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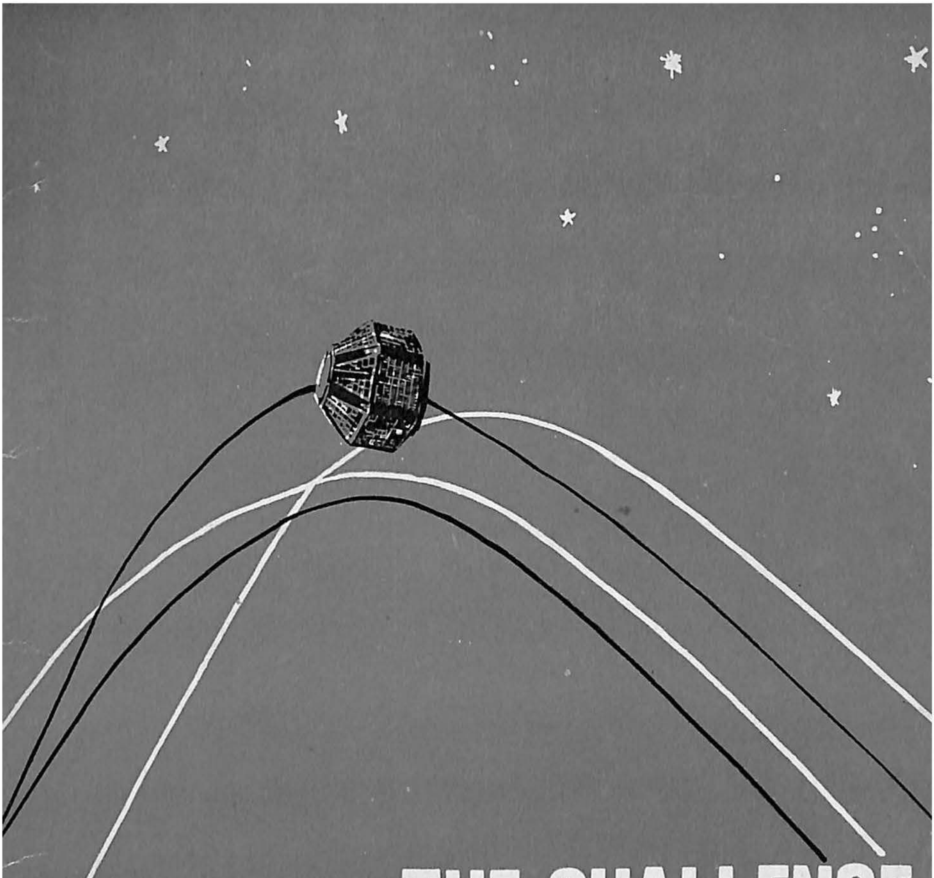

THE CHALLENGE OF ARYABHATA

The Challenge of Aryabhata

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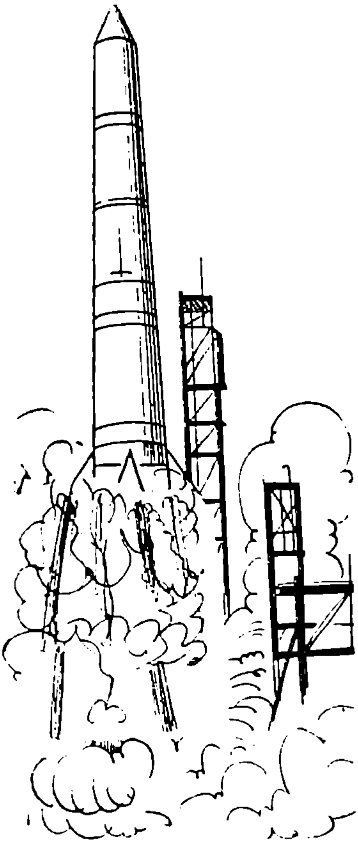
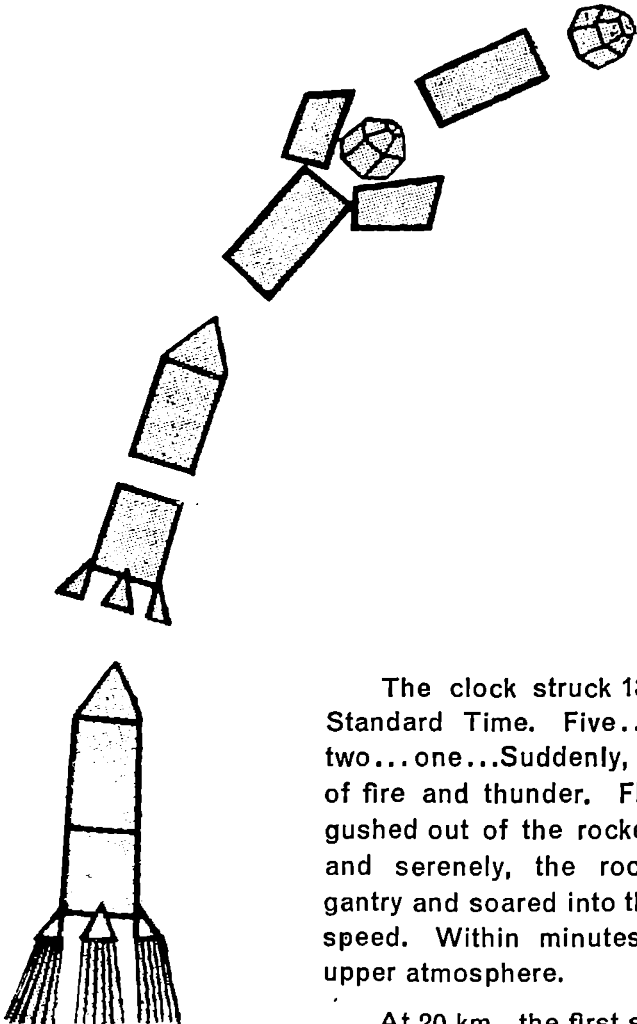
The Lift-Off



