Indian Space Program

S. Krishnan
Professor of Aerospace Engineering
Indian Institute of Technology Madras
Chennai – 600 036, India

(Written in 1999)

WORLD'S FIRST successful satellite launch by Russians in 1957 heralded the beginning of the Space Age. Initially, critical military applications, national prestige, and ability for advanced scientific exploration were the main drivers for the development of satellites and satellite launch vehicles. As was expected, the governments of the erstwhile-USSR and the U.S. played vital roles in this development at its embryonic stage. In later years, however, many civil-applications of satellites have been identified and extensively developed, and these have become the main motivating forces for the present-day developments in the space programs of many other countries.

For the year 1998, as per Euroconsult Report on Government Space Programs, India's civil-space budget stood around $410 million and it is seventh largest in the world. American civil-space budget was $13.5 billion. The other five budgets were of Japan ($1.932 billion), France ($1.427 billion), Germany ($720 million), Italy ($629 million), and Russia ($442 million). Europe's expenditure under the consortium of European Space Agency was $2.9 billion.

There have been many world-class achievements by the Indian space program. However, the comparison of the global developmental trends in space industry with the Indian ones indicates growth-rate inadequacies in India in certain areas. The purpose of this article is to discuss the issues concerned.

Achievements

Infrastructure Sector

In India, the infrastructure sector of space program — construction and operation of satellites and their launch vehicles, ground station and sensors — is with the government's Indian Space Research Organisation (ISRO). However, the “external fabrication” policy of ISRO is a big success. A host of Indian institutions, including also academia, and over 250 private industries are partners in the projects of ISRO. Both public and private sectors are involved in the manufacture of propellant ingredients and the fabrication of a variety of hardware: light alloy structure for inter-stages, motor cases, liquid thrusters, propellant tanks, turbo-pumps, valves, gas generators, heat shields, columbium expansion nozzles, batteries, power systems, electronic packages, and precision coherent radars.

The development of ground-station facility that also includes launch-facility construction has had a large participation of private industries. The second launch facility at Sriharikota at a cost of Rs. 280 crores is under construction through a public-sector contractor. This large civil and mechanical fabrication project, to be completed within a period of 30 months, will evidently have the participation of many private-sector units.

Analysts say that India's launch cost could be a third lower than international averages. Arianespace, the company promoted by the French government as the launch service provider for the European Space Agency, and ISRO's marketing arm Antrix Corporation signed in 1998 an agreement. This is for the joint marketing of ISRO's Polar Satellite Launch Vehicle (PSLV) and Arianespace's Ariane-5 to launch auxiliary payloads in the weight class up to 100 kg, termed as micro-satellites. Under this agreement ISRO, by its recent PSLV-C2 launch on May 26, 1999, has just entered into the launch business. At about 25 per cent “promotional” discount on the usual rate for micro-satellites, ISRO charged around $8000 per kg for the South Korean 107 kg KITSAT-3 and the Germany 45 kg DLR-TUBSAT for a sun synchronous orbit (SSO) — SSO is higher than low Earth-orbit (LEO) but lower than geo-synchronous transfer orbit (GTO).

A Belgian micro-satellite may be launched along with the Indian Cartosat in the next PSLV-C3 flight, scheduled towards the end of 2000 or in the early 2001. The potential of the PSLV to launch replacement satellites for LEO constellation communication systems, such as Iridium, is under discussion between Arianespace and Antrix.

The cost of PSLV-C2, excluding its satellite, is reported to be of $16.5 million (Rs. 70 crores), PSLV-C2 has recently launched payloads totally weighing 1200 kg into an SSO. Also it is claimed that the PSLV with certain modifications can put payloads up to 4000 kg into LEOs and up to 800 kg into GTOs. These figures give the cost of launcher per kg of payload to be about $20600 for GTO, $13600 for SSO, $4100 for LEO. Compared to the prevailing international rates these figures look quite attractive for India to enter into commercial launch industry using its PSLV, although in the present trend the possibility of having an 800-kg satellite in a GTO for telecommunications purpose looks remote.

