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VP News

Vigyan Prasar Brings out Popular Science Books in Braille

The first set of books in Braille brought out by Vigyan Prasar for visually handicapped children was released by Honourable Minister of State for Science and Technology, Shri Bachi Singh Rawat, on the occasion of the National Science Day on February 27, 2002. Also present at the function were Honourable Union Minister for Science and Technology and Human Resource Development, Prof. Murli Manohar Joshi, Prof. V.S. Ramamurthy, Secretary, Department of Science and Technology, Dr. (Mrs) Manju Sharma, Secretary, Department of Biotechnology.



Honourable Minister of State for Science and Technology, Shri Bachi Singh Rawat, releases popular science books in Braille brought out by Vigyan Prasar, in presence of Honourable Union Minister for Science and Technology, Prof. Murli Manohar Joshi. Also seen are Prof. V.S. Ramamurthy, Secretary, DST, and Dr. (Mrs) Manju Sharma, Secretary, Department of Biotechnology.

The Minister presented the books in Braille –*Kahani Map tol Ki, Khel Khel Mein* and *Let's Sing and Play* – to two children from National Association for the Blind (Photo on page 21). Vigyan Prasar plans to bring many more of its popular science titles in Braille in the near future.

Launching of NSTMIS Website

National Science and Technology Management Information System (NSTMIS), Department of Science & Technology launched its website, www.nstmis-dst.org on Internet. The site, designed and developed by Vigyan Prasar, was inaugurated by the Honorable Minister of State for Science & Technology, Shri Bachi Singh Rawat, on the occasion of National Science Day on February 28, 2002, at Technology Bhawan, New Delhi. Prof. V.S. Ramamurthy, Secretary DST, Dr. Y.S. Rajan, Dr. Laxman Prasad, Head, NSTMIS and Dr. V.B. Kamble, Director, Vigyan Prasar, were also present during the function.

The site aims at providing information on continuous basis on resources – manpower and financial – devoted to S&T activities in the country.



Honourable Minister of State for Science & Technology, Shri Bachi Singh Rawat, unveils the website of NSTMIS on February 28, 2002. He is flanked by Prof. V.S. Ramamurthy, Secretary, DST (Left) and Dr. Laxman Prasad

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...think scientifically, act scientifically ... think scientifically, act scientifically ... think scientifically, act...

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Scientific Laws and Society

"Give him a push, otherwise he cannot overcome his inertia!" "Once he gains some momentum he will be on his own!" "Do not hit him, he will hit back!" "Today's world has become so competitive that only the best can survive!" "Not all can do every kind of job, only certain type of people can do certain types of job!" "Unless one puts in a conscious effort, things can only deteriorate!" How often we hear such phrases! Indeed, these and many other phrases employed by us in everyday conversation originate from our experiences in different walks of life. What is more, we rarely come across any exception to these statements in the living world. We accept them as "laws" that govern human behaviour and hence society.

It is during our formal study of science that we become familiar with the laws that govern the natural phenomena. In due course, we realise that the laws of science do find parallels in fields other than science as well - be it in a social context or inter-personal behaviour. At a particular point of time, we feel convinced about the universal nature of the scientific laws and their applicability to almost any field of human activity. We are led to believe that our experiences in life - good or bad - were indeed manifestations of these laws.

As a result, we try to interpret almost every social phenomenon in terms of these "universal" laws. In due course, we tend to develop a faith that these are the laws that are fundamental to understand human nature. Surely, we marvel at the applicability of Newton's laws of motion to human behaviour when we talk about a push to overcome mental inertia which refers to the Newton's first law of motion. The tendency to react either physically or through angry words when hurt by someone is a manifestation of the Newton's third law of motion. When we say that only the best can survive in today's world, we are obviously talking of Darwin's famous law of survival of the fittest. A certain job that requires only certain kind of people to accomplish obviously refers to the natural selection doctrine of Darwin again. Finally, the statement that one needs to put in conscious and continuous effort lest order and discipline might deteriorate is an expression of the second law of thermodynamics. Indeed, one can find many more examples of application of scientific laws in fields other than science.

It is, however, necessary to exercise sufficient caution while applying the laws of science in the social context. Occurrence of an event in society is a result of several complex phenomena taking place simultaneously, or in quick succession. A social event is thus a sum total effect of different scientific laws operating within their domains either at the same time, or in quick succession. To understand or explain a social phenomenon or an event, it would be naive to take recourse to a particular scientific law in isolation, and ignore the rest.

Let us be more specific. Group clashes are often attributed to the Newton's third law of motion. However, if timely intervention is not made, there is every chance that the situation may deteriorate - the second law of thermodynamics making its ubiquitous presence felt.

Incidentally, there was a period in history spanning seventeenth and eighteenth centuries - the centuries in which Galileo and Newton lived - when the philosophers emphasized the use of reason as the best method of learning the truth, and relied heavily on the scientific method, with its emphasis on careful experimentation and observation. Indeed, this was called the Age of Reason. They attacked social injustice, superstition and ignorance. They blamed those who kept others in ignorance to maintain their vested interests and personal power. They believed that each person has a rational will which makes it possible to carry out plans, and has a capacity to reason. However, later on a great change occurred in people's outlook and the value system. They came to value feeling rather than the reason and prefer passion, individuality, and spontaneity to discipline, order and control.

Surely, to understand the complex social phenomena and how the scientific laws operate in the societal framework, it is today that we need the Age of Reason the most. Scientific knowledge and the laws of science should help us transform the society where peace and order prevail, and the quality of life improves. Let us refrain from tossing the names of great scientists to justify our actions or inactions. Let us not blame it on scientific laws for our misgivings!

□ V.B. Kamble

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Forty Years in Space

□ T.V. Jayan

*What you can do or dream you can, begin it
Boldness has genius, power and logic in it*

- Goethe

There are some who question the relevance of space activities in a developing nation. To us, there is no ambiguity of purpose. We do not have the fantasy of competing with the economically advanced nations in the explorations of the moon or the planets or manned space flight. But we are convinced that if we are to play a meaningful role nationally, and in the community of nations, we must be second to none in the application of advanced technologies to the problems of man and society which we find in our country

-Vikram Sarabhai

A dozen operational satellites today in orbit, half of which launched by its own rockets; not a mean feat for the Indian space programme, considering that it has been done on what is called "a shoe-string budget". These satellites, in geo-synchronous and polar orbits, in addition to help carrying communication and broadcasting services to every nook and corner of the country, provide valuable remote sensing data on natural resources and weather information to aid national and state level planning.

The Indian space programme, which commenced with the launch of a tiny sounding rocket acquired from National Aeronautics and Space Administration (NASA) of the United States in 1963, reached a high point when Indian space scientists successfully test-fired a 401-tonne Geo-synchronous Satellite Launch Vehicle (GSLV), the massive-ever rocket to blast off from the Indian soil, from Sriharikota Launch Centre on April 18, 2001. The success of the first developmental flight of GSLV meant that India achieved the capability to launch communications satellites as heavy as 2000 kg into an orbit 36,000 kilometre high, realizing the dream of Vikram Sarabhai, the father of Indian space science, of achieving self-reliance in space technology.

Currently India has six INSAT (short for Indian National Satellites) satellites such as INSAT-3C, INSAT-3B, INSAT-2E, INSAT-2DT, INSAT-2C and Gramsat (which is placed in orbit by the maiden flight of GSLV) in geostationary orbit. These multi-purpose satellites provide communication, broadcasting and meteorology services. Except Gramsat, all other satellites were launched by European Space Agency's Ariane rockets from Kourou in French Guyana during the last seven years. INSAT-3C, the latest to be put in orbit on January 22 this year, would replace INSAT-2C whose life ends by the end of 2002. Out of 17 C-band transponders of INSAT-2E, 11 have been leased to International Telecommunications Satellite organisation (INTELSAT).

Similarly, India currently has six remote sensing satellites in the polar sun-synchronous orbit. These IRS (short for Indian Remote Sensing) satellites, namely, IRS-1B, IRS-1C, IRS-1D, IRS-P3 and Oceansat are used for natural resource surveys and management. Besides, India, in October 2001, put a Technology Experiment Satellite (TES) in sun-synchronous orbit. All these IRS satellites but IRS-1B and IRS-1C were placed in orbit by indigenously-built Polar Satellite Launch Vehicle (PSLV), which was first test-fired in 1993. Though the maiden PSLV flight failed, all subsequent launches were a success. Since then, PSLV emerged as a reliable launcher with three major countries such as Germany, Belgium and South Korea opting for its services to put scientific payloads in polar orbit.

Sarabhai, who scripted a vision for India in space research in the early sixties, had no doubt that a good understanding of science and its sound application in the form of technology is absolutely essential for development of a nation. It is this clear thinking that helped him counter those who raised eyebrows about India embarking on a space programme while its people were finding it hard to have two square meals a day. He also believed that India should not make the mistake of initiating scientific research in new and fashionable fields for the sake of prestige. The selection of a field of activity, he felt, should depend upon the contribution it can make to the defined national goals. In line with these goals, he identified three specific applications for space research in India: remote sensing, communications and meteorology. Even today, these three areas remain the *raison d'être* of the Indian space programme.

