The Role of ISRO in the Growth of Science and Technology in the Space Sector: Post-2014 Development

Introduction

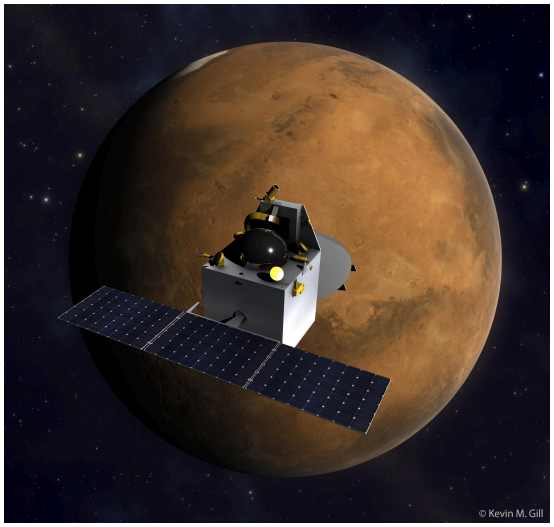
Scientific research is the driving force behind a nation's progress, playing a crucial role in technological advancements, economic growth, and societal development. It fosters innovation, strengthens national security, and improves the overall quality of life by addressing global challenges and enhancing knowledge. In this endeavor the name of ISRO in the area of space science research is immense. Its really a remarkable journey that began in 1962, with transporting rocket parts from carrying rockets on a bullock cart[1] to deploying cutting-edge Mobile Launch Pedestals (MLP)[2]. Today ISRO has transformed into a global leader in space technology, driving India's advancements in satellite communication, remote sensing, planetary exploration, and human spaceflight, ISRO's relentless innovation has propelled India into the elite league of spacefaring nations, making significant contributions to science, technology, and global cooperation.

ISRO: From Foundation to Frontier – A Shift Before and After 2014

Prior 2014

In the year 1963 ISRO, launched its first sounding rocket, and started its journey towards space exploration, prior to 2014, ISRO has achieved historical achievement such as launching of Aryabhata which was first Indian Satellite on board the space journey in 1975[3] then with great success of launching satellite, ISRO aimed to improve the telecommunication of India by launching Ariane Passenger Payload Experiment (APPLE) in 1981 which was ISRO's first indigenous, experimental communication satellite[4] which helped them to upgrade to INSAT(1983)[5] series.

In 2000, ISRO earned its place in Space community by launching of Chandrayaan-1(2008) a first Moon based mission where the satellite was orbiting above 100 km from the lunar surface for chemical, mineralogical and photo-geologic mapping of the Moon and which included 11 scientific instruments installed by India, USA, UK Germany, Sweden and Bulgaria[6]. And another milestone in the early 2000 was Mars Orbiter Mission(2013) in short it's called MOM, was the country's pride as it was the first time ISRO launched a spacecraft to another celestial body, to have scientific research on Mars[7]. With this series of achievements in 2025 ISRO has marked their 100th launch[8].



The growth of ISRO indicates India's overall advancement; however, an ongoing debate persists about whether the nation should emphasize space technology or concentrate on developing a socialist society. Consequently, ISRO faced considerable challenges, requiring more than 60 years to accomplish its 100th launch. On the other hand, NASA reached this milestone far more rapidly, achieving its 100th launch in 2009 within just six decades of its inception[9]. Despite this setback, India remained competitive in the space race.

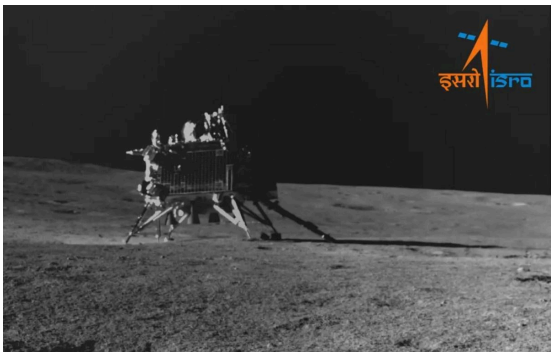
Post 2014

With the great start of placing the Mangalyaan satellite in the orbit of Mars(24th September 2014)[11], ISRO's space related activities continued in its journey of space exploration, benefiting the common people of India while making significant contributions to the world of space science such as Geosynchronous Satellite (GSAT) which is used for conducting communication experiments like digital audio broadcast, internet services and compressed digital TV transmission although this satellite was initially launched in 2001 with up to 9 launches but over the time the technology advancement made by ISRO has increased and over the next 11 years. ISRO thus has conducted 25 launches in total mainly with the purpose to boost Indian economy.[12]

ISRO is known for all of us for its cost cutting technologies, aiming for sustainable use of resources with less cost[13] by developing Scramjet Engine Technology Demonstrator, this was mainly done with a view to reduce the cost of launch and its potential use and applicability.

