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India Foundation is an independent research centre focussed on the issues, challenges, and opportunities of the Indian polity. The Foundation believes in understanding contemporary India and its global context through the civilizational lens of a society on the forward move. Based on the principles of independence, objectivity and academic rigour, the Foundation aims at increasing awareness and advocating its views on issues of both national and international importance.

With a team of dedicated professionals based at its office in New Delhi, the Foundation works with partners and associates both in India and overseas to further its stated objectives.

About India Foundation Journal

The India Foundation Journal is led by an Editorial Board of eminent scholars and leaders from various spheres of Indian public life. The bi-monthly journal covers a wide range of issues pertinent to the national interest, mainly focusing on international relations, national security, legal and constitutional issues and other issues of social, religious and political significance. The journal seeks articles from scholars with the intent of creating a significant body of knowledge with a nationalist perspective and establish a recognised forum for debates involving academicians and policymakers.

India's Space Progamme: Developments and Strategic Concerns

Dhruv C. Katoch*

The end of World War II did not usher in the desired peace; rather, it saw the beginning of geopolitical tensions between two blocs—the United States and its allies on one side and the Soviet Union and its allies on the other. As hostilities between the two blocs did not involve large scale fighting, this period came to be known as the Cold War, which continued for over four decades till the dissolution of the Soviet Union in 1991.

Along with the Cold War began the race for space. This in part was inspired by the nuclear arms race between the US and the Soviet Union. The former began research on nuclear fission in January 1939, and by June 1940, scientists had a fair idea of the potential of atomic energy. Through the Manhattan project, huge investments were made to build a nuclear device, which finally fructified with the successful testing of a plutonium implosion device called "Gadget" on 16 July 1945. While Germany had surrendered earlier in May 1945, Japan was continuing with the war. To force an early Japanese surrender, an atomic bomb was dropped by the US on the Japanese city of Hiroshima on 6 August 1945, using a B 29 heavy bomber. Another atom bomb was detonated over Nagasaki three days later[1], which forced Japan to surrender, marking the end of World War II. The Soviets were now spurred to develop their own nuclear programme, both for national security as well as for ideological reasons. On 29 August 1949, the Soviets successfully conducted their first nuclear test in Kazakhstan.[2] The nuclear race had begun.

The next step was dominating space, which in military parlance is viewed as the ultimate high ground. The Soviets were first off the board, with the launch of Sputnik 1 in a low earth orbit on 4 October 1957. A month later, on 3 November 1957, the Soviets launched Sputnik 2, carrying a dog named Laila into space.[3] Shortly thereafter, the US launched their own satellite, Explorer 1 into space on 31 January 1958.[4] Thus began the race for domination of space flight technologies. This pursuit continues amongst various nation states of the world, encompassing the launch of earth satellites in various orbital configurations, establishing space stations and space probes of the Moon, Venus Mars and other celestial bodies.

The Beginning of India's Space Programme

India began its space programme, a few years after the Americans and the Soviets had launched their first satellites. At that time, applications using satellites were still in an experimental stage, but with the live television coverage of the 1964 Olympic Games in Tokyo, Japan, across the Pacific by the American Satellite 'Syncom-3'—an experimental geosynchronous communications

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satellite[5]—the potential of satellites for communication and other purposes was dramatically demonstrated to the world.

A few years after gaining independence, India started research on nuclear energy. The Department of Atomic Energy (DAE) was established on 3 August 1954, under the direct charge of the Prime Minister and with Dr Homi Bhabha as its Director. The DAE was given the mandate to transact all businesses of the Government of India under the Atomic Energy Act, 1948. On 1 March 1958, the government set up the Atomic Energy Commission with full authority to plan and implement the various measures required for the expansion of the atomic energy programme. In 1961, space research was placed under the ambit of the DAE. A year later, in 1962, the Indian National Committee for Space Research (INCOSPAR) was established under the DAE, with Dr Vikram Sarabhai as its chairman. Subsequently, Indian Space Research Organisation (ISRO) was established in August 1969, in place of INCOSPAR.[6] In June 1972, the Government of India constituted the Space Commission and established Department of Space (DOS). Thereafter, in September 1972, ISRO was brought under the DOS.

Dr.Vikram Sarabhai, the founding father of India's space programme, appreciated the benefits of space technologies and their potential to address the myriad problems of a geographically large developing country like India. He founded the Physical Research Laboratory (PRL) in 1947 and became its first founder director. Dr Sarabhai founded the PRL initially at his residence, to carry out research on cosmic rays and the upper atmosphere. On 11 November 1947, it was formally established in the M. G. Science College, Ahmedabad, with support from the Karmkshetra Educational Foundation and the Ahmedabad Education Society. Research in Theoretical Physics and Radio Physics were added later with grants from the Atomic Energy Commission.[7] As Director, PRL, Dr. Sarabhai got together a number of brilliant scientists from multiple disciplines to spearhead the space programme. These included scientists, anthropologists, communicators, social scientists and others from all over the country.[8] In 1962, he took over the responsibility of organising Space Research in India as Chairman of INCOSPAR and thereafter as Chairman of ISRO. Since then, India's space programme has made tremendous strides, especially in the last decade, placing India as one of the leading nations in space technology.

India's Space Programme

Over the last six decades, the Department of Space has evolved various programmes to promote and develop application of space science and space technology. These include:[9]

- Developing indigenous capability for launching satellites.
- Developing satellites for the purpose of communication, remote sensing, navigation, meteorology, etc.
- Research and Development in Space Sciences and Technology.

Launch Vehicles: SLV and ASLV

In the early 70s, ISRO started to develop the technology to launch satellites. The Satellite Launch

Vehicle (SLV) project aimed to carry a payload of 40 kg, up to a height of 400 km. The first launch mission carried out by India was the SLV 3E1 on 10 August 1979. The mission was unsuccessful, but the very next year, on 18 July 1980, Rohini Satellite RS-1 was successfully launched using the SLV 3E2. This was an experimental project, but the next two projects were designated as developmental, with the fourth and final launch of the SLV taking place on 17 April 1983. The SLV project was followed by the Augmented Satellite Launch Vehicle (ASLV) programme, aimed to deliver a 150 kg payload to Low Earth Orbit (LEO). Four development flights of the ASLV took place, the first on 24 March 1987 and the fourth on 4 May 1994.[10]

Polar Satellite Launch Vehicle

The ASLV project was followed by the third generation Polar Satellite Launch Vehicle (PSLV) programme. Called the workhorse of ISRO, it has been used to launch all the three types of payloads, viz. Earth Observation, Geo-stationary and Navigation. Both Indian and foreign satellites have been successfully launched using the PSLV. Amongst others, the PSLV was used to launch "Chandrayaan-1 and Mars Orbiter Spacecraft in 2018 and 2013 respectively, the former for India's Moon mission and the latter for India's mission to Mars.[11] Its reliability, versatility and affordability has made it a sought after launch vehicle for the launch of foreign satellite also.

Geosynchronous Satellite Launch Vehicle

The Geosynchronous Satellite Launch Vehicle (GSLV) with indigenous Cryogenic Upper Stage has enabled the launching of up to 2.25 tonne class of communication satellites. A fourth generation launch vehicle, GSLV's primary payloads are INSAT class of communication satellites for placing them in Geosynchronous Transfer Orbits. It can also place a payload of up to six tonnes in LEO.[12] With these launchers, India is totally self sufficient for launching its satellites.

Small Satellite Launch Vehicle

The Small Satellite Launch Vehicle (SSLV) is capable of launching a 500 kg satellite in a 500 km planar orbit. The second developmental flight of the SSLV was successfully launched on 10 February 2023. SSLVs require minimal launch infrastructure and can be launched on demand. They are cost effective, have low turn-around time, and can accommodate multiple Nano, Micro and Mini satellites. SSLV-D2 is intended to inject EOS-07, Janus-1 and Azaadi SAT-2 satellites into 450 km circular orbit, in its 15 minutes flight.[13]

Launchers in use and under Development

A total of 94 launches have taken place till date, the most recent being on 02 September 2023 where the PSLV-XL Launcher placed the Aditya L1 satellite into orbit. Of the 94 launches made so far, 85 were successful, giving the Indian space programme a success rate of 90 percent successful launches. In the last nine years, 54 launch missions have taken place of which 52 were successful, giving a success rate of over 96 percent. In the last two years, all the 12 missions launched were successful, giving a 100 percent success rate.[14]

This is indeed an enviable achievement, comparing favourably with other major space-faring nations.

Launchers in use are the PSLV, GSLV, Geosynchronous Satellite Launch Vehicle Mark III (LVM3) and Sounding Rockets. Both the SLV and the ASLV have been retired. The LVM3 was used for launching Chandrayaan 3 to the Moon on 18 July 2023. Launchers under development are the Human Rated Launch Vehicle (HRLV), Small Satellite Launch Vehicle (SSLV), Reusable Launch Vehicle - Technology Demonstrator (RLV-TD) and Scramjet Engine - TD.[15]

Major Satellite Launches

From the launch of the Aryabhata and Bhaskara 1 satellites on 19 April 1975 and 7 June 1979 respectively, both of which were experimental satellites, India has come a long way. Over a hundred Indian satellites have been launched till date, using for the most part, Indian launchers. Satellites have been launched for earth observation, planetary observation, communication, navigation, disaster management, climate environment and for experimental purposes.

Aditya L1. This is India's first space based mission to study the sun. Launched on 02 September 2023, the satellite is set to reach its cosmic destination, Lagrange Point 1 (L1) on 6 January 2024. Aditya-L1 is carrying instruments to observe the solar atmosphere, mainly the chromosphere and corona. In-situ instruments will observe the local environment at L1. There are seven payloads on-board of which four are for carrying out remote sensing of the Sun and three for carrying out in-situ observation.[16]

Chandrayaan 3. India's lunar exploration program has been a source of national pride and a testament to the country's scientific prowess. Chandrayaan 3 was a follow on mission of Chandrayaan 2, designed to demonstrate end-to-end capability in safe landing and roving on the moon. Consisting of a lander and a rover, the former was equipped with Chandra's Surface Thermophysical Experiment (ChaSTE) to measure thermal conductivity and temperature. Other equipment in the lander was to measure seismicity around the landing site and to estimate plasma density and its variations. The Lander also carried a passive Laser Retroreflector Array from NASA for lunar laser ranging studies. The Rover's payload was for deriving the elemental composition in the vicinity of landing site. Launched on 14 July 2023, the Lander made a successful touch down near the lunar south pole on 23 August 2023, placing India among a select group of countries—the US, Russia and China—to achieve this feat and the only country to have successfully landed on the moon's south pole. It positions India as a global hub in the new space economy.

Mangalyaan

India's first inter-planetary mission was the launch of Mars Orbiter Mission (MOM), called Mangalyaan, on 05 November 2013. Mangalyaan orbited Mars from 2014-2022, making ISRO only the fourth space agency after NASA, Roscosmos, and the European Space Agency to achieve this feat. Mangalyaan had a stated life span of six months, but it continued to send data well beyond that prior, for a period of seven and half years, after which the mission was declared closed. It represented a great step forward in developing

technologies to explore the inner solar system. The scientific equipment carried on board was Mars Colour Camera, Thermal Infrared Imaging Spectrometer, Methane Sensor for Mars, Mars Exospheric Neutral Composition Analyser and Lyman Alpha Photometer.[17]

Indian Regional Navigation Satellite System (IRNSS)

India's ambitious IRNSS programme is a constellation of seven satellites in space, the first of which, IRNSS-1A was launched on 01 July 2013 and the seventh, IRNSS-1G, on 28 April 2016. IRNSS is now called **NavIC,** an acronym for Navigation by Indian Constellation. NavIC is designed to provide geospatial positioning information within the Indian sub-continent. It functions akin to the US Global Positioning System (GPS), but unlike the US GPS, which provides global coverage, NavIC provides coverage to the Indian land mass and to areas 1500 km beyond it. NavIC is used for ground, aerial and marine navigation, disaster management, mobile phone integration, mapping and visual & voice navigation for drivers, among others. When fully functional, India's dependency on foreign navigation satellite systems will reduce considerably.[18]

The NavIC space segment consists of 3 Geostationary orbits (GEO) and 4 Geosynchronous orbits (GSO) satellites. The ground segment is responsible for the maintenance and operation of the IRNSS constellation. It consists of the spacecraft control facility, navigation centre, Range and Integrity monitoring stations, Network Timing Centre, CDMA, Laser Ranging stations and a Data Communication Network. The User segment aims to provide Standard Positioning Service (SPS) for civilian research & commercial use, and Restricted Service (RS) for authorised users such as in the defence sector.[19] As per Rajeev Chandrasekhar, Union Minister of State for Electronics and Information technology, all smartphones will have to support NavIC by the end of 2025.[20]

GAGAN is the acronym for GPS Aided GEO Augmented Navigation. Jointly developed by ISRO and the Airports Authority of India (AAI), it uses a system of ground stations to provide necessary augmentations to the GPS standard positioning service (SPS) navigation signal. It was first used by a commercial aircraft on 22 April 2022, when an Indigo flight landed in Kishangarh Airport in Rajasthan using the indigenously developed Satellite based augmentation system (SBAS), making India the first country in the Asia Pacific to successfully develop such a system for aviation use.[21] With this, India's GAGAN becomes the fourth space-based augmentation systems available in the world after US (WAAS,) Europe (EGNOS) and Japan (MSAS).[22]

Strategic Concerns

When India began its space program, it remained focussed on the peaceful uses of space such as for weather forecasting, disaster management, communications, education, remote sensing etc.. India had tremendous development challenges, so to make a case for additional allocation of funds for the space sector which did not have a direct bearing on India's development effort, was a difficult proposition. That India has still made gigantic progress in the space sector

reflects credibly on the aptitude and dedication of its scientists, but that has not lessened the need for allocation of higher budgetary allocations. Today, considering the geo-strategic environment in which we are living, much greater thrust has to be given to this sector, both as an economic necessity as well as on security considerations. India's share in the global space economy is just about 2-3%, which needs to be considerably enhanced to at least 10% by 2030 and to 25-30 % by 2050, commensurate with India's standing in the world. Funding for space-based activities will hence require a quantum increase, year on year, henceforth.

The security challenges which India faces on its land and maritime borders are indeed immense. While success in sending a satellite into orbit around Mars, the demonstration of end-to-end capability in safe landing and roving on the moon, and its success in sending a space-based mission to study the sun is laudable, concerns remain about the vulnerabilities that India's reliance on satellites has created. Doing away with space based assets for communication, earth observation etc.. is really not an option. Increasing focus is hence required on the need to protect space and ground based assets from hostile forces.

In addition, China's controversial testing of an anti-satellite missile in 2007, was a wake up call for India. It took 12 years for India to develop its own ASAT capability, with India successfully carrying out an ASAT test on 27 march 2019.

This was announced to the nation by Prime Minister Modi on the same day. Mission 'Shakti' as the test was called, struck an Indian satellite in LEO, which had been recently launched for the purpose, destroying it. With weaponisation of space becoming a possibility in future, India's ASAT test, besides showing India's deterrence capability, was also required from India's point of view as future arms control agreements will place India on the have category and make it a party to framing that agreement.

Conflicts over the past three decades have shown the power of technology in the battlefield, wherein a missile can be sent to destroy a target with precision, many thousands of kilometres away. This has been made possible by space based capabilities, which play a key role in the military's C4I2SR (command, control, communications, computers, information, intelligence, surveillance, and reconnaissance) systems. ISRO presently has 54 satellites in orbit - both LEO and GEO combined. Some of these are dual use, but only two are dedicated for military use. The dedicated military satellites are the GSAT-7 (Rukmini) and GSAT-7A (Angry Bird), used by the Indian Navy and Air Force, respectively.[23] India has been relying on foreign partners for some of its satellite-based communications and data services. While cooperation in space with friendly countries will continue, India needs to ramp up its space capabilities and dedicate a much larger number of satellites for that purpose. Speaking on this issue, ISRO Chairman S Somanath said that ISRO will launch 50 satellites in the next five years that are based on AI technology and that can interact with each other in space to gather geo-intelligence.[24] This indeed is a welcome step that will bolster Indian space capability and assuage to some extent, India's security concerns.

Since 2014, we have seen the political

leadership taking ownership of the space domain. This too, is a welcome and most desirable development, as it will lead to much greater focus on this segment. But the political leadership has to be consistent in its support for the space programme, especially in terms of setting goals, requirements, and milestones outlining where India wants to be in 2030 and 2050 and thereafter ensure that the stated goals are achieved.

As in the US, there is a need for much greater involvement of the private sector in India's space programme. The Indian space program is entirely state-driven, though ISRO is around 70%–80% reliant on private sector contractors for components and services. The DOS is now proposing reforms to open up the space sector to private industries. NewSpace India Limited (NSIL), which was incorporated in 2019 under the DOS, to commercially exploit the goods and products emanating from the Indian space programme will act as the aggregator of user requirements and obtain commitments. Accordingly, Non Government Private Enterprises (NGPE) could be allowed to take part in space activities through an Indian National Space Promotion and Authorisation Center (IN-SPACe).[25] How this pans out remains to be seen, but it is a welcome step that has the potential to boost the entry of private players in the space segment manifold. We could well see an Indian Elon Musk emerging in the next decade or two, if the private sector picks up pace. In any case, if the private sector can manage some of the tried and tested programmes, ISRO would be able to focus on purely research driven programmes and on interplanetary missions.

Conclusion

Despite limited resources, India's space programme has achieved a great deal and covered many milestones over the last six decades. Space however is the final frontier and a great deal more has to be done for India to come at par with the space programmes of the US, Russia, the EU and China. This would require a very active involvement of the political leadership to fulfil India's space ambitions as also the involvement of the private sector in a big way. Cooperation with other space agencies would also be required, and India joining the Artemis Accord is a step in that direction. The future is exciting. The next decade will determine how India's plans to be a leading space-faring nation plays out. This is one race in which we cannot be found wanting.

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Technological Developments in the Space Domain: The Challenges for India

Amog Nair*

The evolving space domain is marked by advanced technologies which pose both opportunities and risks for India's global economic and national security. Propulsion, satellite, energy, cyberspace, robotics, and surveillance advancements create prospects and challenges. Developments like the Western space startup surge could deepen global economic disparities or offer India substantial gains. Growing space capabilities from influential nations like the U.S., Russia, and China raise concerns for India's space assets. UAPs (Unidentified Anomalous Phenomena), studied by NASA and the Pentagon, add a cosmic dimension. India's response to these developments warrants examination, urging proactive engagement to avoid geopolitical regression and loss of autonomy.

Economic Developments

In the pursuit of evolving into a space-faring civilisation, sustained economic activities within the space domain are imperative. The pioneers in this arena are predominantly from North Atlantic countries, with a notable focus on space factories and the recognition of property rights over space resources.

