

Foreword, January 2012

(a) Major S&T and Related Developments

Speaking at the inauguration of India Telecom 2011 in New Delhi, Dr Singh said, "While telecommunication networks could be set up with imported equipment, it becomes a concern when a large telecom network in a country like ours requires continuous large imports. Keeping in view the growth potential for the manufacture of telecom equipment in our country and our strategic and security interests, there is an urgent need to give impetus to domestic research and development and manufacturing in the telecom sector." "A thriving telecom manufacturing industry would have a large positive impact on many other elements of the electronics manufacturing value chain, apart from generating other benefits like additional employment," he said. The Prime Minister said the Government is committed to doing all it can to ensure successes in the future of telecom sector. "We will work closely with all stakeholders to build upon what we have achieved. I would like to take this opportunity to assure all of you that our government will continue to formulate forward looking policies that will encourage further growth of the telecom sector."

If this indeed a policy statement, it could give a major thrust for self-reliance in the true S&T sense. But is it so? The S&T community would obviously be waiting with great interest.

(1) Business Line has reported that even as the Government is working overtime to calm the simmering public dissent against the proposed 10,000 MW nuclear plant at Jaitapur, the French authorities, which have offered 2 X 1,750 MW reactors in the first phase, is awaiting the Indian parliamentary nod for the liability rules to read the fine print, before inking the contract. Dr Bernard Bigot, Chairman, Atomic Energy Commission, France, said it is important that there is a clear legal framework in the country where one expects to build their reactors. "We understand that the liability is on the shoulders of the operators. It is also clear that the operators can take recourse to suppliers. We cannot comment till your Parliament passes it." Dr Bigot said post-Fukushima, stress tests were performed on 58 reactors in France, which supply about 63,000 billion units and account for 80 per cent of the electricity produced in the country. On November 10, the committee after analysing the complementary evaluation of all the plants said Areva's EPR (European pressurised reactor) has been built with the experience of previous reactors and is well suited to face extreme conditions. There was no single change in the design or key parts and fulfilled their expectations. The final report is expected in January and would be fully shared with the Indian authorities. As of now, four EPR reactors are under construction, one each in Finland and France, besides two in China. The French nuclear reactor manufacturer Areva, in which the French Government is majority shareholder, has offered the EPR reactors to India. Dr Bigot said basically the core of the EPR reactor is the same as the other reactors operating in France. Reactor safety centred round two issues – design and operation and process. The nuclear regulators of France, the UK and Finland, who raised questions on common control of the process – numerical and analytical – were now satisfied that the EPR conforms to the highest safety norms in terms of process control. Dr Bigot said nuclear power plants involve over 20,000 different pieces of contract between buyer and suppliers. It was initially expected that any piece would be validated or rejected in two months, but it took over 11 months. This is besides the technical aspects. The doubling of cost includes provision of dispute. As of now, lawyers from both sides were speaking to each other and an interim decision was expected in January. Dr Bigot said nuclear reactors

require large investments and should last long. It takes 10 years for construction, 50-60 years of operation and 30-40 years for de-commissioning and the supplier has to guarantee the best.

