K. Sivan

The Indian Space Research Organisation (ISRO) under the Department of Space (DoS), Government of India (GoI) was formed in 1969 and is one of the six largest space agencies in the world. ISRO's vision is to 'harness space technology for national development, while pursuing space science research and planetary exploration'. K. Sivan (Chairman, ISRO) in an interview with *Current Science* talked about ISRO's projected road map, missions and its deep involvement with the society and academic community.

Sivan joined ISRO in 1982. He has specialized in aerospace engineering, space transportation systems engineering, launch vehicle and mission design, control and guidance design, mission simulation software design and mission synthesis. He has contributed immensely towards end-to-end mission planning, design, integration and analysis. During his career at ISRO, Sivan has held many responsible positions; he served as Director, Vikram Sarabhai Space Centre, Thiruvananthapuram, until January 2018. He is also the President (Governing Body)/Chairperson (Governing Council) of the Indian Institute of Space Science and Technology, Thiruvananthapuram (an autonomous institute under DoS, GoI) that was started keeping in mind the need for high-quality manpower for ISRO.

Sivan graduated from Madras Institute of Technology in Aeronautical engineering in 1980. He completed his ME in aerospace engineering from the Indian Institute of Science, Bengaluru in 1982. Subsequently, he completed his Ph D in aerospace engineering from IIT, Bombay in 2006. He has received many awards, including Doctor of Science (Honoris Causa) from Sathyabama University, Chennai. He has numerous publications in various reputed journals, including a book in November 2015 titled *Integrated Design for Space Transportation System* published by Springer.

What are the important future missions of ISRO planned during the next 10 years and the timelines of these missions?

Our vision involves applying space science for national development. For national development, our objective is to ensure that we meet the requirements of society. Demands of the future society will not be the same as in the yesteryears. With improvements in technology, the requirements/expectations of people (safety of life, food and water security, etc. at the lowest cost) will continue to increase/change with time. ISRO's space programme needs to keep pace with these changing requirements while ensuring inclusive development. We require multiple advanced satellites to achieve this, which in turn require bigger launch vehicles. At the same time, our objective is also to pursue space science research and planetary exploration which has led to missions such as Chandrayaan-1 and -2, Mars Orbiter Mission, Mission to Venus, and so on.

ISRO has a well-defined road map for the next 30 years. This road map addresses long-term national requirements and capability augmentation required for meeting those requirements. For example, if you take the launch vehicle area, the road map addresses the following.

Capability upgradation of existing launch vehicles – The focus is on existing launch vehicles, to improve the payload and reduce the cost. To achieve this, we are already on the job to uprate the propulsion system performance, optimize the mass and use advanced avionics and alternate cheaper materials. These improvements will also be used in the future launch vehicles of ISRO.

Semi-cryo engine and stage development – As of now, the engine and stage development is in progress. Later we also need to develop a clustered semi-cryo engine stage. This development is crucial for ISRO's road map and is required for future heavy-lift launch vehicles.

Critical technologies for human space flight – At some point in time, we are likely to obtain Government approval for human space flight programmes. To ensure faster execution after approval, all the necessary technologies such as crew module, life-support system, parachutes for recovery, crew escape system, human rating, etc. are being addressed now.

Satellite applications – The focus is on three areas of applications, i.e. earth observation, communication and navigation. Earth observation aims to cover all crops for the farmers. Communication aims to achieve 100 GBPS capability for connectivity to rural and remote areas. Navigation aims to strengthen the user segment by launching Navik-compliant devices for a variety of services.

However, in the case of satellite missions, long-term planning is done for space infrastructure augmentation and replacement of existing fleet of satellites in the areas of earth observation, communication and navigation.

If you take our short-term plans, then the missions lined up are Chandrayaan-2 (October 2018), Docking experiment (2019), EXPOSAT (2019), Aditya L1 (2020), NISAR (2021) and Venus (2023).

Please elucidate some of the important projected missions in terms of objectives and applications.