ISRO is launching also sounding rockets for other countries. Recently it launched some for Norway.

The Mission Control Facility of ISRO near Hassan, 220 km from Bangalore, did orbit raising for a Lockheed Martin satellite and payloads testing for two PanAm satellites, PAS 4 and PAS 7, and got $150-200 million for each of these satellites. This unit of ISRO also successfully trained recruits for Arabsat in Riyadh.

The total cost (satellite, launch, and insurance) of the recently commissioned multi-purpose satellite INSAT-2E is about $130 million. Nine of its seventeen transponders have been leased to the international inter-governmental space consortium INTELSAT for $10 million a year. As per the design, INSAT-2E's nominal life-span is 12 years. But, thanks to the superior launch-orbital parameters and the excellent specific impulse achieved in the satellite's main propulsion system, the life span of INSAT-2E is projected to be longer, even up to 15 years. In that case, but for the expenses involved in the station keeping for 15 years, India will get the service of the remaining 8 transponders and the meteorological payloads free! In addition, $20 million will be the income in excess of the investment. With all these, also commercial telecommunications satellite industry looks very attractive for India.

India is one of the world leaders in solid propellant technology, noting in particular its preeminence in the use of the currently favored hydroxyl terminated polybutadiene fuel for very large solid rocket systems. Also, it has mastered the storable hydrazine (and its variants such as monomethyl hydrazine and unsymmetrical dimethyl hydrazine) and nitrogen tetroxide liquid propellant systems. All over the world, the micro thrusters, main motors, and liquid apogee motors used in satellites are mostly of the type that uses the propellant combination of monomethyl hydrazine and nitrogen tetroxide. The specific impulse achieved by India in its latest radiation-cooled liquid-apogee-motor of this type, fitted to the INSAT-2E, is one of the highest in the world.

Telecommunications

Many large industrial houses in India, such as Reliance, have entered into satellite telecommunications business. There is an explosive growth in the operation of the private Indian-companies engaged in the services of television broadcasting, cable television networking, cellular phone, and Internet. Because of this, the once restrictive Indian official broadcasting and communication policy is getting liberalized in reasonably rapid steps. The new telecom policy of 1999 announced in March allows Indian users to avail themselves of transponder capacity from both domestic and foreign satellites, particularly for access to gateways for Internet-service providers. The new policy also allows the use of Ku band for communication purposes — a Ku band transponder demands larger mass and higher power but offers wider bandwidth with better communications properties compared to the ones of C band or upper extended C (UXC) band. Indian television broadcasting companies on regular basis use transponders of foreign satellites.

All the leased transponders in the recently launched INSAT-2E are reported to have been booked by the Indian television broadcasting companies such as Eenadu TV, Sun TV and Vijay TV. The U.S. television company CNN has also taken on lease a transponder of an Indian satellite.

The current problem of license fee payments by the Indian cellular companies is to be seen only as one of the many temporary travails that are bound to happen in any privatization process in India.

Internet has already made the world a global village. Sam Pitroda headed London based WorldTel is to open community Internet centers in India, under its subsidiary WorldTel India. This is to happen in collaboration with certain states, including Tamil Nadu, in 1990-2000. WorldTel India is a Rs. 400 crores company with Rs. 170 crores in equity. Reliance Telecom is planning to participate also in the Internet service provider business.

Remote Sensing

Indian remote sensing commercial satellites are among the bests in the world (Aerospace America, April 1999). IRS-IC and IRS-ID provide the best high resolution data to the user community anywhere in the world and the data from these satellites are being received and used by several countries including the U.S., Japan, Germany, Korea, Thailand and Dubai.

Global Growth Trends

GEO Satellites

The total global launch-market revenue for the period 1998-2007 is estimated to be $45 billion. Of this, the launches for the geo-synchronous orbit (GEO) satellites will form the major revenue source of 60 per cent, $27 billion. Most of the satellites in GEO are of telecommunications type. Furthermore, there is a continuous enhancement in the market share for large satellites in GEO. For the period 1998-2007, the Euroconsult's estimate is that of the total 335 GEO satellites, 51 per cent satellites will be in the range of 2700 to 3690 kg, 14 per cent in the range of 3700 to 4690 kg, and 4 per cent about 4700 kg. On the point of view of revenues the corresponding total launch revenue for satellites above 2700 kg will be about 80 per cent of $27 billion. Another estimate predicts that by 2006 the number of telecommunications satellites weighing more than 3000 kg will be 80 per cent of the total in GEO.