(2) THE Civil Liability for Nuclear Damages Rules notified on November 11, 2011 completely dilute the liability of the nuclear suppliers, a complete violation of basic jurisprudence, so one feels. The Act clearly laid down the provision of a right to recourse by the nuclear operator in the article 17 of the Act. If there was an accident and the operator was held liable for damages, he could recover the damages from the supplier provided he could show that the accident was due to defective supplies or services. This is what the nuclear suppliers from the US were not willing to accept. According to them, irrespective of defective supplies, they should have no liability whatsoever – the liability should be borne entirely by the operator, in this case the government owned Nuclear Power Corporation. What has now been done in the Rules is that the right to recourse has been restricted to either the period of granting of initial license or the product liability period, whichever is longer. Normally, a product liability period is a standard warranty period, generally of 12 months after commissioning of the plant. The initial license period is again generally of five years duration. Normally, an operator will have to secure a license before he can start construction. Since the plant construction takes more than five years, the initial license period would have expired even before a nuclear plant is commissioned. So with this clause, the government has effectively limited the period of recourse only to the warranty period. If an accident takes place after 12 months, the supplier will then have no liability. The other three clauses all limit the amount of liability. The clause 24 of the Rules state that the amount of liability in the right to recourse will be up to the operator's liability if this is provided explicitly in the contract or the value of the contract, *whichever less is*. As the contractor will not agree – given this choice – of including such a liability in his contract, this effectively limits the liability only to the value of the contract. The key issue here is that all liability regimes carry what are known as consequential damages. This is the position in Indian law as well. There is no restriction that the damages are limited only to the value of your contract or investment. By limiting the amount to the value of the contract, all consequential liability as exists under the current liability regime and even under the original Liability Act is being removed. The third way that liability is being diluted is vide explanation 2 to Clause 24 of the Rules, the operator's claim shall in no case exceed the actual amount of compensation paid by him up to the date of filing such claim. In any case, the total claim of the operator under this right to recourse in the original Act would not have exceeded Rs 1500 crore as this is the limit of the operator's liability. Any

damages beyond this are to be borne by the government – this is the weakness in the Liability Act itself. The bill for the Fukushima disaster is already over \$52 billion! A nuclear reactor supply contract in itself will be in billions of dollars.

To add more “liability” to the government, it is reported that “just when the government felt it had sorted out all the wrinkles in the Nuclear Liability Act, eminent jurist Soli Sorabjee has said the crucial rule restricting the liability of supplier to just five years in case of an accident is *ultra vires* and invalid. Mr. Sorabjee was answering questions from international environment activist group Greenpeace on the detailed guidelines for the Nuclear Liability Act, announced on the eve of last month's Manmohan Singh-Barack Obama meeting in Bali. The United States, France and Russia — the major equipment suppliers for India's nuclear power plants — had all protested the unlimited liability period mentioned in the Act. None has publicly commented after the detailed rules restricting the liability period under the operator's right of recourse to five years were notified. But Mr. Sorabjee's opinion that this rule could be successfully challenged in courts is likely to lead to renewed anxiety among the three suppliers as well as the Government of India just when it thought it had addressed the concerns of the suppliers. Asked whether the Convention on Supplementary Compensation (CSC) for Nuclear Damage was inconsistent with the Indian law, Mr. Sorabjee replied in the affirmative. This view could upset the three suppliers even further, besides the government, which insists that the Nuclear Liability Act is compatible with the CSC. According to Mr. Sorabjee, “Article 10 of the CSC is repugnant to Section 17(b) of the Nuclear Liability Act, which would prevail over the CSC and have overriding effect even if India ratifies the CSC.” The second question was about the rules notified by the government and whether they are repugnant to the parent act. He answered: “It is plain that the proposed Rule 24 is unduly restrictive as it limits the amount which can be claimed by exercise of the right of recourse to the extent of the operator's liability or the value of the contract, whichever is less...“Moreover, in my opinion, Rule 24(1) is clearly inconsistent with Section 6 of the ... Act, read with Section 17, in as much as it scales down and reduces the liability prescribed by the ... Act. Consequently, the ... proposed Rule is *ultra vires* the ... Act and is invalid. “Therefore, the proposed Rule 24 (2), which restricts the time limit, cannot be said to be carrying out the purpose of the ... Act but is in fact in conflict with it. Therefore, in my opinion, Rule 24 (2) is clearly *ultra vires* of the ... Act and is invalid.”

Is it that the Nuclear Liability Act and its Rules amount to the tail wagging the dog, one wonders.

