

Foreword February, 2012.

(a) Major S&T and Related Events.

(1) Addressing scientists of TNAU, Dr Swapan K. Datta, Deputy Director-General (Crop Sciences), Indian Council of Agricultural Research, recently said *“even as we march towards achieving rice production target of 100 million tonnes this year, we should remember that a right policy would be driving force for tomorrow's research and productivity.’ He said how with scientific intervention, policy decisions and management initiatives, the country's rice productivity levels had risen from 800 kg/hectare to 3.7 ton/hectare, while emphasising the need to remain more focused on basic science and rice research.*

Similarly there are reports that, to quote Business Standard, *“The gains from Bt cotton must be consolidated by introducing new genetically modified varieties. In less than a decade since its approval for sowing in 2002, the gene-altered, insect-protected Bt cotton has spread to cover more than 90 per cent of cultivated area, pushing most other varieties and hybrids out of cultivation. Farmers have eagerly adopted the transgenic variety, having seen the effect on their crop output; Agriculture Minister Sharad Pawar told Parliament that income has increased, on an average, by Rs 10,000 per hectare because of a reduction in the use of pesticides and higher yields. However, most of the Bt cotton hybrids available are for long staple cotton; thus, there has been a distortion in the output mix — and therefore in the availability of cotton of differing staple lengths and lint qualities, required for various end-uses. Extra long staple cotton, for example, is needed to make top-of-the line fabric and its harvest is now just a tenth of what it was in 2003-04. Short staple cotton, which is used in hospitals for surgical purposes and by household industries for making quilts and mattresses, has also become scarce, with its output halving. Equally disquieting is the impact on the pest regime of the universal adoption of Bt seeds. True, the most common and dreaded of pests, the American bollworm — targeted specifically by the insect killer gene transferred into Bt cotton from the soil bacteria *Bacillus thuringiensis*, or Bt — has been, by and large, controlled. But conditions have turned positive for the growth of other pests. Sap-sucking pests, such as mealy bugs, thrips, jassids (in the central and southern belt) and others are reported to have become a formidable menace to the crop. Yet those who seek to blame Bt cotton or genetic engineering technology for this unintended fallout are in error. Bt cotton has been a boon for farmers; the real culprit is the virtual monocropping of Bt hybrids because there are simply no other equally useful alternatives. What is needed, thus, is a continuous flow of new seeds to maintain genetic diversity and provide farmers a wider choice of varieties to grow (emphasis — ADD). If this is not done in time, the GM technologies would go the same way as to what is happening to non-availability at affording prices of essential drugs for which also there is none in practice to co-ordinate the multi-departmental governance structure!*

(2) According to a recent book *“The US — India Nuclear Pact: Policy process and Great Power Politics”* written by the well-known policy analyst Harsh Pant, to quote its reviewer Sukumar Muraleedharan (EPW January 14, 2012), *“DAE figures only incidentally in Pant's diligent effort to understand the various actors on the grand panorama of nuclear dialogue. It is an omission that is not surprising since the department remained discretely on the sidelines, except for a famous February 2006 outburst by the DAE head Anil Kakodkar, about the US 'shifting goal posts' in the nuclear dialogue....DAE's role in the nuclear dialogue with the US will be*

remembered basically for Anil Kakodkar's (the then Chairman, AEC) insistence that it would not under any circumstances allow its fast breeder test reactor (FBTR) at Kalpakkam to be designated as a civilian facility, subject to international safeguards. As the cornerstone of the second phase on India's nuclear energy program, the FBTR should have been classified as a civilian facility. But the DAE thought differently. The point that Kakodkar made in his intervention was simply that 'long-term energy security' and the sustenance of India's 'minimum credible deterrence', required that FBTR be kept out of the safeguards regime... India's nuclear weapon doctrine was well advanced..."

Meanwhile PTI has reported from Washington that " A senior Obama administration official has said that Indian should ensure the full implementation of the India-US civil nuclear deal and that New Delhi is aware about this but have not done it yet. "The Indians know very well, how we feel about the necessity to get these things done and they assure us that they are but they are still not done," the Undersecretary of State for Arms Control, Ellen Tauscher, told Washington-based Defence Writers Group at a breakfast meeting.

Will the UPA – II administration accede unceremoniously to such a demand, well we better await the course of our techno-political history! With a publication of a research article by the noted geophysicist-seismologist Prof VK Gaur and his collaborator from University of Colorado, according to which a Latur type earthquake cannot be ruled out in the Jaithapur area, even the Jaithapur Project may come to halt!

(3) The noted finance columnist TN Ninan writes, "The Nobel laureate Michael Spence (of New York University, and head of the World Bank's Growth Commission) made a presentation in Delhi this week, and outlined eight reasons why growth falters. India qualifies wholly or substantially on five of the eight: poor leadership, failures of governance, pursuit of objectives other than growth, low rates of public sector investment, and misguided strategy. Depending on where you stand on the inclusiveness debate (a reasonable take would be that poverty is coming down but inequality is going up), you could add half of the sixth reason: inclusiveness failure. That score is bad enough. What makes it worse is that three of the six are the contribution of the current government: a manifest lack of leadership, the surge in the fiscal deficit after 2007-08, and the pursuit of objectives other than growth. If corruption has become more endemic, you could lay some of the failures of governance too at this government's door, though the problem itself is much older.