IT was a pleasant morning on April 19, 1975. A Soviet launch pad was getting ready for a space shot. In a few moments an inter-cosmos rocket was to blast off. Eight kilometres away, some top Indian scientists, led by Prof. Satish Dhawan, Chairman of the Indian Space Commission, assembled to witness the historic event. The rocket with India's first satellite inside was clearly visible. The count-down proceeded.

There were 45 minutes for the lift-off. All systems were 'go'. The launch crew did the check-out of the rocket. The Indian team under Prof. U. R. Rao, the Director of the project, made the trial check of the satellite and gave a go-ahead signal. As the zero hour neared, everyone made his secret wish or said his special word. Excitement, anxiety and a quiet determination marked the occasion.



The clock struck 1300 hours, Indian Standard Time. Five... four... three... two... one...Suddenly, there was a flash of fire and thunder. Flames and smoke gushed out of the rocket. Rising slowly and serenely, the rocket cleared the gantry and soared into the sky, gathering speed. Within minutes, it was in the upper atmosphere.

At 20 km., the first stage fell off and the second stage with the satellite inside continued its journey. The water released. from the second stage condensed in the upper atmosphere, leaving a beautiful trail behind. The rocket was heading towards south-east Asia.

The launch team was giving information every two minutes. They confirmed that the "corridor" in space through which the rocket should go, was being held. But then came the crucial moment. The heat shield that protected the satellite till then, separated. The satellite was exposed to the harsh environment of space. This was followed by a more crucial manoeuvre. The second stage separated and the satellite was in orbit on its own, 30 minutes after launch. There was spontaneous applause by the launch team. The first critical moments had gone off successfully. It was significant because a large number of failures in space have occurred in the past when the heat shield was jettisoned or when the satellite was ejected into orbit.

A Dream Comes True

Prof. Dhawan and his colleagues were still anxious. "Wait till the signals are picked up", they seemed to say. For the real success of the project depended on the satellite's ability to orbit properly and send signals as predicted. However, there was no way of knowing that immediately, since the tracking stations in India and the Soviet Union were out of reach of the satellite, when it pulled away from the rocket. The satellite then went behind the earth and it took an hour and 10 minutes to reappear over the Soviet ground station in Bears Lake near Moscow. The signals were loud and clear. Within the next ten minutes, Sriharikota in India "sighted" the 26-faced "diamond in the sky". The two stations confirmed to each other on the "hot line" the "signature" of the satellite signals. The telemetry—the data sent by the satellite on its functioning—showed everything was fine. It was also monitored later by the French tracking station in Kourou in French Guiana, near the equator.

This was the moment everyone was waiting for. Prof. Dhawan was overwhelmed by memories of Vikram Sarabhai and his pioneering role. A dream came true.

In New Delhi and elsewhere, the press wires became hot with flashes of the historic event. The name of the satellite—till then kept a secret—was made public. It was called Aryabhata, after India's great astronomer and mathematician who lived about 1500 years ago. He was the first Indian who understood the earth's movement around its axis. He said, "Just as a man sitting in a boat going forward sees a stationary object moving backward, so at Lanka (a hypothetical place) do the immovable stars appear to move westward." By his brilliant leaps in knowledge, Aryabhata enriched the Golden Age of Guptas. The innate genius of a people flowered again.

Why Satellite Technology?

YOU may wonder why India has made and sent up a satellite, instead of growing more food or digging more wells. Perhaps, you may be a little surprised to know that satellite and food are very much inter-related. Let us see how this is so.

For growing more food, we need more accurate data on soil and water resources; crop surveys are also necessary. The data can be gathered by satellites in a scientific manner, yielding several advantages. Just as you see more of a place from a hill-top, cameras on board satellites cover a wider area. What is more, they can report information as and when the event is happening. It will be particularly useful where information is required repeatedly over a vast area under more or less uniform lighting conditions. Imagine, for example, how useful this would be for forecasting floods. Above all, cameras on satellites can see much more than the naked eye. They can, for instance, spot a diseased crop much before the farmer on the ground could notice it.