(3) Tata Steel Jamshedpur blast furnace completes 100 years



Tata Steel has just completed 100 years of its blast furnace operations in Jamshedpur. The blast furnace was first blown on December 2, 1911 while steel production commenced on February 16, 1912. The company was established in 1907 as Asia's first integrated private sector steel company. The Jamshedpur Works of Tata Steel has come a long way to achieving a capacity of 6.8 million tonnes per annum (mtpa) from its initial production capacity of 160,000 tonnes of pig iron, 100,000 tonnes of ingot steel, 70,000 tonnes of rails, beams and shapes and 20,000 tonnes of bars, hoops and rods. It will take another significant leap to become a 10 mtpa plant in next few months, said Tata Steel in a press release on Friday. In the early years, the plant essentially consisted of a battery of 180 non-recovery coke ovens and 30 by-product ovens with a sulphuric acid plant and two blast furnaces, each of 350 tonnes per day capacity, and a 300-tonne hot metal mixer, four open hearth furnaces of 50-tonne capacity each, one steam engine driven 40-inch reversing blooming mill, one 28-inch reversing combination rail and structural mill with reheating furnaces and one 16-inch and two 10-inch rolling mills. In the early days, about 6,300 people were engaged daily at the Works by the company and its contractors. Today, as a Fortune 500 company, the Group employs over 81,000 people across five continents. Tata Steel Group is amongst the leading steel manufacturers in the world with an annual crude steel capacity of over 28 mtpa with operations in 26 countries and a commercial presence in over 50 countries. The Tata Steel Group registered a turnover of \$27 billion in FY '11.

The doyen JN Tata had said, “Modern India would walk on three legs; steel, electricity and industrial science” and was instrumental to go for the hydro-electric power station at Khapoli, steel at Jhamshepur and Indian Institute of Science as a university in Bangalore. Along with Gokhale and Naoroji for political and economic nationalism, Tata could be rightly described as the “Father of Technological Nationalism”, though his third dream is yet to become a vibrant reality!

(4) The Centre for Development of Telematics (C-DOT) has entered into an agreement with seven manufacturing companies for transferring indigenously designed and developed high speed broadband technology. The technology, Gigabit Passive Optical Network (GPON), is being transferred to Indian Telephone Industries Ltd, Bharat Electronics Ltd, VMC Systems Ltd, United Telecoms Ltd, Sai InfoSystem (India) Ltd, and S M Creative Electronics Ltd. In addition, an agreement has also been signed with Tejas Networks Ltd for customised development and Electronics Corporation of India Ltd (ECIL) is in the advance stage of agreement. GPON technology is used for broadband connectivity over optical fibre. C-DOT has indigenously designed and developed GPON technology, which can be used to provide triple play (voice, video and data) through fibre-based networks. The present GPON standards specify 2.5 Gbps (Gigabit per Second) downstream and 1.25 Gbps upstream data capability to customer premise.

A quick search on USPTO shows that there are 56 patents related to GPON the latest of December 2011 being by Huawei Technologies Co., Ltd. (Shenzhen, CN), China!

(6) During his latest visit to Russia Prime Minister Dr Manmohan Singh signed five agreements, including one to produce 42 more Sukhoi jets for the Indian defence forces. This followed an agreement that India's missile systems will receive signals from the Russian Federation's positioning satellite network, called Glonass. The standard method of satellite-based navigation, the ubiquitous Global Positioning System or GPS, is controlled by the US navy. Using an alternative system is a careful reminder that India's security infrastructure needs to be broad-based and widely networked. The space and defence sectors have, of course, been the points where Indo-Russian co-operation survived the fall of the Soviet Union in the 1990s.

(7) China has begun operating a homegrown satellite navigation service in order to reduce its 'dependence' on the US' [Global Positioning System](#) (GPS). The new system called 'Beidou', or 'Big Dipper', would cover most parts of the Asia Pacific by next year and then the world by 2020, said Ran Chengqi, a spokesman for the system.

