such developing nations such as Malaysia and Brazil.

INSAT satellites in orbit

No	Name	GEO position	Transponders	Usage
1	INSAT-2E	83 E	17 C Band with zonal and global coverage	Eleven (36 MHz per unit) leased to INTELSAT
2	INSAT-3A	93.5 E	12 C Band – within which 9 channels with expanded coverage (from Middle East to South East Asia), 6 Extended C band and 6 Ku band	With meteorological Instruments.
	INSAT -3B	83 E	12 Extended C-band, 3 Ku-band	With a mobile satellite services (MSS) payload
4	INSAT-3C	74 E	12 C-band, 6 Extended C-band, 2 S-band to provide	A mobile satellite services (MSS)

[14] "Antrix Corporation Limited." Indian Space Research Organization. Accessed 1 February 2005. < http://www.isro.org/commercial.htm>.

[15] Ramesh, Randeep. "Blast off for Banglore." Manchester Guardian Weekly. Vol. 171, No. 22; P-17. 19 25 November 2004. Accessed 14 February 2005. << http://web.lexis-nexis.com/universe/document?_m=26dad438a3516e804a1feb454d31060f&_docnum=1&wchp=dGLbVzz-zSkVb&_md5=e49bb93789c7e7451bbbbcce16eb7eee>.

No	Name	GEO position	Transponders	Usage
			BSS services	transponder
5	INSAT-3E	55 E	24 C-band, 12 Extended C-band	
6	GSAT-2	48 E	4 C-band, 2 Ku-band	One MSS payload
7	KALPANA-1	74 E	Exclusive Meteorological satellite	Initially known as METSAT-1, renamed as KALPANA-1 on February 5, 2003, in honor of the late Indian-born American astronaut Kalpana Chawla, who died in the Columbia Space Shuttle accident.
8	EDUSAT	74 E collocated with KALPANA1	6 Ku-Band and 6 C-Band	1 Ku-Band transponder with coverage over Indian mainland, 5 Ku-band transponder with spot beams and the 6 extended C band will cover the Indian boundaries

Table 1 Operational INSAT satellites in orbit[16]

SUPERCO (Space and Upper Atmosphere Research Commission):

Pakistan's space agency was founded in 1961 and started functioning in 1964. SUPARCO is the executive branch of Space Research Council (SRC), who's program includes launching of sounding rockets and satellite applications in the field of remote sensing and communications. SUPARCO has its headquarters in the seaport of Karachi, southern Pakistan, with additional facilities at Panjab University in Lahore. There are a

[16] "Geostationary Satellite System." ISRO: Annual Report 2003-2004. Accessed 2 February 2005. < http://www.isro.org/rep2004/Geostationary.htm>.

number of other organizations affiliated with SUPARCO which include the Aerospace Institution in Islamabad, the Computer Center in Karachi, and the Space and Atmospheric Research Center, Karachi.[17]

Pakistan launched its first satellite, Badar-1, on 16, July 1990 aboard the Chinese Long March Vehicle. Badar-1 was a low orbit satellite experimental satellite. After only five weeks contact was lost with the Badar-1.[18]

SUPARCO upgraded its ground stations to receive NOAA (National Oceanic and Atmospheric Agency), Landsat and SPOT data in the 1990's. SUPARCO is also involved in GIS (Geographical Information Systems) standardization in the country and training activities. A second satellite, Badar B, was built by SUPARCO and launched in 2001. Badar B weighs 68.5 Kg and has a life expectancy of 2-3 years. Badar B was sent into space to conduct four major onboard experiments: earth imaging, use of radiation dosimeter, data storage and forwarding, and a charge battery experiment. Most of the equipment used in the satellite was produced in Pakistan.[19]

Pakistan's first commercial geostationary satellite, Paksat-1 started commercial services in March 2003. The satellite began its life in 1996 as the Indonesian Palapa C1. It was renamed to Anatolia and now to Paksat-1 after Pakistan took it over. Pakistan has a contract with Hughes Global Services, Inc., the builder of Paksat-1, for five years for $30 million. Paksat-1 provides Internet services both as a backbone and remote Internet access, business communications, video, audio and data services over 30 C-Band and Ku-

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[17] "Pakistan Space & Upper Atmosphere Research Commission." Accessed 2 February 2005 < http://www.suparco.gov.pk/>

[18]

[19] "Zenit 2 Launches Russian Weather Satellite/4 science Spacecraft." Space and Tech. 10 December 2001. Accessed 14 February 2005. < http://www.spaceandtech.com/digest/flash2001/flash2001-107.shtml>.