Thanks to Sarabhai's persistent efforts, the Indian space programme, had a humble birth in a sleepy fishing hamlet, outside Trivandrum town (now Thiruvananthapuram) in Kerala, when Indian National Committee for Space Research (INCOSPAR), set up in 1959, chose this location for setting up a sounding rocket launching facility four years later. A team of six young scientists and engineers, all in their twenties, were sent to the U.S. for training, before they were asked to proceed to Thumba to launch a Nike-Apache rocket procured from NASA. Their trials and tribulations and sweet success at the end had been well recorded in the annals of history of Indian science.

Four years later, first indigenously designed and built sounding rocket, weighting just 10 kg and having a diameter of 75 millimetre (Rohini-75), was launched from the Thumba Equatorial Rocket Launching Station (TERLS). It attained an altitude of 4.2 kilometre. Rohini-75 (RH-75) might have been a plaything, if compared to the GSLV which was 40,000 times heavier, but it helped Indian space scientists establish a strong foundation in rocketry. Subsequent years saw India building and launching taller and heavier sounding rockets to higher altitudes using home-made propellants. In a matter of five years, the launch weight of Indian rockets increased from 60 kg to over two tonnes. There was a substantial increase in number of subsystems and components that went into rockets as well.

Scientists soon realized the importance of developing and producing suitable propellants for the rocket programme. Propellants which supply energy to the rocket are generally divided into two classes - solid or liquid. While sounding rockets generally use solid propellants, heavier satellite launchers use a combination of solid and liquid propellants. While solid propellants are relatively easy to produce, they have an inherent disadvantage; they cannot be switched off, once ignited. On the other hand, liquid propellant technology is



Vikram Sarabhai
(1919-1971)

complex, but the energy efficiency of liquid propellants is high.

As the know-how to develop propellants was closely-guarded, as being part of missile technology abroad, India embarked on a programme to develop indigenous propellant technology right from the start. While the first few sounding rockets launched from Thumba such as RH-75, RH-100 and RH-125 (numbers indicate the diameter of the rockets) used cordite (a mixture of nitroglycerine and nitrocellulose) procured from a factory in the neighbouring State of Tamil Nadu, the need for developing a new propellant in-house was felt. The efforts to develop new propellants were independently led by two eminent scientists - Vasant Gowariker, who later became the Director of Vikram Sarabhai Space Centre (VSC), Thiruvananthapuram, and Secretary of Department of Science and Technology (DST) and A E Muthunayagam, currently Secretary of the Department of Ocean Development (DoD). Gowariker, a chemical engineer of repute, was working with the UK Atomic Energy Authority, before he was wooed away by Sarabhai to make propellants for Indian rockets. Gowariker, years later, was quoted as jocularly saying his first laboratory in Thumba was housed in a cowshed, adjacent to the St. Mary Magdalene's church!

Whatever be the conditions in which these two teams were working, both were successful in independently developing new solid propellants based on raw materials available in the country. During these initial years of space research in the country, Sarabhai and his band of young scientists were using lightweight sounding rockets for various atmospheric phenomena.

The resounding success achieved in designing and making sounding rockets prompted the Indian Space Research Organisation (ISRO), initially formed as a part of the Department of Atomic Energy (DAE) in August 1969, to commence work on a satellite launch vehicle (SLV). Sarabhai had taken over the mantle of DAE following the sudden demise of Homi Bhabha in a plane crash in 1966. But a satellite launch vehicle was much more complex than a sounding rocket. Unlike a sounding rocket which has to carry its payload till the fuel is exhausted, a launch vehicle has to have complex guidance and control system so that that a satellite is injected into a desired orbit. Besides, it needs to have multiple stages of propellants.

The SLV-3, an Indian SLV thus planned, was to have four stages, all powered by solid propellants. Sarabhai handpicked four young scientists working with him to entrust the task of designing each of these stages. In addition to Gowariker and Muthunayagam, M R Kurup and A P J Abdul Kalam, who later became the chief architect of Indian guided missile programme and later the Scientific Adviser to the Defence Minister and head of the Defence Research Development Organisation (DRDO), were drafted in. SLV-3 was to have a lift-off mass of 17 tonnes, with the solid propellants accounting for three-quarters of the total weight.

Untimely death of Sarabhai on December 30, 1971, at the age of 52, was a major blow to the Indian space programme. A visionary par excellence, Sarabhai's contribution to diverse fields such as science, business and administration was unparalleled in the Indian history. Even while managing the affairs of atomic energy and space research, he was finding time to

run the family-owned business and create institutions in other areas. Among the institutions he built and nurtured are the Physical Research Laboratory (PRL), the Ahmedabad Textile Industry's Research Association (ATIRA), Sarabhai Research Centre and Operations research Group (ORG), a market research organization, besides several private companies. Prof.

U R Rao, one of his students at PRL and former chairman of ISRO, says: "The country as well as the world has seen many a greater scientist, or an administrator, industrialist or a social reformer, manager or a skillful diplomat. Vikram Sarabhai's unique stature lies in brilliantly combining all these roles in himself. He was able to combine his intense desire to establish new institutions and innovative traditions with an excellent sense of economics and managerial skill. Above all, he was a very warm and charming person, always smiling and never losing his poise, even in the face of most adverse situations."

After Sarabhai, Prof. Satish Dhawan, then the director of Indian Institute of Science (IISc), Bangalore, took over the charge of the Indian space programme, even though Prof. M G K Menon was at the helm of affairs for a brief period of six months. In June 1972, the Department of Space and the Space Commission were set up. And ISRO was brought under the Department of Space.

If the Indian space programme owes its birth to the vision of Sarabhai, it was Prof. Dhawan who gave muscles and sinews to the programme. Under Prof. Dhawan, Sarabhai's vision crystallised into a series of successful missions. The first one to be so was the SLV-3 project.

By late 1973, designs of several subsystems that were to go into SLV-3 were finalised and the project was conceived as a major national venture involving some 46 organisations in both public and private sectors. Abdul Kalam, whose team successfully designed the composite fourth stage for SLV-3, was appointed as the project director of the programme. Though originally a four-year schedule had drawn up for the first experimental flight, it took good six years to complete. The first flight of SLV-3 on August 10, 1979, however, was only partially successful. But within less than

one year, the second experimental flight of SLV-3 succeeded in putting Rohini remote sensing satellite in orbit from Sriharikota, a newly-developed satellite launch facility on the eastern coast.

During Prof. Dhawan's initial years in ISRO, a number of programmes were initiated. Designing and development of indigenous satellites and various projects in space application were some of them. Shortly before he took over, India had entered into an agreement with the

erstwhile Soviet Union for launching a satellite that ISRO was planning to build indigenously. This scientific satellite, later named after Aryabhata, the famous astronomer-mathematician who lived in India in the 5th century AD, had to be built. This task of building this satellite with a unique structure with 26 faces and a weight of 350 kg was given to a team of 200 dedicated scientists and engineers led by U R Rao. These experts, drawn from organizations such as the Hindustan Aeronautics Limited, Bharat Electronics Limited, Electronics and radar Development Establishment, Indian Institute of Science and other private companies, worked day and night at an obscure facility in the Peenya Industrial Estate, near Bangalore, for two and half years to make Aryabhata ready for launch from a Russian launching



GSLV lifts off from Sriharikota



Antariksh Bhavan, the ISRO headquarters

Milestones in Indian space research

Jan 22, 2002	INSAT-3C launched by Ariane launcher from Kourou, French Guyana.
Oct 22, 2001	PSLV launches three satellites — Technology Experiment Satellite (TES), BIRD of Germany and PROBA of Belgium — into their intended orbits.
April 18, 2001	The first developmental launch of GSLV-D1 with GSAT-1 on board from Sriharikota.
March 22, 2000	INSAT-3B, first satellite in third generation INSAT-3 series, launched from Kourou, French Guyana.
May 26, 1999	OCEANSAT (IRS-P4), launched by PSLV along with Korean KITSAT-3 and German DLR-TUBSAT from Sriharikota.
April 3, 1999	INSAT-2E, last satellite in INSAT-2 series, launched from Kourou, French Guyana.
January 1998	INSAT-2DT, acquired from ARABSAT, becomes functional.
Oct 4, 1997	INSAT-2D, launched on June 4, 1997, becomes inoperable. An in-orbit satellite, ARABSAT-1C, since renamed INSAT-2DT, was acquired in November 1997 to partly augment the INSAT system.
Sep 29, 1997	First operational flight of PSLV places IRS-1D in polar sun-synchronous orbit.
Mar 21, 1996	Third developmental launch of PSLV puts IRS-P3 in polar sun-synchronous orbit.
Dec 28, 1995	Launch of third operational Indian Remote Sensing Satellite, IRS-1C.
Dec 7, 1995	INSAT-2C launched by an Ariane rocket.
Oct 15, 1994	Second developmental launch of PSLV with IRS-P2 on board.
May 4, 1994	Fourth developmental launch of ASLV with SROSS-C2 on board. Satellite was placed in orbit.
Sep 20, 1993	First developmental launch of PSLV with IRS-1E on board. Satellite could not be placed in orbit.
July 23, 1993	INSAT-2B, the second satellite in the INSAT-2 series, launched.
July 10, 1992	INSAT-2A, the first satellite of the indigenously-built second-generation INSAT series, launched.
May 20, 1992	Third developmental launch of ASLV with SROSS-C on board. Satellite placed in orbit.
Aug 29, 1991	Second operational Remote Sensing satellite, IRS-1B, launched.
June 12, 1990	INSAT-1D launched.
July 21, 1988	INSAT-1C launched. Abandoned in November 1989.
July 13, 1988	Second developmental launch of ASLV with SROSS-2 on board. Satellite could not be placed in orbit.
March 17, 1988	Launch of first operational Indian Remote Sensing Satellite, IRS-1A.
March 24, 1987	First developmental launch of ASLV with SROSS-1 satellite on board. Satellite could not be placed in orbit.
April 3, 1984	Rakesh Sharma, first Indian cosmonaut, was put in space by a Russian spacecraft.
Aug 30, 1983	INSAT-1B launched.
April 17, 1983	Second developmental launch of SLV-3 places Rohini satellite in orbit.
April 10, 1982	INSAT-1A launched. Deactivated on September 6, 1982.
Nov 20, 1981	Bhaskara-II launched.
June 19, 1981	APPLE, an experimental geo-stationary communication satellite successfully launched.
May 31, 1981	First developmental flight of SLV-3 puts Rohini remote sensing satellite in orbit.
July 18, 1980	Second Experimental launch of SLV-3, Rohini satellite successfully placed in orbit.
Aug 10, 1979	First Experimental launch of SLV-3 with Rohini Technology Payload on board. The mission partially failed.
June 7, 1979	Bhaskara-I, an experimental satellite for earth observations, launched.
1977	Satellite Telecommunication Experiments Project (STEP) carried out.
1975-1976	Satellite Instructional Television Experiment (SITE) conducted.
April 19, 1975	First Indian Satellite, Aryabhata, launched.
June 1, 1972	Space Commission and Department of Space set up. ISRO brought under DOS.
Aug 15, 1969	Indian Space Research Organisation (ISRO) was formed under Department of Atomic Energy.
Feb 2, 1968	TERLS dedicated to the United Nations.
1967	Satellite Telecommunication Earth Station set up at Ahmedabad.
1965	Space Science & Technology Centre (SSTC) established in Thumba.
Nov 21, 1963	First sounding rocket launched from TERLS
1962	Indian National Committee for Space Research (INCOSPAR) came into being under the Department of Atomic Energy and work on establishing Thumba Equatorial Rocket Launching Station (TERLS) started.