[Beidou](#) started providing initial positioning, navigation and timing operational services to China and its surrounding areas from Tuesday, a spokesman for the system said. China was keen to assemble a home grown satellite system of its own to reduce dependence on GPS, specially for its armed forces who apprehend that that the reliance on US systems could be dangerous for the security. Six more satellites will be launched in 2012 to further improve the Beidou system and expand its service area to cover most parts of the Asia-Pacific region, spokesman Ran Chengqi, who is also director of the management office of the China Satellite Navigation System, told media here.

(b) Revisiting Homi Bhabha's “Growing Science” Model, Series, 25 – ISRO & the Big Story of SLV -3 (Continued).

1. It is indeed fitting that the New Year issue starts with the story of the historic entry of ISRO into launch vehicle technology through SLV -3 success through a rigorous and systematic process of “learning from the failure” of the first launch and effecting appropriate changes in the new vehicle; literally in the words of its architect Satish Dhawan, putting also its persevering Mission Director Abdul Kalam himself “into space”! Highlighting this technological success story is doubly important in contemporary context when 2012 is beginning through a serious trying period for the nation facing tremendous strain in its economy including the manufacturing sector and with the rupee being “Asia’s worst performing currency (in 2011) and the outlook for 2012 also remaining bleak, despite measures taken by the Reserve Bank of India (RBI) to prevent volatility in the foreign exchange market, weak domestic fundamentals having corroded the India growth story, prompting foreign investors to pull out, subsequently weakening the rupee”, according to prominent financial daily!

2. *The December 2011 issue closed as follows: “It was already pointed out that while the Aryabhata and similar indigenously made ‘long distance’ satellites were being launched through help of advanced nations including US and USSR from their launch pads, the TERLS in Thumba complex was engaged in launching a series of Sounding Rockets and their Satellites meant for atmospheric studies program involving United State, France and so on, with the Soviet systems in use almost every week. The long term significance of those experiments in the ISRO programme would be dealt with in a separate issue. This was also the true beginning of the long-sustained India – French collaboration referred to by the ISRO Chairman Radhakrishnan even recently. In other words, thanks to a very well orchestrated techno-political strategy, ISRO was able to duly achieve meaningful experience and expertise to plan for larger, more resourceful and more versatile multi-purpose (with national coverage to provide TV broadcast, telecommunications and meteorological services) and obviously more economic in the Indian context satellites-based space programs “in the interest of national development”, as projected by its founder late Vikram Sarabhai and more often that not by his true successor Satish Dhawan as well. It was also mentioned earlier that TERLS was already engaged in carrying out a series of sounding rockets based geomagnetic research studies as a UN supported facility in international cooperation. The first launch took place on November 21, 1963 involving a two-stage US Nike-Apache rocket carrying a Sodium Vapour Payload releasing the vapour in the sky between 8- - 180 km altitudes. For conduct of the experiments, the rockets and some ground equipments were supplied by member countries, launch training was provided by NASA and CNES of France and the assembly, integration, etc carried out by the TERLS staff. To quote SC Gupta himself (op.cit) “The rocket flight was completely successful, meeting the objectives in their totality. This was the first historic step taken in the long and eventful march of India for the peaceful and national development oriented utilization of outer space”. Very soon TERLS earned total appreciation from the international community in terms of “inestimable confidence in Indian skills and sense of commitment”. The facility was dedicated to the UN on February 2, 1968, by the then Prime Minister Ms Indira Gandhi in a momentous function attended by the UN Secretary General himself. It was from this centre that was born alongside the Space Science & Technology Centre (SSTC) which itself eventually was renamed as Vikram Sarabhai Space*

Centre (VSSC) after the sudden demise of its veteran founder Vikram Sarabhai. How this expansion in turn gave birth to an equally crucial element of space technology itself is another great scientific-technological saga to be described in subsequent series.