Space Factories

Over the years, the share of global space research and development (R&D) funding from the US government has declined from approximately 70 percent to around 50 percent. Simultaneously, the annual funding of space-related startups has more than doubled from 2010 to 2018. There is a growing trend where commercial funding may surpass government funding within the next two decades. The government is actively embracing this shift and fostering the potential for mutually beneficial public-private partnerships.[1]

Numerous sectors stand to benefit, including semiconductors, health, wellness products, and many more. The unique microgravity and near-vacuum environment in space unlocks novel manufacturing methodologies unfeasible on Earth. Experiments aboard the International Space Station (ISS) have showcased successful ventures in producing human tissues, semiconductors, and new drugs. Recent initiatives by the Biden administration allocated $5 million toward cancer drug research on the ISS.[2] Notably, patents referencing microgravity have shown a tenfold annual increase since 2010.[3] However, the ISS faces a considerable backlog of entities seeking to utilise its facilities, compounded by its impending phase-out. This has prompted countries like China to establish their own space stations.[4]

To reduce dependence on the ISS, startups like Varda Space Industries in the U.S. are

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pioneering space-based manufacturing. Varda focuses on pharmaceutical development in microgravity. Operating an autonomous space module, the company manipulates materials, improving protein crystallisation processes, potentially enhancing existing drugs and fostering new pharmaceutical innovations.[5] They also earn through a $60 million defence contract that uses their space capsule as a hypersonic testbed.[6]

Space Forge is a British company spearheading semiconductor manufacturing in space, with the European Space Agency as its principal customer.[7] Their vision entails manufacturing semiconductors with challenging materials like Gallium Nitrate and Silicon Carbide in space. This proposition suggests enhanced chip efficiency, potentially increasing from 10x to 100x. Space conditions facilitate optimal large single crystal structure production which improves heat dissipation and electron flow. Currently, they produce 500 chips per flight, with plans to scale to a million.[8]

Space Mining

The initial excitement surrounding space mining has waned recently, marked by the acquisition of ambitious companies like Planetary Resources and Deep Space Industries by entities showing minimal interest in space resource extraction. Despite this, interest in space mining persists, albeit accompanied by significant hurdles. Lack of technical advancements in mining tools, exploration modules, logistical concerns, and lingering financial viability questions pose substantial challenges. For instance, missions like NASA's Osiris-Rex, requiring seven years and $1 billion to retrieve under 1 kg of asteroid sample, highlight the cost-prohibitive nature of asteroid mining.[9] Despite these obstacles, startups like Astro-Forge remain hopeful, drawing inspiration from past achievements, and insisting that the true value in space mining lay with extracting metals, and not water[10] [11]. Initiatives like NASA's Psyche mission conducting asteroid sciences for resource mapping offer promising insights for prospective space mining endeavours[12]. Asteroid Psyche 16 is believed to have enough raw materials to make every person on earth a multi-billionaire.[13] Yet, NASA is emphasising the moon as a more viable site for mining.[14] This stems from confirmed water presence at the lunar south pole which is essential for energy, hydration, and oxygen. The moon's proximity, stability and mass make it a more feasible landing site compared to asteroids. This prompts many to view a moon base as an essential logistical hub for an effective asteroid mining value chain.[15]

The US has been advancing private ownership over space resources, evident in the US Commercial Space Launch and Competitiveness Act of 2015. This legislation allows commercial companies operating within its regulatory framework to legally appropriate resources acquired from celestial bodies known as Near Earth Objects. Luxembourg has also followed suit with its Law on Use of Resources in Space Act and the establishment of the Luxembourg Space Agency, aiming to offer a clear legislative framework for space mining activities, thereby reducing uncertainties to attract investment. Furthermore, the UAE's Federal Law No. 12 on the Regulation of the Space Sector in 2019 covers various space activities, including space mining.

Japan's 2021 Act on Promotion of Business Activities Related to the Exploration and Development of Space Resources also focuses on space mining. However, despite these legal strides, there are notable differences among these domestic laws. Divergences exist in their acknowledgment of the Outer Space Treaty's appropriation principle, issues of international cooperation, their definition of terms like "space resources", issuance of property rights, licensing norms, etc. But it is undeniable that despite the legal uncertainties, these countries are clearly trying to lay claim to their stake in the gold rush in space.[16]

Space Logistics

Space logistics stands as a pivotal cornerstone in the burgeoning space sector. Whether facilitating space mining, establishing space factories, or venturing into innovative concepts like space hotels, robust space-based logistics remains vital. DARPA's Orbital Express, initiated in 2007, marked a foundational attempt in this domain. The program aimed to validate the feasibility of autonomous satellite refuelling and reconfiguration to bolster national security and commercial space endeavours. Refuelling satellites promised improved manoeuvrability, coverage, survivability, and extended operational lifespan, while on-orbit electronics upgrades offered performance enhancements and rapid technology deployment.[17.]

Currently, private entities are taking strides in this realm. Atomos Space plans to launch the Quark and Gluon, designed for rendezvous, docking, refuelling, and orbital transfer.[18] Blue Origin is developing the Blue Ring, a versatile spacecraft catering to in-space services, from hosting to transportation, refuelling, and data relay.[19] With a cohort of companies like Impulse Space, D-Orbit, and Momentus in this sector, these innovations mark a shift toward in-space mobility vehicles catering to diverse missions and orbits.

Military Developments

In an era where space capabilities define global power, military operations in orbit have become pivotal. Espionage via advanced satellites and the unsettling rise of anti-satellite missiles underscore a new frontier of strategic competition. These developments, accompanied by cybersecurity threats, shape a landscape demanding critical analysis and proactive defence strategies.

Cyber Warfare

The year 2022 witnessed a significant stride in space-based espionage as SpaceX propelled the classified US government satellite, NROL87, into orbit. This satellite boasted cutting-edge spying capabilities for overhead reconnaissance missions. However, Russia swiftly launched its own spy satellite, Kosmos 2558, and manoeuvred it in close proximity to the American satellite within the same orbit.[20] The global implications of these manoeuvres became apparent, particularly in the context of the United States' use of spy satellites to monitor missile and rocket launches across the globe.

This heightened the awareness of vulnerabilities inherent in many space assets. The inadequacy of these assets in considering the nuances of hacking and employment blasts became glaringly evident. Alarmingly, the simplicity with

which satellites could be hacked has been demonstrated in YouTube several times.[21] Most satellite vulnerabilities come from the fact that they were not designed with cyber threats in mind. This vulnerability escalated into a global phenomenon, with major powers—China, Russia, and the United States—engaging in frequent hacking attempts aimed at the "deny, exploit, or hijack" objective regarding enemy satellites. In response, countries are pooling expertise to counter these threats. The US military, for instance, initiated hackathons where ethical hackers were incentivised to identify vulnerabilities within American satellite systems, subsequently enabling the rectification of these flaws.[22] Notably, these cyber attacks aren't confined to space; the 2019 cyber attacks conducted by North Korea on ISRO ground stations serve as a poignant reminder of the broader scope of such threats.[23]

Anti-Satellite (A-Sat) Missiles

A disquieting evolution in space capabilities has emerged with the demonstration of anti-satellite capabilities by major powers including Russia, China, India, and the United States. These advancements allow the targeted destruction of adversary space assets, posing greater risks than mere espionage due to the potential repercussions of the Kessler Syndrome triggered by space debris.[24]

The inherent danger was starkly highlighted by incidents such as the need for the International Space Station (ISS) to execute evasive manoeuvres to evade debris resulting from the destruction of a satellite.[25] Furthermore, missions like the DART (Double Asteroid Redirection Test) mission elevate concerns as they demonstrate American capabilities to target and potentially attack assets situated far away, accurately using space based platforms.[26] Notably, the limitations imposed by technology prevent the use of anti-ballistic missiles to protect space based assets. This leaves numerous satellites vulnerable to kinetic attacks, thus amplifying the stakes and complexities of space security. Meanwhile, some other nations have joined to pledge to not conduct A-SAT tests in space in an effort to preserve orbital safety.[27]

Unidentified Anomalous Phenomena (UAP)

UAPs, a modern reinterpretation of UFOs, denote flying objects linked to non-human (alien) intelligences. Initially met with skepticism, the discourse has evolved in the last five years. It is progressing from acknowledgement of UFOs to the claims of reverse engineering UFOs and encounters with non-human intelligences. This shift was driven by courageous testimonies from military personnel and government insiders.

After the bombshell 2017 New York Times Article, the U.S. Government had reluctantly admitted to the existence of a UFO/UAP issue and began briefing members of Congress on it.[28] Prominent figures in the political sphere, including Barack Obama, the Clintons, John Podesta, John Ratcliffe, John Brennan, James Comey, and others, have confirmed the reality of UFOs. Obama even stated, "when it comes to aliens, there are just some things I can't tell you on air", before going on to confirm the UFO reality.[29] John Ratcliffe, the former Director of National Intelligence, publicly stated that the U.S. lacks the capability to defend

against these objects.[30] Marco Rubio even felt that it was better for UAPs to be aliens because if they belong to an adversary, Pax-Americana had already ended. The UAPs exhibit abilities that defy our current understanding of physics, including the capability to achieve relativistic speeds, operate in diverse mediums, break the sound barrier without producing a sonic boom, accelerate instantaneously, and execute high-speed manoeuvres without regard to inertia or G-forces. The UAPs also come in various shapes and sizes.[31]

The growing pressure from Congress led to the establishment of the UAP Task Force (now AARO) in 2020, tasked with collecting and analysing UFO reports. They have so far collected over 800 reports to date. While government statements refrain from attributing these phenomena to foreign adversaries, they stress the national security and aviation safety threats posed by UAPs.[32] Bill Nelson, NASA's Director, initiated a UAP study panel that recently published its inaugural report, followed by the establishment of a permanent UFO office within NASA.[33] This is late compared to France's CNES which has long maintained GEIPAN for investigating civilian and military UFO reports.[34]

A pivotal moment occurred when David Grusch, an intelligence official with the NGA and the NRO, emerged as a whistleblower. During his congressional testimony, Grusch revealed the government's involvement in capturing and reverse engineering UAPs. His position within the UAP Task Force and his role in authoring whistleblower protections in the NDAA lent credibility to assertions of UAP possession, reverse engineering, disinformation campaigns, budget misallocation, private contractor involvement, recovery of bodies, and security breaches.[35] Notably, dozens of whistleblowers have now approached Congress and the Inspector General to make protected disclosures.[36] Grusch's claims aren't new though. Similar claims have been made historically by figures such as Canadian Defense Minister Paul Hellyer[37] and Apollo Astronaut Edgar Mitchell.[38] Furthermore, the U.S. Navy's patent filings since 2016, detailing advanced UFO-like technologies were granted following naval intelligence's citation of Chinese advancements in similar fields.[39] The extent of reverse engineering by Russia and China remains uncertain, with some believing that they might be ahead of the US.[40] It has been confirmed that China has established a UFO task force and employs artificial intelligence for UAP study.[41] Meanwhile, some Canadian parliamentarians have concerns about Canada's declining role in UFO retrieval programs within the Five Eyes alliance.[42]

A schism exists between the legislative and executive branches in the United States. John Kirby has affirmed the White House and Pentagon's seriousness of the subject, citing that many of these reports come from restricted areas such as training zones, test sites, and missile bases.[43] Meanwhile Congress, displaying remarkable bipartisan unity, relentlessly seeks answers from the executive. In July 2023, Senate Majority Leader Chuck Schumer introduced the UAP Disclosure Act, an amendment to the 2024 NDAA. This legislation aims to bring transparency to UAP matters, acknowledging undisclosed UAP documents, addressing the misuse of national security provisions, establishing an Expert Review Board for declassifying UAP records, and

enhancing witness accessibility. Importantly, it lays claim to "eminent domain" over recovered UAP technology and biological materials, setting specific deadlines for disclosure.[44]

However, in early December, some Congressmen managed to severely dilute the UAP Disclosure Act to the point where its title may no longer be accurate. Notably, the amendment of the lower house takes away the Eminent Domain and Records Review Board clauses, which many considered central to UAP disclosure. The military industrial complex may have won the battle by killing the amendment. However, they may have also just lost the war by making obvious moves through political agents they publicly donate to.[45] The UAP caucus continues to fight by demanding answers from officials in secure facilities, but so far have been told they do not have clearance to know the information.[46] Congressman Andy Ogles had even threatened to invoke the Holman rule to cut finances to the executive if they continue stonewalling Congress[47] But such drastic measures are yet to be seen.

Opportunities & Threats for India

Economic Developments

India has chosen a more slow and pragmatic approach to their space programs that focuses on learning from others to improve its own efficiency, while adding value to space research. This was demonstrated with the Chandrayaan, Aditya L1 and Mangalyaan missions. ISRO has plans to put independent astronauts on the moon by 2040. ISRO has underscored the technological gaps hindering the feasibility of asteroid mining, thus diverting its focus toward lunar endeavours after joining the Artemis Accords.[48] [49] While the moon offers opportunities, asteroids remain rich in precious resources crucial for burgeoning industries. To avert potential economic vulnerability, ISRO must vigilantly monitor developments and strategise for future mining operations.

Space mining will be driven by demand for critical metals essential in electronics, solar panels, wind power, and electric car components. While some companies consider extracting metals from the seafloor, asteroids offer an alternative with abundant reserves, avoiding environmental concerns tied to wildlife harm during extraction. Asteroid mining emerges as a pragmatic avenue for future resource exploration.[50] Pioneering nations stand to reshape geopolitics by monopolising extraterrestrial resources, potentially leaving India economically disadvantaged if we remain tardy in entry.

Simultaneously, India's support for space startups signals progress in nurturing the space value chain. With India's space economy projected to reach Rs.35,200 crore ($44 billion) by 2033, IN-SPACe's vision prioritises 'Made in India' space products, emphasising co-development and co-production for private sector growth.[51] India must strategically incentivise startups for innovative space logistics solutions, aligning with the success of its satellite launch program. By offering cost-effective services, India enhances competitiveness, enabling broader utilisation in diverse space ventures, solidifying its pivotal role in the global space community. It is crucial that India bring in its own domestic space law that reduces uncertainties for investors. Like the US and Luxembourg, an easy

regulatory and tax regime will greatly incentivise the growth of the space industry.

Military Developments

India's military advancements include the successful 2019 anti-satellite weapon test and its first table-top space warfare exercise - IndSpaceX, demonstrating integrated satellite communications and reconnaissance for enhanced intelligence and firepower.[52] In 2019, India established the Defense Space Agency (DSA) and the Defense Space Research Organisation (DSRO). The DSRO, resembling a U.S. fighter command, coordinates space assets across military branches. The DSA, a research organisation, integrates civilian space technology for military applications. Some suggest India create a Space Force, mirroring the U.S., to strengthen satellite network defence and take assertive actions against adversary networks in the evolving space security landscape.[53] There seem to be some indications of such a move being underway. Meanwhile China, since privatising its space industry in 2015, autonomously developed space warfare capabilities thanks to billions worth of investments in recent decades by the CCP.

To catch up, experts have proposed advancing dual-use technologies and expanding the Navigation with Indian Constellation (NavIC) satellite system. The Space Policy 2023, though discreet about the military aspect, prioritises enhancing space capabilities for socioeconomic development and security. It strategically aims to bolster India's intelligence, surveillance, and reconnaissance capabilities, with implications for both civilian and military applications due to the dual-use nature of these technologies.[54]

India must advance its space capabilities by developing sophisticated space-based weaponry including hard kill guided missile systems, jamming devices, directed energy weapons, and electromagnetic pulse systems for space-to-space operations. Both soft and hard kill systems, such as jammers and directed energy weapons, are crucial components for Outer Space Warfare. This emphasises the need for India to invest in cutting-edge technologies to bolster its defence capabilities in the vast expanse of outer space.[55]

To achieve a comprehensive security framework for space, India needs integrated Space Forces but the idea faces a significant challenge in the form of budgetary constraints. The current commitments of the three services are already strained by existing allocations, and the outlook for a substantial increase in funds is bleak, given the current trend of defence budget relative to GDP. This financial limitation raises concerns about India's ability to effectively respond to potential overt offensive actions by China.[56]

The Government of India has made substantial strides in cybersecurity, earning the 10th global rank in the 2020 UN International Telecommunication Union Global Cybersecurity Index. The National Security Council Secretariat, led by the National Cyber Security Coordinator, aims to integrate cybersecurity policies and architecture. However, the draft National Cyber Security Strategy lacks a focus on space security, despite concerns raised by the Data Security Council of India about potential attacks on critical infrastructure, including space agencies. Integrating space into the strategy is crucial, given its role in security, military functions, and communications.

It has been noted that ISRO defends against more than 100 cyberattacks each day.[57]

Thus, India needs to emulate the US and prepare satellite hacking sandboxes that can be experimented with to find system vulnerabilities. There is a need to integrate critical cybersecurity safeguards into India's national space policy, aligning it with the National Cyber Security Strategy and National Security Strategy. Also, India needs to implement a Purple Revolution, incorporating cybersecurity red and blue teaming exercises under the Ministry of Defence and Home Affairs to enhance offensive and defensive capabilities. India must encourage a whole-of-nation approach, where Chief Information Security Officers allocate two percent of their productivity to National Critical Infrastructure and space cybersecurity. We must urgently increase the space budget allocation from 0.04 percent to at least 0.5 percent of GDP to boost research centres and space standards. Finally, India must enhance space supply-chain resilience and security within QUAD's space cooperation, establishing a central Indian space resilience agency for joint monitoring and incident response exercises.[58]

UAP Issue

India's response to UAPs remains inadequate, evident in the silence from both the executive and Parliament despite regular ITBP encounters[59] and a notable incident above the Prime Minister's residence in 2018.[60] RTI requests yield limited information, with ISRO and the Embassies claiming ignorance, while the ITBP and Airforce have claimed national security exemptions from answering queries. The UAP report by NASA suggests the ISRO collaborated NISAR platform as valuable in studying UAP events. This shows the paradoxical approach by ISRO on the subject. Given the potential decades-long UAP reverse engineering efforts by countries like the US, Russia and China, India's lag could jeopardise its strategic autonomy and pose threats from traditional adversaries, necessitating immediate action. Notably, these issues exist even if we ignore the elephant in the room - alleged contact with non-human intelligences.

Despite the current disadvantage, India can swiftly become a leader in the UAP domain. Leveraging its ancient history, India may discover crashed UAPs, expediting reverse engineering. Like Japan[61], France, and the US, India must introduce protocols for military and civilian aviators' reporting of UAPs while synchronising her land, sea and space surveillance capabilities to give her eyes across domains. Establishing a dedicated public-facing UFO office, akin to the French GEIPAN, helps collect and analyse reports from civilians and the military which improves flight safety and domain awareness. Covert and overt data collection from international partners can offer valuable insights into adversary programs. Participation in global UAP conventions, along with support for San Marino's Project Titan - aiming to establish a permanent UAP office under the UN[62], can position India as a leader in UAP research and benefit sharing, ensuring our strategic advancements in this field. India must also leverage the expertise from universities and create UAP research programs akin to the Galileo Project at Harvard[63].

Interestingly, many UAP researchers consider

India to hold a treasure trove of information regarding the historical and 'supernatural' aspects of the phenomena which are often clubbed under the heading of 'high strangeness'. Thus, India may actually hold crucial pieces of the puzzle that will eventually help the human species unlock the secrets of this enigma. The nullification of the UAP Disclosure Act must be seen as a major opportunity to catch up to other nations before "catastrophic disclosure" pushes us into a paradigm where our autonomy isn't secured.

Conclusion

In conclusion, India stands at the crossroads of both threats and opportunities presented by cutting-edge technologies. Joining the Artemis Accords and gearing up for increased lunar activity by the decade's end places India at the forefront of outer-space advancements and provides the nation with expertise and adaptability for swift program implementation. The introduction of the Indian Space Policy and the establishment of the Defense Space Agency (DSA) and Defense Space Research Organisation (DSRO) signal commendable strides toward enhancing space asset security.

However, there are areas demanding improvement. Notably, fostering growth in space manufacturing through incubating start-ups is crucial. Space-based manufacturing of pharmaceutical ingredients and semiconductors could substantially reduce India's import reliance. Allocating funds to space logistics, monitoring space mining developments, and leveraging public intellect to identify and address cyber vulnerabilities in space assets are imperative. The realm of Unidentified Aerial Phenomena (UAP) demands immediate attention, as a delay in proactive measures may risk compromising India's strategic autonomy. India needs to greatly expand on its all domain awareness to prevent airspace incursions. A transparent and public-facing approach on the issue which actively involves data from diverse sources, is essential to reversing this trajectory and ensuring a secure and thriving space future for India.

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Space Exploration and the Future of India-US Space Cooperation

Ajay P. Kothari*

Introduction

There is something very interesting and intriguing about history and pre-history of India, better addressed now as Bharat. It is romantic history with *'Dev-Lok'* existing above us humans but with almost continuous back-and-forth interaction with us humans, always doing the right thing and even punishing the miscreants! No other country has such engrossing and prolific connections with the space above, except perhaps the Greeks whose mythologies very much parallel India's.

When we think of Space, we also think of Indra and his court, even Narad Muni, traveling back and forth between up there and the ground occupied by kings, kingdoms and us people. There is a connection of heart, in addition to mind.