Band transponders.[20] Buying Paksat-1 was a temporary solution to occupy the only slot remaining in the region at 38° East Longitude. Pakistan is now working to build its own GEO satellite to replace the Paksat-1.

Satellites for Development

Satellite communication has changed the whole telecommunication concept in terms of outreach and accessibility since the technology can be used to convey data, voice and video. The countries of the Indian Subcontinent, taking into account the advantages and usability of space assets in the region, recently have paid more attention to satellites as a way to provide greater connectivity and to improve the living standards of the population. Among these nations, India uses satellite technology for the greatest number of different purposes. Mainly these applications are for development purposes to help address problems of unemployment, natural disasters, illiteracy, unavailability of infrastructure and health facilities and so on. India has proven that space assets can be used for development purposes.

> Dr. Vikram Sarabhai, founder of the Indian Space Program, says that
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> *"*There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the exploration of the moon or the planets or manned space-flight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we

[20] "Pakistan – Markets in Telecomm Convergent Technologies." The South-asian.com. October 2003, Accessed 14 February 2005. < http://www.the-south-asian.com/Oct2003/Pakistan_Markets_in_telecomm_1.htm>.

must be second to none in the application of advanced technologies

to the real problems of man and society. "[21]

The Indian Space Research Program includes INSAT for telecommunication, television broadcasting and meteorological services, and the Indian Remote Sensing Satellites (IRS) for resources monitoring and management. Some of their applications such as tele-education, tele-medicine, and village resources centers (VRCs) are the outstanding examples of communication for development.

Village Resource Center (VRC): When inaugurating the Village Resource Center in 2004, Prime Minister Manmohan Singh noted that "Mass poverty can be removed only if science and technology Reaches Villages."[22] The VRC project uses satellite technology to improve the living conditions of villagers, a good example of using satellites to support the development process. The idea is to give access to communication and earth observation information using a VSAT based network. Villages will be interconnected to Wi-Fi, wireless and fiber optic cable. Such centers will act as hubs for other unconnected villages.

For the time being, the VRC program uses C-band transponders of the INSAT 3A satellite.[23] The services being provided include geo -referenced land record s, natural resources, suitable sites for drinking water, water harvesting, wastelands, rural employment creation, watershed, environment infrastructure and alternative cropping

[21] "Indian Space Department: Indian Space Research Organization." About us. Accessed 14 February 2005. <http://www.isro.org/about_isro.htm>

[22] "Mass Poverty can be Removed Only If S&T Reaches Villages." Financial Times Information. pp 1 of 2. 19 October 2004. Accessed 1 February 2005. < http://web.lexis-nexis.com/universe/document?_m=48bb2f9a2e2914e85ed8bfd75440a876&_docnum=1&wchp=dGLbVzz-zSkVb&_md5=2bec4cec8f1b31d9df478b49494e4447>.

[23] Abid.

patterns. Hewlett-Packard, Intel, Microsoft and Tala Consultancy are ISRO partners in the VRC project, which has a plan to connect 500,000 villages nation-wide.[24]

India also has a plan to connect the remotest of mountain villages to the Internet through satellites. Fixed earth station receivers will up and downlink satellite signals. Wire and wireless technologies will relay the signals to the houses. Though there is a network of fiber optics in every state, 695,000 villages still remain unconnected. In those places where power is a problem, solar power will be used.[25]

Tele-education: One of the major problems in India is illiteracy. Some 350 million of India's population cannot read, and only 13 percent of the whole population goes to high school.[26] Lack of educational infrastructure , especially in rural area s, non-availability of quality teaching and a multilingual population are all causes of the backwardness of the educational system in the country. India has had plans to fill these gaps with the help of satellite technology starting with literacy program based on the Satellite Instructional Television Education (SITE) project in 1975 and then with the INSAT-3A communication satellite. Those services were shifted to the dedicated satellite for education EDUSAT launched in 2004.

EDUSAT is the first interactive satellite-based distance education system for the country through the audio visual medium with direct to home quality broadcast. This

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[24] "A Technological Boost for Wayand." The Hindu. pp 1 of 2. 19 November 2004. Accessed 14 February 2005. < http://web.lexis-nexis.com/universe/document?_m=dd07f8c5530bab1a6c2c5894ae457ccd&_docnum=1&wchp=dGLbVlb-zSkVb&_md5=1dc69f3578f49f572024f96619bd460c>.

[25] "ISRO to Bridge Digital Divide." Deccan Herald News Services. 15 January 2005. Accessed 14 February 2005 < http://search.countrywatch.com/cw_searchdocument.aspx?DocNumParam=46>.