In a recent interview for the prestigious *Science* magazine, Prof CNR Rao describes on our failures of our contemporary R&D system thus: "CNR Rao: `India is the biggest supplier of techno-coolies for the information technology industry but produces only 25 Ph.D.s in computer science. What an irony!"

CNR Rao: `I don't see any potential Nobel laureates in most subjects in India.'

CNR Rao: `This obsession we have with big science, I am a bit unhappy about that. Science is not just atomic energy, science is not just space. Real science is done in small laboratories.'

Is that the S&T component of the same malady, one truly wonders, leave alone the unpardonable attitude of our large industrial sector in promoting state-of-art through universities and even in-house, that too with the TRIPS compliant IPR laws in place with their support wholesale !

(4) According to The Hindu, "The first submarine of the class, INS Arihant, launched in July 2009, has just completed its harbour acceptance trials and is set to undergo the crucial sea acceptance trials in February. "This will be followed by weapon trials before the submarine is formally inducted into the Navy, hopefully in 2013, when the country will attain the much-desired nuclear triad," the sources said". The second one of the series is also reportedly round the corner. *A very Big Leap indeed for our nuclear technology program in strategic directions.*

(5) A "pathfinder" company Eastman Kodak of US has filed for bankruptcy for protection! In 1880 George Eastman leased the third floor of a building on State Street in Rochester and began the Eastman Dry Plate Company with his partner Henry A. Strong. In 1885 George Eastman invented roll film, the basis for invention of motion picture film, in 1895 the first pocket camera, the \$5 Pocket Kodak, was introduced, in 1935 Kodak introduced the first 35 mm colour film Kodachrome, in 1975 the first digital camera, in 1994 it became a Fortune 500 company and in 2005 it posted a \$137 million fourth-quarter loss, December 2010 it was removed from the S&P 500 index and now has filed bankruptcy. A pioneer inventor entrepreneur turned a multi-billion dollar corporation with one of the finest R&D facility in-house, the fall is indeed worth of very detailed techno-commercial-political analysis for every S&T Policy Researcher in the world including India still yearning to go up the ladder within its political-governance system!

When the major 'path-finder' US industrial giant, General Motors Corporation almost went into bankruptcy a few years earlier, we wrote, "GMC is hundred years old techno-industrial giant of United States, also front runner technology path maker and path finder as well. Founded in 1908, GM employs 284,000 people around the world. With global headquarters in Detroit, GM manufactures its cars and trucks in 33 countries. In 2006, nearly 9.1 million cars and trucks were sold globally under its brands.....After 100 years in business and 10 months of frenzied but failed restructuring, GM is weeks from the bankruptcy filing...The fall of such a techno-industrial path finder has happened, thanks to the economic crisis brought about under global melt-down. In essence, the massive efforts of the decades' long top class scientific-technological innovations and commercialization face the threat of a massive fiasco under the suicidal financial-political policies of an otherwise mighty country. *This raises straightaway raises the question: Is it not in order that all involved in S&T development also have a stake in the policies followed by their political/policy leaderships?" If the answer is 'yes', the task of the technology planners becomes obviously doubly difficult! We will leave this here for the present.*

(b) *Revisiting Homi Bhabha,s "Growing Science" Model, Series 24, ISRO (continued).*

1. In Foreword December 2008 www.patentmatics.org, I wrote the following:" These are the best of times, these are the worst of times" to quote Charles Dickens from one of his celebrated novels, whether it be our S&T scenario or that on the economic-development front. ISRO and DRDO have brought out the very best of our S&T capabilities through the successful 'Chandrayan' 1 and the 'Shourya' Missile mission projects. Going into greater details of India's first unmanned mission to the moon: After the launching phase, the spacecraft was meticulously maneuvered and placed in an orbit around the moon at 100 km altitude. The multi-spectral mapping of

the lunar surface was commenced. The moon impact probe displaying the tri-color of our nation also landed successfully on the moon. This indeed was a great technical challenge taken up by the ISRO community. All of us at home were looking with our breaths on hold the great achievement of ISRO in "giving India the moon" , in the eloquent description of ISRO Chairman, that too on the birthday of none other than our late Jawaharlal Nehru who laid the base of modern S&T in post-independent India. The event has now become a glorious element of our nation's history adding another feather to the memories of our great founder fathers, Homi Bhabha, Vikram Sarabhai and Satish Dhavan, not at all to forget or in the least ignore the many other doyen leaders of ISRO.