Prof. Satish Dhawan

facility on April 19, 1975. Placed in an Earth circular orbit at an altitude of 594 kilometres for 17 years, the satellite sent data for a period of five years, even though it was designed for an active life of six months. By the time it re-entered the atmosphere on February 10, 1992, Aryabhata completed 92,875 orbits of the earth. Certainly not a mean achievement for a first indigenously-designed satellite!

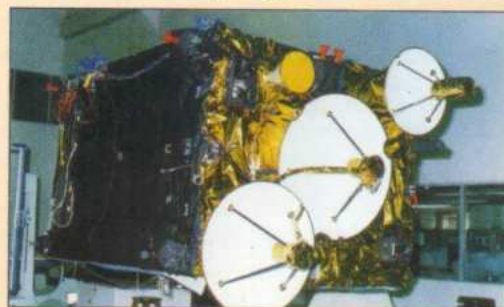
Subsequently, the Bhaskara-I and Bhaskara-II, two earth observation satellites were launched from Soviet union in 1979 and 1981

respectively. These satellites, along with Rohini satellites, which went up aboard the SLV-3, were the precursors of the operational Indian remote sensing (IRS) series of satellites. The Ariane Passenger payload Experiment (APPLE), put in a geo-synchronous orbit by an Ariane launcher in June 1981, gave India the hands-on experience needed to build the second-generation INSAT class satellites within the country.

The Indian space programme's greatest asset has been Sarabhai's vision. In the early and mid-sixties when applications using satellites were in experimental stages even in the United States, Sarabhai was quick to recognize their benefits for India. He foresaw that satellites could usefully supplement ground-based systems for providing many services in communications, direct TV broadcasting, remote sensing and meteorology.

The Indian space programme, has been application-driven right from the beginning. Building satellites and launch vehicles were a means to that end, not an end in themselves. To achieve this, Sarabhai chalked out a clear step-by-step strategy. He was very clear that ISRO would not wait for its own satellites to begin application development. Instead, foreign satellites would be used in the initial stages so that applications could be proven, ground systems could be put in place and users and scientists could be familiarised with the new technology. Later on these technologies could be mastered to make indigenous systems. ISRO had strictly adhered to this in all its major space projects such as INSAT, IRS, PSLV and GSLV.

Remote sensing was one of the first space applications to be put to use in India. An aerial survey using infra-red film was carried out from a helicopter in 1970 to study root-wilt disease of coconut plantations in Kerala. Also, ISRO in association with France developed an infra-red scanner which was used for various applications in 1972. Even before the Americans had launched the world's first civilian remote sensing satellite, the Earth Resources Technology Satellite (later renamed as Landsat), India had requested access to data from the satellite. As a result, India became one of the earliest users of Landsat when the first satellite was launched in mid-1972. Subsequently, a ground station to receive data



INSAT-3C

It all started in a church.....

When an expert team led by E V Chitnis zeroed in on Thumba, a sleepy fishing village, on the outskirts of Trivandrum (now Thiruvananthapuram), to set up India's first sounding rocket facility some 40 years ago, there existed nothing but an old church and a few hundred thatched huts. Scientists, however, had no difficulty in acquiring land for the facility in less than 100 days, thanks to the efforts of the then collector of Trivandrum, K Madhavan Nair and Bishop of Trivandrum, Right Rev. Dr Peter Bernard Pereira. The Bishop not only gifted the land in which St. Mary Magdalene's Church stood, but persuaded the fishermen, most of them Christians, to vacate their dwellings for a better cause.



St. Mary Magdalene's Church

The 600 acres-land, thus acquired, was transformed to the rocket launching facility, Thumba Equatorial Rocket Launching Station (TERLS). Thumba became an ideal choice for launching sounding rockets because it lies very close to the Earth's magnetic equator.

When a team of young scientists and engineers descended on Thumba to launch Nike-Apache rocket, a sounding rocket gifted by NASA, in 1963, the church and its parsonage became their first laboratories and offices. The church has since been preserved as a space museum.

According to R Aravamudan, one of the team members who had returned after a six-month training in sounding rocket launching at Goddard Space Flight Centre and at the Wallops Island Facility in the United States, the scientists had a shock of their life in seeing the facilities available to them at Thumba for undertaking the first-ever rocket launch from the Indian soil. Aravamudan, who later became the director of Sriharikota Launch Centre (SHAR) and ISRO Satellite Centre, wrote in his piece "Then...And Now" in "20 years of Rocketry in Thumba: 1963-1983", published by the Vikram Sarabhai Space Centre (VSSC), Thiruvananthapuram, in 1983: "Coming straight from NASA, both Trivandrum and Thumba proved to be shock. Our facilities at Thumba consisted of one launcher, a church and some old fishermen's dwellings - a very far cry indeed from the luxury in terms of equipment and facilities which we had got used to at Washington DC and Wallops Island. At Trivandrum, too, it was difficult to get convenient accommodation, and food was a problem...Every morning, we would walk up to the railway station, eat breakfast at the canteen, pick up some packed lunch and take a bus....At Thumba, we sat in the church building, which we shared with generations of pigeons. All those facilities which Sarabhai had talked of were still very much a dream."

The first launch that took place on November 1963 was also not devoid of any anxious moments. The scientists and engineers operating from the church building had bare minimum facilities to assemble the rocket and launch it. The only equipment available to transport the rocket to the launch pad was an old jeep and a manually operated hydraulic crane. When the rocket was about to be placed on the launcher, the crane developed a leak and the scientists had to lift the rocket manually, using their collective muscle power!

TERLS, which successfully launched hundreds of sound rockets subsequently, was dedicated to the United Nations on February 2, 1968.

directly from the satellite was set up. Currently, India is said to have some of the best civilian remote sensing satellites - IRS class - in orbit. India has also developed and perfected launch technology for these satellites. Today, even some advanced countries are using PSLV rockets for launching their micro and mini satellites.

Similarly in the area of broadcasting. In 1969, India signed an agreement with NASA for the Satellite Instructional Television Experiment (SITE). As a result, NASA lent its ATS-6 satellite to India for a year in 1975-76 to demonstrate direct TV broadcasting as an instructional medium for reaching numerous villages in different states in the country. SITE Became the earliest large-scale experiment with direct broadcasting in anywhere in the world.

In 1975, ISRO signed an agreement to use the Franco-German satellite, Symphonie, for Satellite Telecommunication Experiments Project (STEP). One of Symphonie's two transponders was made available to India from June 1977 for experiments with communications over satellite, radio networking and TV transmission.

It was in the late sixties, India first started examining the feasibility of a domestic geostationary satellite system. A paper presented by Sarabhai in March 1970 worked out the broad details of an Indian National Satellite (INSAT) system. The paper suggested that India should procure the first set of satellites from abroad and build the subsequent series in India. A high-level committee set up in 1975 to work out the scope, timing and implementation strategy for satellite communication, proposed a three-in-one satellite concept. This means that each INSAT series satellite will provide telecommunications, television and weather data. Though such a design was complex, it was found to be very cost-effective and suitable to a developing country like India.