China has Chang'e, the Moon princess, Japan has Amaterasu, the Goddess of Sun and the Greeks have Icarus who flew too close to the Sun. However, the Abrahamic Religions, both Christianity and Islam, do not have any such equivalents. Vedic Bharat has a lot more. Why? It is a connection to everyday life, through traditions and traditional stories. One wonders why only India? What was so special about ancient Indian civilisation? Even Ramayana stories of 'Ram-Setu' which may have occurred in the middle of Holocene period connects to the actual geological and even anthropological Earth history; a connection to possible reality?

This is why we Indians as well as the Indian diaspora identify, even unknowingly, with Space and are excited about Space, more than many bean-counting countries and civilisations that decide to do it for economic benefits mostly. The palpable excitement in Indians after Chandrayaan 3, Aditya L1 and Gaganyaan Crew Escape System (CES) test points to something more. It should. It is quite possible that such excitement abates with time, but then it is equally possible that newer unknowns will come to light which will excite Indian brains, which in my opinion are quite fertile – a strong point for India.

In June 2023, Prime Minister Modi, during his state visit to the United States, signed the Artemis Accords, India becoming the 27th country to do so. This US-led international partnership on planetary exploration and research heralds new opportunities for India as also for the US. In early 2024, NASA and ISRO are scheduled to launch Earth-observing satellite NISAR[1] which will help scientists monitor how climate change is affecting Earth's varied landscapes. In 2025, an Indian astronaut will likely be taken to ISS (International Space Station), likely aboard a Falcon 9 reusable rocket in the Dragon Crew Capsule of SpaceX.

A paper written by visionaries such as Dr. Ravi

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Sharma in 1975, previously under the tutelage of stalwarts like Vikram Sarabhai and Homi Bhabha, and still available in ISRO HQ Library, outlined how India could participate in the Shuttle and Station program of NASA. That may not have occurred then, but we are doing it now through the Artemis Accords.

But that is not all. The technological, Western ideas of recent centuries point to the same path which could be more than a coincidence; certainly an intriguing one worth taking a deep look-see into. The dots of the arguments above and below are connected. But that indeed is not all either. The love for all life forms as purveyed in Indian culture becomes an integral part of the scientific argument made below. It is not merely a selfish fetish of loving all humans or being caring of the next generation. It includes all life forms that exist on Earth. This is why we love them all, even the ones roaming in the streets!

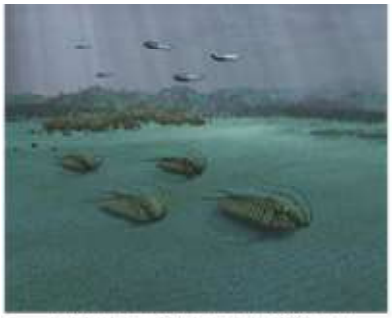
Why Space Exploration?[2]

Why should we, as humanity pick up this baton and run with it? The answer is perhaps more profound than simple arithmetic of how Space has brought us tangible benefits, like the smart phones and many others. More profound than us getting there before some other country occupies parts thereof (Lunar resources), or all the potential minerals we someday may earn from some asteroids. Or remaining number one in this competition, or even have a place to migrate to in case of demolition of planet through internal or external actors. It is more encompassing and overwhelming. Through Drake equation and Fermi paradox, it has gone far deeper.

I came to the U.S. from India, 50 or so years ago, after listening to Apollo splashdown on a decrepit old Phillips radio on my father's farm in the middle of a jungle[3] in North Gujarat. I became a Rocket Scientist here but have never thought those two sides are in conflict. Here, I offer a thesis as to why space exploration endeavours are not just the field of space scientists, but others too who are more humanities and arts inclined, and how we can bridge that divide through scientific as well as emotional arguments. We must.

Our Earth has been around for about four and a half billion years with multicellular life for about the last billion. In that, we have gone through 4-5 major mass extinction events as depicted pictorially below:

The last one, termed Cretaceous, wiped out the dinosaurs. Millions of species were wiped out during each of the above periods. It is estimated that anywhere from 50-95 percent of the then existing species were wiped out, but due to the resilience of the Earth, after each period of extinction, millions of species were created lasting



Ordovician-Silurian (~440 million ya, species extinct ~85%)

Late Devonian (~365 million ya, species extinct ~75%

Permian-Triassic (~253 million ya, species extinct 96% marine 75% terrestrial)

Triassic-Jurassic (~201 million ya, species extinct ~80%)

K-Pg extinction (~66 million ya – species extinct ~75%)

millions more years. But the most intriguing thing, interesting, and as yet unexplainable, is that not one single species out of those billions so far ever did a simple thing like clothing itself or even thought about it except one - humans! How is that even possible? Shelter, yes but clothing themselves, No.

So are humans superior? No, I do not prefer to say that nor do I portend that. Now let us look at the Drake Equation, attributed to Dr. Frank Drake who passed away a few years back. It basically is a probabilistic argument used to estimate the number of active, communicative extraterrestrial civilisations in our own galaxy, the Milky Way. It is made up of these terms:

N = R_* f_P * n_e * f_l * f_i * f_c * L

N = number of civilisations with which humans could communicate

R_* = mean rate of star formation

f_P = fraction of stars that have planets

n_e = mean number of planets that could support life per star with planets

f_l = fraction of life-supporting planets that develop life

f_i = fraction of planets with life where life develops intelligence

f_c = fraction of intelligent civilisations that develop communication

L = mean length of time that civilisations can communicate

While the Drake Equation cannot be "solved" or even accurately calculated, it retains considerable utility for discussions about extraterrestrial life and intelligence. And that, after all, was the reason for its invention. But assigning some reasonable numbers to each term yielded N equal to anywhere from many thousands to millions. Remember that this is just for Milky Way, and there are trillions of galaxies in this universe.

In the summer of 1950, at Los Alamos National Laboratory in New Mexico, Enrico Fermi and co-workers Emil Konopinski, Edward Teller, and Herbert York had one of several lunchtime conversation discussing recent UFO reports and the possibility of faster than light travel. After sitting down for lunch, Fermi suddenly blurted out, "But where is everybody", an obvious reference to extra-terrestrial life. This gave rise to the Fermi paradox. We cannot see any sign of such life in our observable universe which of course has expanded with Hubble and now considerably with the Webb telescope. But the question still remains: "Where is Everybody?"

So, whether the Fermi paradox holds or not, we have been granted a humongous responsibility by God (for the believers among us) and by happenstance, (for the atheists). If it does, which appears to be the case at least in the observable universe, we are extremely unique and need to be an excellent steward of the precious cargo of all lifeforms. If the Fermi paradox does not, we need to be ready to protect us all in case needed. In either case the answer is the same.

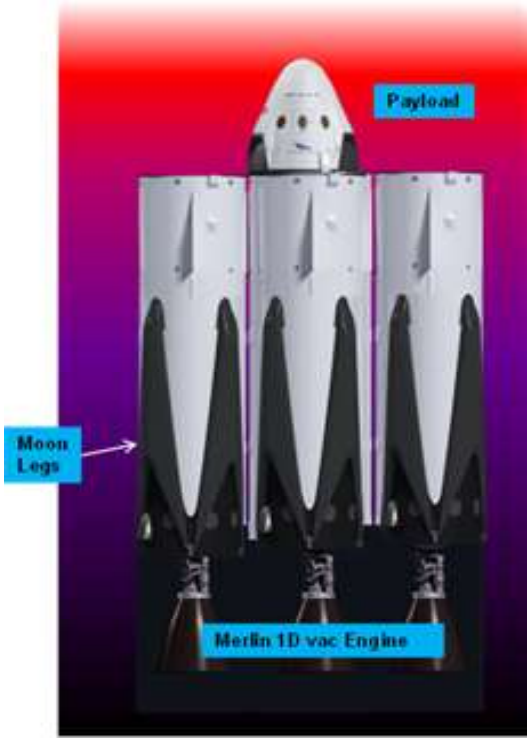
To me, this does not mean our species is superior to others; I love the plant life, and the animals, and always will, sometimes even more than humans! But we, as humans, have been given or have a special responsibility, a stupendous one at that, in this universe to figure out things, shepherd them and continue this evolution, the evolution now in the third dimension which is Space, the 'Z' direction for the nerds among us. We must not only shepherd Earth, but also all life forms within it. They may be fantastically special. Even the ants, insects and roaches.

This includes furtherance of evolution. Evolution requires that more intelligent things are done almost continually. That requires that a society find ways to demarcate and appreciate it and its potential cause. This is perhaps a far higher calling than other callings – climate change or even human species survival. This is why devaluing appreciation of merit for other causes may hurt us as humanity, or even as Earthlings, in future. A huge effort is needed. An intellectual effort. This includes merit in myriad of fields – from art to literature to science to space to sports and others. This is why, what NASA and ISRO are doing, and the space efforts of other countries, are extremely important. Not just to India or U.S. or even just humanity but also to the entirety of life forms in this observable universe - whether the famous Fermi paradox holds or not! Art produces visions and it assuages. They touch the "not-yet-imagined" part of this equation that we scientists need, to fulfil the entirety of progress.

We will need help of many strata of society, artists, writers, poets, philosophers, thinkers and scientists to realise the next step. We should care for the truly unfortunates, truly downtrodden but should not lose sight of the above.

Reusable Rockets

Fortunately, and coincidently, there has been a paradigm shift in our ability to start to address the above points. The recent and upcoming developments in reusable rockets may allow for this paradigm shift in being able to traverse the solar system, establish large settlements on the moon that, as a concept, was previously discarded due to costs involved. The large settlements would mean 100-1000 people living there at any time, perhaps intermittently and changeably every few months. It may be possible to do this at about USD 3000 per pound to Lunar surface, possibly a factor of ten reduction, due to the use of reusable first stage as delineated by advancements by SpaceX primarily, with Blue Origin and RocketLab following. China has decided and is pursuing the reusable rocket avenue for their state owned Long March versions and also at private industries,[4] but India is not. India needs to. ISRO needs to.



This method was described earlier in The Space Review in two articles: A Giant Leap for America[5] and Six-Pack for Mars: A railroad to the Moon and Mars.[6] This particular work identifies a spectrum of possibilities, from Moon to Mars, from payload of 2500 lbs to 114,000 lbs on lunar surface, using the same virtual railroad.[7]

Principally, the method calls for launch of one of the commercially available reusable first stage rocket systems, the most immediately available being the eminently proven Falcon Heavy, the expendable upper stage (call it S21) to reach LEO first, remain in orbit for a day with the intended payload. Next, append that with another Falcon Heavy launch, the second upper stage now (call it S22) docks with the first (S21) already in orbit, but S22 does not contain any payload, rather that much extra propellant. Do this procedure multiple times as needed to increase the propellant fraction of the combination needed for the DeltaV (energy) required to reach the mission goal. say get to the moon and use the tanks for habitats there. We have been docking items in LEO for more than fifty years. We do not need to be proficient in refuelling for now. The question answered here is can we possibly get to a large enough propellant fraction to land on moon or mars? This particular work identifies a spectrum of possibilities, from moon to mars, from payload of 1200 kg to 50,000 kg on lunar surface, using the same virtual railroad.

Upper Stages Docked (not refuelled)*:

Two Flights of Falcon Heavy (F9H) w RP/LOX US			
Prop Fraction (PF) Required			0.810
	Upper Stage	RP/LOX	
	tonnes	**Actual**	Prop
Payload Capacity	54.4	**10**	44.4000
Dry Weight	6		# Mated
# flights	**2**		**2**
	Gross in LEO	Propellant	PF
Refueled	114.8	98.8	0.8606
Partial Mated	120.8	98.8	0.8179
Mated	**120.8**	**98.8**	**0.8179**

Three Flights of Falcon Heavy (F9H) w RP/LOX US			
Prop Fraction (PF) Required			0.810
	Upper Stage	RP/LOX	
	tonnes	**Actual**	Prop
Payload Capacity	54.4	**20**	34.4000
Dry Weight	4.5		# Mated
# flights	**3**		**3**
	Gross in LEO	Propellant	PF
Refueled	167.7	143.2	0.8539
Partial Mated	176.7	143.2	0.8104
Mated	**176.7**	**143.2**	**0.8104**

Figure 1 Two and Three Flights of Falcon Heavy

Four Flights of Falcon Heavy (F9H) w RP/LOX US			
Prop Fraction (PF) Required			0.810
	Upper Stage	RP/LOX	
	tonnes	**Actual**	Prop
Payload Capacity	54.4	**26**	28.4000
Dry Weight	4.5		# Mated
# flights	**4**		**4**
	Gross in LEO	Propellant	PF
Refueled	222.1	191.6	0.8627
Partial Mated	235.6	191.6	0.8132
Mated	**235.6**	**191.6**	**0.8132**

Five Flights of Falcon Heavy (F9H) w RP/LOX US			
Prop Fraction (PF) Required			0.810
	Upper Stage	RP/LOX	
	tonnes	**Actual**	Prop
Payload Capacity	54.4	**32**	22.4000
Dry Weight	4.5		# Mated
# flights	**5**		**5**
	Gross in LEO	Propellant	PF
Refueled	276.5	240	0.8680
Partial Mated	294.5	240	0.8149
Mated	**294.5**	**240**	**0.8149**

Figure 2 Four and Five Flights of Falcon Heavy

The elegance of this approach is that the combination and permutation of number of Falcon Heavy flights, how many upper stages are docked and/or refuelled, the payloads desired, and the destination DeltaV, we will have almost infinite variations available that builds a real "railroad" to most destinations in solar system. India could do this too and then would not have to wait for 40+ days to reach the moon doing numerous Hohmann transfers. It is not necessary nor wise to develop bigger and bigger rockets for larger and larger payloads or more energy demanding destinations. Someday, all nations will use this method for space explorations.

As examples, the following tables delineate how much payload can be taken to land on lunar surface with these few permutations/ combinations. The last row in each table (bolded) are the solutions proposed where the upper stages are merely mated/docked together. Many of them are superior, for example, to the SLS (Space Launch System) of U.S. or potential ISRO system

in development, in capability and cost both. With the Artemis Accords signed by India, it would be the method that both U.S. and India need to work together on.

*Falcon Heavy to the Rescue: https://www.thespacereview.com/article/4582/1 (Space Review: May 2023)

Living in Space

To begin with, a reasonably sufficient standard of living in Space, primarily the moon and then mars, should be what we should aim for - and move a single or a few steps at a time. Such living would invariably require energy, and highly preferably an incessant supply, 24x7x365 and at high enough power level to run equipment and paraphernalia along with providing us heat, possibly at a few MW to hundreds of MW.

We do not have much choice. Space Solar Power (SSP) just is not enough to meet the demands, and obviously falls as the inverse of square of distance from sun - not too attractive a scenario! Primordial elements gifted to us as fissionable or fertile are uranium and thorium, which contain a million times more energy per unit mass than the best chemical (HydroLOX). Of these, thorium (Th232) is fertile only and hence easier to handle and abundant on Earth, enough to supply net-zero and pollution free energy on Earth for thousands of years.

Addressing climate change, especially reducing carbon dioxide emissions while at the same time producing needed energy, is engaging humanity worldwide, and is apt to occupy many countries ever more so. While developing various technologies, one should also bear in mind this potential solution that is much simpler, cheaper, and faster to implement, while we wait for other solutions such as controlled fusion. Within the past few year some countries in the EU and Asia announced their intention to pursue nuclear power for their energy needs. In China, in June 2023, the Shanghai Institute of Applied Physics (SINAP) has been granted an operating license[8] for the experimental TMSR-LF1 thorium-powered liquid molten-salt reactor, construction of which started in Wuwei city, Gansu province, in September 2018. U.S. and India need to work together on this technology as allowing for the Chinese domination of it would be a dire mistake.

And Thorium is available on the moon as well. So why not combine our efforts for terrestrial net-zero solution with a clear possibility of using it for our off-planet needs as well—for energy and propulsion?

As one can see above, India has the most amount of thorium in the world. India can become the new Middle East of energy with the mostest! But India is not developing this energy source correctly. Th232 as solid fuel is not the right way as being done at Kamini. It must be the Molten Salt Reactor way.[9]

As an addendum to the Reusable Rocket Revolution that has occurred, the next name of the game for living in Space will be "Repurposing". Shown below are two examples of repurposing the reactor part of the nuclear propulsion system that landed on moon/mars, that can be disjointed and utilised for electricity and heat generation.

The "Evolution in Third Dimension" does not mean only taking the species to other habitable planets. That would be quite simplistic. What is

Thorium

What does it look like?

Astron

Country	Tonnes
India	846,000
Brazil	632,000
Australia	595,000
USA	595,000
Egypt	380,000
Turkey	374,000
Venezuela	300,000
Canada	172,000
Russia	155,000
South Africa	148,000
China	100,000
Norway	87,000
Greenland	86,000
Finland	60,000
Sweden	50,000
Kazakhstan	50,000
Other countries	1,725,000
World total	6,355,000

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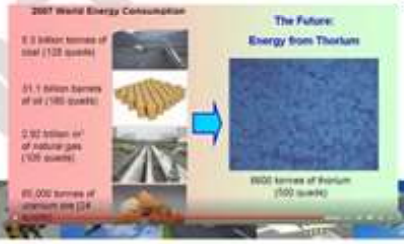
Comparison - NO COMPARISON!



ONE tonne of Th is roughly equivalent to 5 million barrels of oil. So total Th reserves are equivalent to 30 millionmillionbarrels of oil reserves (or 30 trillion)!

Whereas the TOTAL world reserves of oil are ~1.8 Trillion barrels

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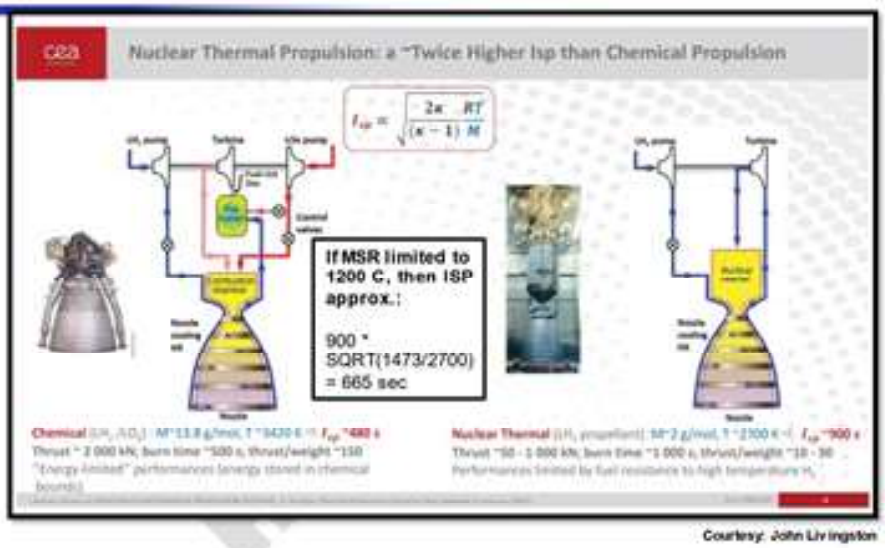
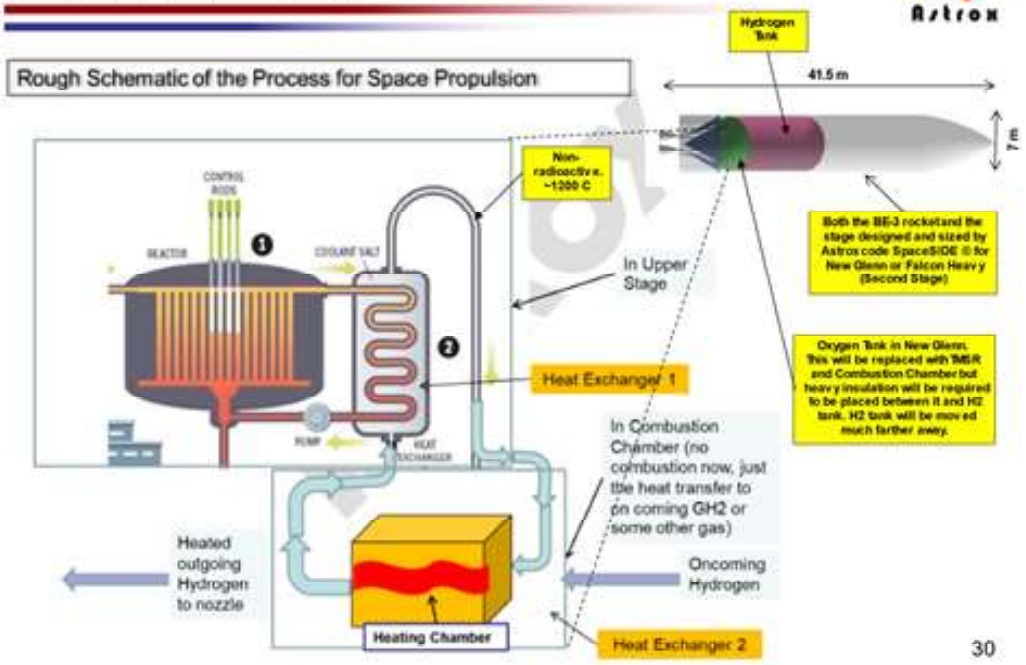
Space Propulsion



Courtesy: John Livingston

With considerable reduction in size and weight compared to NERVA type solutions, MSR maybe more attractive at system level.