Chandrayaan-2: It is a follow-on mission of Chandrayaan-1. However, Chandrayaan-2 is a fully indigenous mission and comprises an orbiter, lander and rover. The objective is not only to expand the technologies from Chandrayaan-1 mission, but also to demonstrate technologies required for future interplanetary missions. The scientific objective is to expand the lunar scientific knowledge on topography, regolith characteristics, surface chemical composition and so on, for which a variety of payloads are mounted on the orbiter, lander and rover.

Aditya L1 mission: This will be the first Indian mission to be placed at Lagrangian point L1, about 1.5 million kilometres from the earth, from where continuous solar observations are possible. This will be a comprehensive solar and space environment observatory. The mission will carry seven payloads for studying various sun activity-related phenomena, including solar photosphere, corona, etc. in near IR, optical, X-ray and UV spectrum.

NISAR: This is a joint project between NASA and ISRO, and will be launched on-board GSLV. This is basically an Earth observation satellite which will use dual frequency both in S and L bands. It is planned to be used for remote sensing to observe and understand natural processes on Earth. NASA will provide the L-band Synthetic Aperture Radar (SAR) and associated systems, while ISRO will provide the S-band SAR and associated systems along with satellite bus and remaining systems. Data collected from NISAR will reveal information on the evolution and state of the Earth's crust, help scientists better understand our planet's processes and changing climate, and aid future resource and hazard management.

Venus: Venus is often described as the 'twin sister' of the Earth because of similarities in size, mass density, bulk composition and gravity. It is believed that both planets share a common origin, forming at the same time out of a condensing nebulosity around 4.5 billion years ago. Venus is around 30% closer to the Sun when compared to the Earth resulting in much higher solar flux. Hence there is a high level of curiosity for studying Venus. Venus orbiter mission is planned to study the atmosphere of Venus. Initial elliptical orbit around Venus is expected to have 500 km periapsis and 60,000 km apoapsis. The satellite configuration and payloads are yet to be finalized.

ExpoSAT: This again is an astronomical mission and the aim is to study the angle of polarization of bright X-ray sources in our universe.

You are embarking on Chandrayaan-2 shortly. Are there any plans to send an astronaut to the moon in the near future?

Presently we do not have an approved human space flight programme. Even after approval, the initial attempt will send an astronaut to a Low Earth Orbit (LEO). As far as the Moon is concerned, all the human activities can be done by robotic missions. In fact, at ISRO we are initiating a space robotics programme to take up this challenge. However, the Moon is a good candidate as a staging point for carrying out our deep space human spaceflight missions. Chandrayaan-2 mission will assess the suitability of the Moon for such activities. We are working on all fronts; however, we do not have an immediate plan to send humans to the Moon.

In terms of space science and technology where does India stand today compared to other countries that are involved in space missions?

India started late. Our primary effort is to meet the national requirements in the area of earth observation, communication and navigation services. Space science missions are considered expensive. However, India has shown that such missions can be achieved on smaller budgets. Chandrayaan-1, Mars Orbiter Mission and Astrosat mission have provided excellent path-breaking results and improved our understanding of the solar system. We have already reached the moon and Mars. We will shortly be landing on the moon and be reaching Venus and the sun. We also have ExpoSAT in the pipeline. In essence, we are doing good work both in deep space interplanetary missions as well as space astronomy missions. A large number of universities are involved in these missions. Of course, the scope for space science is very vast. The only area where we do not have immediate plans is establishing a space station for science experiments. However, we have plans to demonstrate docking capability which is crucial in establishing a space station in LEO. All other technologies are available.

Are all critical components required for space missions designed, developed and manufactured in India as of today? If not, to what extent does India depend on other advanced countries? What are the future plans?

ISRO has always believed in self-reliance. Indigenous capability in all associated areas is a must for a thriving and vibrant space programme. If you take PSLV, when the project was started, the import content in terms of cost was 32%. Today, it is around 7–8%. Most of the imported items are non-strategic and available with multiple sources. Some of these items are electronic components, high-pressure hoses, precision bearings, C/C fibres and aluminium alloy sheets. These items are not specific to the launch vehicle or satellite, and are used in several industries. However, as our requirements are small and the items are generic in nature and easily available, it does not make sound economic sense to indigenize each and every thing. In fact, the import content for space systems in other counties is much higher. ISRO is interested in indigenizing electronics as well as C/C fibre. However, ISRO alone cannot do it; efforts are required at the national level to achieve the same.