“Undoubtedly the positioning of our tri-colour on the moon surface on November 14, 2008, would ever be remembered in the history of our great S&T odyssey. In the description of the senior retired ISRO scientist P Radhakrishnan, “A small step on November 21, 1963 on the shores of Trivandrum; a giant leap in November, 2008! Nothing in our recent history has captured public imagination as excitingly as Chandrayaan-1 – a mission accomplished flawlessly to the envy of other nations. Most fittingly on November 14, the birthday of India’s first Prime Minister Pandit Jawaharlal Nehru, the Moon Impact Probe (MIP) joined the company of man-made objects already on the moon deposited by other space faring nations. Needless to say, every Indian should pay homage to his memory, for it he who laid the foundation of science and technology in our country. Of course, he was insightfully advised in matters concerning space research by Dr. Homi Bhabha and Dr. Vikram Sarabhai who took the helm and sowed the seeds of the right kind of culture, which, we see today, is paying the dividends. That is how India then took her first tottering steps in SPACE. Now merely 45 years later, and starting from nowhere, with no background in aircraft technology (as the other players had), the MIP (Moon Impact Probe) has become the first souvenir from the earth with a ‘Made in India’ inscription! For the next two years, Chandrayaan-1 will keep sending interesting scientific information about the moon. Congratulations, ISRO! You have made INDIA proud!

“Chandrayaan-1 has, no doubt, turned a new page in the book of space with India playing the lead role. USA lent us one of her sounding rockets, Nike Apache, for our first launch in 1963. Today, ironically, she is taking a ride in our spacecraft. There is nothing unusual about this in current times, for international co-operation in space ventures has become the order of the day. Most significantly, presence of foreign payloads in Chandrayaan-1 symbolizes the international recognition India has won!

“Though we are not the first to do a lunar mission, this is our first and we did it without a hitch! That is the uniqueness of Chandrayaan-1, for nobody else has done this the first time the way we did!” concludes Radhakrishnan (Read the full article in ‘publications’). And for the design chief of the MIP, Shri Manohar Lal, this was his dream come true, though it could happen only after his formal retirement from ISRO! And so on....*This was described again as a path-breaking discovery (water on the moon!) and as “And this Great Leap coinciding almost exactly not only with the Birth Centenary of Homi Bhabha but also (more significantly?) the eighty ninth birthday of late Professor Satish Dhawan, truly described as the ‘gentle colossus who lent substance to Vikram Sarabhai’s vision and built the Indian Space Research Organization into a vibrant body’, in the words of Dr Manoranjan Rao, formerly of ISRO”.* This much earlier quote has been brought here essentially to bring home our decade long effort through this website to choose and highlight our nation’s S&T and related achievements on the one hand and concurrently also the new challenges and

even threats emerging from contemporary policy changes in the S&T and related regimes brought about essentially as part of the new national policies themselves. In essence, this could be interpreted as the techno-political content of this site.

2. The January issue concluded as follows:

This issue is concluded by quoting Satish Dhawan from his Sir M. Visweswarayya Memorial Lecture, Institute of Engineers(India), Hyderabad, February 8, 1981 under the title "Space Launchers for India",

"Mission planning begins by first establishing the major aims and goals. Mission definition begins by answering questions such as 'Is it a scientific mission.....or a specific application, namely, telecommunication, remote sensing, meteorology?...The four major elements of a typical space system are (a) Launch vehicle (b) Spacecraft (c) Mission Control and (d) Utilization...In general terms an essential component of a space mission reduces to the placing of a spacecraft of a given weight(mass) in a specific orbit around the earth or...in a trajectory starting from earth and leading into interplanetary space for a definite predetermined purpose...The energy necessary to propel space vehicles by launchers powered by rocket systems, primarily chemical rockets.....Rocket thrust is generated by the combustion of chemical fuel with the help of an oxidise – the two together being contained in the propellant system....The propulsive thrust force is primarily produced by the momentum of the expelled gases...practically realizable values---is not realisable with a single stage.....Multistaging provides a clear advantage since the unnecessary weight of the burnt out stage can be dropped, improving the mass ratio and resulting in increased velocities in each stage....After lift-off the vehicle must follow as closely as possible an optimum trajectory to traverse the atmosphere, reach the orbital altitude with the appropriate orientation so that the final stage impulse or burn achieves the planned mission orbit – low-earth, sun-synchronous or geo-synchronous as required by the mission – During this phase it is essential to guide or navigate the vehicle course". Then Dhawan describes the design and development of SLV -3 illustrating this process in great detail. Here he also emphasizes and describes the unique project management structure of a mission thus,

"Of particular importance are the management aspects of a complex space project such as SLV -3. The approach was to conceive and execute the overall mission as a unified project with the key role assigned to the Project Director and his 250 –man project team of which two-thirds were engineers/scientists and technical personnel. Full support to the project was provided by VSSC, the lead centre in Launch Vehicles Technology. Roles were also assigned to all other ISRO centres of identified tasks enmeshing with the mission goals" and so on with the Chairman himself with his team reviewing all developments in quite details publicly in presence of all scientists (above a minimum level of service and experience in their fields within) in VSSC. Such an organized Project Team concept was certainly unknown and even alien in our country!



With Abdul Kalam as the Project Director, the successful fulfilment of the SLV -3 project indeed marked “a giant leap for India” in all sense of the term though only through a “tiny launch vehicle” by world standards in the 1980s. While it also ‘broke the monopoly of the advanced countries in space technology, ISRO had all the same ‘miles to go’ to fulfil its projected national mission, throwing to itself at every stage larger challenges in multifarious areas. This series would try to give some highlights, constrained by the author’s professional background alone, of a few major items like new propellants, new alloys and composites, new engines to supplement the required thrusts with increasing weights of payloads and so on essentially to present the great challenges which ISRO had to overcome to attain its present stage which included the historic launching successfully a Moon Impact Module to the surface of the moon and for the first time, jointly with NASA, the identification of water on its craters.