Moreover the Indian GPS System improved so much that even Indian courts use the GPS image to give judgment, and all thanks to ISRO Navigation Indian Constellation (NavIC)[14] which is designed with a constellation of 7 satellites and a network of ground stations operating 24x7. NavIC offers two services: Standard Positioning Service (SPS) for civilian users and Restricted Service (RS) for strategic users which assists the Indian Army, Air Force and Navy.

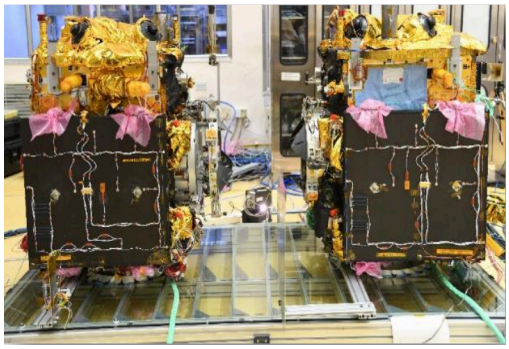
ISRO has also faced failure's of one such mission as Chandrayaan-2 to deploy a lander in the south portion of the moon in 2019 but failed to land on the moon due to technical difficulties. However the ISRO Scientists never gave up and launched the instrument Chandrayaan-3 within the timestamp of 4 years. This shows remarkable achievement done by ISRO in the area of Space science and the landing site was named as Shiv Shakthi and Indian Astronomy studies are on a competitive edge all thanks to ISRO XPoSat (X-ray Polarimeter Satellite) first space mission dedicated to studying X-rays from powerful space objects like black holes, neutron stars, and galaxies. It carries two main instruments: POLIX, which measures the direction and strength (called polarization) of X-rays and XSPECT, which studies the types and timing.



India's vision toward autonomous has achieved in the manufacture of Reusable Launch Vehicle Technology Demonstrator (RLV-TD)[18] is a pioneering initiative by ISRO aimed at developing India's capability in reusable space transportation. In this demonstration, the vehicle successfully performed the landing after lift-off, remaining in a condition suitable for reuse. After making use of this within the span of one year it launched the Reusable Launch Vehicle

Autonomous Landing Mission (RLV-LEX-03)[19]. In this updated version, the vehicle achieved a fully autonomous landing without any manual intervention, marking a significant milestone in the development of reusable launch systems

Another major invention by ISRO is Aditya-L1 is India's first space-based mission dedicated to studying the Sun, and it will be positioned in a halo orbit around Lagrange Point 1 (L1) of the Sun-Earth system, approximately 1.5 million kilometers from Earth. This unique location enables continuous, uninterrupted observation of the Sun without any eclipses or occultation, allowing real-time monitoring of solar activities and their influence on space weather.[20].