It would be interesting to note how this is done. Almost everything on the earth emits or reflects radiation. This is known as infra-red radiation. It is picked up by special sensors put on the satellite. The radiation differs from object to object like fingerprints. The diseased trees will look blue instead of red to the sensors whereas both will look green to the farmer. Similarly, heat differences can point to streams below the ground or under water. This technique will help in locating new fishing areas in the sea, evaluation of snow, minerals and oil.

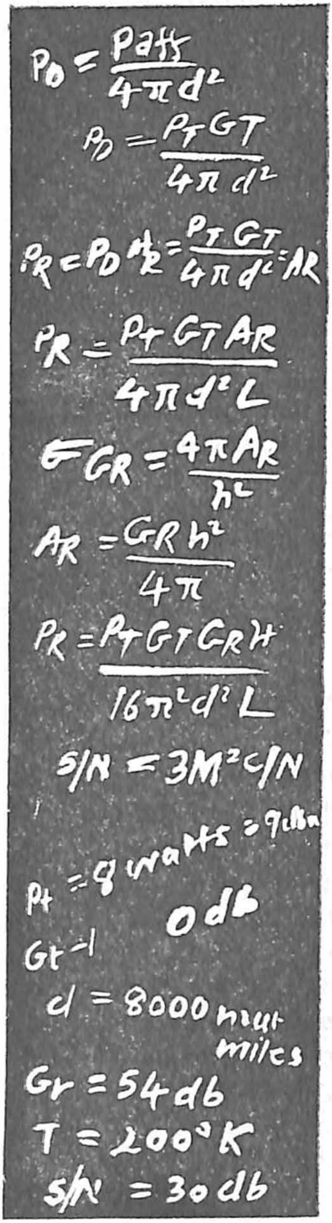
Related to these tasks is weather forecasting. Cyclones, rain and monsoon can be predicted with better accuracy. Recently it was found that interesting changes happen over the Arabian sea, before the onset of the south-west monsoon. Similarly, the snow in the Himalayas could be a guide for estimating the flow of water in the rivers some months later.

Another area where satellite technology would be useful is telecommunications. Land-based lines are subject to several limitations. It would take a long time for the terrestrial links to be extended to interior areas. A satellite can connect these places in one go. New facilities like fast transmission of data and TV between cities would require a satellite to supplement the links on the land. Remote areas and interior villages can hope to have good communication facilities.

There is also need to provide mass communication facilities in villages. If television is to be provided in almost all the villages, satellites can do it much quicker than any other means. Advances in technology have made it possible to provide several language channels or different pictures for different areas through the satellite.

These are some of the applications of the new technology. Before we start using them, we must take the first step of building a satellite ourselves. The first main purpose was technological ability. This has now been achieved.

What about a launcher to put the satellite into orbit? Though India had started making rockets, it was realised that it would take some time for her to develop one big enough to launch a satellite. A Soviet offer to launch it was therefore readily accepted as it would give our scientists the much needed experience in this field. An agreement was signed in 1972 under which India would design and build a satellite and the Soviet Union would launch it from its territory using an inter-cosmos rocket. The agreement marked a new high in the friendly relations between India and the Soviet Union. For the first time, a space power helped a developing country to launch its satellite. The project promotes the idea of using space only for peaceful purposes.

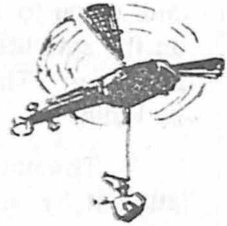


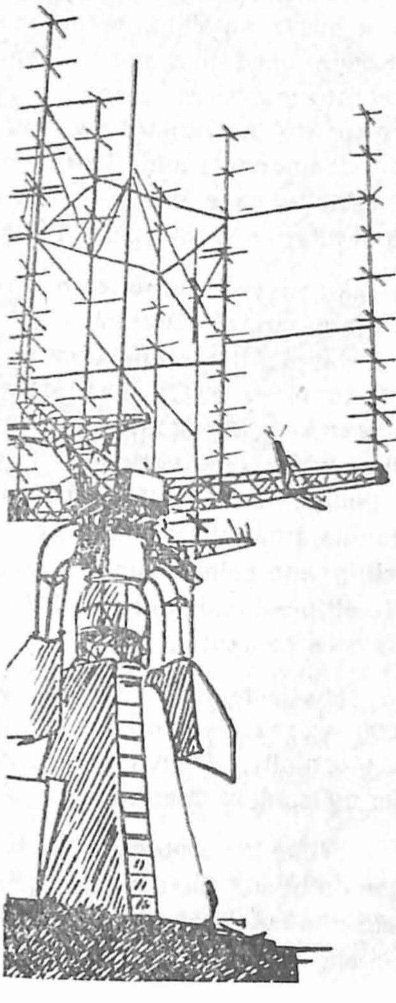
A Sleepy Village Wakes up

SOME people doubted whether India could build a satellite. But the team of dedicated workers built one in a record time of two and a half years. It may be said that they had the advantage of the knowledge already acquired in this field. This is true only as far as what is published is concerned. But there are several things that one has to master before what is stated on paper could be made a reality. Moreover, Indian scientists did not have the modern infra-structure to back them. They had to work under severe constraints. To begin with, they had only some sheds of a small industrial estate in Peenya, near Bangalore. But soon the most modern facilities were set up inside. The sleepy little village of Peenya became the birth-place of the country's first satellite. Several industries in the public and private sectors were involved. A team of 200 young men and women, under the direction of Prof. U. R. Rao, set themselves to the stupendous task. They scanned available literature. The black boards overflowed with equations.