A summary of ISRO launch vehicles is as given below (source: ISRO website):

Launch Vehicles are used to transport and put [satellites](#) or spacecrafts into space. In India, the launch vehicles development programme began in the early 1970s. The first experimental Satellite Launch Vehicle ([SLV-3](#)) was developed in 1980. An Augmented version of this, [ASLV](#), was launched successfully in 1992. India has made tremendous strides in launch vehicle technology to achieve self-reliance in satellite launch vehicle programme with the operationalisation of Polar Satellite Launch Vehicle (PSLV) and Geosynchronous Satellite Launch Vehicle (GSLV).

PSLV represents ISRO's first attempt to design and develop an operational vehicle that can be used to orbit application satellites. While SLV-3 secured for India a place in the community of space-faring nations, the ASLV provided the rites of passage into launch vehicle technology for ISRO. And with PSLV, a new world-class vehicle has arrived. PSLV has repeatedly proved its reliability and versatility by launching 52

satellites / spacecrafts (25 Indian and 27 [Foreign Satellites](#)) into a variety of orbits so far.

ISRO also makes the Rohini series of sounding rockets used by the Indian and international scientific community to launch payloads to various altitudes for atmospheric research and other scientific investigations. These rockets are also used to qualify some of the critical systems used for advanced launch vehicles.

The SLV -3 to the present level journey of ISRO was undoubtedly a challenging trajectory and it is not feasible for any meaningful summary of this technology saga through these columns. Some inkling of this colossal epic is available from the ISRO website. Thus, the Satellite Launch Vehicle-3 (SLV-3), India's first experimental satellite launch vehicle, was successfully launched on July 18, 1980 from SHAR Centre Sriharikota, when Rohini satellite, RS-1, was placed in orbit. SLV-3 was a 22 m long, all solid, four stage vehicle weighing 17 tonnes capable of placing 40 kg class payloads in low earth orbit. It employed an open loop guidance (with stored pitch programme) to steer the vehicle in flight along pre-determined trajectory. The first experimental flight of SLV-3, in August 1979, was only partially successful. Apart from the July 1980 launch, there were two more launches held in May 1981 and April 1983, orbiting Rohini satellites carrying remote sensing sensors. Augmented Satellite Launch Vehicle (ASLV) was developed to act as a low cost intermediate vehicle to demonstrate and validate critical technologies. With a lift off weight of 40 tonnes, the 23.8 m tall ASLV was configured as a five stage, all-solid propellant vehicle, with a mission of orbiting 150 kg class satellites into 400 km circular orbits. The strap-on stage consisted of two identical 1m diameter solid propellant motors; Under the ASLV programme four developmental flights were conducted. The first developmental flight took place on March 24, 1987 and the second on July 13, 1988. ASLV-D3 was successfully launched on May 20, 1992, when SROSS-C (106 kg) was put into an orbit of 255 x 430 km. ASLV-D4, launched on May 4, 1994, orbited SROSS-C2 weighing 106 kg. It had two payloads, Gamma Ray Burst (GRB) Experiment and Retarding Potentio Analyser (RPA) and functioned for seven years. ASLV provided valuable inputs for further development. And so on. *The next version, namely, the PSLV has indeed become the work horse of the ISRO program over the years!*

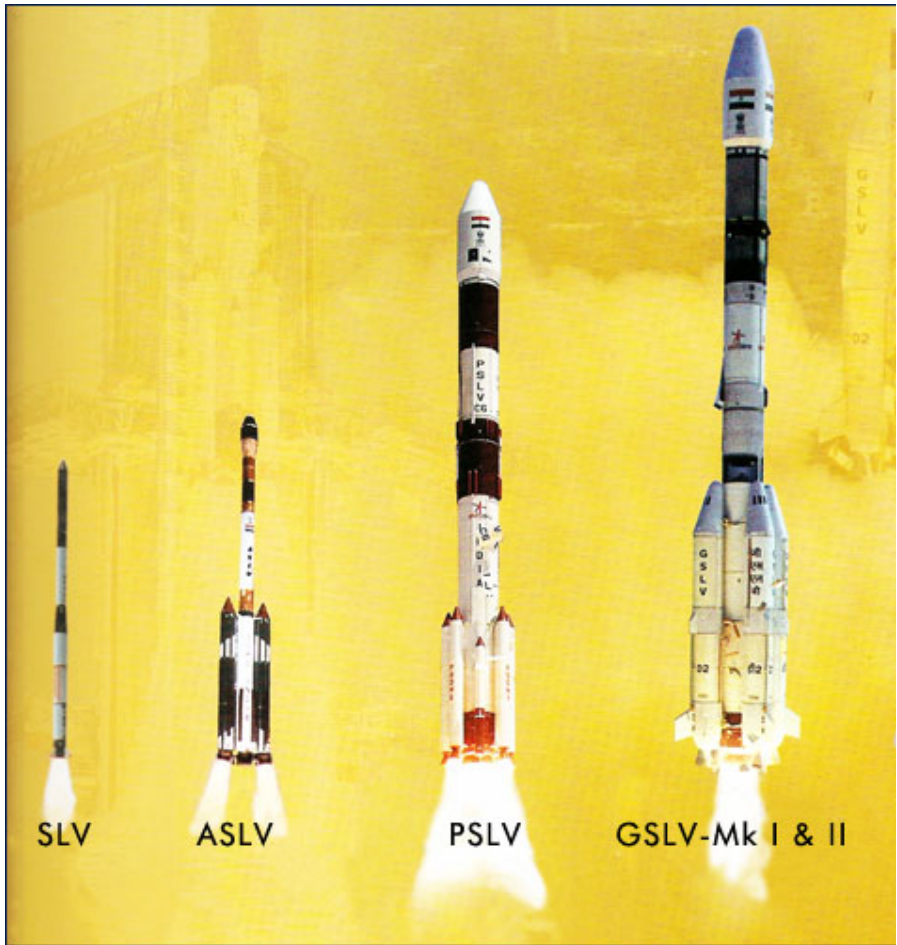
The landmark achievements of ISRO's Launch Vehicle &satellites Development program is summarized as below (Ref: ISRO website).