[26] "India Launches Satellite to Boost Education, Stem Illiteracy." Agence France Presse. pp 1 of 2. 20 September 2004. Accessed on 1 February 2005. < http://web.lexis-nexis.com/universe/document?_m=e76262a710132fc40efc5169cd703099&_docnum=1&wchp=dGLbVzb-zSkVb&_md5=194251aa62a9be3dd3e99e0271618175>.

satellite has multi spot beams with both C-band and Ku-band transponders to cover different parts of the country. The purpose of EDUSAT is to connect classrooms in remote areas of India. In its first phase, the project links universities of three states, then, it will cover two more states and connect more than 1,000 classrooms. For mass production of EDUSAT ground systems, ISRO will provide technical knowledge to manufacturers and service providers.[27] The beams will cover all states with 30 uplinks and about 5000 remote terminals per uplink.[28] The EDUSAT "School in the sky" project transmitting lectures and classes nationwide, in seven years is expected to reach 37 million schoolchildren.[29]

Tele-medicine: Another important satellite communication application is tele-medicine. Tele-medicine is the exchange of video, audio and data information between doctors and patients separated by distance to improve the quality of healthcare. Because of the advantages of space based communication over other channels of communication, telemedicine over satellite is one of the most attractive applications of new technology in the developing world. India has initiated several such health projects. One of these connects 60 remote hospitals to 16 "super specialty" units in cities.[30] Another will be implemented in Jharkhand where 54 percent of the population is living below the poverty line. The $2.9 million project is intended to connect doctors from the best hospitals in India with patients in Jharkhand. This project will be launched with the help of ISRO to

[27] Abid.
[28] K. S. Jayaraman. "India Launches Communication Satellite Dedicated to Education." Space News. 4 October 2004. Accessed 2 February 2005.
<http://www.space.com/spacenews/archive04/indiaarch_092704.html>.
[29] Ramesh, Randeep. pp2 of 3.
[30] Ibid. pp 2 of 3.

provide satellite connectivity to district hospitals equipped with video conferencing, telemedicine software and hardware, a VSAT communication system and diagnostic equipment and medical equipment.[31] Mobile vans will also be used.

Earth Sensing: Another application of satellite communication in the region is remote sensing. As the area is frequently hit by natural disasters, there is the strong need for satellite remote sensing and imaging applications. The December 2004 Tsunami disaster proved that satellites can help in disaster recovery and relief efforts. India made use of its space assets to help the relief activities in the effected areas. ISRO has established video conferencing to provide connection for telemedicine through VSAT technologies and it also used satellite mobile services.

Satellites are used in India to inform the fishing industry where the largest catches are. When the whereabouts of fish are tracked through the color of the ocean seen from Indian space imaging satellites, the yields are said to increase 150 to 200 percent.[32]

Future Directions

A number of further initiatives are planned in the region. As the major regional player in space communication, India plans to launch six INSAT-4 communication satellites by 2007. This will increase the agency's transponder capacity to 250. Two satellites will be equipped with hybrid C and Ku band transponders for maximum flexibility.

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[31] "India's Jharkhand to go in for Telemedicine." Xinhua News Agency. pp 1 of 2. 14 January 2005. Accessed 1 February 2005. <http://web.lexis-nexis.com/universe/document?_m=99a553a2602adddc140e47ad21bf89b7&_docnum=1&wchp=dGLbVzz-zSkVA&_md5=65ff26fa31c1f2f4f0c50d1a84b1ac96>.

[32] Ramesh, Randeep. pp 2 of 3.

In terms of remote sensing, India is working to build an active microwave remote sensing satellite called Risat, to be launch in 2006. Risat will be able to see the earth through darkness, dust and clouds. For imaging, ISRO will have two more satellites Cartosat-1 and Cartosat-2. Both will provide higher resolution images. Cartosat-1 will have two panchromatic (color sensitivity extended to cover the entire visible spectrum) cameras capable of providing 2.5 m resolution images covering a 30 km ground swath. Cartosat-2 is expected to provide even more precise images. It will have only one panchromatic camera providing 1 m resolution pictures covering a 10 km swath.[33]

ISRO has also developed an astronomical satellite called Astrosat. This project will enhance India's basic science capability providing a platform for observing our planetary system and beyond. ISRO will have the increased performance MkIII version of its Geosynchronous Satellite Launch Vehicle (GSLV) ready for launch in 2009. The GSLV-III will be capable of launching 4,000kg satellites.[34]

Design of the spacecraft Chandrayaan, a moon mission, has been completed and the unmanned satellite will be launched aboard a PSLV by 2007 or early 2008.[35] The moon mission will cost $100 million. The goal is get images of the moon's surface for gas and minerals. With the Chandrayaan satellite, India will be the fifth power after the US, Russia, Japan and Europe sending a mission to the Moon.