Every idea was critically evaluated. At last, the design was frozen and work began.

Along with the construction of the satellite, the building of facilities for testing it was also taken up. Everything on the satellite has to be tested rigorously; even minute flaws get amplified to a large extent in space. A special chamber was constructed to simulate the conditions of space. Facilities were set up to test its tolerance of balance and acceleration. Facilities at other laboratories in Bangalore, such as Collectorate of Inspection in Electronics (CIL), National Aeronautics Laboratory (NAL) and Bharat Electronics Ltd., (BEL) were used for testing tolerance to temperature and vibration.





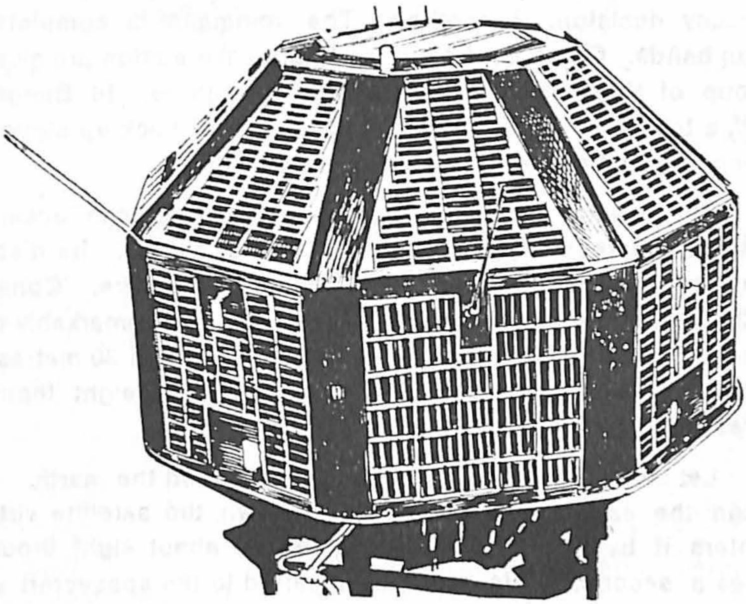
The mechanical model emerged first. It was tested and sent to the Soviet Union to see if it can be matched properly with the rocket. Then they made an electrical prototype, tested in a helicopter over Sriharikota to ensure that the signals can pass between them without difficulty. Thereafter two flight models were made and taken to the Soviet Union. Almost every technological item on the satellite was duplicated so that if one failed, the other could take over. The entire designing, fabrication and testing were done by Indians.

The satellite weighs 360 kg. It is the heaviest for the first attempt by any country. But it is more than that. No country made such a sophisticated satellite in its very first attempt. Though it is a heavy satellite, most modern miniaturised components have been used on a scale characteristic of the ventures of the space powers. For example, one small capsule-like electronic piece can do the work of two hundred components. Evaluation of these components and their integration with the other systems in the satellite gave the engineers as well as those in industry an idea of future requirements in this field.

An essential requirement in the satellite is to keep the inside temperature constant. As the spacecraft alternates between day and night, the temperature on its skin varies widely from about 100°C to minus 60°C. The inside temperature (now around 20°C) has been kept constant by coating the surface with special paints. Just as white clothes ward off heat, the paints help in controlling the temperature. The operation required them to find the right materials, treat them suitably by various methods, including sand-blasting and paint them in a zebra-like fashion. The black and white stripes inside are not done at random; the calculations were done by a computer.

The satellite derives its power from the sun. There are 17,000 solar cells mounted on its body, which convert sunlight into electricity. Even if micrometeorites in space hit some of the solar cells, all of them will not go wrong.

When the spacecraft is in the shadow, nickel-cadmium batteries on board the satellite take over. There are provisions on board the satellite to ensure the change-over between the solar cells and the battery.



If the temperature on the skin is more, power production comes down. The system is capable of giving 60-65 watts of power. The minimum yield is 40 watts. About half of this is required for working the sub-systems. The rest of the power is required for charging the batteries, running the tape-recorders and the three experiments on board. After the first 50 orbits, a malfunction developed in the power supply to the three scientific experiments. Hence, the experiments were turned off. The satellite of course has been in good shape.