■	PSLV has 19 consecutively successful flights out of 20 launches
■	PSLV used for launching a total of 27 satellites for foreign customers under commercial agreements, demonstrating its multi-satellite launch capability
■	PSLV used to launch Space capsule Recovery Experiment (SRE-1), Chandrayaan-1 and ISRO's exclusive meteorological satellite, KALPANA-1 , proving its versatility
■	GSLV with four successful flights of seven launches can launch 2 to 2.5 tonne satellite into Geosynchronous Transfer Orbit (GTO)
■	Successful testing of indigenously developed cryogenic upper stage on November 15, 2007.

ISRO's Launch Fleet at a Glance

■	ISRO developed two experimental satellite launch vehicles, SLV-3 and ASLV
■	Polar Satellite Launch Vehicle(PSLV) commissioned in 1997
■	Geosynchronous Satellite Launch Vehicle (GSLV-Mk I) commissioned after second successful flight in May 2003
■	GSLV - MK II will use indigenously developed cryogenic Upper Stage

GSLV - MK III is under development



Obviously this program included the development and production in adequate quantities a variety of materials and systems for the first time. And all through ISRO planned and executed the famous

policy dictum of Satish Dhawan,

“.....we must utilize the national expertise and capabilities in all our programs”.

Its key elements were, to quote PP Sinha from his 97th Indian Science Congress, (a) Make use of national expertise and infrastructure (b) Identify the most suitable industries in the relevant areas (c) Treat industries as partners (d) Provide necessary guidance and technology input in process development) (e) Establish necessary infrastructure and (f) Develop quality systems. Sinha gives lots of details of the sub-elements of this process including the methodology, selection of vendors, evaluation of vendors, quality audit systems, contract management and so on. Accordingly, new delegated structures with matching administrative-financial sanctioning powers were formulated to work out and standardize its own new models of public-private partnership to enable its project team to create new enterprising vendors willing to take up ISRO projects in time and to required quality specifications (one should not forget that perhaps Homi Bhabha was the first ever in the GOI departments to systematically promote high quality fabrication capabilities in even private sector many decades ago and perhaps it was this ‘precedence’ that was borrowed and developed further by Satish Dhawan to meet the ISRO requirements). This ‘fabricated in India’ model along with its own unique project management and review strategies undoubtedly enabled ISRO to create a totally new management concept, in turn enabling it to meet project targets much better than its counterparts in the government. This aspect itself perhaps needs a new separate chapter and which could serve as a valuable model of study for our students in management studies!

Within the expertise of this author it is not possible or even appropriate to describe the massive ‘indigenization’ process of ISRO highly complex space technology achievements. We would restrict the same through giving a bird's eye review of a few critical items in materials and systems to essentially to give an idea of the immense *intensity and content* of the program. Among the metallic materials include in required cast/extruded and welded shapes maraging steel, stainless steels, HSLA steels, aluminium / magnesium alloys (aluminium-lithium alloy included), super alloys, titanium alloys, copper alloys, special ceramics, and so on. The ‘materials summary’ could be read for details by interested reader in a commemorative volume “Evolution of Materials Research for Indian Space Programs” dedicated to MK Mukerjee the ‘founding father of materials research in Indian Space Programs’ by Suseelan Nair and PP Sinha and which gives a comprehensive account of the massive work undertaken and successfully completed by the VSSC materials research team, all of them meeting strictly to ISRO specifications. One of its major achievements is the indigenous development and production to required shapes of the celebrated maraging steel (not at all to minimise the very many other crucial ones) and incidentally also the studied invention of an Indian cobalt-free maraging steel (*the first such case of invention of a new alloy perhaps in our country?*). Being classified as a strategic item in normal parlance, Maraging steel has and is always been treated as a ‘*dual use material*’ denied by its foreign suppliers to our country. And when the Brahma Prakash (formerly of DAE and then Director, VSSC) Committee finally took the decision to go for maraging steel replacing the earlier one as the structural material, the initial R&D program of the same was converted obviously to the high priority scale-up and large scale production category. Along with the indigenous development of zircaloy for use in nuclear reactors by the Indian nuclear establishment, the development and commercialization of maraging steel into required shapes including large rings and cylindrical containers by ISRO should perhaps form the two bright jewels of national

self-reliance in dual-use strategic materials, NOT in any manner to minimize at all the importance of many others!