Space Propulsion – for journeys within CiSLunar space and to Moon/Mars



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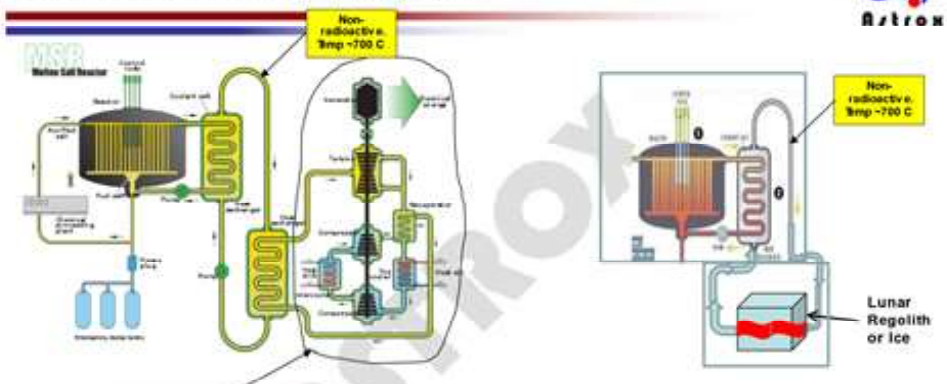
Repurposing TMSR on Moon/Mars



- Repurposing allows for reuse of the reactor
- Temperature of the molten salt is reduced to ~700 C whereby the corrosion of containment/pipes would be nil to limited (as ORNL 2 MW reactor showed)

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meant here is that the knowledge base we have amassed over last 10K years (for humans) and longer but more simplistic for other life forms has been based on surface of Earth (with some ocean depth and sky high thrown in). Our evolutions have been war centric, exploration (of Earth) centric.

We need to continue this evolution now in the much larger (light years? Or at least billions of miles) dimension too. Upsurge our grey cells (as Poirot would say) to think that way as well. Not a plan to shepherd all existing species by taking them there. Rather, shepherd them here, take care of them so they do not disappear. Even roaches, bacteria, and viruses may be extremely unique as are all animals and even the plant kingdom. We need to protect them all. "Shepherding" does not have to mean dynamic. It could be static and/or combination of both.

Other point is that the populace of the world needs to feel a stake in space exploration, or they would not support it, and perhaps could create roadblocks. The argument is that many others, artists, authors, poets, philosophers and many more should feel a stake in it. We should try to bring them in. Without that, it may still happen but will take longer and we (the rocket scientist types) may have to rely on some Earth-shaking discoveries to excite the populace. Not wise, and not needed to do it that way. Let us not be self-centred. Bring many others into this "game". Let them also feel their contributions made a difference for Earth.

And this is just not a ploy. Thinking Drake equation and Fermi paradox makes me convinced that there is truth in the argument too. It is not just a 'Kumbaya argument' as some allude to. That particular side of the argument is partly technical but also philosophical. We must take it that way too.

Space exploration could and should encompass not just left or right (be it brain or the unfortunate political divisions everywhere). It is ambidextrous.

References:

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4 *https://spacenews.com/chinas-space-pioneer-raise-funding-for-its-falcon-9-class-rocket/*
5 *https://www.thespacereview.com/article/3374/1*
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7 *https://www.youtube.com/watch?v=C42Lw7ob6js*
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FOCUS

Six Decades of Space Experience and India's Role in Emerging New Race for Space

Ravi Sharma*

Preamble

Major events that started the Space Race was the launch of Sputnik 1 - the first artificial earth satellite in a Low Earth Orbit (LEO) by the Soviet Union on 4 October 1957. Subsequently, Yuri Gagarin, a Soviet pilot and astronaut, aboard Vostok 1, completed one orbit of earth on 12 April 1961. This was the first successful crewed spaceflight in the world. In response, US President John F Kennedy gave his vision to put man on the Moon by end of the 1960's and get him safely back to earth.

Tagore wrote on freedom of mind "Mana mere megher shangeet, udi jaye dig digantar pani, nisshim shunye, Shravan varshan shangeete." (My mind is like the music made by clouds in rainy season, it flies high with freedom). Similar reference is found in Syen Chiti and Dwa Suparna of RigVed. In his book 'Jonathan Livingston Seagull', Richard Bach writes about a seagull who is trying to learn about flying, personal reflection, freedom, and self-realisation. This spirit of freedom lived in most of the 140,000 people team, including most Americans but several percent new-world citizens like me for coming together to make the Apollo 11 programme a success, which led to the first crewed mission to the moon on 20 July 1969.

In the Indian context, PM Modi factors in creating spark in the eyes of youth of 2023 India. The late President Kalam was focussed on igniting the young minds around New Millennium 2000, and Dr. Vikram Sarabhai gave forth his vision (he inspired me, Prof. UR Rao, and Dr. Vasant Gowarikar, among others, to return to India and contribute).

A wonderful result in a fearful world polarised by superpowers but with decisive victory of sustained democracy and freedom of mind, with political stability, made the decade 1962-1972 a great history of human space exploration. In sum, 12 men set foot on the Moon, 12 additional men orbited the Moon without landing, and resulted in smaller space programs later. Our team of a dozen NASA HQ scientists and engineers (myself included) trained them and provided oversight for all experiments that astronauts performed on the Moon and in cislunar space. Our Apollo Motto was *Fail-Fail-Failsafe*! This related to primary, secondary, and tertiary backup systems. We had no loss of human life in space, only one mission could not land on moon, and we routinely provided 60 observatories to optically track all Apollo missions. When such mottos are ignored or alerts compromised by authority over freedom, mishaps happen such as Shuttles Discovery, Columbia and initially INSAT satellites in India.

Almost 55 years later, still waiting for two more years before seeing other humans land on the

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Moon, the world realises the risks and costs but there is upsurge in seeing the benefits in future to make investments and costs (ROI and TCO) worthwhile today, with a mix of robotic and live human mix in the overall space race—the second wave after Apollo. Imagine the accomplishments that the US would have had if there were no gaps in human space programs! These gaps were due to shortsighted vision of those funding the space program, namely the US Congress and the Executive, with 4-year term vision, while such programs require wisdom with longer time horizons.

In human space program accomplishments, many firsts were from former Soviet Union with Mir, Soyuz, duration in space, women in space etc.. Today, Skylab, Apollo-Soyuz, Space Shuttle, International Space Station are excellent international cooperation examples, which raise hopes of future successful programs between democratic free world and the countries with dictatorships. After the signing of Artemis Accord, India has realigned itself with the freedom block where it can unleash pent-up energy of young minds, hopefully catching up and maybe someday soon, exceeding China's already excellent accomplishments. It is not out of place to mention that in the former Soviet Union, now Russia as also in China, after the supreme authority, the next level of autonomy has often been in the hands of technology and science leaders, such as academicians in the former USSR.

Top level Human Space Flight Enablers include proven capabilities e.g., launch vehicles (LV), life support systems, rendezvous, docking, ingress, reentry, and landing. Other infrastructure needed is communications, power, food and supplies, systems for experiments, laboratories, software, backup, etc. Critical for the US was development of Saturn V (stages I, II and IVB) and now three US large LVs—SpaceX Falcon 9, Starship (including Falcon Super Heavy) and United Launch Alliance SLS used for Artemis. Next decade's human space missions will use these three LVs.

After Apollo 3-Man Command and Service Module, (CSM), an advanced Orion CSM has been built, supporting crew of up to 6 astronauts for Moon and beyond, with Command Module being reusable. Other important elements are Gateway as a lunar orbiting station for transfer of humans to lunar surface using Starship-Orion combination, other options for cargo and astronaut lunar habitat buildup, and return to Earth. Mars human mission capability will perhaps be Artemis combination of Starship and Orion and multiple countries modules.

China has plans for sending humans to Moon while it has nearly a decade's human space stations experience and very safe program. India has only one flight experience; that of astronaut Rakesh Sharma with 1984 Soyuz mission. Gaganyaan is India's current program where astronauts and related systems are based on Russian help and training. It is an independent LEO program signed up before Artemis Accord. Now, there are at least two paths available to India, one as country program and other leveraging Artemis Accord. It is important to note that I wrote a 25-page report in 1975 (still in ISRO HQ library), that proposed India's participation in the NASA Space Shuttle program. If that had been accepted, we would have raised the number of Indian astronauts to a dozen or more today as ISS had opened more

opportunities beyond the space shuttle. But it takes courage like Sarabhai's and real leadership at the apex level like Modi's—and both were not available for 50 years—to leverage such opportunities.

Historic ISS and Shuttle missions have gained lot of human spaceflight results including life and health data and genomics data over last 20-30 years of LEO missions. I proposed two experiments for ISS prior to 2000, one on particle movements in microgravity which was not approved; the other was bioinformatics based, for detecting genes suitable for microgravity survival and for exploring mutations triggered by microgravity, by keeping track of natural and space based successive generations of rodents on ISS. This was accepted in principle for 100 generations (10 years), but funding was not available. Subsequently, one-year human genomic map, including changes, for astronauts during their stay on ISS and comparative data on flight of identical twins (Kelly) are available to NASA.

Similarly, not only for Earth use, microgravity manufactured drugs have been tested to treat ailments of long duration spaceflights for future astronauts. We can guess alternative medical and health paths for spaceflight in future decades related to controlled hibernation (like yogis) and for social and mental wellbeing (*Yajurved: Tan me Manah Shiva sankalpamastu*) to enable action using noble thoughts.

History is witness to the fact that human energy can be harnessed to wonderful capabilities when given an atmosphere of freedom. Dr. Werner Von Braun (my mentor and guide along with Chuck Mathews for my participation in Apollo, Skylab, Shuttle and Space Station) is the hero who made Saturn V possible. His counterpart in the German team also made Soviet rockets possible after Hitler's defeat, as this team was under pressure, producing V2 rockets. These two teams were heading US and USSR programs. Future generations will recognise similar leadership and vision of Elon Musk. Starship, with double the capabilities to deliver payloads as compared to SLS and with reusability, is likely to become the LV of choice for lunar and other human and robotic missions.

China's LV program owes its existence to Qian Xuesen (Tsien Hsue-Shen) a prominent Chinese aerodynamicist and cyberneticist who contributed to rocket science and established engineering cybernetics (He had Caltech and MIT background). I had participated in a contract at Hughes at Maryland facility in 1998 to train a dozen Chinese space engineers in building remote sensing satellites, payloads and software-based multiplexers for efficient data processing. They have grown a strong Earth observation satellite program. Subsequently, such facilities for China were denied by US Congress in early 2010.

In Indian context, as Scientific Secretary ISRO HQ, I was having technical oversight of all major ISRO programs; the solid rocket fuel development indigenously was by Dr. Vasant Gowarikar's team and integration of first solid fuelled LV for non-human payloads was by APJ Abdul Kalam who later became President of India. There were many others who were first in building satellites such as Prof UR Rao. In remote sensing programs, I was able to conceptualise and produce Bhaskara satellites, and also in establishing an agency now called National Remote Sensing

Center, ISRO. Later, after I left ISRO, under Dr. Kasturirangan's and Dr. George Joseph's leadership, IRS program thrived while INSAT program went through a decade of mission failures due to faulty design, estimated too risky by me and was the primary reason for my leaving ISRO 5-6 years before the satellites were launched.

Subsequently with technology developments and design changes, satellite programs have advanced, including Communication, Earth Observation and Navigation. Only now have scientific satellites been emphasised including 3 Chandrayaan missions, one Mars mission and Aditya L1 solar observatory. An Xray astronomy satellite has also recently been announced. Prof. S. Chandrasekhar (Nobel Laureate) has been honoured by NASA by having the Chandra Observatory named after him.

Today, we need to ponder over the fact that we have polluted Earth and overpopulated it beyond its capacity to maintain the recycling processes to keep its beauty serene. While how much is its capacity is debatable and how much 1.5 deg K increase in average temperature would shut us down, progressively disabling breathing and availability of clean water among other resources, this certainly will go down in history as the folly of humankind. Commitments to restore the Earth and environment are hence of paramount importance. This does not preclude nuclear and other types of calamities due to virus, pandemics, and terrorism as also due to natural calamities due to interplanetary space objects disturbing the Earth. Hope the readers of this article will appreciate the wisdom of Space Launch Vehicle Expert, Dr Ajay Kothari. He is recognised by NASA and US Defense and is my colleague on Board of American Society of Engineers of India origin. His article has been published in this journal along with my article, which provides another excellent perspective, which I will not repeat here. Sufficient to say that serene peace in nature and ethics agreements are at least one way to make Earth pleasant and last a bit longer. This is a challenge, and every challenge is an opportunity for all entrepreneurs including budding enterprises from India.

Environment monitoring – author started contributing from 1972 onwards by doing band selection on ERTS 1 and 2 re-designated Landsat, and by participation in Terra, Aqua and Aura and Poes satellites, and for contributing to NASA EOSDIS Active Archives enabling anyone to access and assess Earth's health changes over past 5-6 decades. Continuity of such programs is a global responsibility and if the US, ESA, and other participants slow down funding, emerging space countries have to at least fill the slack.

Two excellent examples, although not perfect, are LHC at CERN and ITER at France, more mature models of international funding must evolve for sustenance and meaningful earth goals, not micky-mouse egoism that is plaguing international politics today. Apollo like commitments in fusion research would have reduced thermal fossil fuel damage to environment as would have the hydrogen or early adoption of green electric vehicles.

The biggest challenge to stability is authoritative regimes and terrorism, and without population control and agreement on ethical civil societies, progress can be wiped out due to

unpredictable events and risks. It is true that true justice for all is an utopian concept in reality, and it is amazing that despite such disturbances through history, humankind is making progress even though not very proudly.

India's overpopulation is a threat and China's is better controlled now but still next largest; also the rate of population growth in economically challenged countries is unsustainable. The feedback loop mechanism automatically reduces population as prosperity rises and affordability of offsprings quality of life enters the consideration. As we have made Earth almost unenjoyable through pollution and overcrowding, we have been doing the same already in LEO with 6k or more inactive debris (satellites and other parts, cascades of fragmentation) with no easy way to clean due to lack of regulation. Who will curb this bad Earth type culture? The UN seems to have taken a back seat, and when I represented India as alternate delegate in 1974 and 1977, the Outer Space Committee had more control than it has now as both superpowers and non-block consortium had more decision-making ability, despite slow progress. The fear is hence of similar chaos in new Space Race era while we explore Moon, asteroids and beyond for economic, knowledge and security reasons.

The Future

Where is near future taking us in these established areas in the next 10-20-50 year scenario! We can expect the following:

Communications : Wide-spectrum electromagnetic to laser optical and then quantum computing entangled states.

Planetary and natural satellites (moons): Remote sensing with hyperspectral imaging, and using other properties such as BRDF, polarisation, goniometry and AI enabled robotic missions as precursors of intelligent robots and human missions.

Energy: Solar is a big limitation impacting all outer planetary and interstellar robotic and remote observatories outreach. RTGs proven from 60 year old vintage are being used by other nations but for some reason not by India despite my recommendations in 2020 - Space.com article analyzing Chandrayaan-2 and suggestions for future ISRO missions**.** But for higher power requirements, active nuclear fission (preferably thorium) and fusion reactors will be required.

Reconnaissance and remote sensing: Situational Awareness, quantum computing, AI, Information curation, etc.

Exploration: Combination of above applications and infrastructure, as well as robotic and intelligent robotic missions. Present orbiters, landers, rovers, and helicopters on Mars for example have some of this especially with Systems Software upgrades from earth stations to on board systems. Sample returns from moon, planets and asteroids are going to be prevalent over next few decades at least.

Materials in and from Space: For long term survival (human habitat) and easy harvesting rare minerals for earth use, the renewed interest on lunar and asteroid material is increasing. China has brought automated Samples from Moon, US, EU and Japan from asteroids and Mars samples are encapsulated for return in future. This includes potential use of helium from Moon. India has begun

planning lunar sample returns for Chandrayaan-4.

Manufacturing: Space based manufacturing in microgravity of crystals, pharma and other products for Earth use has been accomplished in Shuttle Spacelab and ISS. Automating and returning this on robotic missions is yet to happen for economy oof scale. But lunar material processing and building habitat under regolith for radiation protection is on design boards and will be part of Artemis program.

Robots and humans: Robots first for reconnaissance, establishment of infrastructure capabilities and thereafter rarely humans for their expertise and analytical abilities.

V2-Saturn-Starship and then where are we going? Candidates after achieving LEO payloads beyond chemicals are driven by success in developing fusion, nuclear fission, low deltaV ion propulsion, and other propulsion systems. Very long space robotic missions will likely use from these as they mature.

NASA Solar Studies next 2 Decades: Parker Solar Probe. Beside Parker, other active solar missions include Solar Orbiter, SOHO, ACE, IRIS, WIND, Hinode, the Solar Dynamics Observatory, and STEREO. Other International Probes include India's first serious attempt Aditya L1. The coronal and cosmic solar emissions affect not only Van Allen belts and NEO/GEO space assets but also affect Earth Grids and other space weather phenomena. The studies concentrate in tracing the CMEs and particles from a few solar radii, Alfven region, and all the interplanetary space but most important is its effect on satellite services and earth. A breakthrough project is taking shape to combine solar studies, quantum annealing and information use with very high success rates promised.

Next 50 (~100) years are Solar Interplanetary Exploration Era: With inclusion of Kuiper belts, Oort cloud objects, asteroids, comets, and interstellar intrusions not limited by solar power and ensuring nearly 100+ year life of outer orbits missions, transforming Pioneer like probes with higher information links to Earth.

Search for intelligence: Environmentally conducive exoplanets and satellites (moons) for having life (even cellular) and success of efforts such as SETI.

Fallouts: Like those from space program in new unforeseen and planned use of space suitable technologies and for repurposing them.

Quantum computing: If the current efforts at quantum computing mature to a few thousand or beyond Qubits and entanglement is beneficially used, one may see huge space communications as well as deep space probes results capabilities and beyond such as higher success rates identifying exoplanets and eventual communications with other intelligence in space albeit with associated risks warned by Hawking among others.

Decadal and beyond Pathway for India

Cognisant of past reasons for break in tempo, India is poised to strengthen recently opened entrepreneurship pathways free from bureaucratic interference, ensuring continuity of policies for freedom of doing global business relating to space and related infrastructure, subsystems, components, services and consulting globally for other space entities. Ability to scale is the key parameter.

Leverage current and projected 15-20 years growth of India assuming even adverse situations such as border and economic challenges and local conflicts.

Make alliances that are more stable like Artemis that align open democratic accords likely to have pool fundings and shared costs. Contribute and use shared facilities to establish reliable partnerships sincerely as shown in past for military and space cooperation with Russia.