Satellite Mission Control

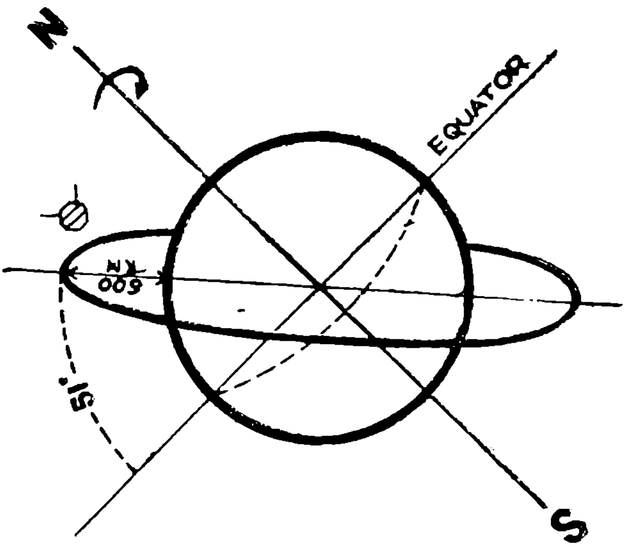
The Mission Control in Bangalore had kept a 24-hour vigil on the satellite in the first month. The commands are generally pre-planned and programmed. However, the Mission Control can alter any decision, if need be. The command is completely in Indian hands. Commands from the Bears Lake station are given by a group of three Indian experts stationed there. In Bangalore itself, a telemetry station was set up, as a mini back-up station for getting information to the Mission Control Centre.

The orbital mechanics group in Peenya can accurately calculate where exactly the satellite would appear. Its distance from the ground can be predicted within one kilometre. Considering the vast distance in space it travels, this is a remarkably close range. The scientists can predict its speed within 30 metres per second. This also is significant, as it travels at eight thousand metres a second.

Let us see how the satellite goes around the earth. Even though the earth's gravitation pulls it down, the satellite virtually counters it by travelling at the speed of about eight thousand metres a second. This speed is imparted to the spacecraft when it is hurled into orbit by the rocket. Its distance is maintained at more or less 600 km. Hence it is called a circular orbit. Its inclination with reference to the equator is 51°. The satellite's path is kept by sensors, which maintain a reference with the earth's magnetic field and the sun. It goes over South America, Europe, the Soviet Union, India, South-East Asia and Australia. As the earth is also rotating, the satellite's path will change from orbit to orbit by about 2500 kilometres.

A Steady Spin

The satellite in orbit should remain steady. This is done by the spin system. Like a spinning top, its axis should be steady.

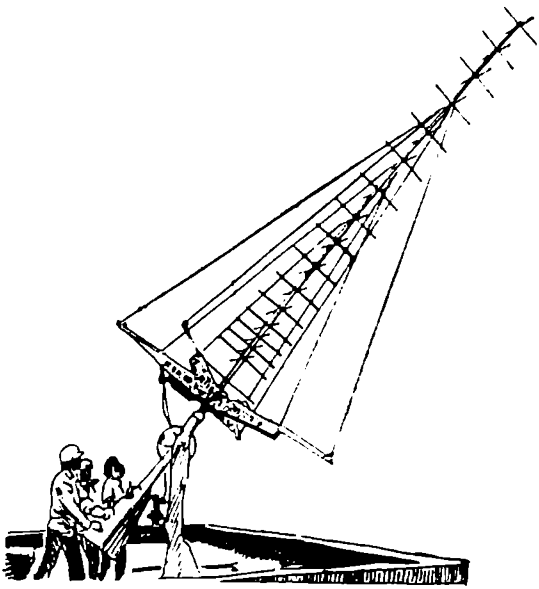


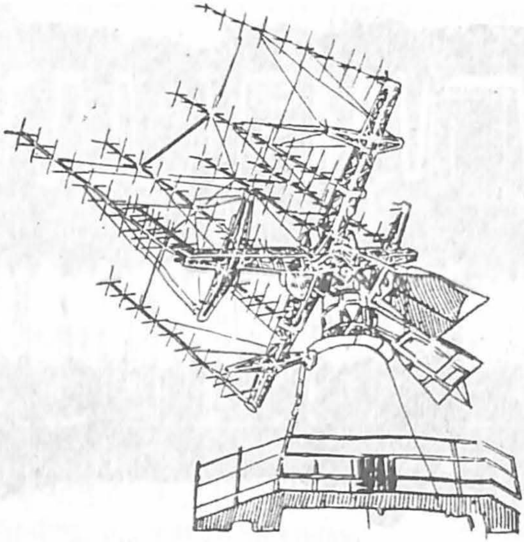
The spin is given to the satellite by forcing out compressed air kept on board in six containers made of titanium. When the satellite separated, the first gas outlet was to be effected automatically. The other containers were to be opened by commands from earth, one every month, as and when the spin rate came down below ten revolutions per minute. The satellite did not spin due to some problems. These were solved by sending a ground command to spin the satellite to 50 revolutions per minute. The spin decay (due to many natural factors) has not been as quick as was expected. In one month, the spin rate has come down from 50 rpm to 42 rpm only, and not to 10 rpm, as calculated. If the satellite remains steady for a longer period, the gas will be saved and the satellite's active life will be prolonged.