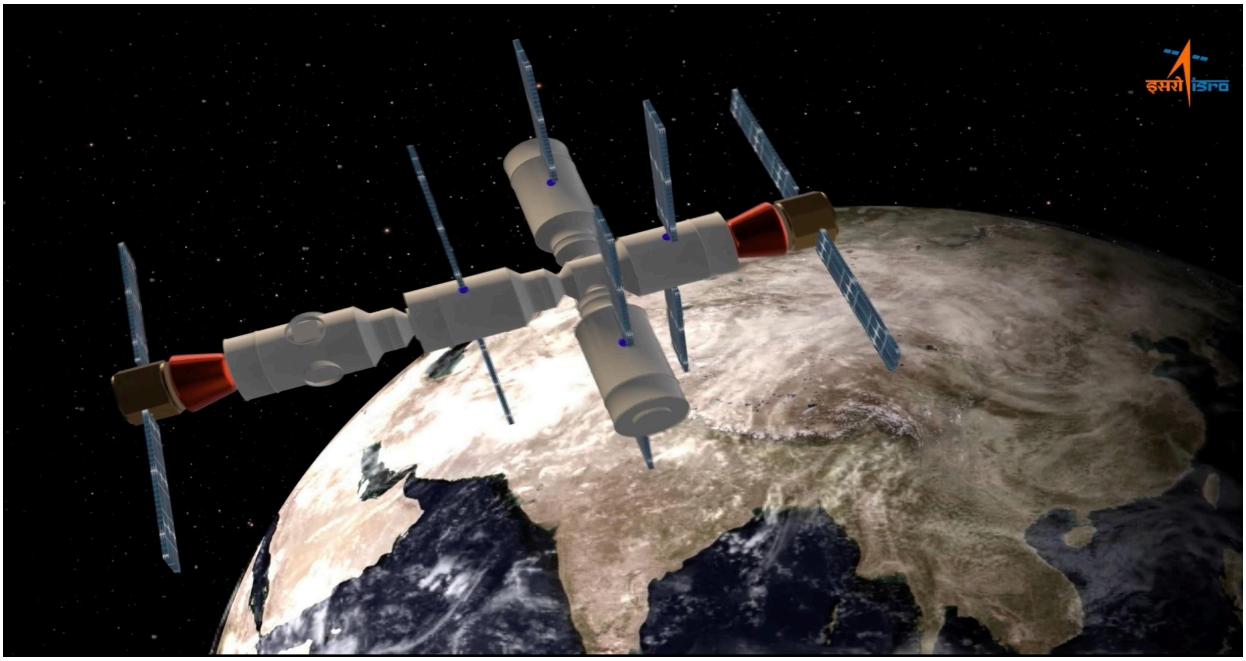
Furthermore ISRO ambition towards space station has come one step closer with successful launch of SpaDeX (Space Docking Experiment) mission aimed at developing and demonstrating the critical technologies required for the rendezvous, docking, and undocking of two small spacecraft in orbit. This mission plays a key role in advancing India's capabilities in autonomous space operations, which are essential for future applications such as satellite refueling, and complex on-orbit missions involving multiple spacecraft[21].

Future Prospects of ISRO

All past missions have been stepping stones, connecting the dots toward a visionary future. Through immense knowledge gained and lessons learned from failures, ISRO has continuously evolved, taking bold strides toward making India a leading spacefaring nation and their very own vision toward human in space become reality in the missions Gaganyaan, with the help Institution of Aerospace Medicine(IAM)[22], ISRO has successfully selected 4 Astronauts, Group Captains Prasanth Balakrishnan Nair, Group Captain Ajit Krishnan, Group Captain Angad Pratap and Wing Commander Shubanshu Shukla, who are been trained to be in space for 7 days, which will help ISRO to learn Human capability in space, by 2026.

Furthermore the most ambitious lunar mission Chandrayaan-4, aiming not only to achieve a soft landing near the Moon's south pole but also to bring back around 2–3 kilograms of lunar soil and rock samples to Earth. This marks a major upgrade from it will be India's first sample return mission. Scheduled for launch around 2027[23]