Conclusion:

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[33] "Development Radhakrishna Rao/ Bangalore; India to launch improved GSLV booster by 2009; Vehicle will be able to place 4,000 Kg satellite into geostationary transfer orbit." Airline Business. p. 29. 25 March 2003. Accessed 1 February 2005. Ohio Link < http://etextb.ohiolink.edu/bin/gate.exe?f=fulltext&state=53f40g.30.2>.

[34] Ibid. 1 of 1 pp.

[35] "India Completes Design for Moon Mission Spacecraft." Country Watch. 17 November 2004. Accessed 15 February 2005. <http://search.countrywatch.com/cw_searchdocument.aspx?DocNumParam=79>.

The usage of space assets on the Indian Subcontinent can be summarized in three directions. First, satellite communication provides connectivity and support of the existing communication networks. Space assets are being used to provide broadband connectivity to the remotest areas of the region. Second, space assets are supporting the development process. Usage of the satellite technology to reduce the digital gap is now a reality. India has successfully started implementing several development projects and intends to expand its programs using satellite technology for development. Finally, the space assets are used in management and preservation of the natural resources. The Indian subcontinent is a region frequently hit by natural disasters. Satellite technology can be used both for protection and management of natural disasters. Environment degradation, droughts, floods, severe thunderstorms, earthquakes, poor agriculture, and pollution are all those areas that can be detected by satellite technology. Images provided by IRS satellites also help to find water, combat deforestation and calculate crop yields.[36]

Notes

"7 Million Consumers Using Cellular Phone in Pak." Pakistan Press International. 16 December 2004. Accessed 1 February 2005. < http://web.lexis-nexis.com/universe/document?_m=8704e08e8aef35ab8a4dcdbcbef134ff&_docnum=1&wchp=dGLbVzz-zSkVb&_md5=beb36ee76339618771c5378ec75ddabf>.

"Antrix Corporation Limited." Indian Space Research Organization. Accessed 1 February 2005. < http://www.isro.org/commercial.htm>.

"A Technological Boost for Wayand." The Hindu. pp 1 of 2. 19 November 2004. Accessed 14 February 2005. < http://web.lexis-nexis.com/universe/document?_m=dd07f8c5530bab1a6c2c5894ae457ccd&_docnum=1&wchp=dGLbVlb-zSkVb&_md5=1dc69f3578f49f572024f96619bd460c>.

[36] Ramesh, Randeep. pp 2 of 3.

CIA – The World Factbok – Bangladesh. pp 10 of 13., Accessed 14 February 2005. < http://www.cia.gov/cia/publications/factbook/geos/bg.html>.

CIA – World Factbook – India, pp 10 of 13. Accessed 14 February 2005 < http://www.cia.gov/cia/publications/factbook/geos/in.html>.

CIA – The World Factbook – Nepal. pp 11 of 13., Accessed 14 February 2005. < http://www.cia.gov/cia/publications/factbook/geos/np.html>.

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"Development Radhakrishna Rao/ Bangalore; India to launch improved GSLV booster by 2009; Vehicle will be able to place 4,000 Kg satellite into geostationary transfer orbit." Airline Business. pp. 29. 25 March 2003. Accessed 1 February 2005. Ohio Link < http://etextb.ohiolink.edu/bin/gate.exe?f=fulltext&state=53f40g.30.2>.

"Earth Observation System." Annual Report 2003-2004: ISRO. Accessed 2 February 2005. <http://www.isro.org/rep2004/Earth%20Observation.htm>.

Flournoy, Don. "THE BROADBAND MILLENNIUM: COMMUNICATION TECHNOLOGIES AND MARKETS." Chicago: International Engineering Consortium, 2004.

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"India's Jharkhand to go in for Telemedicine." Xinhua News Agency. pp 1 of 2. 14 January 2005. Accessed 1 February 2005. <http://web.lexis-nexis.com/universe/document?_m=99a553a2602adddc140e47ad21bf89b7&_docnum=1&wchp=dGLbVzz-zSkVA&_md5=65ff26fa31c1f2f4f0c50d1a84b1ac96>.

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"Indian Space Department: Indian Space Research Organization." About us. Accessed 14 February 2005. <http://www.isro.org/about_isro.htm>

"ISRO Launch Vehicles." Indian Space Research Organization. Accessed 1 February 2005. < http://www.isro.org/launch.htm>.

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