Use commercial opportunities with better focus, by increasing LV production, safety and reliability of contracted launches. Fabrication of satellites, components and launch, software and control, communications, and services globally, increasing the historic Antrix Corporation share enhanced by IN-SPACe and other space industries including new small and large ones for export enhancements.

Create strategic pricing and reliability to offer to NASA and SpaceX, ULA and others, use Artemis Accord to offer services, partnerships and joint / collaborative missions and services to make space more affordable and increase revenue share of India on agreed terms. Also include ESA and international customers.

Increasing presence of space assets in NEO and GEO has been a force multiplier for economic benefits, security enhancements and expansion of use of space-based systems and services for many aspects. Situational Awareness and use of AI play crucial part in operational and science objectives of space utilisation. Space Governance is at best in nascent stage and appears mostly chaotic, and India's leadership has to be established in UN Outer Space Policies.

Today there are more than 8 to 12 K satellites and related objects orbiting the earth and beyond. SpaceX alone has put more than 5k satellites in orbit, has permission to launch up to total 12k satellites today and has asked for permission to launch 30K more satellites.

How does India increase its meagre share of global satellite launch market? To date, only 400-500 international satellites have been launched from, and by India and only 150 of its own in the last 50+ years of its space program! Indian entrepreneurs and student satellites helped by IN-SPACe cannot bring India to a global player status with this low progress strategy.

Combination of SpaceX type strategy would help because every launch was quick, satellites were part of LV strategy, applications emerged and revenues increased, success was faster than fat corporations' such as LM, Boeing, etc., with their delays, cost overruns, low numbers did not prove reliability. Concatenating one-with-other sequence or in parallel such as reusability, and repeatability of mass production of satellites and LVs gave SpaceX the financial success and orders started flowing from NASA. SpaceX saved NASA image by being the only backup after Space Shuttle and Russian dependence was eliminated, but Russian collaboration saved the ISS. Similar synergy is emerging from Starship, and it will become a workhorse like Falcon with eventual high reliability. From experience of growth of China and SpaceX, the strategies of Indian space program's new spirit can be strategised so as to capture global share by offering competitive costs, services, and operations as preferred vendor, partner and collaborator.

Envision clusters of synergy such as Silicon Valley, not traditional incubation models that are not scaling. IN-SPACe is a good attempt, but MOUs and assistance are only promoters; we need collaborations and international team-building. India needs to break free. While this is happening, India must merge its goals of space capability with leveraging the internal strengths for globally mutual benefits.

Repeating again, select a strategy that gives India the edge in services, producing products, dependability with low risks, with upgrades and new technologies. Simulations, AI, VR tools can prequalify, smart materials and self-healing systems can make success robust. Build up on cross domain fusion of technologies. Smart defect free production, especially partnering in weak performance areas such as VLSI and Quantum computing.

Jumpstart with events such as Chandrayaan-3. Find innovative ways to utilise fantastic youth energy gainfully and peacefully with space interests. Continue smart use of limitations such as unique orbits for Chandrayaan and Aditya L1 and smaller LV but smart results as was the use of propulsion module for earth orbit return. One glaring gap has been science and interest in science needing government support and boost not just in more universities and IITs but in terms of India originated journal articles and publications (see those originating from EU and China). Quality and numbers to become significant, even though enhanced by Indians scientists abroad or visiting in global institutions. It is fair to say that occasionally small unknown institutions produce good papers but knowledge discovery leadership for the country is not yet globally established in new papers from India's geography root. Science policy must allow rise to Nobel and other equivalent recognitions beyond Padma Awards which are often self-praise and by clans. Ask the Question! Would Sarabhai or Bhabha have liked this snail pace? Yet the last decade of progress is made in spite of past 50 years of cocoons of closed leaderships, like family or regional clans. There is difference between community excellence skills and nepotism, yet societies succeed! Hopefully current leadership will break wrong trends.

Compare with China quantum jump in 20 years on multiple fronts even though it is said that Huns clan rules mostly**!**

Lunar and Solar Aditya experiments have proven that India can build reliable science experiments and instruments. Use cultural and historic learning traditions and fusion into modern science. Leverage these for commerce and export.

Reduce dependency on earth for expensive chemical launches but promote SpaceX like reusability, not 20-50 years after it is proven elsewhere, but keep teams engaged to risk evaluation based early adaptation of innovation or better yet, become the leaders of innovation!

Biggest gain can be achieved by encouraging and nurturing the young minds excited by successes such as Chandrayaan-3 and hopefully Aditya L1, to open awareness of space benefits to India and globe and how this large potential of human power can transform global space scenario by becoming leaders and entrepreneurs with a global share of making the change possible, for example in satellites recovery after end of life, debris removal,

launching others payload, etc. This will gainfully employ promising youth.

A lot is happening, but vision to achieve global participating leadership is to execute future robotic manufacture, return from space manufacture, establish space observatories, and space hardware, subsystems excellence, and more! Market, if free, will determine the selection of those who meet the demand fairly. Success will also be measured by happy science, engineering and industry entrepreneurs, satisfaction of course is taught and rooted in Indian culture.

Shivaste Santu Panthanah, Safalaste Santu Manorathah – for Indian Space Leaders of future, may your paths be noble and may you achieve your dreams!

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India's Space Programme: An Interview with Dr. G. Satheesh Reddy*, President of the Aeronautical Society of India

Rami Niranjan Desai*

Rami Niranjan Desai:

Over the years, India has made some path breaking successes in the space domain. How do you think is India's space program progressing today?

G. Satheesh Reddy:

India has done exceedingly well in the space sector. We all should complement the Department of Space (DOS) and the Indian Space Research Organisation (ISRO) for this fantastic feat. We have developed our own launch vehicles, whether it is the Polar Satellite Launch Vehicle (PSLV) or the Geostationary Launch Vehicle (GSLV) for launching the satellites into 36,000 kilometres orbit and the variance of it and becoming completely self-reliant in that area by developing our own cryogenic engines, building varieties of payloads and satellites. And then taking up many missions like Mangalyaan, Chandrayaan and others. India stands very tall among the developed nations in the space segment. India is one of the few countries which has its own satellite-based navigation system - the Indian Regional Navigation Satellite System (IRNSS), ISRO has done exceedingly well in the area of space activities including the various base stations and ground stations, that are required for communications, weather forecasting, education, agriculture, earth observation, imagery, etc.

Rami Niranjan Desai:

You mentioned the Mangalyaan and the Chandrayaan programs. You know both of them, Mangalyaan and Chandrayaan 3 were very, very successful. What are the future programs which are of importance as far as space exploration is concerned?

G. Satheesh Reddy:

Firstly, we are one of the few countries who have done Mangalyaan and Chandrayaan. And lot of data has been generated in the Chandrayaan where we landed on the lunar South Pole. We again should congratulate ISRO for this fantastic feat, for what they have done and the data that is being collected. As we hear from the Department of Space and the ISRO Chairman, Mr Somnath, the next Chandrayaan mission will be to collect some soil samples from the moon and bring it back to the earth for analysis. Second, Gaganyaan, sending a human being into space is another important activity which ISRO has taken up and probably in the next two years this activity also should be successfully completed. Thirdly, lots of other space exploration activities are being taken up. Mission Aditya has been taken up to observe the sun. From this mission, we will get data on cosmic rays, the suns temperature, etc.. many similar activities are planned and nation is justifiably proud of ISRO.

*Dr. G. Satheesh Reddy is President, The Aeronautical Society of India, Former Secretary DD R&D, Chairman DRDO and Scientific Advisor to Raksha Mantri, Government of India.

*Rami Niranjan Desai is a Distinguished Fellow at India Foundation.

Rami Niranjan Desai:

We've also been hearing a lot of terms like 'space war'. What exactly is space war and what are the different technologies used in this domain?

G. Satheesh Reddy:

Firstly, space has become the fourth dimension of warfare. Space has been used for defence purposes by multiple nations now. One of the first things is observing the various activities from satellites, through ground based sensors. This could relate to movement of troops, location of weapons and equipment, location of radars, and missiles and many others. If you look at some of the wars which have taken place recently, satellites are being launched or satellites are already in the space, and they keep observing everything and data is completely generated. That's what has happened in the Iraq war. You know everything where a radar is located, where troop movement is taking place, and where the tanks and vehicles are moving. A lot of satellites carry payloads to gather Electronic Intelligence (ELINT), Communication Intelligence (COMINT), Signal Intelligence (SIGINT) and image intelligence and related things. Lots of payloads are being developed by the various nations.

Rami Niranjan Desai:

You said that there are a lot of applications in the defence domain. How is it affecting our defence preparedness?

G. Satheesh Reddy:

As I said, firstly, satellites provide surveillance and intelligence information. So, whatever the resources you have, right from the troops to the various sensors, weapons, and things like that will be known to the enemy if they have placed the satellite and it's continuously observing through images or through other payloads like ELINT, COMINT, SIGINT or image intelligence. So, you probably can track the communication. You probably can track where the radars are. You can track various sensors and various weapons. This is one of the important things which any nation gets affected by. And so, some of the nations, as I just mentioned, are looking at how to counter these satellites. So, there's ASAT missions, some of them are putting lasers and some of them trying to put other electromagnetic things and trying to have some robotic related activities in space. And so, these are some of the activities which are happening which actually concern any nation because your information is known to the enemy.

Rami Niranjan Desai:

India has also carried out an anti-satellite mission. Is space then becoming a war zone? And what do you think is the stand of India?

G. Satheesh Reddy:

See, firstly there are three countries other than India which have done the anti-satellite missions- Russia, America and China. India became the fourth nation to have demonstrated this capability. As far as the space is concerned, as I said, as you are able to observe the entire movement and locations of it, it's a concern for any nation that its information is known to the adversary. So that's how the anti-satellite missions have come. But then this is a concern that space is getting weaponised and it is not good for the world. So, India has been saying that the space should be used for the

peaceful purposes. But then the Prime Minister was very clear that the mission what India has taken up, anti-satellite mission called 'Shakti' is only a technological demonstration. We wanted to show it to the world that India has such capabilities to take up such complex and critical missions. So, India is very clear that the space should be used for the peaceful purposes and should not be weaponised.

Rami Niranjan Desai:

Are any further programs like Mission Shakti being planned? Also, could you tell us a little bit about what are the various types of offensive anti-satellite technologies?

G. Satheesh Reddy:

Firstly, as far as India is concerned, the honorable Prime Minister, when he gave the direction, said that we will take up this mission to demonstrate to the world that India has such technological capabilities. The intent was to do a technological demonstration only and not take it further. But then, if you look at technology, there are multiple technologies which are developed for anti-satellite. One is to use a missile to destroy a satellite. Second is to use high power lasers to neutralise a satellite. High-power electromagnetics can again be used to neutralise, which can be satellite based or ground based or airborne. Thee are payloads being put on satellites to try to destroy an adversary's satellite. There is something called Co-orbit satellites, meaning you also travel close to it and then attack the other satellite. They have a robotic arm and things like that to achieve one's objective. So, these are multiple technologies that entire world is talking about. Probably somebody is working, somebody is only doing the research, somebody is thinking of and things like that. But technologically, these are the technologies which are being worked out for the anti-satellite missions.

Rami Niranjan Desai:

Which countries do you think are very advanced in this sort of offensive anti-satellite technologies?

G. Satheesh Reddy:

Very clear. It is Russia, China, USA. These are the known ones for which actual public information is available. But there are other nations definitely attempting it. Probably some other nations in Europe and then maybe in the other countries probably attempting it. But unless there is a test done, it will not be very clear about what exactly is the way they're going at.

Rami Niranjan Desai:

Are there any sort of laws that govern space?

G. Satheesh Reddy:

The Outer Space Treaty of 1967 outlines the principles for peaceful exploration and use of the outer space and celestial bodies. It prohibits the stationing WMD as well any military activities in outer space. India signed the treaty in 1967 and ratified in 1982 with the conviction of keeping the space from militarisation.

There are space laws which have come into picture. In fact, in our own Indian universities also, space laws are introduced into some of the law universities. But then we have to see how much the treaties are there, where the world is abiding to these treaties and people are accepting these treaties has to be seen.

Rami Niranjan Desai:

Let me now bring your attention to India's ASAT mission that created a lot of debris in space. People have expressed concerns and apprehensions on the test. Is this concern legitimate?

G. Satheesh Reddy:

See firstly, when India has done this test, there have been a very clear direction from the honorable Prime Minister to see that the debris are minimum. So, the test has been planned, the collision has been planned in such a way that the debris created was minimal. And also, it was carried out at a lower orbit at about 300 km, so that the debris decay very fast. About 400 debris or so were detected, but this decayed very quickly. Today, websites that track space debris do not show any debris from the Indian ASAT test. So, India has behaved as a very responsible nation. We have conducted a test to show technological capability and we have ensured that the debris decay very quickly.

Rami Niranjan Desai:

But how is the world going to finally handle any sort of space debris? Are there any actions that are already in the pipeline to manage space debris? And also, could you clarify to our viewers what are the dangers of space debris?

G. Satheesh Reddy:

Since space debris are of grave concern, all the nations are looking into this issue very seriously, individually and even collectively. The estimated space debris today of the size of about more than 10 cm is about 25,000. This debris are a danger to satellites and to space stations. Also, debris can impact launch activities, or even the interplanetary motions. To deal with debris, we must take up the missions in such a way that debris will be minimum on the launch path and on the satellite orbital path. Secondly, we must also try to collect these debris through various mechanisms and then remove them from space. We could also look into using high powered lasers to break the debris into smaller pieces. Small pieces are of little concerns compared to debris of 10 cm, 15 cm or bigger objects. So, these are all various technologies which are being thought of, both from space itself or from the ground, or from the air. How to actually eliminate or destroy or remove this debris is a serious concern and entire globe, all the nations have to sit together, work collectively on these technologies and try to as a world, as one nation try to eliminate these debris.

Rami Niranjan Desai:

Clearly this sort of debris would affect everybody equally, but has there been any sort of, you know, common legal sort of rules, regulations made amongst the nations on this? Is there any consensus?

G. Satheesh Reddy:

There have been a number of discussions and various nations have been sitting together. They have been several conferences. Recently also there was a conference in Bangalore and people are trying to workout this issue. But there have been general guidelines which have been brought in that whatever space activities we take up, minimum debris should be generated from it. As I said, the technologies which need to be developed

and nations which have to take up the activity to mitigate this, plans are being worked out and various nations are sitting together to come out with an action plan.

Rami Niranjan Desai:

As we come to the final part of this discussion, can you explain to us how does the Department of Space and the Department of Defence cooperate with each other?

G. Satheesh Reddy:

See, one thing is these two are two separate departments, but both are scientific organisations, technology development organisations. So likewise, there is Atomic Energy and Department of Science and Technology, or CSIR, are also there, where a lot of science and technology developments happen, and we all cooperate with each other. All these departments cooperate with each other in various developmental activities, research activities and even technology development activities. Particularly ISRO and DRDO have some common technology, like ISRO does launch vehicles, DRDO does missiles and some of the payload's technologies which are there in the missile, navigation system, control systems and related things, they are common. So, technologically some dialogues discussions and cooperation do happen between the two departments. We are one nation. The entire scientific capability what is there in this nation, right from academic institutes to various research organisations and industry, have to synergistically work towards the science and technology development of the country and make the nation advance in science and technology hub. That's the goal. So, all the departments cooperate on science and technology.

Rami Niranjan Desai:

That is absolutely very promising to hear. But let me ask you my final question, in 2024 what can we expect to see from ISRO?

G. Satheesh Reddy:

I think I'm not the right person to answer. But I think some activity towards the Gaganyaan should take place. That's what I hear from the sources and a lot should happen. The country would become more and more Atmanirbhar. The country has become Atmanirbhar in a big way in all the activities of space or defence or other activities. Lot of indigenous activities systems are being developed, technologies being developed. And it is very, very happy to know that lots of youngsters have joined into this frame. Lots of startups have come up. They're working on very advanced technologies and innovations. The type of innovations which are coming up from the youngsters and startups is fantastic. And I'm sure 2024 will be a great year with lots of innovations and lots of science and technology achievements.

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Energy Policies for India

Ajay Shankar*

Provision of reliable quality round the clock affordable power supply to all is a core energy policy objective. This is an essential prerequisite for all economic activity of the industrial era. For households, it is a minimum need. The provision of clean cooking energy to all households transforms the quality of life of women. It is the objective of the Ujjwala program and is a key SDG (Sustainable Development Goal). Being Atma Nirbhar and increasing energy security is a strategic requirement. The transition away from fossil fuels and reaching net zero is imperative to save mankind, including ourselves, from the impending disaster of global warming. The simultaneous pursuit of these objectives in a coordinated, harmonious and mutually consistent manner have to propel energy policies which need to evolve, adjust and adapt based on experience and the needs of changing circumstances.

The provision of clean cooking energy makes such a remarkable difference to the quality of the lives of women. The time spent in collecting firewood or preparing cow dung cakes, which were the biomass energy sources for cooking of the preindustrial era is large, a few hours at least. The smoke is neither good for the lungs nor for the eyes. One could perhaps attribute gender bias to the provision of clean cooking energy not getting much higher priority earlier. Not that efforts were not made; for decades attempts were made to design and make smokeless cook stoves using biomass. Success was claimed and demonstrated. But switchover from the traditional modes of using biomass on a significant scale did not happen. Over 85% of households continued to use traditional biomass.

The decisive transformation began with the commencement of the Pradhan Mantri Ujjwala Yojana (PMUY) in 2016. Under this program a free gas cooking stove and cooking cylinder along with the gas (LPG) connection are being given to women of Below Poverty Line (BPL) rural households. This is being provided by the central government. This funding has made the achievement of the success of the program possible. The OMCs (Oil Marketing Companies) have done a tremendous job in extending their supply network into rural India at such extraordinary speed. The program is being implemented in phases with the present sanction going up to 2025-26. As of 25th December 2023, 9.998,939 households had got connections under the program. The objective is to cover all households. India is well poised to achieve this SDG goal well before 2030.

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Along with achieving full access the objective is the complete switchover to clean cooking and giving up using biomass. The LPG cylinder refill is now being subsidised by Rs 200. For the really low-income households, finding money for a refill remains a challenge. In the recent state elections, promises of providing cylinders at Rs 500 upped to Rs 400 were made. At the political grassroot level such a promise seemed worthwhile. This issue will not easily go away. Sooner rather than later a way forward for providing cheaper refills would be worth considering. Two options suggest themselves. One would be to go back to the old ways and get the OMCs to cross subsidise; provide cheap refills and recover the cost from all their other consumers. An alternative more direct way would be to impose a cess on the sale of oil, petrol and diesel, and gas to raise the resources to provide explicit direct subsidies to the OMCs.

Going forward and thinking of the medium to long term objective of getting to net zero, LPG would need to be replaced by biogas, a renewable source of energy, or by electricity which in turn would be becoming green and carbon free. Seen from this perspective, LPG becomes an interim mediate solution. The transition to electricity is easier to promote. State governments have started giving higher quantities of free electricity to households in fulfilment of the election promises of the parties in power ranging from 100 to 300 units per month. It turns out that in 100 units basic cooking of simple meals can be done. The simpler challenge is to promote the sales of induction stoves to get ordinary households to discover that with the newer variants developed in India in recent years Indian food can be cooked on electricity conveniently. There is good case for doing bulk procurement to get prices to fall as was made to happen with LEDs and distribute them at a subsidised rate through the electricity Distribution Companies with the cost being recovered in instalments. Giving it practically free also makes sense. The subsidy on LPG needed from the central government would decline, the subsidy for free electricity comes from the state government. Further, the per unit cost of energy in electricity terms is lower than the per unit energy cost in LPG. Taking an overall macro view the subsidy needed for electricity is lower than for LPG.