Since Ministries of Communication, Information & Broadcasting and Science & Technology were the major users of the data available from such satellites, the Government decided to involve them in the INSAT programme right from the scratch. It was in 1978, India awarded a contract to design and build two INSAT-1 satellites to Ford Aerospace Corporation of the U.S. (now Space Systems/Loral). Two more satellites, INSAT-1C and INSAT-1D, built abroad, were put in orbit, before India embarked on indigenously building INSAT 2 series satellites. Though it was originally decided that the first INSAT-2 test satellite would be launched in 1989, the mission was delayed by about two and a half years. Subsequently, ISRO had launched four more satellites in INSAT-2 series, the last one being INSAT-2E, launched in April 1999. Since then, ISRO has launched two third-generation INSAT satellites - INSAT-3-B and INSAT-3C. GSLV, demonstrated for the first time in April last year, is capable of launching INSAT class satellites into geo-synchronous orbits. The operationalisation of GSLV technology, expected in the near future, will make it possible for ISRO to launch all its satellites on its own and even offer launch services to other countries as well.

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Indian Space Programme : Achievements and Future

Dr K Kasturirangan, the present Chairman of the Indian Space Research Organisation (ISRO), answers questions on the achievements and future of Indian space programme in an E-mail interview to *Dream-2047*.

Dream-2047: From sounding rockets to latest Geosynchronous Satellite Launch Vehicle (GSLV), from Aryabhata to multi-purpose INSAT series satellites, Indian space programme has come a long way in its 40-year-long history. What, according to you, have been the major factors that made these significant achievements possible?

Dr. K Kasturirangan: It is indeed a significant achievement, especially for a developing country like India to have successfully implemented the space programme that is well tuned to the national developmental task. What is more important is the self-reliance that has been established over the years.

The most important factor that helped ISRO to succeed in its programme is the vision that was provided by Dr Vikram Sarabhai - the father of Indian space programme. He was succeeded by eminent leaders — Prof Satish Dhawan, a great scientific administrator who could see the Indian space programme go through the experimental phase in the 70's, thus laying a strong foundation and, succeeding him, Prof U R Rao made the space programme enter the operational phase of providing space services. In the last 8 years, We have tried to consolidate the efforts in bringing maturity to the space programme and match the launch capability of the Indian launch vehicles with the requirement of our satellites like IRS and INSAT.

The right type of leaderships provided at different phases of the Indian space programme matched by the dedicated efforts of the ISRO personnel, a majority of whom have come from the Indian universities and institutions. More importantly, the political support, irrespective of the parties to which they belong, has played a catalytic role in our success.

Dream-2047: GSLV, whose first development flight took place in April last year, is often cited as the chief element of Sarabhai's vision. The next few years will see ISRO perfecting and reinforcing its GSLV launch capabilities. But what next? What will be the next major technological challenge that ISRO plans to take up?

Dr. Kasturirangan: The successful flight of GSLV in April 2001 is, in a sense, a fulfilment of Dr Vikram Sarabhai's vision. Dr Sarabhai wanted India to design and develop, indigenously, satellites and launch vehicles to meet the national developmental requirements like satellites for remote sensing and communication, television broadcasting, meteorology, disaster management, etc. Today we are capable of building our Indian remote sensing satellites (IRS) and the INSATs which are meeting the national requirements. Our PSLV has enabled us to launch the IRS satellites indigenously. Once commissioned, GSLV will enable us to launch the INSAT class of communication satellites also with our own launch vehicle. Thus, it is a fulfilment of Dr Sarabhai's dream of an indigenous space programme, precisely tuned to the national development.

Certainly we cannot be satisfied with what we have achieved so far. The technologies continue to change fast. We have to constantly update the systems that we have developed. We are already working on the follow-on satellites in the IRS and INSAT series. The planned CARTOSAT and RESOURCESAT will have much better spatial and spectral resolutions than the present IRS satellites. We are also working on microwave remote sensing

satellites to overcome the limitations of present satellites, that operate in visible spectral-bands and hence cannot be used for imaging in cloudy conditions. Similarly, we are planning the INSAT-4 series of satellites, which will take into account the projected requirement of transponders by the users in the coming five to six years.



Dr. K. Kasturirangan

We are also embarking on advanced scientific missions one on launching an exclusive satellite for astronomy called ASTROSAT and we are conducting studies for a possible scientific unmanned mission to moon.

Our PSLV capability is constantly being improved to take heavier IRS satellites. We have already embarked on improved versions of GSLV, so as to improve its capability to take up to four tonne payload into GTO in about six years.

All these provide us sufficient technological challenges.

Dream-2047: It is said that ISRO is planning an unmanned Lunar Mission. What is the significance of such a mission, considering the fact that the man had landed on Moon in the late sixties itself? How is it going strengthen our space technology programme?

Dr. Kasturirangan: A Lunar Mission Task Force set up by ISRO is now considering various possibilities for sending an unmanned spacecraft to orbit the moon.

The Lunar Mission can provide impetus to science in India, challenge to technology and, possibly, a new dimension to the international cooperation. It can also serve as a test bed for future missions that could be undertaken by India to explore outer world in the new millennium. It can maximally use the scientific and technical capabilities that India has acquired so far in terms of launch vehicles, satellites and scientific, technological and application payloads thus integrating the knowledge for Lunar exploration.

The Indian Lunar Mission will take into account the missions carried out so far which have been mainly exploratory in nature. Some of the possible scientific objectives could be extensive investigation of particle and radiation environment in the vicinity of moon, understanding distribution of rare elements through Gamma-ray spectrometry, study of detailed aspects of surface composition and sub-groups of rocks, study and analysis of cometary dust over moon's surface and detailed mapping with high resolution stereoscopic photography.

Dream-2047: India is said to be the only space power that has gone for multi-purpose satellites? Why is it so? What are the benefits accruing from packing varied payloads in a single satellite?

Dr. Kasturirangan: As I said earlier, Indian space programme is tuned to our national requirement. Our space programme cannot be derived from those of others whose requirements are entirely different. When we took up the INSAT-1 series of satellites, the

socio-economic and other requirements for a large country like India made us to design a unique multi-purpose satellite that combined telecommunications, television broadcasting and meteorology on a single platform. It did work well for us and when we developed our own first two satellites, INSAT-2A and INSAT-2B, and subsequently, INSAT-2E, we went for multipurpose satellites. INSAT-3A will also be a multipurpose one.

However, with the increasing communication capacities required on these satellites, we are now planning exclusive satellites for communications and meteorology. It is in this direction that we are going to have the first satellite exclusively for meteorology, namely, METSAT. This will also help us to launch the METSAT using our own PSLV. Therefore, we have been tuning and revising our space systems depending upon the actual requirement, the economy and the time factors for implementing them.

Dream-2047: Does a multi-purpose satellite offer more challenges for a satellite designer than that carry a single payload?

Dr. Kasturirangan: The multipurpose satellite is certainly more complex to design and build. For example, when we have a meteorology payload like the Very High Resolution Radiometer (VHRR) with a thermal infrared detector, it calls for special thermal management. The reference detector has to be maintained at a constant temperature. This is achieved by making the reference detector to look at north and we do not even allow the sunlight to disturb the temperature of the detector. Therefore, in these satellites, we cannot have a solar panel on the north side that can reflect sunlight on to the detector and it becomes necessary to have solar panel only on the south side and balance its weight with a long boom and sail on north which is deployed in orbit. It is a very complex system, but we have mastered it and used in our multi-purpose INSAT satellites.

Dream-2047: Considering that commercialisation of GSLV technology is just a couple of years away, in what time frame could ISRO become completely self-reliant in launching technology?

Dr. Kasturirangan: We are already self-reliant as far as launching Indian remote sensing satellites are concerned. Once GSLV is commissioned after another two flights, we should be self-reliant for launching the INSAT class of satellites. We have also planned to develop a new series of spacecraft bus weighing about 2000 kg that can be launched by GSLV in its present configuration but with a slight improvement.

Dream-2047: Indian industry has been playing a significant role in our space programme. Do you perceive a much bigger role for Indian industry in the near future? If so, what are the steps being taken by ISRO to make this a reality?

Dr. Kasturirangan: ISRO started involving the Indian industries since the beginning of the space program. India hardly had any industrial infrastructure to take up complex task of space hardware fabrication. In the last four decades, we have developed a good industrial base for taking up jobs from ISRO. In fact, a few industries have even set up separate process lines for meeting the requirement of space hardware. We do expect a much bigger role for the industries in the future. We want ISRO to predominantly remain an R&D organization and industries to take up the regular production of satellites and launch vehicles. We are working in this direction and having several discussions with the industry professionals through their fora like Confederation of Indian Industry (CII).

Dream-2047: What are the prospects of India offering its services to other countries in the field of space technology say satellite

launchers, fabrication of satellites, etc?

Dr. Kasturirangan: We have already made a mark in the international space market. The data from our remote sensing satellites are now received in about a dozen countries outside India under commercial agreements with the Antrix Corporation under the Department of Space. We have launched so far four small satellites, two of Germany, one of Korea and one of Belgium on our PSLV. Several space agencies use our tracking and telemetry support. We have also supplied several spacecraft hardware to other countries and offer training facilities to personnel of other countries under commercial agreements.

T.V. Jayan

Letters to the Editor

I received DREAM 2047, Nov. Issue. Thanks for regularly sending me this monthly newsletter of your organization. After going through this newsletter I circulate it among the graduate students and subsequently the issue is displayed in my college library for the benefit of other science faculty members.