Cryogenic Propulsion Technology

Liquid oxygen (LOX) was the earliest, cheapest, safest and eventually the most preferred oxidizer for large launch vehicles. Germany developed the rocket technology using LOX and alcohol in its A-4 rocket engine, fitted to the V-2 rocket. It successfully tested the A-4 engine on October 3, 1942. After the World War II, Americans, Russians, and French used the A-4 technology to develop quickly their own rocket engines using LOX. The Chinese, through Russia, obtained the A-4 technology and developed their Dong Feng I in 1960. In later years, among the semicryogenics, LOX-kerosene combination was found to be the best and is currently preferred worldwide for its price, safety, least toxicity, and specific impulse.

All the leading rocket visionaries identified liquid hydrogen (LH2) as the theoretically ideal rocket fuel. Its combination with LOX gives the highest specific impulse with the least toxicity — the LOX-LH2 rocket exhausts essentially steam. The U.S. mastered LH2 technology for its highly classified Lockheed CL-400 Suntan reconnaissance aircraft in the mid-1950's. The technology was transferred to the Centaur rocket stage program, and by the mid-1960's the U.S. was flying the Centaur and Saturn upper stages using LOX-LH2 combination.

Russia developed its LOX-LH2 upper stages by the mid-1970's. The RD-56 — the one to be flown for the first time in the Indian Geo-synchronous Satellite Launch Vehicle (GSLV) — was the first Russian cryogenic engine developed in the mid 1970's. However, the Russians never seem to have found the extra performance in flight to be worth the extra cost. The first Russian cryogenic engine to be flown was RD-120 in 1987.

France, Japan, and China developed LOX-LH2 engines for upper stages of their respective Ariane (HM7-A, 1979), H1 (LE-5, 1986), and Long March (YF- 75, 1994) launch vehicles.

Cryogenic propellants, semi-cryogenic propellants, and storable liquid propellants — in that decreasing order — are of higher specific impulse than solid propellants. More of semi-cryogenic and cryogenic liquid propulsion systems — mostly LOX-kerosene and LOX-LH2 — are being adopted in the construction of new launch vehicles for large satellites, say 2000 kg and above.

Reusable Launch-Vehicle Technology

All over the world, the readily available missile-propulsion technology has been "adopted" all along for realizing the launch-vehicle technology. Now the launch vehicle's "own technology," namely, the reusable launch-vehicle technology is emerging. The two principal market-forces for this evolution are the launch-cost reduction and the launch-reliability enhancement. These two point to, as solutions, the component reusability and the reduction in the number of components in a launch vehicle: less number of stages, less engine-clustering in a stage, and high-specific impulse propellants. Two-stage-to-orbit (TSTO) and single-stage-to-orbit (SSTO) reusable launch vehicles, under various stages of development in different countries, invariably use LOX-kerosene or LOX-LH2 combinations — SSTO vehicles use only LOX-LH2.

Indian Status

GTO Launches

India's GSLV with the Russian RD-56 in its upper stage may fly in one or two years. GSLV was originally configured for a satellite mass of 2500 kg. However, it may not be possible to have that much mass in its first few flights due to the traditional developmental "weight growths" in many of the vehicle components. It is not definite whether the Russian upper stage with RD-56 engine will be available after first three GSLV flights. However, India is now vigorously developing its cryogenic-engine technology. No definite time has been given for the first flight of its GSLV fitted with an indigenous cryogenic engine. It may be expected that ISRO can have its indigenous operational cryogenic engine of GSLV class or higher in about four to five years time. All these indicate that India, at least for the next four to five years, has to depend on foreign launch vehicles or foreign cryogenic engines for launching into GTO its telecommunications satellites of average weight class.