Biogas is emerging as an option that is worth pursuing now. Cow dung which was being used for cooking is now available. Compulsions of electoral politics led to promises of buying cow dung at Rs 2 per kg. Cow dung is a renewable source of energy. It can be converted at a far lower cost in a decentralised manner at the village level into useful commercial energy. Cooking biogas was attempted in a big way in the 1980s. It failed as pilot projects were not done to bring the technology to a level where biogas for cooking could be supplied to households round the clock at full pressure to take care of all cooking needs. The maintenance back up for repair services was not put in place. Then no business model for sustainable operation was put in place. Even if the capital investment is a grant, the operation and maintenance has to be financially sustainable. The operator in the village has to be thought of as a franchisee who should earn enough to have the right incentive to grow the business. It would be good to take up small pilot projects in different regions and evolve the viable technological processing and delivery system and in parallel the business model, and then see how much subsidy is

needed and how best to provide it so that the transaction costs and subsidy delivery points are the least.

Reliable quality round the clock and affordable electricity supply to all is the goal which India is achieving much earlier than expected. In the year 2000, India had more than 400 million people without access to electricity, the largest number in the world and more than sub–Saharan Africa. According to the IEA (International Energy Agency) India was likely to achieve full access in the 2040-50 decade. India has surprised itself and the world by providing full access before 2020. The IEA acknowledged that the achievement of providing access to over 500 million people in a decade was the best in the history of electrification in the world.

Electrification had been the responsibility of the states. A huge gap emerged by the 1980s. Some states had completed village electrification and were proceeding well with electrifying households. On the other hand, in the weaker states extension of rural electrification came to a near standstill. Parliament was informed in reply to a question in 2001 that Bihar was expected to take over 700 years to complete village electrification. There were 125,000 unelectrified villages, primarily in the states which were being left behind in development; UP, Bihar, West Bengal, MP, Assam and Orissa. The central government recognised the need for doing something, sanctioned an interest subsidy scheme which did not even take off, and then after much deliberation came up with a National Mission which went on to transform India. The central government took the big decision to finance the program fully with a 90% grant and a10% loan. The real innovation which made for success was to bypass the state government and provide funds directly through the Rural Electrification Corporation for specific projects for completing village electrification in a compact area and implemented through a turnkey contract. For a weak state like Bihar the services of the public sector undertakings (PSUs) were used to enable the execution of a very large programme with many projects. Bihar alone had 40,000 unelectrified villages. Once village electrification was complete, the complete electrification of all households under the Saubhagya Program was taken and completed by 2019.

In parallel, the landmark legislation of the Electricity Act,2003, which delicensed investment in power generation and promoted competition led to a surge in private investment in generation. New generation capacity rose sharply and the country for the first time had adequate generating capacity. Rural areas in Bihar started getting 16-18 hours of power supply every day. The shortages being experienced were due to inadequate investment in last mile distribution to be able to carry the electricity needed for meeting full demand. Or the state distribution did not buy all the electricity they needed for meeting full demand as they did not have the money to pay for it.

The financial health of distribution companies has remained an intractable problem. This is a state issue. The situation varies from state to state and across time. In the states, this is so important politically that Chief Ministers have to take decisions. The Electricity Act had solved this problem by giving the independent State Electricity Commissions (SERCs) the responsibility of fixing tariffs which would give revenues for the commercial viability of the distribution business.

Separately, it empowers the state governments to provide for subsidised power supply to any class of consumers by paying the money to the distribution companies for subsidised supply. As a result, the state governments are giving money for the free or nearly free supply of electricity to farmers. About 80, 000 crores are being given annually. This is support for agriculture. More recently, some states are providing 100 to 300 units free to households as a welfare measure, treating this level of consumption as a minimum need. Here again they are required to pay for subsidised power supply to the power distribution companies. But as the finances of the states are constrained and political parties do not have internal robust processes of debating the costs and benefits from different welfare measures and affordability in terms of state finances to take prudent sustainable decisions, adverse consequences result.

The SERCs get politically constrained and do not give the tariff increases that are required. In Delhi there is the strange situation of Regulatory Assets of over Rs 20,000 crore existing in the books. These are dues to be paid for by consumers in the future through tariff increases. In many states loans are taken to pay for current power purchases leading to an unsustainable pile up of debt. With inadequate cash, investments in upgrading the last mile network to meet increasing demand gets neglected and parts of India get more power cuts when demand rises at the height of summer when the air conditioning load peaks. Then in some states the governance culture is of entrenched large scale rent seeking. Privatisation is the solution in these states, either explicitly as in Delhi which is the best route or in a disguised form through franchisees which many states are attempting. It is for each state to choose. The positive development is that the central government is affecting the long overdue closure of soft options. These were supply of electricity by generating companies without full timely payments, provision of essentially working capital loans to meet revenue shortfalls without enforcing any conditions of tariff increases required to repay debt. If these hard constraints are sustained the states would have no option but to act. The actions would be overdue tariff increases in efficient states and privatisation in states where governance is the real problem.

Going forward, we have to make the energy transition to becoming net zero. Prime Minister Modi has consistently displayed ambition and leadership, whether in making the Paris Agreement possible, or in taking the world by surprise by announcing at COP26 in Glasgow in 2021 that India would have 500 GW of non-fossil fuel capacity by 2030, probably the largest increase in 2030 target by any country after Paris. By then India was well on the way to achieving far more than its Paris commitments which in turn were higher than what the policy establishment had then considered as being feasible. In Glasgow, the Prime Minister also announced that India would become net zero by 2070 giving a reasonable ten-year additional time from China's declaration of 2060 as the year they would become net zero.

The remarkable feature of India's ongoing successful energy transition is that it is taking place with competitive private investment. This is the result of smart pragmatic policies crafted to suit Indian realities. The key is the repeated invitation of bids for the supply of solar, and wind power by SECI (Solar Energy Corporation of India) with the selected bidders entering into long term Power

Purchase Agreements (PPAs) of 25 years. The price and off-take certainty from the state distribution companies for the duration of the long-term contract with the implicit guarantee of the state behind the process provided extraordinary risk mitigation. Successful bidders have been able to raise money from domestic and international markets at highly competitive rates. Competitive pressures from repeated bids where a number of developers had emerged has led to efficiency gains. India is now among those having the lowest costs for solar power. Scaling up of the quantities being bid out is taking India steadily towards the 500GW mark by 2030.

The share of renewables in electricity has reached 10%. It is rising rapidly. This poses new issues. As the sun does not shine and generate electricity at night, how is demand to be met at night. In the short run this can be done by thermal power but for greater decarbonisation of electricity, storage of renewable energy becomes essential. Fortunately, there are mature technologies for storage. Pump storage hydro projects (PSPs) on rivers where there are hydropower projects can be developed. Off river pump storage projects can be developed wherever the natural topography permits the creation of two reservoirs at two different heights. Electricity is used in these projects to pump the water up to the reservoir at the greater height. When needed the water is allowed to fall to run a turbine and generate hydro power. If only green carbon free electricity is used to pump the water, we get carbon free electricity at night from these projects. The Ministry of Power has issued user friendly guidelines for PSPs and there is rising interest in developers and state governments. In addition to PSPs there is the technology of Concentrated Solar Thermal Projects (CSPs) with storage. In this, the sun's ray are reflected from large mirrors to a single point, stored in molten salt and the stored heat is used to run a conventional thermal turbine when needed at night to generate electricity. Battery storage is needed for EVs (Electric Vehicles). For large scale grid level storage batteries are still being evolved and are at present the most expensive option. The CEA (Central Electricity Authority) has estimated the need for 72GW of storage by 2032.

In a recent SECI contract under execution the price of renewable and storage for supply during the day and at night is lower than from a new thermal plant. Hence, on purely commercial and price considerations, India need not build any new thermal plants. As the pace of execution of storage projects gathers momentum, there would be confidence that reliable round the clock power supply for increasing demand can be ensured only with renewables and storage. After all additional demand is met by renewables and storage, a view would need to be taken about winding down the existing thermal capacity in the next decade in a just transition. The costs of winding can be comfortably met by well planned decisions of extracting the gains from the appreciation of land values in the thermal generation value chain of coal mines and thermal plants. So, one can visualise the path to fully carbon free green electricity which is not only the least cost way of meeting additional demand but also where the cost of a just transition of closing down all thermal capacity may not only finance itself but could even generate some surplus.

The recent rapid success of the EVs in increasing market share raises the expectation that India may be moving along with the rest of the

world away from the internal combustion vehicle. In Europe, the sale of fossil fuel vehicles is scheduled to end by 2035. As all surface transport, 2, 3 and 4 wheelers including buses and trucks, becomes electric and all electricity in parallel becomes carbon free, India would be reducing about 555 of its total emissions. India is already moving in this direction.

The challenge of getting to net zero lies in industrial processes in products like steel and fertiliser, and in sipping and civil aviation where electricity cannot replace fossil fuels. Green hydrogen is seen as the solution for most hard to abate sectors. India has launched its own Green Hydrogen Mission and aims to be at the global frontiers in terms of cost of producing green hydrogen and its downstream uses. The Mission is being well funded and is covering the full value chain of the manufacture of electrolysers, production of green hydrogen, its storage and transport and downstream uses for the production of green steel, green ammonia for further use in producing green fertiliser and shipping. The challenge would lie in developing competitive industry structures, nudge movement down the cost curve and achieve globally competitive industrial capacities in the entire value chain of downstream uses with the minimum outgo of scarce budgetary resources. Once downstream projects go into production and cost discovery takes place for each segment it would then be possible to take rational decisions of which sectors to be given higher priority for scaling up depending on the cost disadvantage and carbon footprint. India could then choose the pace at which it would begin to decarbonise its hard to abate sectors and move to net zero.

India is gaining competitive advantage with its rapid energy transition. The transition is gathering momentum. The reduction of 55% of all emissions by having a carbon free electricity system and only EVs on the road is feasible and the process is already under way. For the rest, the picture would start getting clearer by the end of this decade as the first pilot projects of the Hydrogen Mission in the hard to abate sectors get completed. India could even find itself in a position to move to net zero much earlier.

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India's Ancient Scientific Knowledge

Jijith Nadumuri Ravi*

India has a rich intellectual heritage that spans millennia. It is as old as the Rgvedic Period (3300-1900 BCE), during which Indian civilisation laid the foundation for advancements in diverse scientific domains. The Vedas, Itihāsas, Brāhmaṇas, Āraṇyakas, Upanishads, and Purāṇas, not only delved into philosophical and spiritual realms but also contained profound insights into mathematics, astronomy, medicine, and more.

It will require an entire book to elaborate on all the mathematics, science and technology born in India. Nevertheless this article points to some of the most important achievements in the field of mathematics, astronomy, medicine, and metallurgy in which the ancient Indian scholars, often known as sages or poets, excelled.

In the field of mathematics, the decimal system was the most significant which impacted the entire world. This discovery involves decimal place value system, the use of zero as a number and the notation of zero while writing numbers. Brahmagupta (598-668 CE) elaborated on the rules of arithmetic using zero. The concept of zero as a numeral and as a placeholder in positional notation was a groundbreaking idea. Indian mathematicians, such as Aryabhata (476-550 CE), played a crucial role in defining the properties of zero. The Brahmi numerals are today known as Hindu-Arabic numeral system[1].

Ancient Indian mathematicians made advancements in algebra[2] and trigonometry. Aryabhata's work named Āryabhatiya contained solutions to quadratic equations. He introduced trigonometric functions in the context of astronomy. Trigonometry was used to construct fire altars in various shapes like bird (Garuda) shape, as described in texts like Yajurveda. Baudhāyana (800-740 BCE), provided an approximation for the value of pi in the form of the ratio of the circumference to the diameter of a circle. The Baudhāyana Śulba Sūtra states the famous rule:-

दीर्घचतुरस्रस्याक्ष्णया रज्जुः पार्श्वमानी
तिर्यग् मानी च यत् पृथग् भूते कुरूतस्तदुभयं करोति॥

The diagonal of an oblong produces by itself both the areas which the two sides of the oblong produce separately. This rule is known today as the Pythagorean Theorem. Baudhāyana discovered it much earlier than Pythagoras.

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Śulba Sūtras contains rules for constructing various Vedic fire-altars in various geometric shapes. This demonstrates a profound understanding of geometry. Mādhava of Saṃgama Grāma (1340-1425 CE) and the Kerala School mathematicians discovered the infinite series expansions for trigonometric functions. They are the foundation of calculus. The Jesuit missionaries learned this mathematics from Kerala scholars and propagated in Europe. Isaac Newton (1642-1726) learned it from them.

There are references in the Vedic literature about Vaidyuti (electricity). It is often understood as a force with the potential for shock or spark, which can also create light. The manipulation of metals, including the creation of alloys, indirectly contribute to the understanding of electrical conductivity. Many texts like Rāmāyaṇa and Mahābhārata make mention of 'Yantras' which is understood as complex machines, often employed in warfare. Yantras are often attached to the walls of fortresses. They can strike multiple number of enemies. Śataghni is a Yantra which can kill hundred enemies at a time. Other Yantras like Tāttālaka (turret), Kaca Grahani (hair-grasper), Ustrika (camel shaped catapults), Huda Śrngika, Hudāguda and Yantrajāla too are frequently mentioned in the Itihāsas. Most of these are mentioned in Vana Parva of Mahābhārata in the battle of Krsna with the king of Śālva.

Vimānas of various complexity are mentioned in the Itihāsas. Often, they are described as flying vehicles, though a Vimāna could also mean the tall tower of a building. The poet of Mahābhārata reports the arrival of a Vimāna to take Arjuna from Himālaya as follows (MBH 3.43.3-6):- "Removing the darkness from the sky and splitting the clouds, it made a thundercloud like sound. It had Asi (swords), Śakti (spears), fearsome Bhīma Gada (huge clubs) and Prāsa (lances) with divine power. It had Vidyuta (lightning) flashes. It had Hudāguda with Cakra (wheel). It had Vāyu Sphota - implements that created bursts of winds. It produced sounds of Barhi (peacocks) and clouds. It had terrible and huge Nāgas with glowing mouths, tall as white clouds and hard as rocks."

Here, the swords, spears clubs and lances could be objects like antennas and globular structures. Hudāguda with Cakra and Vāyu Sphoṭa could be its main engine with air compression chambers and thrusters, that eject gas for maintaining thrust. High pitched sounds (peacock sound) and low-pitched heavy sounds (sounds of clouds: - thunder cloud or cloud-burst) could be various sounds of the engine. What is described as Nāgas could be external coils and wires of the vehicle.

The binary system is evident in the ancient Indian text Chandah Śastra of Piṅgala (3rd or 2nd century BCE), a treatise on prosody, which used binary representations for the poetic meters. Binary system is the foundation of today's computers and electronics. Neither electronics nor computer science were possible without the Indian discovery of zero and the decimal system. In linguistics, the study of languages, the ancient Indians did pioneering work with texts like Nirukta (etymology) and Vyākaraṇa (grammar). This study is what led to the creation of etymology

and grammar to all languages of the world. The development of computer programming languages is indebted to these fields of knowledge developed by ancient Bhāratīyas.

The Bhagavat Yāna episode in Udyoga Parva of Mahābhārata describes the Viśvarūpa of Kṛṣṇa . The poet mentions Kṛṣṇa showing the 30 (Tridaśa) Devatas including Brahma, Rudra, Lokapālas, Ādityas, Sādhyas, Vasus, Aśvins, Indra, Maruts and others as thumb-sized holograms (MBH 5.129.4). They were radiant as fire! This description resembles the digital hologram technology used in today's Augmented Reality and Virtual Reality, broadly described as Extended Reality. Similar descriptions are seen in Bhīṣma Parva, as part of Bhagavad Gita where Kṛṣṇa showed Viśvarūpa to Arjuna.

The contributions in astronomy were equally remarkable. Āryabhata proposed a heliocentric model of the solar system in Āryabhatiya. He suggested that the earth rotates on its axis and provided calculations for the positions of the planets in a heliocentric framework. Ancient Indian astronomers developed precise methods for calculating the positions of celestial bodies. The Siddhāntas, astronomical treatises, provided mathematical models for planetary motion, eclipses, and the positions of stars. The Indian calendar system, known as the Pañchāṅga, was developed to accurately measure time, celestial events, and festivals. Pañca Siddhāntika of Varāhamihira (505-587 BCE) discussed various methods for calculating calendar dates based on planetary positions.

Ancient Indian astronomers used ecliptic coordinates, a system for locating celestial objects along the ecliptic plane. The Surya Siddhanta[3] described the measurement of celestial longitude and latitude. the division of the celestial sphere into lunar mansions, or Nakshatras, played a significant role in Indian astronomy. These divisions were used for timekeeping, especially in the context of lunar and solar calendars. Ancient Indian astronomers were skilled observers. They documented celestial events such as eclipses, comets, and the positions of planets, contributing to a growing body of astronomical knowledge. Such observations, recorded in the texts like Vedāṅga Jyotiṣa, Rāmāyaṇa and Mahābhārata aid in dating the events mentioned in these texts or dating the text itself, after normalising it with other disciplines like archaeology.

Indian astronomy had a profound impact on Islamic astronomy during the medieval period. Scholars like Al-Biruni studied Indian texts and incorporated Indian astronomical methods into Islamic traditions. Through them, Indian astronomy also influenced the European astronomy.

Indians made profound contributions to what we today call physics. The Vaiśeṣika Sūtra dated to between 6th to 2nd century BCE is a work of Kaṇāda. It had some early insights into the Newtonian laws of motion. However, it was not formalised into a formal theorem with mathematical formulas like Newton has done. Bhaskara II (1114-1185 CE) proposed the idea of gravity, recognising that objects are attracted towards the Earth due to a force. It was an early insight to the gravitational laws, few centuries before Newton.

Surya Siddhantha included discussions on optics and the nature of light. It explained the phenomenon of refraction and correctly described the apparent motion of the sun caused by the Earth's axial tilt. The Nātya Shastra, an ancient Indian treatise on performing arts attributed to Bharata Muni, contained insights into acoustics. It discussed the principles of sound, including the classification of musical instruments based on their sound-producing mechanisms. Brahma-gupta made contributions to fluid dynamics by discussing the nature of liquids and the formation of waves. His work included insights into the behaviour of fluids in motion. The concept of atoms (Aṇu) is found in early Indian philosophical texts like the Vaiśeṣika Sūtras. These texts proposed the idea of indivisible particles as fundamental building blocks of matter. It served as the philosophical basis for the atomic theory, which later developed into formal theorems in Europe, backed with mathematical formulation.

Later, this Classical Physics transitioned into Quantum Physics. The philosophical foundation for Quantum Physics is seen in Vedanta. The philosophy of Vedanta, quite similar to Quantum Physics, posits that the observer influences what is observed. In other words, the mind with its act of observation collapses the abstract probabilistic quantum superpositions and creates the concrete reality. Correspondingly, the Advaita Vedanta insists that it is our mind that creates our reality – viz, this observable universe. Similar to Advaita Vedanta, Quantum Physics is nearing the conclusion of universal Oneness of the multiplicity apparently observed by the observer.

Indian contribution to chemistry is numerous, especially in metallurgy. The Copper Age in India started by 4000 BCE, Bronze Age by 3300 BCE, Iron Age in 2000 BCE. Ancient Indian artisans were skilled metallurgists, and their expertise is evident in the extraction and processing of metals. The iron pillar in Delhi, dating back to the Gupta period (4th-5th centuries CE), is a remarkable example of advanced metallurgical knowledge, showcasing corrosion resistance and a mastery of ironworking techniques. The ancient Indian tradition of chemistry was known as Rasa Śastra. It involved the systematic study of minerals and metals for medicinal and transmutational purposes. Texts such as the Rasa Ratnākara and Rasa Kāmadhenu provided detailed instructions on the preparation of various chemical compounds, including alloys, acids, and medicines. The Arabs translated these as alchemy texts.

Ancient Indian metallurgists were skilled in creating metal alloys. Artha Śastra, mentions methods for alloying metals and describes techniques for testing the purity of metals. This knowledge was crucial for ensuring the quality of metal products. The development of alloys, such as bronze (copper and tin) and brass (copper and zinc), played a crucial role in various industries, including sculpture, coinage, and tool manu-facturing. Copper was widely used in ancient India for making tools, utensils, and decorative items. Bronze, an alloy of copper and tin, was employed to create durable and corrosion-resistant artefacts.