Prof. Subhash Dondé

Dept. of Zoology, Kirti College, Dadar (West), Mumbai-400 028

Thanks for sending me copies of 3 recent issues of DREAM 2047. It not only has a catch title but is perhaps the only real bilingual popular science journal. Thanks for bringing it to my notice. The presentation is good and topics covered have a wide range. I feel a little more coverage could be given to science happenings in India and to accomplishments of Indian scientists and Indian scientific institutes. I will look forward with interest to future issues and would like to congratulate you and your colleagues involved in this unique and difficult work.

B.N. Dhawan

Former Director, Central Drug Research Institute,
3, Ram Krishan Marg, Faizabad Road, Lucknow-226007, (UP)

I would like to express my deep sense of appreciation for your bringing out such a nice monthly newsletter as the DREAM which gives scientific exposition on a given topic in a very lucid and easy-to-understand style.

Prof. B.P. Mukherjee

Bidisha Housing Complex, Flat No. 333, Abanindra Bithi, City
Centre, Durgapur-713216, West Bengal

The article on Mr. G.N. Ramachandran (1922-2001) by Subodh Mahanti and biography of Radha Gobind Chandra by Ranatos Chakrabarti are best for our knowledge.

Anil Gahlot

MIMS CLUB, 254/1, Nehru Nagar, Meerut

Dr. Subodh Mahanti has written an informative and compact article on J.D. Bernal; a great thinker of the twentieth century. According to 'Encyclopaedia Britannica', Bernal was "a man of wide public and scientific interests". It is a matter of glory that Bernal came to Calcutta (now Kolkata) on 11 January, 1950 to attend the inaugural ceremony of 'The Institute of Nuclear Physics' (now famous as Saha, Institute of Nuclear Physics) established by Prof. M.N. Saha. After Bernal's demise, Royal Society started 'Bernal Memorial Lecture' in his memory and in the year 1977 this memorial lecture was delivered by famous Soviet Physicist P.H. Kapitza.

Utpal Mukhopadhyay

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Robert Hutchings Goddard

Pioneer of Modern Rocketry

□ Subodh Mahanti

"I feel we are going to enter an era comparable in its progress to that in which the airplane advanced... It's just a matter of imagination how far we go with rockets and jet planes... I think it's fair to say you haven't seen anything yet."

Robert Hutchings Goddard

No one knew better than Robert Hutchings Goddard how far the journey was, or how fast one had to travel. His were the first footsteps in the human quest for unknown worlds. His memory soars with every rocket; his spirit mingles with the stars.

Suzanne M. Coil in *Robert Hutchings Goddard : Pioneer of Rocketry and Space Flight* (1992)

The earth is the cradle of mankind—one cannot remain in the cradle forever.

Konstantin Eduardovitch Tsiolkovsky

As the US aviator *Charles Augustus Lindbergh* (1902-74) said, "We live in a world where dreams and reality interchange." Yesterday's dream becomes today's hope and tomorrow's reality. If this has been possible in the past and it will be in the future it is because of such visionaries and dreamers like Robert Hutchings Goddard. In 1920 Goddard was ridiculed by the *New York Times* for his impossible vision of launching a rocket that could travel through the vacuum of space. On March 16, 1926 Goddard launched the world's first liquid fuel rocket. The *New York Times* issued a public apology to the late Goddard after Apollo astronauts took off for the first lunar landing.

Goddard was a great physicist. He had a unique genius for invention. Goddard was the first scientist to realize the potentialities of missiles and space flight and also to contribute directly in bringing them to practical realization. Along with Konstantin Eduardovitch Tsiolkovsky of Russia and Hermann Oberth of Germany, Goddard envisioned the exploration of space. Goddard designed and built the world's first liquid-fuel rocket, early high-altitude rockets and the first practical automatic steering device for rockets and to prove experimentally the efficiency of rocket propulsion in a vacuum. Goddard was among the first to develop a general theory of rocket action. Goddard laid the technical foundations for today's long-range rockets, missiles, Earth satellites and space flight.

Goddard was the first to receive a US patent on the idea of multistage rockets in 1914. The same year he also received a patent for a rocket using liquid fuel. During his life time he received 88 patents on his rockets and space travel ideas. Even after his death 131 patents were granted for his rocket-related ideas documented in his research notes and diaries. During the lifetime of Goddard, the US Government showed little interest in his work. It was after his death that Goddard was given due recognition for his pioneering work which led directly to National Aeronautics and Space Administration (NASA) and the US space exploration programme.

It was Goddard who first developed and launched a liquid fuel rocket on March 16, 1926. In 1929, Goddard first launched a scientific payload consisting of a camera and a barometer in

a rocket flight. Many things related to rocketry and space flight were first invented by Goddard viz. pumps suitable for rocket fuels, self-cooling rocket motor, variable thrusts rocket motors and practical rocket-launching devices. For developing rocket for space flight Goddard had to be specialist in metallurgy, aerodynamics, thermodynamics, structural engineering, mechanical engineering and hydraulic engineering. He almost single-handedly translated his ideas, which seemed mere fantasies, into reality. For him experimental failures were 'valuable negative information'. He sought results and not recognition.

Goddard was born on October 5, 1882 in Worcester, Massachusetts. In 1883, Goddard's parents Nahum Danford Goddard and Fannie Hoyt Goddard moved to Boston where

they were offered a partnership in a machine knife shop. Because of recurring illness (bouts of bronchitis and pleurisy - an inflammation of the lungs) Goddard could not attend school regularly. In spite of this Goddard did quite well in school. As his frail health did not permit him to take part in games and sports Goddard turned his attention to books. From his school days he developed a passion for space travel. This also reflected in his reading. Some of the books which influenced him were : Allan Poe's *Lunar Discoveries*; Joseph Atterlay's *A Voyage to the Moon*; Percy Greg's *Across the Zodiac*; Edward Everett Hale's *The Brick Moon*; Jules Verne's *From the Earth to the Moon*; H.G. Wells'

War of the Worlds and Garrett P. Serviss's *Edison's Conquest of Mars*. Goddard also read about the celebrated "Moon Hoax" of 1853, when a series of newspaper articles reported that lunar creatures had been seen through the telescope of Sir John Frederick Herschel (1792-1871). This episode demonstrated people's vulnerability in believing the existence of extraterrestrial life.

From his early readings Goddard concluded that space travel could be a reality if by some means one could propel a spacecraft far enough and fast enough to escape Earth's gravitational pull and with all sincerity he started experimenting with ways of launching objects into space. Goddard set up a laboratory in the attic of his house and started experimenting with ways of launching objects into space. At times his



Robert Hutchings Goddard (1882-1945)

experiments created unwanted problems for him. For example once when he was testing his well-reasoned theory that a mixture of hydrogen and oxygen might produce a force strong enough to lift an object in the air he ended up shattering his attic windows. Thus he learnt that while his reasoning was correct but a mixture of hydrogen and oxygen could be dangerous if not handled properly.

He tried to repeat Montgolfier brothers' hot-air balloon flight of 1783 by building a balloon of aluminium. He did not succeed in his early experiments. But his early failure or his well-wishers' advice against wasting time on haphazard experiments did not deter him from pursuing his goal. Goddard in his later years said that on October 19, 1899, he firmly decided to devote himself to the exploration of space while sitting on a high limb of a cherry tree. To quote Goddard: "It was one of those quite colourful afternoons of sheer beauty which we have in October in New England and as I looked forward the fields at the east, I imagined how wonderful it would be to make some device which has even the possibility of ascending to Mars, and how it would look on a small scale, if sent up from the meadow at my feet... It seems to me that a weight whirling around a horizontal shelf, moving more rapidly above than below, could furnish lift by virtue of the greater centrifugal force at the top of the path... I was a different boy when I descended the tree from where I ascended, for existence at last seemed very purposive." And since then the dream of space flight never left Goddard till he made it a reality.

In 1901 Goddard joined the South High School in Worcester where he found to his delight well-equipped science laboratories and enthusiastic teachers. While following his dream of building rockets and travelling in space, Goddard was also engaged in many other activities. He studied French, edited the school newspaper, acted in school plays, sang in a quartet at school shows, became class pianist and attended concert whenever he got the opportunity. For Goddard every branch of science was important and every phenomenon of nature was of interest for him. He developed a habit of writing detailed daily records of what he thought and planned. As early in 1901 he wrote an article entitled "The Navigation of Space" which he sent to a science magazine but it was rejected. He wrote more articles though none was ever published. For Goddard there was none who would take his dreams of space flight seriously and encourage him to go ahead with his ideas. His teachers thought the whole notion of rocketing was silly and impractical and there was no future for rocket inventors. Goddard was not discouraged. He later wrote, "The dream would not down... for even though I reasoned with myself that the thing was impossible, there was something

inside which simply would not stop working".

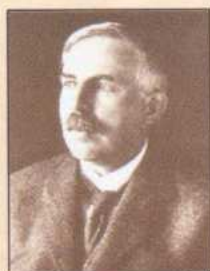
In 1904 Goddard joined the Worcester Polytechnic Institute. Though he was enrolled in the general science programme, he was mainly interested in physics - which he thought held the key to space travel. His first article on space flight entitled "The Use of the Gyroscope in the Balancing and Steering of Airplanes" was published in 1907 in *Scientific American*. The same year his paper entitled "On the Possibility of Navigating Interplanetary Space" was rejected by *Popular Astronomy*. While citing the reason for its rejection the editor wrote: "The speculation about it is interesting but the impossibility of ever doing it is so certain that it is not practically useful. You have written well and clearly, but not helpfully to science as I see it."