Telemetry, Tracking and Command Network

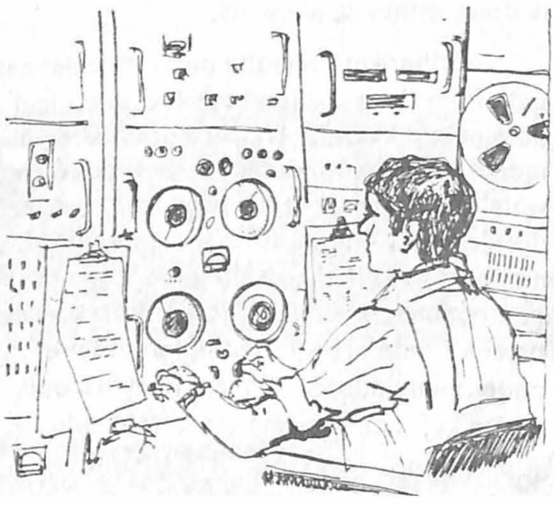
Besides the satellite, the most interesting features of the project are the tracking network, the facilities for getting data from the satellite and the ability to send commands to it, the total system being called the Ground Station. Designed and built by Indian engineers in a record time, they are significant not only for the success of this project but for others too. They are among the permanent assets of the nation.

The main Ground Station is located in Sriharikota, an island in Andhra Pradesh on the eastern coast, some 100 km north of Madras. Prominent among the newly built facilities is what is known as a Yagi antenna. It looks like an improvised television antenna. Its performance has surpassed the expectations of its makers. It receives the signals when the satellite is about 2,500 kms away. Originally, the station personnel planned to get the data only when the satellite was clearly above the horizon of the range. Now it can be contacted as soon as it comes within the radio horizon. The Ground Station is capable of catching the signals which are broadcast by four antenna rods of the satellite. They distribute the energy in all directions.



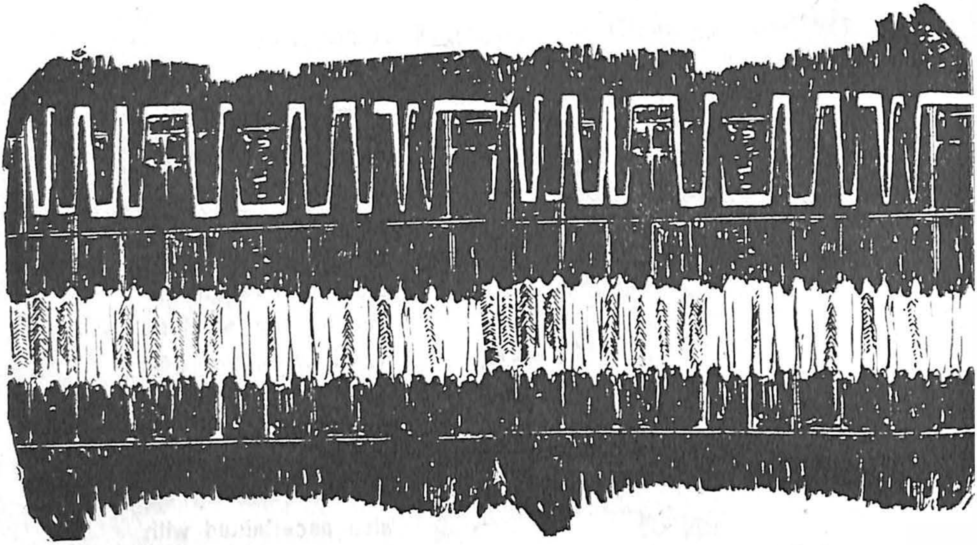


The distance of the satellite is calculated by the tone ranging equipment. Electrical signals sent from the ground are retransmitted by the satellite. The time delay in getting the signal back is proportional to the distance. The angle of the satellite is also ascertained with interferometry. The Ground Station has a doppler system which measures the velocity of the satellite. This is done by measuring the change in the frequency at the receiving end, of the signals from the satellite, when it moves across, just as the pitch of the whistle of the approaching engine changes, as it moves away from you.



A voice communication experiment was made. Recorded voice was transmitted and relayed on command.

Thirtyfive different commands can be sent



to the satellite. The telecommand station at Bears Lake was built by Indian engineers, with their own equipment. It is noteworthy that the scope for wrong commands has been eliminated. Each command is automatically repeated five times. It is checked on the ground and again on board the satellite. If the satellite recognises the command at least three times out of five, it will obey it. All this is done within 30 seconds.