3. It was highlighted in an early issue that prior to his accepting the post of Chairman/ISRO, Prof Dhawan had submitted a fairly detailed and targeted work-plan to Government of India based on what had been projected by his predecessor Vikram Sarabhai and which included a AEC/DAE like administrative structure and in-principle acceptance of also a tentative yearly financial allocation. *In other words a Dhawan followed a Sarabhai as the apt successor in implementing the space odyssey for our country.* In the case of Homi Bhabha, the twin roles had essentially been worked out by himself: first through projecting his nuclear dream for India through his pioneering efforts in establishing the Tata Institute of Fundamental Research with support from Sir Dorabji Tata Trust, having been convinced and motivated since 1944 that “when nuclear energy has been successfully applied for power production in say a couple of decades from now, India will not have to look abroad for its experts but will find them at home” and secondly, for establishing the AEC/DAE structure and the Trombay Establishment as the ‘launching pad’ to implement the nuclear technology program in a self-reliant mode through his celebrated “*Growing Science*” model. *It is so unfortunate that he was not alive, like Sarabhai, to witness most of what happened in subsequent years under the persistent efforts of his celebrated successors – the inimitable ‘nuclear brigade’ which made the nation a self-reliant a nuclear power with also limited weapons capability.*

4. Let us come back to the VSSC story once again. Much of the information given below has been drawn from SC Gupta (op.cit.) as given in his pioneering monograph. Having had the initial experience from the UN sponsored joint efforts, the Indian leadership decided to go for the next step, namely, that “the launch station should also provide the sounding rockets, sensors and associated electronics and mechanisms”. This vision gave birth to the Rohini Group in 1965 and then the SSTC at Veli Hill adjoining Trivandrum with a multi-disciplinary team of engineers in the areas of propellants, propulsion, aerodynamics, structures, materials, mechanical engineering, control guidance and instrumentation, electronics and systems. The Centre identified the areas of specialization on the model of The Institute of Space and Aeronautical Science, Tokyo University, on the advice of its Prof. H. Itokawa. The Centre eventually was mandated with the following objectives (a) R&D in relevant areas (b) Design and Development of a series of launch vehicles and related sub-systems with specific performance and time targets (c) building specialist/interdisciplinary teams and facilities including for QC (d) requisite methodologies for peer reviews for mid-course corrective action and (e) develop effective program review techniques to meet specified time targets.

5. Almost in line with the DAE practice, concurrently for a “quick and assisted take-off” (!) ISRO entered into an agreement with M/S Sud Aviation of France to *manufacture under license their CENTAUR sounding rocket.* To quote Gupta, “*The Space Program, which was evolving at that time, got a more concrete shape in the vision document of the Department of Atomic Energy, named “A Profile for the Decade 1970-80”... (in turn) projected a master plan, the profundity of which established for the posterity Prof Sarabhai as the main Architect and the Father of India’s Space Program.*”

6. As per the terms of agreement with Sud Aviation, TERLS set up with its T/T support a Rocket Fabrication Facility, a Rocket Propellant Plant and so on, complimentary to building others indigenously. An early development project undertaken by the Rohini Group was the Rohini – 75 Project with a mere 5kg propellant load and no targeted specific payload mass and apogee value. When this *first and totally indigenous* RH – 75 was test flown on November 20, 1967 and the resultant flight data revealed that with respect to the essential parameters, namely,

combustion chamber pressure, thrust, acceleration and flight trajectory,"there showed a fair degree of match between prediction and actual results, carrying forward the concept of the learning cycle", to quote Gupta. This was obviously followed by more RH – 75 test flights, another two times in 1967 and 12 times in 1968. Then came the successive ones, RH – 200, RH – 300 and its variant, RH – 560 and its variant. *And thus was begun the historic journey of ISRO's tough and challenging technology march in developing and mastering the launch vehicle technology to its present stage.*