Edgar Allan Poe (1809-49)



Herbert George Wells (1866-1946)



Ernst Rutherford



Jules Verne (1826-1905)



Albert Abraham Michelson (1852-1931)

In 1908 Goddard graduated from Worcester Polytechnic Institute with high grades. He wanted to join the Clark University, also located in Worcester. But his parents were not in a position to finance his education at the Clark University and so Goddard accepted a teaching job at the Worcester Polytechnic Institute with an annual salary of US\$ 850.

At the Polytechnic Institute Goddard's activities were not confined to teaching only. He pursued his ideas about space flights vigorously. During this time he realised that Newton's reaction principle (or Newton's Third Law) held the key to launch rocket into the space. He tried to work out the basic mathematics of rocket propulsion. He developed a skeleton plan for a multiple-stage or step rocket. He also formulated a theory for using explosive jets fueled with hydrogen and oxygen to obtain lift.

In 1909 he joined the Clark University. At that time among the teachers at the Clark were A.A. Michelson, Ernest Rutherford, Vito Volterra and Robert Williams Wood. Goddard obtained his Master's degree in 1910 and one year later he took his Doctorate in physics. His PhD supervisor was Arthur G Webster, a famous mathematical physicist and his thesis was titled, 'On some Peculiarities of Electrical Conductivity Exhibited by Powder, and a few Solid Substances.' The subject of his PhD thesis was not of his liking. Otherwise on the basis of his work he could have made a career in the new field of radio as suggested by his teachers. After his PhD he spent another year at Clark though he had obtained lucrative job offer from Columbia University in New York and the University of Missouri. In September 1912 Goddard joined Princeton University in New Jersey, where he was offered a one year research fellowship for working on 'electricity, magnetism, infrared and electron theory'.

At Princeton while during day-time he worked on displacement-current experiment, in the night he continued to work on his theory of rocket propulsion. He was so excited and engrossed in his work that often he spent the whole night

working. His frail health could not withstand such long hours and hard work. He developed tuberculosis in both the lungs and that was the end of his work at Princeton University. He was forced to take complete bed rest for several weeks. But when he was allowed to work for only one hour a day Goddard produced, within a month, material for two US patents covering the essential of rocket propulsion — plans for multi-charge solid-propellant rocket, liquid propellant rocket, multi-stage rocket, technique for sending fuel into a rocket's combustion chamber and an exhaust nozzle to control the ejection of gases. In fact, these patents gave, as Goddard had observed, "as nearly as possible an answer to the question as to what the 'Goddard Rocket is.'"



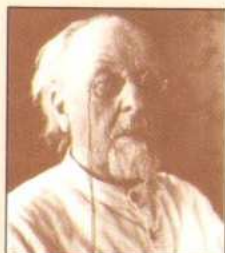
Vito Volterra

On September 1914 Goddard joined Clark University as part-time physics instructor. After the classes Goddard spent all his spare time experimenting to test his thesis on rocket propulsion.

Goddard was working on his own. He built his own equipment with the help of the mechanics at his father's company. A local industrial laboratory, the owner of which found 'it was almost impossible to turn him (Goddard) down,' tested gunpowder mixture for him. But there was a limit of stretching Goddard's own limited funds to support his research. He had to find financial support from elsewhere. The first outside financial support he got was from one of the most unlikely places - the Smithsonian Institution in Washington, D.C., established in 1846 'for the increase and diffusion of knowledge among men.' On being asked by Charles D. Wolcott, the then Secretary of the Smithsonian Institution that how much a high-altitude rocket might cost, Goddard wrote: 'I do not think that the work I have outlined could possibly be done within the time as short as one year for less than \$5,000.' His proposal for developing 'A method of Reaching Extreme Altitudes' was accepted and on January 8, 1917 Goddard got an acceptance letter along with a cheque for US \$1,000 as an advance for starting his work.

Orville Wright
(1871-1948)

When the USA entered the First World War the US Army Signal Corps asked Goddard (who was recommended to them by the Smithsonian Institution) to develop rocket for using in battle. Goddard moved his laboratory to Mount Wilson Observatory in Pasadena, California. On November 7, 1918, Goddard demonstrated two rockets - a long-range bombardment-rocket and another rocket that was fired from a light-weight recoilless launcher, a forerunner to modern bazooka. But four days after Goddard's successful demonstration the first World War ended and US Army did not find it necessary to go ahead with the production of Goddard's war rockets. And so Goddard came back to Worcester to

Konstantin Eduardovich
Tsiolkovsky

resume his work in the laboratories at Clark University.

Goddard's proposal submitted to Smithsonian Institution in 1916 requesting funds for continuing research became a classic of rocketry. This document along with his subsequent research and Navy work was published in January 1920 by the Smithsonian Institution. It was titled 'A Method of Reaching Extreme Altitudes'. The document is now considered as one of the fundamental classics of rocketry. However, at the time of its publication it resulted in public embarrassment for Goddard. This was because the media picked up Goddard's scientific proposal about a rocket flight to the moon described in the last section of Goddard's book titled "Calculation of Minimum Mass required to Raise one Pound to an 'Infinite' Altitude". In this section Goddard speculated that one

Charles Augustus
Lindbergh

day it would be possible to send a rocket to the moon. He even outlined the possibility of a rocket reaching the moon and exploding a load of flash powder to mark its arrival. In the 1920s such an idea surely looked crazy and ridiculous.

On March 16, 1936, the Smithsonian Institution brought out Goddard's report titled *Liquid-Propellant Rocket Development*. The report which briefly described Goddard's experiment since 1919 clearly established that Goddard was

Wilbur Wright
(1867-1912)

the first man who construct and launched the world's liquid fuel rocket (16 March 1926). Goddard had constructed and tested successfully the first rocket using liquid fuel. The original rocket flew from Goddard's aunt Effie's farm at Auburn, Massachusetts, to an altitude of 41 ft and landed 184 ft away, crashing into the snow. The flight took 2.5 seconds. Though the experiment was primitive but the flight of Goddard's rocket on March 16, 1926 at Auburn Massachusetts was a feat as epochal in history as that of the Wright brothers at Kitty Hawk. However, like in the case of Wright brothers, Goddard's rocket failed to impress upon Government officials. He did not receive any Government support for his research and testing. He received only very modest support from the Smithsonian Institution and the Daniel Guggenheim Foundation. He was also granted the leaves of absence by Worcester Polytechnic Institute of Clark University.



Hermann Oberth

It may be noted here that Goddard first attracted public attention in 1907 because of the cloud of smoke from a powder rocket fired in the basement of the physics building in Worcester Polytechnic Institute. Fortunately school officials did not expel Goddard. This was the beginning of Goddard's lifetime of dedicated work.

Goddard's historic flight of March 16, 1926 was not reported immediately. In fact it was not known to general public for a decade. Goddard was reluctant to make his results public



The postage stamp issued in USA in 1964 to honour Robert H. Goddard

until he had achieved more substantial results. Accordingly Goddard's flight of March 16, 1926 did not immediately open up the way to the development of modern rocketry. Unaware of detailed knowledge of Goddard's work, other rocket theorists and experimenters independently developed their own rockets. In fact, it is believed that Tsiolkovsky, a Russian school teacher, had understood the reaction principle as early as 1883. He had no means to test his theories. However, by 1919 he had thoroughly worked out the theoretical aspects of rocket propulsion and interplanetary flights. In his writings he described both the multistage rocket and the use of liquid nitrogen and liquid oxygen as fuel. Tsiolkovsky continued his theoretical research until his death in 1935. Another scientist who is acknowledged as one of the great pioneers of rocketry and astronautics was Hermann Oberth, a Hungarian-born German physicist. Oberth became Germany's foremost rocket expert. Among Oberth's students and followers were such scientists as Werner von Braun and Willey Ley.

Goddard died on 10 August 1945.

In 1951 the US National Aeronautics and Space Administration (NASA) announced "Dr. Robert H. Goddard's work as a universally recognised pioneer in rocketry has recently found the basis of a settlement of \$1,000,000 for right to use of over 200 of Dr. Goddard's patents, which cover basic inventions in the field of rockets, guided missiles and space exploration". In memory of Goddard, a major science laboratory, NASA's Goddard Space Flight Centre was established on May 1, 1959 at Greenbelt, Maryland. In USA, following a bill passed by the House of Representatives, March 16 is regarded as a day of national tribute to Goddard.

The Books written by Robert H. Goddard

1. *Liquid-Propellant Rocket Development*, Washington, D.C. Smithsonian Institution, 1936.
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5. *The Papers of Robert H. Goddard*. 3 Vols (Ed) Esther C. Goddard and G. Edward Pendray, New York : McGraw Hill. 1970.

For Further Reading

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2. *This High Man* by Milton Lehman. New York : Farrar, Straus and Company.

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6. *The Exploration of Space* by Arthur C. Clarke New York : Harper & Brothers, 1951.
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Children from National Association for the Blind who received books in Braille from Honourable Minister, Shri Bachi Singh Rawat

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The salient features of the NSTMIS Website are:

- Genesis, activities and role of NSTMIS in S&T policy planning in the country.
- Publications on Research & Development Statistics, Directory of Extramural R&D Projects, S&T Data Book, Directory of R&D Institutions etc.
- Database Search - (i) R&D Institutions Database, (ii) Extramural R&D Projects Database
- Sponsored Research - Details of the guidelines and proforma for submission of project proposal.
- Project Reports - Summary of the selected policy completion reports under the NSTMIS sponsored scheme.
- Useful S&T Resources - A collection of S&T policy documents of the Govt. of India.
- Links - A collection of useful website addresses in the field of S&T management including international websites.