In the next few years time India is planning to launch its INSAT-3 series of satellites, four in number, each weighing about 3000 kg. INSAT-3B is planned to be launched before the end of 1999 by the Arianespace. Recently, it has been reported that India will be paying $82 million (Rs. 352.7 crores) to Arianespace for the launch of INSAT-3A in the middle of 2000. It paid $68 million for the launch of 2550 kg INSAT-2E. The launch of its four INSAT-3 satellites by foreign launch vehicles will be costing around $330 million (Rs. 1420 crores).

Criticizing the U.S. government's decision to launch its satellites using Chinese launch vehicles, many U.S. space-analysts said that the loss of a single satellite launch to another country was worth 5,000 jobs, one third of which could be medium to high level scientists category. The loss of any segment of the space industry to another nation could mean an irreversible loss of market growth, they added. China is reported to be indirectly pressurizing the foreign television-broadcasting companies beaming their programs into China to use its vehicles to launch the satellites they use.

Transponders

Satellite telecommunications is poised to take on new and expanded roles in the national and global information sector. With the almost saturated C and UXC band frequencies, the use of high band width Ku band (12 to 14 GHz) and Ka band (20 to 30 GHz) transponders is growing in a very fast rate. In the Iridium constellation that is operational in India, the inter-satellite communication is through Ka band transponders — recall the telephone messages from a young news-reporter from certain bunkers in the Kargil sector to a television broadcasting station; the reporter used an Iridium satphone.

In the present or near-future Indian-satellites, Ka band transponders are not available. And, the availability of Ku band transponders for the use of Indian private companies may be limited. With the proposed launches by Arianespace of INSAT-3B and INSAT-3A, the number of Ku band transponders will increase from 3 to 12 by the middle of 2000 — 3 in INSAT-2C, 3 in INSAT-3B and 6 in INSAT-3A.

Many private companies in India have been permitted to take on lease Ku band transponders of foreign satellites. Although these companies are not presently permitted to use Ka band transponders, the growing demand for better-quality services and the expanding privatization process in the Indian telecom sector will necessitate soon the grant of permission. Evidently then the Indian private telecommunications companies will have to depend on the Ka band transponders of foreign satellites for quite sometime to come.

Concluding Remarks

India has an excellent scientific human resource that has demonstrated outstanding feats on the space projects assigned in the construction and operation of satellites and satellite launch vehicles. Even though delayed due to techno-political decisions, India is expected to prove its operational expertise in the area of cryogenic propulsion technology in about four to five years time.

In India the development of satellite technology appears to have considerably overtaken that of the critical launch vehicle technology, resulting in the India's dependency on foreign countries for launching its telecommunications satellites.

The inadequacy of Ku band transponders and the absence of Ka band transponders in the present or near-future satellites of India may result in the Indian telecommunications-sector depending more on the services of foreign satellites.

Globally, in ten years from now, the present technology of “disposable” launch-vehicles will not be in favor. The two-stage-to-orbit and single-stage-to-orbit reusable launch-vehicles propelled by semi-cryogenic and cryogenic engines will be in commercial operation. The launch cost by these reusables will be at least one-fifth of the current cheapest-rate, if not one-tenth as claimed.

Majority of the communications satellites in GEO will be of 3500 kg or more. And, at least one order of magnitude enhancement in the existing commercial space-activities will take place. These global realities are to be weighed against the projected space plan in India.

For India, its self-reliance on the operation of the satellites and the launch vehicles, constructed in tune with the global technology, is of paramount importance. By its own experience, India has clearly seen that the investment in space always pays through remote sensing and telecommunications satellites. By becoming fully self-reliant in space activities, it is definite that the resulting contribution from the space program to the Indian GDP will be quite significant. Annual growth rate of the GDP can become significantly higher than the present 6 to 7%. In this process, if anything dramatic happens to India under the ongoing "space gold rush" it will be a bonus or may be even a windfall!

— A version of this article appeared in one of the national newspapers in India: *The Hindu*, October 7, 1999.