7. Going from the sounding rocket stage to the launch vehicle per se could not have been that automatic and smooth a program as one wished. To quote Gupta again, "Unlike the flight duration of a few minutes of a sounding rocket payload, a satellite is required to stay in space around Earth for a much longer period, from several days to a number of years....A satellite launch vehicle, SLV, lifts its satellite payload from Earth and following a sequence of in-flight operations takes it to a predetermined altitude, then imparts it the requisite orbiting velocity increment and releases it into the desired orbit". In other words, going for an SLV stage meant a *quantitative jump* in all sense of the word. Be it so, the Rohini program was followed by the SLV, ASLV and PSLV and somewhat later the powerful GSLV. Not unexpectedly ISRO also introduced new methods of Project Management for the new ventures. To repeat the description by MGK Menon, "Even today, the review procedures and checks that are carried out from the component to the final system level bear the stamp of Satish Dhawan...The tight monitoring procedures that he introduced had a great deal to do with the success of the space program". In his inimitable management mode a young Abdul Kalam was chosen as the Mission Director for SLV3 with many other equally or more senior members of the ISRO team to support him wholeheartedly in fulfilling the Mission! Something mostly unknown in the arena of Indian S&T project management practices then and perhaps even now (DRDO seems to have had a similar policy, thanks perhaps to its earlier chief Abdul Kalam himself)! To quote the young Kalam himself on the pioneering SLV project from his well-known autobiography "The wings of Fire" referring to the visit of the rocketry doyen von Braun to VSSC and discussions with him on the project,

"SLV is a genuine India design and you may be having your own troubles. But you should always remember that we don't just build on successes, we also build on failures....Hard work is not enough in rocketry. It is not a sport.....Here not only do you have to have a goal but you have to have strategies to achieve it as fast as possible....Total commitment is not just hard work, it is total involvement. Building a rock wall is back-breaking work. There are some people who build rock walls all their lives...But there are other men who while placing one rock on top of another have a vision in their minds. ...When they finish, they have more than a wall. It is the goal that makes the difference. Do not make rocketry your profession, your livelihood – make it your religion, your mission".

8. The first experimental flight trial of SL3 was scheduled for 10 August 1979. The primary goals of the mission were, to quote Kalam, "to realize a fully integrated launch vehicle; to evaluate on-board systems like stage motors, guidance and control systems and electronic sub-systems, to evaluate ground systems like check-out, tracking, telemetry and real-time data facilities in launch operations built at Sriharikota launch complex. The 23 metre long four-stage SLV rocket weighing 17 tons finally took off elegantly at 0758 hours and immediately started following its programmed trajectory. Stage I performed to perfection. There was a smooth transition from this stage to the second stage. We were spellbound to see our hopes flying in the form of SLV3. Suddenly, the spell was broken. The second stage went

out of control. The flight was terminated after 317 seconds and the vehicle's remains....splashed into the sea 560 km off Sriharikota.

"...A post-flight review conducted on 11 August 1979 ...established that the mishap had occurred because of the failure of the second stage control system...vehicle became aerodynamically unstable resulting in altitude and velocity loss...caused the vehicle to fall into the sea even before the other stages could ignite.

"The findings of the committee were presented to Prof. Dhawan at a meeting of top ISRO scientists and were accepted....On the spur of the moment I stood up and addressed to Prof. Dhawan'.....As a Mission Director....I take responsibility for the SLV – 3 failure'. For quite some there was pin drop silence in the hall. Then Prof Dhawan got up and said, 'I am going to put Kalam in space!' and left the place signalling that the meeting was over"

9. Kalam brings the guidance of Dr Brahma Prakash to the forefront in those days of agony. To quote, "He always cautioned me against haste. 'Big scientific projects are like mountains, which should be climbed with as little effort as possible and without urgency. The reality of your own nature should determine your speed. If you become restless, speed up. If you become tense and high-strung, slow down. You should climb the mountain in a state of equilibrium. When each task of your project is not just a means to an end but a unique event in itself, then you are doing it very well', he would tell me". Who else but Brahma Prakash could have spoken like this, a philosopher-par-excellence and a practical technologist and yet a colossus in wisdom?