The potential users for the site are the policy makers, planners, researchers, academicians, scientists and technologists, S&T institutions, vendors, equipment suppliers as well as International organisations in the field of S&T.

For the latest information on S&T resources in the country and for further details, you can log on to www.nstmis-dst.org.

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Pascal and His Triangle

□ Utpal Mukhopadhyay*

Blaise Pascal (1623-1662) was born on June 19, 1623 at Clermont in Auvergne of France. He lost his mother at the age of four. His father Etienne, although a lawyer by profession, was an amateur mathematician also. It should be mentioned here Etienne, not his son, was the originator of 'Limacon of Pascal', the curve that looks like human kidney. Although Pascal showed signs of talent very early, yet his physique was not at all sound. So, Pascal's too



Blaise Pascal (1623-1662)

much affinity towards mathematics was a matter of anxiety for his father. As a teenager, Pascal's mastery over geometry became a legend. At the age of fourteen, he began to accompany his father to the meetings of mathematicians of Paris. Pascal stunned the world by presenting his famous "Hexagrammum Mysticum" theorem in a paper entitled "Essai pour les coniques" as a boy of sixteen. At present, this theorem is known as "Pascal's Theorem" (Fig. 1). This theorem states - "The three points of intersection of opposite sides of a hexagon inscribed in a conic are collinear". Two years later he invented the first calculating machine of the world. From this time his health condition deteriorated further and dyspepsia, insomnia and mental depression became his companions for the rest of his life. In spite of these, he continued his mental exercise over various topics of mathematics and physics. Finally, this mathematical genius breathed his last in August 1662. At that time he hadn't reached even forty. Pascal will remain memorable forever for at least two works, viz. Pascal's Theorem mentioned earlier and his pioneering works with Pierre Fermat (1601-1665) in the field of Probability Theory. But here another mathematical work of Pascal, viz. Pascal's Triangle will be discussed.

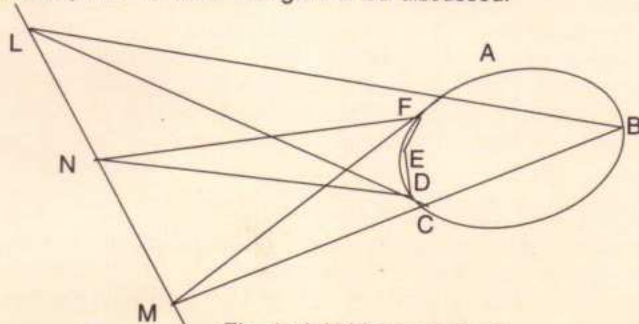


Fig. 1 : L,N,M are collinear

Pascal's Triangle

Unlike geometrical triangles, Pascal's triangle is a rectangular array of numbers. In his 'Traite du triangle arithmetique' (Treatise on arithmetic triangle) Pascal discussed about this triangle. This book was published posthumously in 1665. Lower portion of Pascal's triangle extends to infinity. In Fig. 2, a part of the triangle is shown.

						1							
						1		1					
					1		2		1				
				1		3		3		1			
			1		4		6		4		1		
		1		5		10		10		5		1	
	1		6		15		20		15		6		1
1		7		21		35		35		21		7	1

Fig. 2 : Pascal's Triangle

It should be mentioned here that many years before publication of Pascal's book, Niccolo Fontana (1500-1567), better known as Tartaglia, wrote a book entitled "General Treatise on Number and Measure" in which he discussed about a rectangular array of numbers. The numbers of this array are identical with the numbers of Pascal's triangle but their arrangement is rectangular (Fig. 3). Although this triangular array was known much earlier to the Chinese and to Girolamo Cardano (1501-1576) in the sixteenth century, yet this triangle is known as 'Pascal's triangle' because it was Pascal who identified properties of this arrangements and applied them in various field of mathematics. While working on various properties, Pascal discovered 'Principle of Mathematical Induction' which is one of the pillars of modern mathematics. Using this principle different properties of this triangle can be proved very easily.

1	1	1	1	1	1
1	2	3	4	5	6
1	3	6	10	15	21
1	4	10	20	35	56
1	5	15	35	70	126
1	6	21	56	126	252
1	7	28	84	210	462
1	8	36	120	330	792

Fig. 3 : Tartaglia's Rectangle

The rule for formation of Pascal's triangle is known as "Pascal's law" and the lines of this array are called "Pascal's lines". In fact Pascal's triangle is an infinite array of numbers. Two sides of this arrangement is formed by using 1 only and any intermediate number A is the sum of two numbers of the line just above A. One of these two numbers of the lies to the left of A and the other one remains to the right of A. For instance, the second number of the fifth line, i.e. 10 is the sum of the 4 and 6 situated in the fourth line just above 10. It should be remembered that the topmost line is known as zeroth line and any number lying at the extreme left hand side of any line is known as zeroth number. Pascal discussed in his book about the triangular array like Fig. 2. If we rotate the triangle of Fig. 2 in anticlockwise direction through an angle of 45°, then we get Fig. 4. The arrangement of Fig. 4 possesses various properties

of which only three are mentioned below.

1	1	1	1	1	1	1	1	1	1
1	2	3	4	5	6	7	8	9	
1	3	6	10	15	21	28	36		
1	4	10	20	35	56	84			
1	5	15	35	70	126				
1	6	21	56	126					
1	7	28	84						
1	8	36							
1	9								
1									

Fig. 4 : Changed version of Pascal's triangle

Properties

(1) Any number A of this array is the sum of all numbers (up to the numbers just above) of the horizontal line immediately above the line which contains A (Fig. 5).

P	Q	R	S	T		
				A		

Fig. 5 : $A = P + Q + R + S + T$

(2) Any number A of this array is the sum of all the numbers, up to the number lying just to the left to A, of the vertical column that lies immediately left of A (Fig. 6).

		P				
		Q				
		R				
		S	A			

Fig. 6 : $A = P + Q + R + S$

(3) If A be any number of this arrangement, then the sum of all the numbers of the rectangular array formed by all the rows and all the columns which lie above and to the left respectively of the row and column in which A lies is equal to $(A-1)$ (Fig. 7).

P	S				
Q	T				
R	U				
		A			

Fig. 7 : $A-1 = P + Q + R + S + T + U$

Now, let us return to the original form (Fig. 2) of Pascal's triangle. The numbers of any line of the triangle are designated, starting from extreme left, as zero-th, first, second, third, etc. For example, the second number of the sixth is 15. If, k-th number of

the n-th line is denoted by $T(n,k)$ then evidently, $T(0,0) = 1$, $T(6,2) = 35$ etc. Here, $n > 0$ and $k = 0, 1, 2, \dots, n$. If keeping k fixed we change n, then we get the numbers $T(0,k)$, $T(1,k)$, $T(2,k)$, $T(3,k)$ etc. and when $k = 1$, three numbers become 1, 2, 3, 4, 5, 6 etc. These numbers are nothing but the numbers of the first horizontal row (or vertical column) of Tartaglia's rectangle. These numbers are called Triangular numbers because if we want to form a triangle using balls of same size, then these particular numbers of balls are required (Fig. 8).

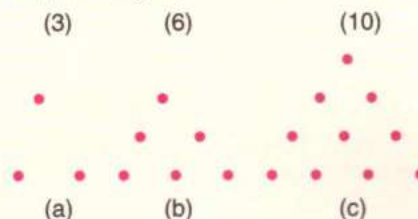


Fig. 8 : Triangular Numbers

Again, when $k = 3$, we get the numbers 1, 4, 10, 20, 35, 56 etc. known as Tetrahedral numbers because if we want to form a tetrahedral structure using balls or spheres of same size, then those particular number of spheres are required (Fig. 9).