Gold and silver were extensively used in

ancient Indian art and jewellery. Skilled artisans crafted intricate ornaments and artefacts using techniques like repoussé, filigree, and granulation. Metal was used in architectural elements such as pillars and gates. The exquisite detailing on metalwork in temples and palaces reflects the craftsmanship of ancient Indian metallurgists.

Ancient Indian metallurgists were proficient in various casting techniques. The lost-wax casting method was commonly used for creating intricate metal sculptures, particularly during the period of the Chola dynasty (9th-13th centuries CE). India has a long history of metal coinage, with various dynasties issuing coins made of copper, silver, and gold. These coins were often adorned with symbols and inscriptions, showcasing the metallurgical skill of the time.

Ancient Indian texts describe various methods of salt production, highlighting a practical understanding of chemical processes. The Artha Śastra, of Chanakya (4th century BCE), detailed techniques for extracting salt from saline water and soil. The ancient Indians were skilled in glass making, and the use of glass vessels is mentioned in various texts. Additionally, dyeing techniques for textiles involved chemical processes, and the knowledge of plant-based dyes and mordants was well-established. Ancient agricultural practices involved the use of various chemical processes. Artha Śastra provided guidance on soil fertility, irrigation, and the use of organic and inorganic substances for enhancing agricultural productivity.

Ayurveda, the ancient Indian system of medicine, incorporated principles of chemistry in the preparation of medicines. Charaka and Sushruta, ancient medical scholars, documented the properties of various substances, including minerals and plant extracts, and their therapeutic uses. The Ayurvedic pharmacopoeia included processes like distillation and sublimation. The ancient Indian system of taxonomy, as found in texts like the Jīvaka Chintāmaṇī, categorised living organisms into various classes based on their characteristics. This classification system included divisions such as plants, animals, and microorganisms.

Ancient Indians had a comprehensive understanding of plants and their medicinal properties. The Ṛgveda contains references to various plants used for medicinal purposes, and later texts like the Nighantu explored plant classifications and their therapeutic applications. The Panchatantra and other ancient texts included study of animals (zoology)—observations of animal behaviour and characteristics. Artha Śastra discussed wildlife management, wildlife resources and conservation. The Sushruta Samhit" contains insights into embryology, describing the development of the foetus in the womb. It includes discussions on various stages of foetal growth and the formation of organs. Artha Śastra deals with the study of insects (entomology). It provided information on insects and their impact on agriculture. The text suggests measures for pest control and emphasises the importance of understanding insect behaviour.

Suśruta, was an ancient Indian physician and surgeon. His Suśruta Samhita (6th century BCE) was a comprehensive treatise on medicine and

surgery. It is one of the earliest known works on surgery. It covers a wide range of topics, including anatomy, surgical instruments, and various surgical procedures. The Suśruta Samhita contains detailed descriptions of various plastic surgery procedures, including reconstruction of the nose (rhinoplasty) and repair of torn earlobes. Suśruta's techniques for skin grafting and reconstructive surgery were remarkably advanced for the time. The Suśruta Samhita describes surgical procedures for cataract removal. Ancient Indian surgeons used a curved needle to push the opaque lens aside and allow light to enter the eye, a technique known as couching. Suśruta emphasised the importance of understanding human anatomy for successful surgical interventions. The text provides details on the dissection of cadavers to study anatomy, showcasing a profound commitment to empirical observation.

Ancient Indian surgeons were skilled in setting fractured bones and treating dislocations. The Suśruta Samhita outlines various methods for bone-setting, including the use of splints and braces. The Suśruta Samhita mentions the use of wine and other substances to induce a state of anaesthesia during surgery. While the methods might not align with modern anaesthesia practices, the recognition of the need for pain management during surgical procedures is noteworthy. The ancient Indian surgeons used a variety of surgical instruments, many of which are described in detail in the Suśruta Samhita. These instruments included scalpels, forceps, needles, and specialised tools for specific surgical procedures. The importance of cleanliness and hygiene in surgical practices is emphasised in the Suśruta Samhita. Ancient Indian surgeons recognised the significance of maintaining a sterile environment to prevent infections. The use of herbs, Yoga, and meditation for healing purposes reflects the integration of physical and mental well-being in ancient Indian medical practices.

India's maritime knowledge is evident in Artha Śastra. It provided guidelines for shipbuilding, navigation, and trade. The existence of maritime trade routes between India and other civilisations underscores the proficiency of ancient Indian sailors and navigators. The term Navi and navigation has its origin in the Sanskrit term Nāvam (meaning boat or ship). Indians were foremost ship builders. Indian ships travelled in Indian Ocean and reached the shores of Africa and South East Asia. Ancient Indians had trade relationships with Greece, Rome and China both through land and sea.

The concept of environmental conservation, as seen in the reverence for nature in various scriptures, reflects a deep ecological understanding. Practices such as water harvesting, afforestation, and sustainable agriculture were embedded in ancient Indian societal norms. Ancient Indian were excellent city builders and town planners. Water management with excellent sanitation and drainage system with flush toilets, concealed or underground water pipelines, public baths, interior bathrooms, water canals, well paved rectangular roads, four-squares and buildings are evident in the Harappan city

planning. The Harappan Civilisation is named as such since the first settlement of this civilisation was found in Harappa. Its geographical span is now understood as Western UP in the east, Eastern Afghanistan in the west, Jammu and Kashmir in the north and Northern Maharashtra in the south. This vast region of North West India was watered by the rivers - Sarasvati, Sindhu and Narmada. Hence, it is to be more aptly renamed as Sarasvati Sindhu Narmada Civilisation (SSNC).

A need exists now, to record and reclaim India's ancient scientific knowledge. We have been taught that everything that is science emerged from the Western world. This is simply not true. Hence, India's scientific achievements from ancient times need to be made part of the curriculum and syllabus of the schools and colleges. Some Western universities now acknowledge that the theorems like Pythagoras Theorem was discovered by Indian scholars. Yet, these simple truths are not properly taught to Indian students. This situation needs to change. Indians need to proactively read their ancient texts and understand the scientific information contained therein, through primary sources. This will help them to think and develop modern applications of our ancient knowledge, or at the minimum, it will inspire them to be pioneers in scientific discoveries and technological innovations.

Dharma Digital is a platform initiative of this author, which focuses on blending Generative AI with Digital Hologram Technology of Extended Reality. Through this platform, more than hundred interactive 3D digital holograms of Devatas like Indra, Viṣṇu, Śiva, Brahma, Sarasvati, Pārvatī, Lakṣmī, Rāma, Sīta, Hanumat, Ganeśa, Skanda, Ayyappa, Kṛsṇa along with Pāṇḍavas and Pāñcālī are created.

These Devata Holograms are thumb-sized, as is mentioned in the Viśvarūpa Darśana and Bhagavat Yāna episodes of Mahābhārata! They

Figure: Dharma Digital Holograms rendered on a table.

glow in their own light. They can appear in the real world and are capable of conversing with us using Generative AI. They can walk with us, smile at us or interact with us. They can be used to teach the students about concepts of Sanātana Dharma. Dharma Digital platform can also recreate ancient personalities like Aryabhata and Bhāskara who can teach the ancient scientific knowledge of India to today's generation in an interactive and intimate way. They can work as knowledge Gurus, and guides for the young generation.

These knowledge Gurus can reside in their mobile phones or their Augmented Reality and Virtual Reality devices. They can be invoked into the real world as and when required, to guide our new generations.

I also similarly note the development in creating software tools by other technology experts to help bring the ancient scientific knowledge of India to the current generation. These include Sanskrit-to-Indian-language translation and Sanskrit-to-English translation using Panini's grammar rules. Similarly, the text-to-speech software can read and speak Sanskrit text and the speech-to text software can convert spoken Sanskrit to Sanskrit text. Such tools will help in the learning of Sanskrit through daily conversation. Pāṇini's Sanskrit can be used as a bridge language between machine language and human language. Research in this area has seen some progress, after a recent discovery about a simplifying principle of Pāṇini's grammar. These developments can easily bring back the ancient Indian knowledge to the current generation, and inspire them to improve them and apply them into the field of electronics, Virtual Reality (VR), Artificial Intelligence (AI), Space etc.

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1 It was the Arabs who popularised it in Europe.

2 The term algebra is Arabic since the Arabs popularised it in Europe

3 The current version of Surya Siddhantha we get to read is dated to 4th or 5th Century CE

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Going Beyond Misconceptions to Comprehend the Vedic Term "Bali"

Vandana Sharma 'Diya'*

Abstract:

Misconceptions surrounding the Vedic texts" endorsement of animal or human sacrifice, often attributed to the term "Bali," are explored in this study. It is demonstrated that "Bali" holds a multitude of meanings, ranging from divine epithets to offerings and acts of selflessness. "Bali" encompasses a spectrum of interpretations, including its association with deities like Lord Vishnu, Lord Krishna, and Demon King Mahabali, as well as its connection to ancient cultures and practices. The study also examines the terms "Pashu" and "Bali." The misinterpretation of these words is attributed to a lack of understanding, linguistic barriers, preconceived biases, and deliberate misrepresentations. To appreciate the wisdom and values inherent in Vedic traditions, it is crucial to approach their interpretation with an open, unbiased mind and respect for diverse perspectives. The Vedas, in essence, promote nonviolence, reverence for all life, and universal harmony, which should be upheld in their study and practice.

Introduction

A segment of scholars, seemingly influenced by preconceived notions, assert that the Vedic texts condone rituals involving the sacrifice of animals or humans, often referring to it as "paśu" or "manav Bali." This interpretation, however, stands on shaky ground. Much like the intricacies of the English language where a single word can take on diverse connotations, the Sanskrit term "Bali" too carries a rich tapestry of meanings and interpretations.In any language, the semantic versatility of words becomes apparent, their significance fluctuating in response to the context and usage.

Bali: A term with Multiple Meanings

Just as the English word "round" can denote a shape, a stage in an interview, a directionless motion, or perplexing dialogue, and "crane" can signify a bird, a mechanical lifting apparatus, or a tilting action, "Bali" illustrates this inherent linguistic flexibility by encapsulating a spectrum of interpretations. Let us now delve into these various facets of"Bali,"

In the Atharvaveda, "Bali" is used to signify the physical, mental, ethical, and emotional strength that originates from the Supreme, who is the ultimate source of strength.[1] In the Vishnusahasranama, a sacred compilation featuring 1,000 names of Lord Vishnu, we encounter "Bali"[2] as one of His appellations. This

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name underscores the facets of strength, power, and might that are inherently connected to Lord Vishnu.

Within the divine and spiritual realm, "Bali" serves as one of the 108 names attributed to Lord Krishna. This nomenclature transcends its worldly meaning, transforming into a profound divine epithet that encapsulates the qualities, attributes, and celestial manifestations of Lord Krishna. Each name within the list of 108 names holds a unique significance, representing a distinct facet of the deity invoked. In the case of Lord Krishna, the name "Bali" shines a spotlight on his divine strength, power, and unwavering commitment to safeguarding and upholding righteousness.[3]

"Bali" is one of the names of Balrāma,[4] the brother of Śrī Kṛṣna. "Bali," when attributed to Balrama, embodies the connotation of strength and power. Renowned for his remarkable physical prowess and his pivotal role as a guardian, he is frequently portrayed brandishing both a plow (hala) and a mace (gada), which vividly symbolise his exceptional might and his unwavering dedication to defending and preserving righteousness. An additional layer of significance linked to the term "Bali" relates to the Demon King Mahabali,[5] who earned this epithet due to his unparalleled strength and power. It was his extraordinary might that bestowed upon him the titles of "Bali" or "Mahabali." However, his reign came to an end with his defeat at the hands of Vishnu"s Vaman Avatar.

Within the grand narrative of the Mahabharata, we encounter the character "Bali," portrayed as the Vanar Raja, or the king of monkeys.[6] To be more specific, he is identified as Anava, signalling his unique role and identity within the epic"s intricate storyline. Bali"s importance lies in his leadership role among the 'vanaras', a tribe of intelligent and robust humanoid monkeys. His presence and actions vividly underscore the vanaras valour and capabilities as formidable warriors and steadfast allies.

The Kathasaritsagara, known as the "ocean of streams of story," features a mention of "Bali" and is a renowned Sanskrit epic tale that centres around Prince Naravahanadatta and his aspiration to ascend to the throne of the Vidyadharas, celestial beings. It is believed to be an adaptation of Gunadhya Brihatkatha, which comprises 100,000 verses, and this, in turn, is a part of a more extensive work encompassing 700,000 verses.[7]

"Bali" is the name of a Yakshagana, Mahamayuri Vidyarajni,[8] that is present in Mahayana and Vajrayana Buddhism. "Bali" is also linked to the sixth Prativasudeva,[9] an anti-heroic figure in Jain mythology. Prativasudevas are regarded as formidable beings who stand in opposition to the spiritual teachings and progress of Tirthankaras (spiritual leaders) and their disciples. The sixth Prativasudeva, known as "Bali," is believed to possess immense strength and is portrayed as an antagonist in Jain narratives.

In tantric traditions, the name "Bali" is connected to the malevolent force governing Patala, the underworld realms. These realms are believed to be inhabited by a variety of beings, including Daityas, Nagas, and Rakshasas.[10] `The term "Bali" can also allude to a ascetic or hermit-

like figure who, through the power of rigorous spiritual practices known as Tapas, dedicates himself to the welfare of the cosmos. With unwavering mental strength, he willingly sacrifices personal interests and desires, placing the well-being of humans, animals, birds, and the entire world at the forefront. This interpretation underscores his selflessness, unwavering commitment, and the profound influence of his actions.

"Bali" also alludes to the Kingdom of Bali, a historical sequence of Hindu-Buddhist realms that governed sections of Bali Island in Indonesia. This kingdom thrived from the 10th to the 20th centuries, boasting its Balinese monarchs and a distinctive court culture. These rulers harmoniously blended indigenous beliefs, reverence for their ancestors, and Hindu customs acquired from India via Java. This cultural amalgamation profoundly shaped the vibrant and diverse Balinese traditions we are familiar with today.[11]

"Bali" can additionally signify a mandatory tax or tribute collected from individuals and presented to the king. It symbolises a financial offering that citizens are obligated to provide to sustain the ruling authority. Typically, this tax is allocated for the upkeep, governance, and administration of the kingdom. The gathering of "Bali" plays a pivotal role in maintaining the financial stability and smooth operation of the royal establishment. It also conveys the essence of a gift or offering, representing the act of voluntary giving, often in the form of a tribute or donation, to a deity, spiritual figure, or esteemed entity. This concept of "Bali" is deeply ingrained in religious and spiritual customs, where individuals manifest their devotion, gratitude, or reverence through the presentation of such gifts. These offerings may manifest in various forms, including food, flowers, incense, or valuable items. The act of offering a "Bali" holds a sacred significance, symbolising one"s unwavering dedication, devotion, and yearning to establish a profound connection with the divine.[13]

"Bali" extends beyond the mere act of worship and adoration, carrying a profound and transformative meaning. It encompasses the art of relinquishing one"s ego and wholeheartedly surrendering to the Supreme. This selfless surrender involves releasing attachments, overcoming addictions, shedding greed, anger, and other negative inclinations. By sacrificing these impurities, one embarks on a journey towards inner purification, aligning themselves with elevated virtues and spiritual values. The practice of "Bali" serves as a transformative path, urging individuals to transcend ego-driven desires and nurture a pure, selfless mindset. It is an invitation to release selfishness and embrace a profound connection with the divine, resulting in inner growth, spiritual ascension, and a harmonious existence.[14]

"Bali" carries a profound significance in the context of oblations presented during Yajna (sacrificial) rituals or in Havan (ritualistic fire worship). It encompasses the act of dedicating an array of materials, including ghee (clarified butter), grains, herbs, and other sacred substances, to the sacred fire. These oblations symbolise expressions of gratitude, devotion, and surrender to the divine forces. Through the offering of "Bali" into the fire, individuals aim to forge a connection with higher realms, invoke blessings, and convey their deep reverence for the divine.

The practice of "Bali" in Yajna and Havan ceremonies is believed to purify the environment, elevate spiritual energies, and foster a harmonious atmosphere conducive to spiritual growth and well-being. It stands as a sacred bridge uniting the human and divine realms, nurturing a sense of unity, gratitude, and divine communion.[15]

"Bali" encompasses the daily ritualistic act of sacrificial offerings made as tokens of reverence and compassion to various beings. These offerings entail the provision of food, water, and essential provisions to sages, the impoverished, dogs, cows, and crows. This practice underscores the understanding that all living beings are interconnected and deserving of care and sustenance. When individuals present "Bali" to sages, it signifies their respect and the seeking of blessings from the wise and enlightened. Extending offerings to the less fortunate embodies acts of charity and compassion, providing support to those in need. The act of feeding dogs, cows, and crows is considered auspicious, honouring the sanctity of these animals. It is believed that such offerings usher in blessings, safeguard against negative influences, and generate positive karma. Through the practice of "Bali," individuals nurture a sense of empathy, selflessness, and gratitude, acknowledging the intrinsic worth and interconnectedness of all living beings within the cosmic tapestry.[16]

"Bali" also implies the notion of self-sacrifice, often referred to as "Balidana." This concept involves willingly forgoing one"s personal comforts, alms, food, or time for the betterment of others. It embodies the ethos of selflessness, compassion, and service toward those in need. Through the practice of Balidana, individuals prioritise the welfare of others over their own desires and willingly make sacrifices to provide support and uplift those in less fortunate circumstances. This can encompass actions such as providing food and resources to the hungry, extending assistance and care to the under-privileged, or dedicating time and effort to charitable causes. Balidana underscores the acknowledgment of our interconnectedness as human beings and the responsibility to contribute to the well-being of the community and society at large. Through acts of self-sacrifice, individuals nurture virtues such as empathy, generosity, and altruism, fostering a sense of unity and harmony in the world.

The act of presenting "Bali" encompasses more than merely offering uncooked or unbaked food to divine entities; it extends to sharing with other beings as well. This practice underscores the significance of selflessness and the art of giving before receiving. By offering "Bali" before partaking of any sustenance, it leaves a profound mental imprint, instilling in individuals the virtue of generosity and emphasising the importance of prioritising the well-being of others. It acts as a poignant reminder to cultivate a mindset of sharing and giving in every facet of life, nurturing compassion and fostering a profound sense of interconnectedness with all living beings.[17] The word carries the significance of a ceremonial food offering, particularly dedicated to Shiva, the protector of all beings, as prescribed in the Saivagamas. This ritual holds profound importance, involving the presentation of food to Shiva as an expression of reverence and devotion. The act of offering "Bali" to Shiva symbolises a profound spiritual connection and signifies the

devotee's complete surrender and devotion to the Divine presence of Shiva. Rooted in the Saivagamas, this sacred practice serves as a guiding principle for followers in their worship and unwavering devotion to the Divine.[18]

In the Rasashastra, a distinguished branch of Ayurveda dedicated to the study of chemical interactions among metals, minerals, and herbs, the term "Bali" that originates from the word "Bal" serves as a technical term denoting "wrinkles." This specialised domain of Ayurveda delves into the intricate understanding of substances and their impacts on the human body, encompassing the comprehensive examination of wrinkles and potential remedies for them.[19]

In the domain of Gajayurveda or Hastyaayurveda, the term "Bali" is employed to denote oblations utilised in the treatment of elephants. This ancient branch of Ayurveda specifically focuses on the health and well-being of elephants, providing insights into their anatomy, diseases, and therapeutic measures. The use of oblations, including specific substances or offerings, forms an integral part of the treatment protocols designed to promote the vitality and recovery of these magnificent creatures.[20]

"Bali" refers to one of the topics dealt with in the Matrsadbhava, one of the earliest Shakta Tantric works from Kerala[21]. In Shaktism, "Bali" signifies the ritualistic worship of fifty-three deities in accordance with their designated compartments within a constructed Balimandapa. This sacred act involves offering Payasa, a preparation of rice boiled in milk, to these revered deities. The purpose of this worship is to honor and celebrate the divine entities who played a pivotal role in vanquishing the demon Vastu. Through this ritual, devotees express their devotion, seek divine blessings, and commemorate the triumph of good over evil in the cosmic realm.[22]

In the context of Vastushastra, "Bali" refers to a diagram consisting of eighty-one squares and a cluster of deities that are drawn on the ground as a blueprint for the construction of a structure. This diagram serves as a guide for the positioning and alignment of various elements within the building, ensuring harmony and auspiciousness. The inclusion of deities in the diagram signifies the spiritual aspect of the construction process and emphasises the belief in divine blessings and protection for the structure and its occupants. It is considered a sacred practice to follow the principles of the "Bali" diagram in Vastushastra to create a harmonious and auspicious living or working environment.[23]

Multiple meanings of Paśu

Let us now also have a look at the various meanings of the word Paśu. Within the philosophy of Shiva Siddhanta, the term "Pashu" is employed to denote an individual soul or sentient being, encompassing humans and other living creatures. It symbolises the finite and conditioned nature of the individual soul, which is ensnared in the cycle of birth and death and constrained by the limitations of the physical realm. In contrast, "Pati" refers to the Supreme Controller, which is Shiva, the ultimate divine reality. The objective of the individual soul is to surpass its restricted existence as a "Pashu" and achieve union with the Supreme, identified as Pati or Shiva. Through spiritual disciplines, devotion, and the realisation of one's authentic self, the individual soul can

progress toward liberation and the ultimate unity with Pati. This philosophy underscores the voyage of the soul from enslavement to liberation, from self-identification as the finite self to the recognition of its divine essence and unity with the Supreme.[24]

In the realm of the Shilpashastra, an ancient Indian treatise on art and architecture, the term "Pashu" is employed to encompass all embodied souls, including humans. It acknowledges that every living being, irrespective of its shape or species, falls under the category of Pashus. This concept is founded on the notion that all beings are interconnected and share a common existence. It underscores the unity among all life forms and acknowledges the innate divinity within each individual. This perspective fosters veneration and regard for all living beings, advocating for an all-encompassing and comprehensive approach to life and creation.[25]

Rishi Kashyapa is regarded as the progenitor or forefather of various beings, encompassing humans, animals, plants, and other celestial entities like Gandharvas, Devas, and Asuras. This belief symbolizes the common lineage and interdependence of all living entities, notwithstanding their varied shapes and manifestations.