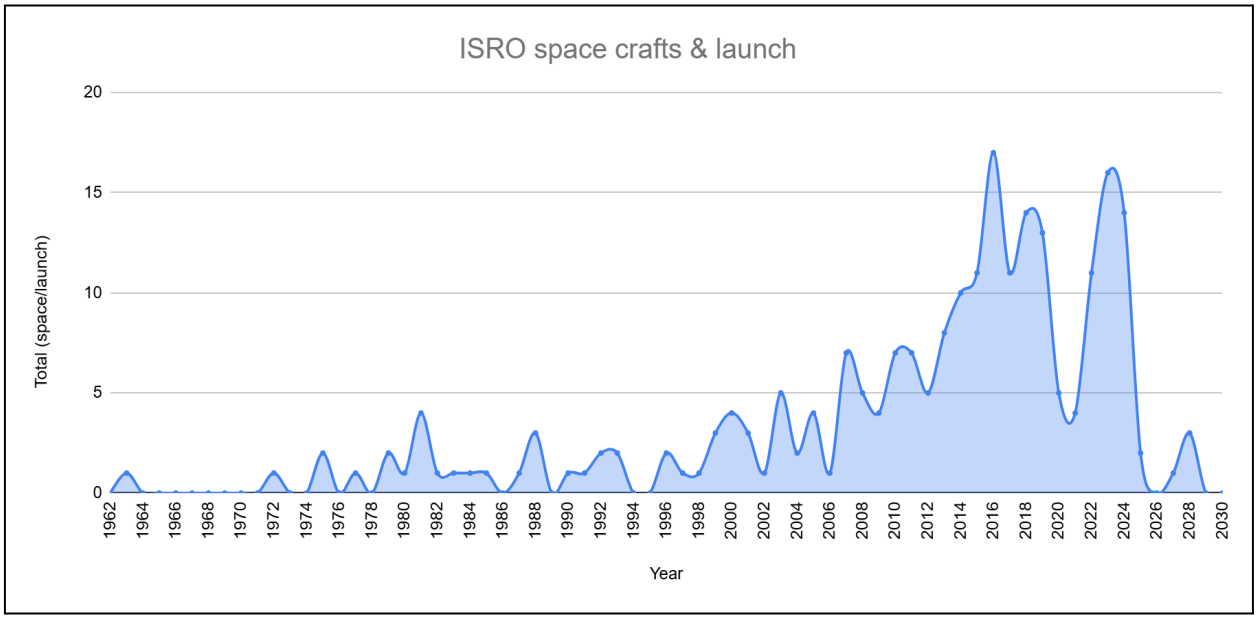
Another interplanetary endeavors mission after Mars taken up by ISRO, The Venus Orbiter Mission which is achieved by only four countries having successfully placed a spacecraft in Venus' orbit will make us the 5th nation to study Venus. With respect to exploring Venus' atmosphere, surface, and its interaction with solar activity.



ISRO is planning to make its very own space station, Bhartiya Antariksh Station[24], which will facilitate space research and etc, and the bringing this idea into life, ISRO has achieved SpaDex mission, which achieve Rendezvous the two objects and connected, this type of technology is very much need to make a space station. These are all the missions planned by ISRO.

Policy implementation in post 2014

The sharp spike in the graph reflects a notable increase in the number of



missions undertaken by ISRO. This sudden rise can be attributed to a 50% increase in ISRO's budget[25], granted by the Government of India[26]. Furthermore, the space policy reforms introduced after 2014 encouraged greater public-private partnerships[27], which not only improved operational efficiency but also opened new revenue streams. Between 2015 and 2024, ISRO successfully launched 393 foreign satellites[28], significantly boosting its resources, manpower, and funding. These developments have collectively strengthened the backbone of India's space sector.

Another key factor behind ISRO's recent success is its enhanced rocket production capacity. To put this in perspective, in the 53 years prior to 2014, ISRO launched only about 40 rockets. In contrast, over the last 11 years alone, it has manufactured and launched more than 60 rockets[29]. This substantial increase was made possible through government approval establishment of the Integrated Cryogenic Engine Manufacturing Facility (ICMF) in Hindustan

Aeronautics Limited (HAL) since 2016, with a budget allocation of ₹208 crore[30], played a crucial role in expediting the production of cryogenic engines, an essential component for heavier launch vehicles which helped increase the GSAT satellite in orbit compared to prior[31]. Additionally, the implementation of flexible space policies and the emergence of commercial arms such as IN-SPACe, along with government-sanctioned contracts awarded to private players such as PSLV manufacturing, to L & T partnered with HAL and with the help of Wipro 3D printing technology ISRO successfully carried out extended-duration hot tests of a liquid engine developed using additive manufacturing techniques[32](3D printing) another achievement of ISRO to make its mission cost effective hence this has ushered in a new era of public-private collaboration, efficient and effective.

Conclusion

ISRO's phenomenal journey from carrying rockets on bullock carts to leading cutting-edge missions to the Moon, Mars, and beyond is a testament to India's scientific acumen and strategic foresight. While its early achievements laid the foundation, the post-2014 era marked a transformative phase marked by rapid advancements, increased budgetary support, and a collaborative ecosystem between public and private sectors.

Missions like Mangalyaan, Chandrayaan-3, and Aditya-L1 to futuristic goals such as Gaganyaan, Chandrayaan-4, and the Bharatiya Antariksh Station, ISRO has consistently pushed the boundaries of space science and technology. The development of indigenous technologies such as reusable launch vehicles, NavIC, and advanced cryogenic engines demonstrates ISRO's focus on innovation, sustainability, and cost-effectiveness; this was possible with policy reforms and global partnerships that have accelerated the organization's progress, positioning India as a leading nation in the Space industry.

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