Another major area related to the area of materials is the pioneering work on development of hydroxyl-terminated poly-butadiene (HTPB) as the solid propellant base for all its major programs. The review publication by KN Ninan, himself an ISRO veteran, under the title “Chemical Systems for Indian Space Program” in Chemical Industry Digest, May 2009, gives an excellent summary of the same *chemical systems program* in fair detail, an “overview of the challenging tasks undertaken in ISRO for the development of chemical systems that have contributed immensely towards the success of their accomplished missions as well as tasks planned and pursued currently for the future endeavours” - The list specifically includes the “plasticizer-free and aluminium-free HTPB-based system” for the Moon Impact Probe “to be spin-stabilized and de-boosted to reduce the velocity for landing on the moon’s surface” in the historic Chandrayaan – 1 project. Here again ISRO has travelled a truly long way in the field starting from the initial years when France helped India to set up its first ever pilot scale Rocket Propellant Plant and achieving over the years its truly worldly status in solid propellant technology in all sense of the word. Without in any way ignoring or minimizing the importance of many other critical items in this case also, we highlight only the very well realized case of the HTPB based composite propellant with its 140 ton HTPB-based PSLV/GSLV booster being the third largest solid booster in the world. A very recent ISRO press release summarizes its state-of-art capacity in innovation and technology development. To quote,



“Indian Space Research Organisation successfully conducted the static test of its largest solid booster S200 at Satish Dhawan Space Centre (SDSC), Sriharikota today (January 24, 2010). The successful test of S200 makes it the third largest solid booster in the world, next to the RSRM solid booster

of Space Shuttle and P230 solid booster of ARIANE-5. The S200 solid booster will form the strap-on stage for the Geosynchronous Satellite Launch Vehicle Mark III (GSLV-Mk III) which is currently under advanced stage of development for launching 4 ton class of communication satellites. S200 solid booster contains 200



tonnes of solid propellant in three segments. The motor measures 22 meter long and 3.2 meter in diameter. The design, development and successful realisation of S200 solid booster were a pure indigenous effort involving Vikram Sarabhai Space Centre, Thiruvananthapuram and Satish Dhawan Space Centre (SDSC) at Sriharikota with the participation of Indian Industries. The S200 solid booster derived its heritage from the solid boosters developed earlier for the ISRO launch vehicle programme. The preparation and casting of S200 solid booster segments were carried out at the newly established Solid Propellant Plant (SPP) at SDSC, Sriharikota. During the test, the S200 booster was fired for 130 seconds and generated a peak thrust of about 500 tonnes. The performance of the booster was exactly as predicted. Nearly 600

health parameters were monitored during the test and the initial data indicates normal performance. Today's successful test of S200 is a major milestone in the solid rocket motor programme of ISRO and a vital step in the development of GSLV Mk III". Rediff.com in one of its columns comments the propellant story thus: "In the new state-of-the-art propellant, the fuel which burned is a liquid polymer, but this formed only 13 per cent of the total weight. The rest is solid, comprising aluminium powder and ammonium per-chlorate, which supplied oxygen while burning. These materials had to be developed and then mixed into uniform slurry which could be cast into blocks. Vasant Govarikar's team took four years to develop the propellant. A manufacturing facility for ammonium per-chlorate was established at Alwaye in Kerala. Later, another state-of-the-art solid propellant, hydroxyl-terminated poly butadiene was developed, giving ISRO a world-class capability in solid propellants". And this was the one which now has resulted in the glorious S200 success!

In a similar manner, ISRO has developed its own heavier Liquid Engine systems, also starting from the Viking/Vikas engine developed jointly in the earlier years with France through their carefully worked out and unique technology-sharing arrangement and successfully implanted by Dr AE Muthunayagam and his team in the Liquid Propulsion Science Centre, entrusted with the responsibility of research and development of Earth Storable and Cryogenic Propulsion systems and delivers Engines, Stages, associated Control Systems and Components for Launch Vehicle and Spacecraft programmes of ISRO. Using unsymmetrical hydrazine as the liquid fuel and fuming nitric acid as the oxidizer. According to a recent IBN News quoting ISRO sources, "Indian Space Research Organisation (ISRO) has successfully conducted a long-duration static test of a crucial liquid core stage for a new generation heavy rocket- GSLV Mark III. The second static testing of ISRO's liquid core stage (L110) of Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mk - III) was conducted for 200 seconds at 3-50 pm in southern Tamil Nadu's Mahendragiri. The test was conducted at the ISRO's Liquid Propulsion Systems Centre (LPSC), an ISRO release said. The GSLV-III or Geosynchronous Satellite Launch Vehicle Mark III is a launch vehicle currently under development by the ISRO. It is intended to launch heavy satellites into geostationary orbit, and will allow India to become less dependent on foreign rockets for heavy lifting. L110 is one of the heaviest earth storable liquid stages ever developed by ISRO. L110 stage had two high pressure Vikas engines in a clustered configuration. Nearly 500 health parameters were monitored during the test and the initial data acquired indicates its normal performance. This successful test of L110 for its full flight duration of 200 seconds, is a major milestone in the earth storable liquid rocket programme of ISRO and a significant step forward in the development of GSLV-Mk III launch vehicle". And yet.....