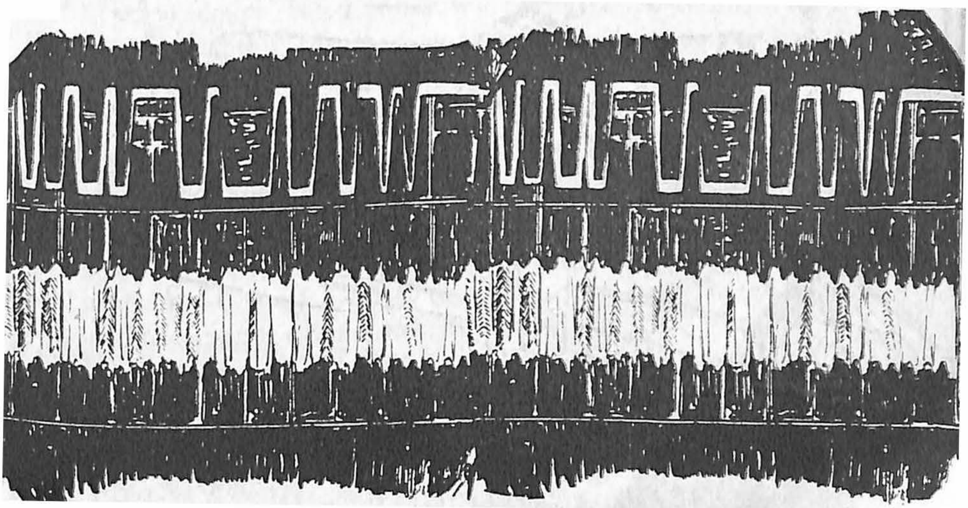
Sriharikota has the most sophisticated method of handling data from the satellite, both technological and scientific. Different parameters like the temperature or power are sensed by instruments on board and they are converted into electrical waves, which are later sent as broadcast waves. These waves contain the data in a digital form, as a string of pulses, or bits of information. (A bit shows the presence or absence of a signal). The data comes in a mixed form, but can be separated as different types of data are allotted different time slots. This is called pulse code modulation. In an oscilloscope, the data appears as a series of compressed or stretched-out lines, corresponding to

1 and 0 respectively. This is the language of the computer. Eight bits correspond to one word. The experts can read these numbers and tell the corresponding meaning. It sends real time data at the rate of 256 bits per second.

The data can also be recorded at the rate of 256 bits per second during the orbit and dumped ten times faster, at the rate of 2560 bits per second, during its pass over Sriharikota. Generally, out of 16 orbits in a day, it can be tracked four times by Sriharikota and four times by Bears Lake. In four minutes of reception, data recorded for 40 minutes could be sent. These modern methods of data transmission would be useful in future for application satellites.

The technological task, set before the satellite, has been fully accomplished. This assures the country of the capability of building application satellites.

The success story of Aryabhata is not that of ISRO alone but of India as a whole, as many local industries were involved in the fabrication of satellite-related items. The Karnataka Government gave great logistic support in terms of buildings, electricity etc. The Posts and Telegraphs department speedily commissioned the Moscow-Shar-Bangalore link vital for satellite launch operations.

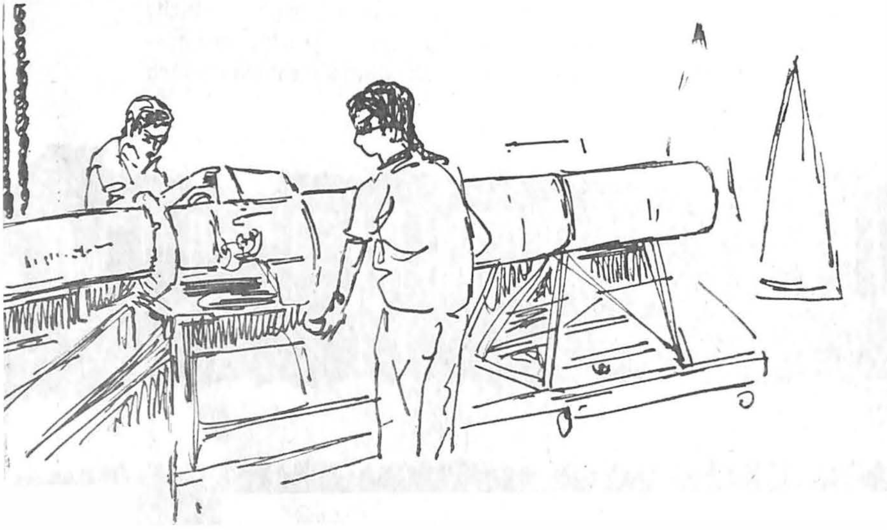


What Next ?

ONE of the two flight models of Aryabhata will now be available for orbit. It is proposed to put on it a new experiment package. Work has started on the second satellite. This would make a survey of some of the material resources of the country.

The nature of the resource survey satellite demands a different type of control over its spin rate. The satellite sensor should always point towards the earth during photography of earth. Its spin rate should facilitate the taking of photographs in such a way that there is neither an overlap of pictures nor a long gap between them. It might include some instruments to gather weather data.

Satellites are only platforms for experiments and surveys. Several related facilities on the ground are necessary. They include computers to analyse the vast amount of data and the participation of scientists from different fields.



Rohini-I, India's 40 kg. satellite, will be launched by her own rocket in 1978. The main purpose of that satellite is to evaluate the rocket which is carrying it, so that operational data could be had on the indigenous launch vehicle.

The experience of building Aryabhata has given the Indian scientists and engineers the ability to make experimental communication satellites which can relay radio, TV and tele-communications.

SLV-3

Work is in full swing in Thumba on India's first satellite launcher. It is expected to be fired from Sriharikota in 1978. Scale models are being tested in wind tunnels, where the forces which would act on the real one, would be simulated. There are thousands of components and scores of sub-systems. Parts of the rocket will have to be ready for test earlier than 1978. The project started only in 1973. The production schedule is indeed rather tight. For, it involves the timely supply of the materials needed for it by a wide variety of industries.