ISRO is helping other countries to launch their satellites. What are the plans for the future?

The primary mandate of ISRO is to serve the national interest. Our national requirements are in the areas of remote sensing, communication, navigation and space science. Due to the reliability of our missions and low cost of launching, there are requirements from other countries to launch satellites commercially. Hence, whenever we have spare payload capacity or launch slot, we accommodate satellites (remote sensing, low-orbit missions, etc.) of other countries in our missions. This is done after catering to national requirements and only to ensure that we are effectively utilizing the extra capacity to benefit us. ISRO will continue to launch satellites of other countries in a similar fashion.

To what extent have the space programmes in India helped the common man? What are the societal applications of ISRO's satellite programmes?

I would not be exaggerating if I say that the life of each and every citizen of India is in one way or the other connected with the space programme. Today satellites have made seamless communication possible. Satellites also provide a variety of DTH channels for people to watch. Disaster management services have averted several tragedies and saved thousands of lives. A variety of agriculture-focused satellite services have supported sustained agriculture which has ensured food security. Multitude of GIS services have enabled faster execution of many mega projects like roadways, railways, etc. PFZ services have improved the income of thousands of fishermen. Similarly, telemedicine and tele-education services are benefiting thousands in remote areas. The GAGAN service is being used for efficient air-traffic management and manning of unmanned railway crossings. Space technology is contributing in all the major flagship programmes of GoI from MGNREGA to Digital India to Make in India.

Do you think that ISRO has made progress in space science in India as envisioned by Vikram Sarabhai? If not, which missions need attention?

ISRO has always been guided by the vision of Sarabhai of being 'second to none' in the application of advanced technologies for the service of the common man. In fact, during Sarabhai's time, the scope of space activity was very limited. It was Satish Dhawan who structured ISRO to transform and work in an organized manner. Later stalwart's like U. R. Rao, Kasturirangan, Srinivasan and Madhavan Nair played a key role in developing indigenous capability in the areas of launch vehicles and satellites. Today, the scope of ISRO activities is much larger than envisioned by Sarabhai.

However, even though the space activities in India started with space science – the sodium vapour experiment, today ISRO has transformed itself as a service organization catering to national requirements. In doing so, we have not neglected space science. With the series of missions as mentioned earlier, we are on the right path.

How is ISRO engaged with the student and academic community?

Scientific temper and lateral thinking are two attributes required to work in an R&D organization like ISRO. With regards to the student community, we are planning to launch a programme that will identify students with scientific temper through different competitions in urban and rural schools. Such students would be brought to ISRO, where they would be trained and exposed to new areas. ISRO is also planning to encourage such students through awards along with providing the opportunity to watch satellite launches. Such an exposure will increase their curiosity, provide new insights and enable students to contribute better. These new insights may also trigger in students, a new idea that could be beneficial to the public. ISRO is also planning to engage students with its Navik receiver. Students will be allowed to create new applications that are beneficial to the society and pursue the same as an entrepreneurial venture.

The academia along with industry have always been crucial partners of ISRO. ISRO has always carried out many research programmes with support from academia in the country. Through ISRO's RESPOND programme, academia submit research proposals of mutual interest which are funded by ISRO. A large number of RESPOND projects have been completed as well as are in progress. As part of our capability building, we have a programme called institutional support, wherein an ISRO cell is created in the university to encourage and coordinate space-related R&D. At present, it is functional in a few universities, but efforts are being initiated to expand the programme. In addition to this, all major universities participate in ISRO's space science missions. ISRO has also supported many student satellite projects in universities, where both students and professors participate. Senior professors who are eminent experts also participate as reviewers of ISRO's flagship projects and in many other activities. We have a very healthy and vibrant relationship with academia, which we will continue.

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