In Vedic culture, the term "Pashu" is employed to encompass all beings in the world, signifying that its significance extends beyond just animals. It signifies the acknowledgment of the interconnectedness and shared existence of all life forms. "Pashu" represents the idea that all living beings, including humans, animals, and plants, are bound by the cycle of life and death and are subject to the laws of nature. Similarly, the word "Bali" holds multiple meanings and should not be confined to the interpretation of "animal sacrifice." While the term "Bali" can be associated with offerings made in Vedic rituals, it does not imply the act of causing harm or bloodshed. Instead, these offerings symbolise acts of devotion, surrender, and selflessness. The purpose of such offerings is to establish a spiritual connection and seek blessings from the divine forces.

Why the terms Pasu and Bali are misunderstood

The misunderstanding of "Pasu" and "Bali" as animal sacrifice may have originated from a limited comprehension or cultural biases imposed on Vedic rituals. However, it is essential to acknowledge that Vedic rituals and the Vedas themselves promote veneration for all life forms and advocate for non-violence. They emphasise the principles of harmony, equilibrium, and spiritual progression. By embracing a holistic understanding of "Pasu" and "Bali" within the broader context of Vedic culture, we can recognise the profound wisdom and universal principles that underpin these age-old traditions. It is vital to approach the examination and interpretation of Vedic texts with an open perspective, honouring the diversity of interpretations and avoiding misrepresentations that could perpetuate misunderstandings regarding Vedic rituals and their genuine essence.

The reasons behind the misinterpretation of the word "Bali" could stem from various factors, including:

- Insufficient comprehension of the original texts, their context, philosophy, and the method by which they should be

understood, considering factors like location, time, and circumstances.

- Inadequate knowledge of Sanskrit, the language in which the Vedas are written.
- Approaching the Vedas with pre-existing predispositions, biases, and pre-conceptions.
- Deliberate distortion of Vedic texts to advocate for violence, non-vegetarianism, and social divisions.
- Purposeful attempts to undermine the authority of the Vedas with the goal of eradicating Vedic culture, philosophy, and historical significance.
- Vedic texts often employ symbolism and allegory, which can be difficult to decipher, without a Guru.

Conclusion

This paper enumerates the intricate web of meanings interwoven into the term "Bali" as it exists within the Vedic tradition. This word encompasses a wide array of interpretations, spanning from divine appellations to symbolic offerings and selfless acts. The misunderstandings revolving around "Bali" and "Pashu" have their origins in several factors, including a limited grasp of the concepts, linguistic challenges, preexisting biases, and deliberate misrepresentations.

To gain a genuine understanding of the wisdom and values that underlie Vedic traditions, it is essential to approach their interpretation with an open, impartial mindset. The Vedas, at their core, advocate principles of non-violence, reverence for all life, and universal harmony. These foundational ideals should illuminate the path for studying and practicing Vedic traditions, with an emphasis on unity, compassion, and respect for all living beings.

Moreover, why the term "Bali" is misconstrued can be attributed to various influences, including a lack of comprehension of the original texts, language barriers, preconceived notions, deliberate distortions aimed at promoting violence or discord, and endeavours to diminish the significance of the Vedas.

Ultimately, it is crucial to acknowledge and address these influences when delving into Vedic texts, striving for a comprehensive comprehension, and embracing the profound wisdom and universal values they encapsulate. The Vedas stand as a testament to harmony, balance, and spiritual growth, emphasising reverence for all life forms and the interconnectedness of all existence. Approaching the Vedas with an open and unbiased mindset, while seeking knowledge and insight from qualified mentors and scholars who can provide accurate guidance and interpretation, is paramount. It is equally important to emphasise that the Vedas neither condone nor endorse actions that cause harm or sacrifice living beings for the sake of appeasing deities. Instead, these texts elevate animals to the status of the Supreme and advocate for their worship as manifestations of the Highest Reality. The teachings of the Vedas underscore universal compassion and discourage rituals, sacrifices, or ceremonies that inflict harm, disharmony, pain, or suffering on any living being. The essence of Vedic teachings lies in promoting harmony, respect, and veneration for all forms of life.

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- *Vishnusahastranamavalli*

1 *Atharvaveda, 2.17.3 (*बलमसि बलं दाः स्वाहा ॥*)*

2 *Vishnusahasranamavali, 172nd name of Vishnu "Mahabalah"*

3 *Fifty eighth name of Lord Krishna (Om Baline Namaha)*

4 *19th out of 100 names of Balrama*

5 *(i) Williams George, Handbook of Hindu Mythology, Oxford University Press, London, 2008 pp.73–74.*
*(ii) Rakshasbandhanmantra (*येन बद्धो बली राजा दानवेन्द्रो महाबलः *I yena baddho balī rājā dānavendro mahābalaḥ)*
(iii) Meghadoot, 59

6 *Harivamsha, v.1.31; Ch.9:Mahabharata, Adiparva*

7 *Kathasaritsagara (ocean of streams of story), chapter-45.*

8 *Mahamayuri Vidyarajini Sutta, 104*

9 *Muni Amar, Sachitra Tirthankar Charitra, Padma Prakashan, Delhi, 1995, p.274.*

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12 *(i) Bhagavatapurana, v.1.13,40-41;*
(ii)Brahmandapurana, v.2.31, 48 ;
*(iii) Manusmriti 7.8;8.37 (*प्राजिघाय बलिम तथा*; prajighāya baliṃ tathā)*

13 *Uttarramacharitra, 1.5 (*निवारबलीं विलोकायतः*; nīvārabaliṃ vilokayataḥ)*

14 *Kumarasambhava, 1.6 ; Meghadoot, 57 (*अव–सीतानि बलिकर्मपर्यापतानि पुष्पाणि*; ava- citāni balikarmaparyāptāni puṣpāṇi)*

15 *Gobhilagrihyasutra, 3.7*

16 *(i) King Shudraka, Ryder Arthur William(Tr), Mrichckatikam –Samskrit Play (The Little Clay Cart), Harvard University, Massachusetts, 1905, v.1.9, pp.6-8, (*यासां बलिः सपदिमद्गृहदेहदेहलीनां हंसैः च सारस गणैश्च विलुप्तपुरवः*; yāsāṃ baliḥ sapadimadgṛhadehalīnāṃ haṃsaiś ca sārasa gaṇaiśca viluptapūrvaḥ |)*
*(ii) Manusmriti, 3.67.91 (*भूतायज्ञ*; bhutayajñã);*
(iii) Gobhilagrihyasutra, Khadiragrihya 1; 5; 20.

17 *Ashtanghridayasamhita, 2.33*

18 *Goodall Dominic, Parakhyatantram: A Scripture of the Saiva Siddhanta, Institut Fancis De Pondicherry, Pondicharry, 2004.*

19 *Jha CB, Ayurvediya Rasashastra, Chowkambha Prakashana, Varanasi, 2000.*

20 *Garudapurana, Pashu Ayurveda (The worship of Sūrya (Sun), Śiva, Durgā, Śri Viṣṇu was for protection of the elephant. bali (Oblations), offerings must be given to Bhūta (five elements) and the elephant must be bathed with caturghaṭa (four pitcherfuls) of water. The diet consecrated by reciting the proper mantras shall be given to the elephant and the elephant must be smeared with holy ashes. The sacred rites act against the influences of malignant spirits and grant immunity.)*

21 *Matrudevobhava is a Kerala Tantric ritual manual dealing with the worship of Goddess Bhadrakali (also known as Rurujit) along with sapta-matris or seven mothers. The text is believed to be the first Shakta worship text from Kerala. The text is a summary of Southern Brahmayāmala texts and it systematizes and organizes the Yamala cult of mothers in twenty-eight chapters.*

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Does India need a De-Radicalisation Strategy?

Anmol Mahajan*

In my article titled The Psychology of Radicalisation[1], I attempted to broadly cover why and how individuals and groups become radicalised. Here, I will attempt to explore the concepts of de-radicalisation and counter-radicalisation in the context of the internal dynamics of India. The word radicalised in this article will refer to individuals who meet the following criteria:

1. The individual must have an extremist mindset.
2. The individual follows, practices and/or advocates for a certain set of beliefs with an extremist mindset.
3. The individual finds violence to be justified in the process of following, practising or advocating for her/his beliefs.
4. The internal justification of violence extends to anyone or any group that doesn't practise, follow or advocate for the same or similar beliefs as that of the radicalised individual.

Most individuals don't become fully radicalised overnight and a lot of the groups and individuals who provide support to extremist organisations aren't fully radicalised but meet one or more of the above criteria. In the Indian context, the discussion on de-radicalisation and counter-radicalisation is a difficult one due two major reasons:

1. The collectivistic nature of Indian society as well as its demographic profile is such that even radicalised individuals prefer not to engage in outwardly violent acts if there is a chance of getting caught and if the act will impact their immediate community or family in a negative manner. This is especially true in places where the community is not dominant or powerful.
2. To have a discussion on effective de-radicalisation and counter-radicalisation measures for India, experts first need to come to terms with the extent to which the problem of radicalisation has grown in India.

According to an article published by Pew Research Centre[2], the median age of the India population as a whole is 28. More than 40% of the Indian population is below the age of 25 years. Shafqat Munir, Head of Bangladesh Centre for Terrorism Research at the Bangladesh Institute of Peace and Security Studies (BIPSS) in a 2020 article[3], explains that younger individuals tend to lack any criminal records, they are much more active and they are easier to indoctrinate due to their age as well as lack of experience. Jacob Ware, a research associate for counterterrorism at the Council on Foreign Relations and an adjunct assistant professor at the Edmund A. Walsh School of Foreign Service at Georgetown University, in his 2023 article[4] highlights how the new generations are radicalising themselves via online platforms. Constant exposure to hate, negative and outrage provoking content on social media and some key "role models" taking matters into their own hands

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and fighting for "justice" is enough to make most youngsters extremists. The ability to constantly get validation for a view by joining online echo chambers just adds fuel to the fire. This is especially concerning in a post pandemic age where socialising predominantly over the internet is not only normalised but also at times preferred over in person interactions. This setup provides a prime group of targets for extremist organisations to indoctrinate into their ideological framework.

Studies on youth radicalisation in India have mostly focused on Islamic or Jihadist radicalisation but the present and future reality is that with the growth of social media, extremist thought is not limited to Islamic ideologies. For instance, with the present Israel-Palestine conflict, we see a large portion of the online extremist discourse focusing solely on taking sides for a war that has nothing to do with India. These extremist groups, use any and every world event to formulate a them vs us environment online, leading their members further down the rabbit hole of radicalisation. Which is why you will find articles like "Pro-Khalistan group donates $21,000 to Palestinian refugees"[5] circulating in Indian left wing extremist circles as an example of solidarity in the fight against the injustice and the same article in Indian right wing extremist circles as an example of how the entire left wing justifies actions of Hamas and supports separatist movements in India. This brings forth a situation where youth get radicalised without any particular ideology or movement being involved in the process. Michael Hameleers & Desirée Schmuck's[6] 2017 paper, 'It's us against them: a comparative experiment on the effects of populist messages communicated via social media', provides further insight into the build-up of this us vs them mindset online.

Indian society is collectivistic in nature; in most cases those born in Indian society form their identities in context of their family, friends, neighbourhood, community and so on. More often than not individuals within Indian society have a tendency to seek acceptance and validation for their actions from their inner social circles and they seek assistance from the same circle at times of need. This makes family, friends and communities an important part of life and sometimes even survival. Therefore, even a radicalised individual is less likely to overtly or obviously commit violent acts if their immediate circle will be impacted by the action. Conversely, when looking at the terrorists recruitment processes, the whole idea, as it is sold to the targets is, "individual risk and sacrifice in service of the promotion of group intentions"[7]. In India, we get to see both dynamics play out. In those places where extremist groups are less influential, we see advocacy of their goals and movements via non-violent means and in areas where the groups have more power, we see higher willingness to engage in violence.

Due to the current demographic distribution of India, most radicalisation driven violence is restricted to a select few areas. However, with the rise of the social media age and the new outrage culture seeping into day to day lives of the present and future generations, we are looking at a future where young people may be more willing to engage in violent acts. Therefore, counter-radicalisation strategies in India need to be implementable in the short-term such that they are relatively cost effective as well as effective on the masses.

Here the distinction between de-radicalisation and counter radicalisation becomes important. The table below, derived from a 2017 paper by Bajpai G. S. and Kaushik A.[8], clearly illustrates the distinction:

Strategy	Targeted Behaviour	Aim of Program	Main Objective
Deradicalisation	Insurgency	Rehabilitation	Cessation of Violence
	Terrorism		Reintegration
Counter Radicalisation	Transition to terrorism	Mitigation	Disengagement
	Violent Extremism		Reintegration
			Rehabilitation

Bajpai G. S. and Kaushik A.[9] also mentioned another term, 'Anti Radicalisation' which was targeted at those vulnerable to risk from radicalisation and violent extremism. However, as explained in my article on radicalisation, everyone fits into this category and anti-radicalisation as such is more of a social responsibility.

Each state of India differs in the type and degree of extremism within its population. Therefore, the type of strategy to counter efforts of extremist groups must also differ accordingly. This is what we observe in current practice as well. For instance, one of the policies that the central government has been collaborating with the state governments on, is the surrender-cum-rehabilitation policy. According to the Ministry of Home Affairs[10], "Surrender-cum-Rehabilitation policy is part of the overall policy to build consensus and evolve an acceptable and peaceful solution to violence perpetrated by extremist groups, to usher in peace and development, especially in the disturbed regions. Though policies for rehabilitation of militants have been successful in J&K and North Eastern States, implementation of similar policies in Naxal affected States has not been impressive for various reasons. This policy has been evolved, keeping in mind the specific geographical and social landscape to help those Naxalites who want to abjure violence, surrender and join the mainstream. As the Naxal problem has arisen on account of real and perceived neglect, deprivation and disaffection, mainly towards the downtrodden, the solution should aim at providing gainful employment and entrepreneurial opportunities to the surrendered Naxalites so that

they are encouraged to join the mainstream and do not return to the fold of Naxal movement." Keeping in line with this, one may note that this policy is not targeting the separatists in Punjab. This could be because the Khalistan movement doesn't have actual support from the local population in Punjab, making a hard crackdown[11] on extremist groups a better approach. Another approach towards deterrence of violence, that is used in Uttar Pradesh, Delhi, Maharashtra, Madhya Pradesh, Karnataka, Uttarakhand and Punjab, is confiscation/destruction of assets that are acquired/built illegally by members of extremist groups or extremists inciting violence, especially the ones found engaging in violent acts such as destruction of government property.

The International Centre for the Study of Radicalisation and Political Violence published a policy report[12] on Prisons and Terrorism Radicalisation and De-radicalisation in 15 countries. In the report, it is argued that "prison regimes for terrorists need to be informed by a sophisticated understanding of the motivations and behaviours of politically motivated offenders, who, unlike 'ordinary prisoners', may want to mobilise outside support, radicalise other prisoners, and (in the case of terrorists) recreate operational command structures". It also notes that, "terrorist groups differ in relation to their internal structure and cohesion. Terrorist groups are no longer always coherent, firmly structured entities, but – like al Qaeda – they may constitute loose networks which revolve around personal relationships rather than military hierarchies. Some of these groups are said to have implemented the idea of 'leaderless resistance' whereby a movement's leadership and its followers have no direct contact". While India is not one of the countries sampled in this study, it might not be a far reach to assume that some of the findings are applicable to our approach when it comes to dealing with extremists as we see in a 2020 report[13] by Dr V Balasubramaniyan on Jihadist Recidivism in Tamil Nadu.

While some states have found a range of counter radicalisation measures such as the ones mentioned above, there are some states that have found potential in counter-radicalisation programmes that are similar to the de-radicalisation programmes popularly discussed in international circles as well. One promising case is that of Maharashtra Police deradicalisation project[14], which has helped pull back 120 youth, including six women, from the brink of jihadi recruitment. The programme, the only one being run by a state police force, is being looked at closely by J&K, Punjab, Karnataka, Madhya Pradesh and Gujarat. This project involves short-term monitoring of individuals suspected of being radicalised based on inputs from family, friends and/or field officers. This model is different from the ones in Indonesia, Singapore, Saudi Arabia etc., in the fact that the candidates are not prison convicts as the program is preventative in nature. The deradicalisation program is built on four prongs – the candidate, her/his family, psychologists, clergy and the police. Another structured program similar to this which seems to have produced promising results[15] is, 'Sahi Raasta' programme[16] in Kashmir. As part of this initiative, young people who have been radicalised or have become inclined towards violent extremism (identified based on inputs from Jammu and Kashmir police, senior army officers and

others), are brought back and integrated into the mainstream through a 21-day residential programme run by experts from various fields and several senior army officers interact with them.

Conclusion:

- Radicalisation is a complex and ongoing phenomenon which doesn't immediately translate to violence but increases the risk of violence.
- The collectivistic nature of Indian society as well as its demographic profile, provides a natural environment conducive to counter-radicalisation strategies.
- With more people exposed to and even dependent on social media platforms, the risk of radicalisation has become greater, especially for the younger generations.
- There is a difference between counter-radicalisation and de-radicalisation. This difference is mainly in the groups targeted and the aim of the program. The aim of a counter-radicalisation strategy is mitigation and prevention.
- Counter-radicalisation strategies are more suited for India than wide scale de-radicalisation programmes as they are less costly, easier to implement and require less human resource as well as infrastructure.
- The nature and situation surrounding the phenomena of radicalisation differs in each part of the country. Counter-radicalisation strategies must be made based on what is most effective for the situation in the particular area of concern and its people.
- There is a need for each state to identify radicalisation hotspots, the reason for emergence of these hotspots and effective long term counter radicalisation programmes to prevent violent extremism in these areas.
- Any approach to counter-radicalisation or de-radicalisation in India must be holistic and address the root cause of radicalisation.

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