As it often could happen in many technologies- intensive development programs the world over, ISRO also has been lately going through major setbacks in its launch vehicle program in view of its set-backs in cryogenic engine technology and which undoubtedly would affect the schedule of its future schedules particularly with respect to its plans to independently put its communication satellites into geostationary orbits from SHAR centre. To quote from The Hindu dated December 25, 2010 by TS Subramanian,



A SETBACK: The GSLV-F06 explodes in a plume of smoke and fire moments after taking off from the Sriharikota launch site, some 80 km from Chennai, on Saturday. Photo: V. Ganesan

The launch of the Geo-Synchronous Satellite Launch Vehicle (GSLV-F06) from here on Saturday ended in a failure, with the vehicle losing control 47 seconds after its flight, breaking up into pieces and erupting into a ball of flame. As the vehicle veered off the safety corridor and the flaming debris could have fallen on the residential areas around Sriharikota, Range Safety Officer (RSO) V.K. Srivastava pressed the “destruct” button and the explosives around the vehicle ignited and destroyed it. The destruct command was given 63 seconds after the lift-off. When the vehicle disintegrated over the Bay of Bengal, it had reached an altitude of eight km and 2.5 km from the Sriharikota coastline. Gloom engulfed the Indian Space Research Organisation’s engineers as they saw disaster striking the vehicle. ISRO Chairman K. Radhakrishnan said at a press conference: “The controllability of the vehicle was lost after 47 seconds because we found that the command to control it did not reach the actuator system in the first stage of the vehicle... We suspect that a connector chord, which takes the signal down, has snapped.” Director of the Vikram Sarabhai Space Centre in Thiruvanthapuram P.S. Veeraraghavan explained that the command to control the vehicle from the Equipment Bay, the electronic brain of the vehicle resident atop the rocket, did not reach the actuators in the first stage. “So it was not basically a design problem but a problem of the connector snapping.” The GSLV-F06, carrying communication satellite GSAT-5P, had a flawless lift-off at the appointed time of 4.04 p.m. It climbed majestically into the sky as the four strap-on booster motors around the core first stage and the first stage itself ignited on time. The vehicle performance was normal up to 50 seconds. Soon afterwards, it lost control, went here and there, exploded into a ball of fire, and then it was destroyed. White, reddish orange and dark grey smoke filled the sky even as the flaming debris, like shooting stars, rained down. The previous GSLV flight in April 2010 also failed. *Out of seven GSLV flights from 2001, four, including the latest one, have failed.*

According to reports, the Preliminary Failure Analysis Team was chaired by the former ISRO Chairman, G. Madhavan Nair, and analysed the flight data along with members of the Launch Authorisation Board, the Mission Readiness Review Committee as well as senior functionaries of the GSLV Project and experts. The ISRO has now constituted a Failure Analysis Committee to carry out an in-depth analysis of the flight data of GSLV-F06 and data from the previous six flights of GSLV. The committee will establish reasons for the failure of GSLV-F06 and recommend corrective actions on the GSLV vehicle, including the remaining solitary Russian Cryogenic engine. The Failure Analysis Committee has 11 experts drawn from within ISRO and outside. The ISRO has also constituted a Programme Review and Strategy Committee to look into the future of the GSLV Programme and the launches of the INSAT/GSAT Series, INSAT-3D and Chandrayaan-2. It will work towards the operationalisation of the indigenous Cryogenic Stage and come up with a strategy for meeting the demands of communication transponders in the immediate future, the statement said. This seven-member committee will be headed by K. Kasturirangan, former ISRO chairman. In a Current Science publication (Ref: Rao, U. R., Gupta, S. C., Madhavan Nair, G. and Narayana Moorthy, D., "PSLV D-1 mission"; CURRENT SCIENCE, VOL. 65, NO. 7, 10 October 1993, pp 522 – 528), the ISRO methodology of "learning from successes and failures" has been ably described by the authors. One of its authors, the ISRO veteran SC Gupta, has summarized the essentials as follows:

Definition of success Part 1

ISRO has launched 4 SLV-3, 4 ASLV, 19 PSLV and 7 GSLV missions. How many of them were successful? The answer depends on the definition.

If I may say so, there are two types of definitions:

- (i) Managerial and
- (ii) in the spirit of science

For managers, if a launch mission takes the payload to the intended destination, it is a success. After all as they say in Hindi, 'paise basool ho gaye'.

Definition of Success Part 2

In the spirit of science, success is measured in terms of the data gathered in flight, signifying the lessons learnt. Regarding the first flight of SLV-3, even though for managers it was unsuccessful, the scientist in Prof. Satish Dhawan said it was 'partly unsuccessful'. He counted on the wealth of data gathered and invaluable lessons learnt.

In the same manner, even though managers called PSLV D-1 mission a failure it was a success in the spirit of science, as it proved many technologies which were successfully developed afresh. One can claim justifiably that PSLV D-1 opened the door for subsequent grand successes.