10. *With all the necessary corrections and modifications the SLV -3 was ready for its second flight in another year and "In the early hours of 18, July 1980 – 0803 hrs to be precise, India's first Satellite Launch Vehicle SLV -3 lifted off from Sriharikota. At 600 seconds before take-off, I saw the computer displaying data about stage IV giving the required velocity to the Rohini Satellite(carried as payload) to enter its orbit. Within the next two minutes, Rohini was set into motion in a low earth orbit. I spoke in the midst of screeching decibels the most important words I had ever uttered in my life, 'Mission Director calling off stations. Stand by for an important announcement. All stages performed to mission requirements. The fourth stage apogee motor has given the required velocity to put Rohini Satellite into orbit'. There were happy cries everywhere. When I came out of the Block House, I was lifted onto the shoulders of my jubilant colleagues and carried in a procession... Prof. Satish Dhawan threw his customary guardedness to the winds and announced that it was now well within our ability to explore space. Prime Minister Indira Gandhi cabled her congratulations....The next SLV -3 flight, SLV3 – D1 took off on 31 May, 1981. I witnessed this flight from the visitors' gallery"...And so on. "By the world standards prevailing in the 1980s, SLV -3 was a tiny launch vehicle. But it was a giant leap for India", to quote from SLV -3 Silver Jubilee Souvenir, VSSC.*

11. *Undoubtedly through the SLV -3 successes ISRO also had created a team of launch vehicle specialists for its future programs, To quote Gupta , "India ventured on the development of self-reliance in rockets and space launch vehicles with the involvement of a small number of young Indian graduates and post-graduates, a few of them educated abroad. Only a few of them had exposure to Space Technology.....It was clear at the outset that self-reliance would happen only through self-help and self-learning. It was also clear that sustaining methodology of learning will be none other than the age old methodologies of learning by doing,*

doing with understanding, understanding enough to make physical as well as mathematical cum quantitative models of the items under design. Utilizing these principles, ISRO evolved and utilized a concept of a 'learning spiral'...including 'simulate and predict' and 'compare actual and predicted', 'interpret difference' and 'identify redesign parameters'.....There is an obvious corollary to the learning cycle, 'do not test before predicting the results', because ability to predict is a test of the level of knowledge possessed by the designer...Also one should not characterize the test results in mere binary terms of 'success or failure', but should interpret them in the larger word length of differences between the profiles of prediction and test results. The learning spiral has been immensely effective in producing steadily improving results speedily... –

12. "ISRO in general and the launch vehicle team in particular made concerted efforts to evolve and practice not only the work culture delineated above but also a few more attributes to meet the challenges". This included (a) Clear objectives (b) micro level planning and implementation from end to end (c) Comprehensive quality and reliability policy (d) Professional growth of individuals in the team ((e) Conscious use of resources available elsewhere to reduce in-house work load (f) Simplifying industry interaction and utilization and so on. Gupta goes into fair detail in Chapter 6 the major challenges and how they were solved through the second SLV -3 flight success. To give major example, "It was a major achievement in the learning process when the team developed during the course of the SLV -3 project an innovative analytical method for solving the problem of determining allowable tolerances...The method has since then become the standard method for the design of all the subsequent launch vehicles, such as ASLV, PSLV and GSLV". And so on with respect to many systems, sub-systems, propellants, FRP components, etc., just to mention only a few etc. The interested reader may refer Gupta for further details Cf. "Building Rockets and the Team". The detailed profile and contributions of the complete SLV -3 team has been exquisitely described in the VSSC – Astronautical Society of India joint publication "Development of SLV -3" as a souvenir commemorating its Silver Jubilee Celebration in 2005.

13. 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!



14. 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.

(To be continued).