It is a four-stage rocket. The diameter of the first stage will be one metre. A novel way of building the first stage is going to be tried. It is called clustering of three rocket motors. This would help in designing rockets of increased power, with the rocket propellant facilities available presently in the country. Reaction control rockets, which will fire for a few seconds, are being developed to keep the rocket in the desired path during flight. The four stages will fall off one by one as planned. Gyroscopes sense the direction and help in correcting the path.

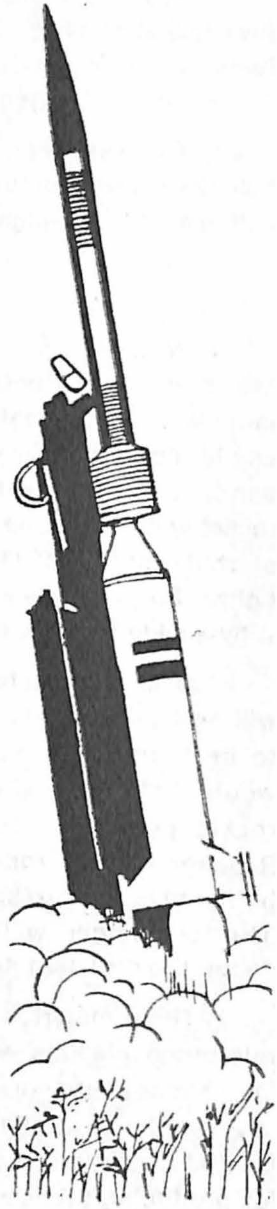
New materials are being made for the rocket. Fibre-reinforced plastics will be tried for some parts. This material has already proved its use, not only in space technology but in a variety of civilian applications, ranging from grain silos to printed-circuit boards. A factory is coming up near Trivandrum for producing this material on a large scale.

Rockets and Propellants

The different rockets which have been made by India are being used to test the various sub-systems needed for SLV-3. The Rocket Fabrication Facility in Thumba makes these rockets. A rocket is not just a lump of metal. It has hundreds of components. They have to be integrated properly. The welding has to be perfect.

The first Indian rocket, Rohini-75, was launched in 1967. Bigger rockets followed, including the Centaures being manufactured under a French License. Over ten different rockets, including Indian Centaures, are now being fabricated. The biggest rocket launched so far is Rohini-560. It is a two-stage rocket, the diameter of the first stage being 560 mm. Work has begun on liquid propellant rockets too.

Propellants for the rockets are also being made in Thumba. They can be solid or liquid. A solid propellant is a mixture of fuel, oxidizer and a binder. Once ignited, it will go on burning and will help in propelling the rocket. Thumba engineers are constantly trying to increase the energy of propellants, so that the velocity of gases, when they burn, also increases. Indian-made propellants have proved their worth. Commissioned in 1969, the Rocket Propellant Plant has produced several solid propellants for various types of rockets. Facilities to increase the production of solid propellants are being set up in Sriharikota also.



In order to make the raw materials for the propellants, a propellant fuel complex has been set up in Thumba. Many of the processes have a direct application in the chemical industry. A beginning has been made in the manufacture of liquid propellants.

Hundreds of gadgets that go with the rockets are being made in Thumba. They relate to control and guidance, electronics, chemicals and special materials.

An Eastern Range

The new rockets, including those carrying satellites, will be launched from Sriharikota. It is a definite advantage to launch a rocket eastward, to make use of the earth's west to east movement. Sriharikota is ideally situated for this.

Elliptical in shape, the island is 30 km long, with a maximum width of eight km. It has an area of 12,800 hectares, almost uninhabited and allows a great safety margin, unlike Thumba, which is quite close to populated areas.

The range became operational in 1971. New facilities are being added to it. More powerful radars and data receiving systems will be built. They will receive, decode and record the data. There would be facility to test rockets on the ground inside a special building where the atmospheric conditions at certain altitudes will be simulated. However, only certain conditions can be reproduced on the ground. Testing them in actual flight would generally result in the destruction of the payload. In order to find out what happens during high-speed operations, a special facility called SLED is being built. It is a perfectly straight rail, about five kilometres long. A rocket vehicle, carrying the test specimen, will be propelled by means of rocket motors on the rail. At the end of the fast run, it is either stopped or left unchecked. The vehicle

goes on the rail at about four times the speed of sound. The facility would be useful for testing parts for high-speed trains, aircraft and control and guidance systems.

Great Expectations

Sriharikota is but one of the many spin-offs from the space project. The band of devoted young men and women is another. Interestingly, astronomer Aryabhata was in his twenties when he propounded his main theories. Most of the scientists behind Aryabhata, the satellite, are below 30, full of hopes and ideas.

Will Aryabhata remain an isolated instance of perfection or will it spread its message to other areas of our daily life? The young scientists behind the satellite seem to demand an answer, perhaps with great expectations.