Accomplishments of PSLV D-1 Mission

"Satisfactory performance of practically all the vehicle subsystems gave confidence in the design and development of large rocket motors, their control systems, guidance, navigation and auto pilot, structural hardware, software for implementing various onboard functions, mission design and launch campaign management encompassing vehicle integration, propellant servicing, check out operations as well as real time computer system and TTC network. The data collected through telemetry and tracking confirm satisfactory performance of almost all the 79 subsystems." (Ref: Rao, U. R., Gupta, S. C., Madhavan Nair, G. and Narayana Moorthy, D., "PSLV D-1 mission"; CURRENT SCIENCE, VOL. 65, NO. 7, 10 October 1993, pp 522 – 528). So, this is a success in the spirit of science. In a successful

mission in the managerial sense, many abnormalities bordering on catastrophic failure may occur. We have had many such abnormalities in PSLV missions. The alert teams detected them and attended to them, thereby keeping unbroken the chain of PSLV successes. On the GSLV missions, may be, a few abnormalities in the first three successful GSLV missions were over looked. However, to achieve continued successes all abnormalities in the so called successful flights have to be detected and followed up diligently, because, there may be significant lessons to be learnt”!

In essence ISRO has attained its present state of capability through its well established policy of ‘learning not only from successes but also failures”! And undoubtedly in the near future ISRO should bounce back, within its well-tested techno-managerial frame work, with its success in the cryogenic engine technology and of the GSLV as well, to put the nation capable of launching its communication satellites by itself. *Vikram Sarabhai is reported to have said on more than one occasion, “The maturity of an organization is revealed from the way in which it rides over crisis situations” and undoubtedly his ‘breed of engineers and scientists’ in ISRO would rise up to the challenges and make the nation proud of them!*

It is essential that at this stage one should go back briefly to the history of the cryogenic engine development program itself. In continuation of its long history of mutual collaborative efforts in space technology in the early seventies, ISRO and the former Soviet Union had entered one again into an agreement to enable the former to absorb and eventually develop its own cryogenic engine technology. As part of this agreement, India was initially provided with seven engines. ISRO's previous GSLV flights had carried Russian cryogenic engines procured earlier. In total, seven cryogenic stages were procured from Russia of which five stages have been utilised. *The space agency had to undertake independently the indigenous cryogenic engine development programme since 1996 following the technology denial in the 1990s consequent to the fall of the Soviet regime and the US forcing the new pro-Western regime in Russia to stop giving India the engine technology supposedly under the MTCR denial regime. There has not yet been any change in the above policy though perhaps later its rigour would have become somewhat less. In other words ISRO has been left to itself to get over its difficulties; and knowing how complicated the technology is even between the proverbial ‘cup and the lip’, the delay could be serious; and this set-back is certainly set to have its impact on its future programs. Nevertheless ISRO is justifiably confident that it would come out of the same in the near future, with its PSLC –C19 filling the in-between gap to a good extent for launching up to two tons payloads.*

In essence and to repeat, ISRO has attained its present state of capability through its well established policy of ‘learning not only from successes but also failures”! And undoubtedly in the near future ISRO should bounce back, within its well-tested techno-managerial frame work, with its success in the cryogenic engine technology and of the GSLV as well, to put the nation capable of launching its communication satellites by itself.

And finally one is also concurrently tempted to quote what this site had written earlier on the challenges of the *denial regimes*. Thus, on January 26, 2006, in a write-up in patentmatics.org, we wrote, “A pertinent question is – Does the Henry H. Hyde United States – India Peaceful Atomic Energy Cooperation Act of 2006 leaves behind any ‘potentially harmful fall-outs’ to our Space Program as well through the back doors? As per Hyde Act, (1) The Indo – US cooperation in nuclear technology is subject to India’s adherence to the MTCR in accordance with the procedures of the Regime for unilateral adherence and (2) there is not any materially significant transfer

by an Indian person of ballistic missiles, missiles-related equipments or technology that is not consistent with MTCR guidelines. According to its official definition, MTCR considers 'missiles' to include ballistic missiles, space launch vehicles (SLVs) and sounding rockets. Weapons of mass destruction (WMD) include nuclear, chemical and biological categories. These clauses obviously could pose serious restrictions on future programs of ISRO and DRDO and even interactions between them, details of which will have to be worked out - an onerous task indeed for the policy planners of ISRO and DRDO". *In essence one should expect that our strategic departments like DAE, ISRO and DRDO would certainly have to face many new hurdles in getting its projects implemented in time under the growing techno-denial regime whirlpools in international geopolitics; and there is no alternative than to persistently augment our efforts to circumvent them by ourselves. When the space scientist and former chairman of ISRO died, late President KR Narayanan had said, "India's space programmes owe to a great extent its spectacular growth and high level of maturity to the stewardship and visionary leadership of Prof. Dhawan". ISRO's future challenges amidst the changing geopolitical restrictions were also not unknown to him as is clear from his illuminating and statesman like KPS Menon Memorial Lecture on "Space and Foreign Policy" in 1988 itself; undoubtedly those thoughts of his would continue to inspire and lead the nation in fulfilling its ever-changing Tryst with Destiny in technological self-reliance. More of these issues will be described in the next issue.*

(To be continued)

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