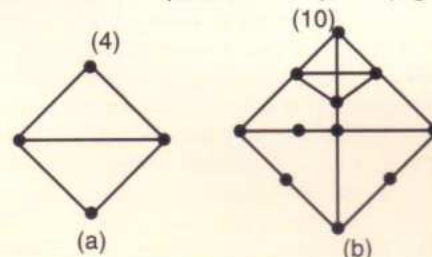


Fig. 9 : Tetrahedral Numbers

Binomial Coefficients

We know,

$$\begin{aligned}(1+x)^0 &= 1 \\ (1+x)^1 &= 1 + x \\ (1+x)^2 &= 1 + 2x + x^2 \\ (1+x)^3 &= 1 + 3x + 3x^2 + x^3 \\ (1+x)^4 &= 1 + 4x + 6x^2 + 4x^3 + x^4 \text{ etc.}\end{aligned}$$

A close look at the above binomial expansions suggests that the binomial coefficients can be found from different lines of Pascal's triangle. For instance, the coefficients of different powers of x in the expansion of $(1+x)^2$ can be found from the second line, the coefficient in the expansion of $(1+x)^3$ can be found from the third line of Pascal's triangle and so on. Again, the binomial coefficients in the expansion of $(1+x)^n$ are ${}^nC_0, {}^nC_1, {}^nC_2, \dots$ etc.

$$\text{Therefore, } {}^nC_k = T(n,k) \dots \dots \dots (1)$$

Again, a close look at Pascal's triangle reveals that the sum of the numbers in the second line is 2^2 , sum of the numbers in the third line is 2^3 , sum of the numbers in the fourth line is 2^4 and so on. Thus, in this manner, we can say that the sum of the numbers in the n-th line is 2^n . Since, the numbers in the n-th line are nothing but the coefficients of different powers of x in the expansion of $(1+x)^n$ then,

$${}^nC_0 + {}^nC_1 + {}^nC_2 + \dots + {}^nC_n = 2^n \dots \dots \dots (2)$$

Again, the left hand side of equation (2) is the total number of ways in which any (one or two or three etc.) number of objects

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Marine Biological Research Station

Geared to local needs

□ Dilip M. Salwi

Fishing has assumed considerable importance in recent times with seas and oceans being commercially explored not only for food but also for minerals and medicines. Today, fishing is a growing industry in India and a career in fishing lucrative. One of the research stations which brought about such a sea-change in fishing in India, is the little known Marine Biological Research Station located in the idyllic coastal town of Ratnagiri in Maharashtra. The station has conducted pioneering researches not only on a variety of marine beings, including fishes, of commercial interest to the local fishermen and on the neighbouring coastline, islands and continental shelf but has also studied and improved the local fishing practices and recommended rules and regulations to curb overfishing in the region. It also produces and supplies aquarium fishes and their feeds and seeds of commercially important marine beings for fish-farming in the region and elsewhere, which are today earning revenue for the station. "We also conduct workshops," said Dr. S.G. Belsare, Scientist in charge, "to impart fishery-related hands-on skills to local people so that they can earn their livelihood".

More than 40 years ago, the station was set up in 1958 by the Government of Maharashtra for scientifically planned development of fisheries in the state. The renowned fishery scientist Dr. H.G. Kewalramani was appointed the station in charge and to assist him was selected the young U.K. - trained Dr. Madhav R. Ranade. It was under the able and dynamic leadership of Dr. Ranade that the station grew, prospered and assumed the status it has acquired today in the world of fishery science. Before he died in 1980, his vision had been fulfilled – fisheries had become a vocational subject in the local colleges and the College of Fisheries had been established at Ratnagiri.

Dr. Ranade conducted some pioneering studies and demonstrations for the benefit of the local fishermen. He also rectified their misconceptions about fishes, nets and fish products. For instance, he introduced motorized fishing to the local population by bringing in the research vessel *R.V. Varsha* to the station. "In those days, fishermen feared that the noisy, motorized boats would scare fish away. They needed considerable demonstration and persuasion before they adopted motorized boats for fishing", recalled his son Prof. Anil Ranade of Konkan Krishi Vidyapeeth's (University's) College of Fisheries, of which the station is now a part.

Once the local fishermen became convinced about the

considerable higher yield of fish catch made possible by motorized boats and trawlers, fishing industry received a major boost in the region. Thereafter it grew up very fast. Today, fish-related industries have mushroomed in the neighbourhood of the station. With the establishment of a jetty for fishing boats in the vicinity, the station has further receded into the background. At present, there are about 800 fishing trawlers in Ratnagiri.

Nowadays, the station is more popular as 'Machalaya' (Aquarium) to the local population rather than a marine research station because of the aquarium of local fishes that the new, multistoreyed building of the station houses in its ground floor. Besides the aquarium, it also houses a small well-kept museum containing the local marine flora and fauna found by the station researchers, with two major attractions - one, a skeleton of a

whale that stranded and died on the neighbouring coast and the other, the first motorized fishing boat *R.V. Varsha*. A good effort in 'Outreach programme' in a place more famous for its scenic beauty and alphonso mangoes, notwithstanding it being the birthplace of B.G. Tilak. Every year, 50 to 60,000 people, including tourists to Ratnagiri, visit the aquarium and museum fetching enough gate-money for the upkeep of the station.

Whereas the aquarium and museum occupy most of the ground floor of the building of the station, the rest of the upper floors houses its various specialised laboratories, namely, Aquarium Fish Lab, Algal Culture Lab, Marine Prawn Breeding Lab, Freshwater prawn Breeding Lab and Muscolan Lab. Since 1971 the station has been incorporated into the Konkan Krishi Vidyapeeth with the headquarters in Dapoli. It is now directly

associated with the Vidyapeeth's College of Fisheries present in the nearby Shirgoan for better liaison among researchers, students and fishing industry. It has presently three experimental breeding sites, one at College of Fisheries, one at Agricultural Research Station, Kudal, and one at Kharland Fisheries Research Station, Panvel.

Over the decades, the station has made several important contributions towards the growth of fishing industry in the 720 kilometre long coastline of

Maharashtra. The station researchers have conducted surveys to assess the local varieties of marine beings found at various depths in the neighbouring Arabian sea, estuaries and creeks and on sea beds. They have developed new strains of fast growing marine beings, namely, prawns and oysters, which are of great commercial importance in the region. They have also established experimental hatcheries for their breeding, evolved techniques for breeding popular home aquarium fishes, such



Marine Biological Research Station at Ratnagiri, Maharashtra



Prawn seeds in polythene bags getting readied for market

as, goldfish, round the year, and created new value-added products from 'trash fish', such as, fish balls, fish fingers, fish and prawn powder and cakes. Trash fish has also been converted into poultry and aquarium fish feed for their faster growth.

The station researchers have also studied various types of fishing nets and their effectiveness. Fishing nets with optimum hole sizes of 38.1 mm have been recommended for use to avoid catching growing baby fishes. The effectiveness of a mix of coal tar and diesel to combat damage to nets by puffer fish has also been demonstrated to the local fishermen. An anti-fouling paint for boat hulls to save them from damage by marine beings has also been demonstrated. The researchers have also developed techniques to isolate 'chitosan' from prawns, which is used in wine and pharmaceutical industries. Under the National Agriculture Technology Project, they have also conducted studies on fishes for their valuable by-products,

for instance, ornaments from shark teeth, industrial filters from air-bladder fishes, surgical twine from fish gut, etc.

Besides, the station regularly conducts workshops to give hands on training to local farmers and unemployed youth on how to set up hatcheries for breeding prawns and oysters in brackish and fresh waters and to rear and breed a variety of aquarium fishes which are in popular demand. "In the coming years, we intend to conduct research on aquarium fishes so that they could be exported abroad", said Dr. Belsare telling about the activities at the station. "We're planning to study how fish gear should be changed with the seasonal changes; how to undo damage to purse sein type of fishing nets; how pearls could be grown in freshwaters. And more important of all, we intend to study the present problems caused by overfishing in the region so that fishing remains an economically sound industry", he said.



A Training programme of rearing and breeding aquarium fishes for unemployed youth in progress at the station

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can be selected from in different objects. Thus, we find that the total number of ways of choosing any number of objects from a certain number of objects can also be determined from Pascal's triangle.

An Interesting Problem

Let us consider a network of roads like Fig. 10. Suppose 2^{1000} people start from A. Half of those people follow the L direction while follow the L direction while other half follow the R direction. Again, on reaching the first junction, half of the people following the L direction go along the L direction while other half go along R direction.

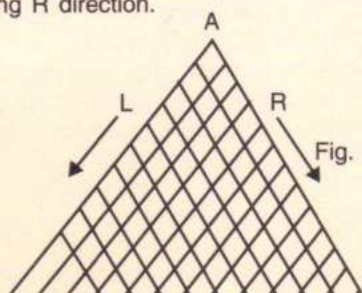


Fig. 10 : Triangular Numbers

Similar is the case for the people following initially R direction. If this process continues at each junction, then what will be the number of people at each of the 1000 junctions in the 1000-th line of the network?

It can be shown using Pascal's triangle that the number of people at each junction in the 1000-th line of the network will be equal to the numbers in the 1000-th line of Pascal's triangle.

Power of 11

Values of different powers of 11 can be found from Pascal's triangle. If we consider the numbers in any line of Pascal's triangle as digits of a larger number, then this larger number is a power of 11. For instance, the second line of Pascal's triangle contains the three numbers 1, 2, 1. So, the larger number is

121 which is the square of 11. Similarly, the third line contains the four numbers 1, 3, 3, 1. So, the larger number is 1331 which is the cube of 11. So, the larger number formed by the numbers lying in the n -th line of Pascal's triangle is 11^n .

Application in Theory of Probability

Pascal's triangle can also be used in the probability theory in various ways. Here, let us consider only one example. If we 'toss' with different number of coins, then the number of ways in which 'head' or 'tail' can appear will be found from different numbers of any line of Pascal's triangle. For example, if we toss with two coins, then the result can be - (1) two heads, (2) a head and a tail and (3) two tails. Now, two heads can appear in two ways (HT, TH) while two tails can come in one way (TT). Again, the numbers in the second line of Pascal's triangle are 1, 2, 1. Similarly, the outcome of tossing three coins can be found the numbers 1, 3, 3, 1 lying in the third line of Pascal's triangle.

A Genius

In the world of mathematics, Pascal is one of those short-lived geniuses who disappear suddenly from the earth keeping a bright glaring trail which mesmerises us for years to come. In this regard he can be put into the same class as that of Bernhard Riemann (1826-1866), Srinivas Ramanujan (1887-1920) etc. In this brief, ailment - stricken life the pioneering works done by Pascal will guide us as a light house for many many years.

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