Nuclear On-board: Prospects and Challenges of Outer Space Exploration with Nuclear Power Sources

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Abstract

Since ancient times we have references to space/sky watching. After the Second World War, space exploration became the new frontier. The space-age began with the Soviet's first satellite, Sputnik 1 *launch in 1957. Many space agencies of the world, including NASA (USA) and ISRO (India), are working for inspiring space missions. Powering the spacecraft/object is a major concern in space exploration. Solar power is not adequate for deep space missions. Nuclear power sources (NPS) are the most suitable options for going beyond Moon and Mars. Paper examines the socio-economic-legal concerns of NPS along with technical challenges at the national/international level.*

Keywords: Nuclear Power Source, Space exploration, Law

I. Introduction

Humans always showed their love for space, the moon, stars, and celestial bodies. Astronomy/astrophysics is not a completely new or modern wing of study. Since ancient times we have references to space exploration, sky watching, and observation. During the Second World War airplanes started functioning and during this time Nazi Germany used long-distance rockets as a weapon. By that time technology, assured that humans can go against gravity and reach to the sky and go beyond to the Universe. After the end of the Second World War, space became the new frontier, and race to the outer space[3]

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[3] As per the Outer Space Treaty, 1967, Outer space includes the moon and other celestial bodies, which has the legal status of '*res communis omnium*' (It is characterized as a freedom of exploration and use).

exploration began. The whole cold war era was filled with space missions[4]. The space-age began on Oct. 4th, 1957; when the Soviets launched the first artificial Earth satellite, *Sputnik 1*[5]into space. After this surprising achievement, U.S. responded and two months later it the United States tried to launch its first satellite but it failed[6]. The first failed attempt created panic and insecurity in the U.S. and lead the foundation for the successful space mission ahead with more focus work and allocation of huge financial budget. The U.S. launched its first successful satellite, *Explorer-1*[7]on Jan. 31st, 1958.

The Russian Lt. Yuri Gagarin became the first human to orbit[8] Earth in *Vostok* 1 on April 12th, 1961[9]. In the same year (1961) Alan Shepard became the first

[4] Dora Holland and Jack O. Burns, *The American Space Exploration Narrative from the Cold War through the Obama Administration*, 46 *JSP* 9-7 (2018). (both links last visited on Dec. 15, 2020) https://arxiv.org/ftp/arxiv/papers/1803/1803.11181.pdf and https://www.sciencedirect.com/journal/space-policy/vol/46/suppl/C.

[5]In Russian, the word '*Sputnik*' means companion. *Sputnik-1* was launched from Baikonur Cosmodrome at Tyuratam in Kazakhstan, the earlier part of the former Soviet Union. (last visited on Dec. 11, 2020), https://www.history.com/this-day-in-history/sputnik-launched.

[6] (last visited on Dec. 11, 2020), https://www.space.com/38331-sputnik-satellite-fun-facts.html.

[7] (last visited on Dec. 11, 2020), https://www.space.com/17825-explorer-1.html.*Explorer-1* is a start of Space age in U.S. The *Explorer-1* Satellite was made by the NASA Jet Propulsion Laboratory; it carried a cosmic ray detector which led to the discovery of radiation belts around Earth held in place by the planet's magnetic field. (last visited on Dec. 14, 2020), https://www.jpl.nasa.gov/missions/explorer-1/#:~:text=ABOUT%20THE%20MISSION,of%20the%20U.S.%20Space%20Age.

[8] An orbit means it is a regular, repeating path that one object (satellite or planet, etc.) in space takes around another one. For example, Earth orbits the Sun. Satellite orbit to the Earth.

[9]Lt. Yuri Gagarin's flight was for 108 minutes and he reached an altitude of 327 Kilometers (around 202 miles).The Vostok program was a Soviet space program and placed the first man in space, the first woman (Soviet Cosmonaut Valentina Tereshkova) in space through *Vostok 6*, and the first joint flight of two different crewed orbiters (last visited on Dec. 15, 2020), https://www.space.com/vostok-program.html.

American to fly into space and John Glenn with his flight on Feb. 20th, 1962 became the first American to orbit Earth[10].

President John F. Kennedy is known for his iconic words in his celebrated *'We choose to go to the Moon'* speech[11]. He quoted, "*We choose to go to the moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win.The growth of our science and education will be enriched by new knowledge of our universe and environment, by new techniques of learning and mapping and observation, by new tools and computers for industry, medicine, the home as well as the school*[12]".

This statement not only became the American dream but the whole world was hoping to achieve this goal. Later, the moon landing became the historical and globally celebrated achievement of mankind. Nuclear technology was the invention that created headlines during the Second World War and became the prime reason to end the war. After that, 'space' became the next happening thing to show dominance. The cold war era was full of space missions/experimentations, various nuclear tastings on Earth, underground, sea, and outer space. This necessitated having international consensus on limiting and prohibiting certain kinds of tastings with or without nuclear technology.

[10] It was the Mercury-Atlas 6 mission. John Glenn during his almost five-hour flight, circled Earth three times and return home safely (last visited on Dec. 14, 2020),https://aerospace.org/article/brief-history-space-exploration.

[11] On Sept. 12, 1962, the 35th U.S. President John F. Kennedy (JFK) gave speech at the Rice University in Texas about going to the moon. This dream was accomplished through *Apollo-11* first crewed moon mission of the U. S. which landed on the Moon on July 20, 1969 but JFK was not alive by that time.

[12](last visited on Dec. 14, 2020), https://er.jsc.nasa.gov/seh/ricetalk.htm#:~:text=We%20choose%20to%20go%20to%20the%20moon%20in%20this%20decade,to%20postpone%2C%20and%20one%20which.

Especially those scientific and technological advancements were proposed to limit which may hamper human existence and damage the environment[13].

The whole international community was convinced with this idea to limit the inhuman and immoral experiments for military applications. The use of such scientific advancement for the betterment of humanity was then started giving priority. As a result, international institutions such as the United Nations and its specialized agencies started monitoring all such activities[14]. These institutions also created a strong international legal framework to prohibit illegal activities and observe developments in this domain[15].

Since initial discoveries, space exploration has provided multiple benefits to mankind. The study of space and Earth observation has proven to be helpful in many areas of human life, such as remote sensing, weather updates, early warnings of disasters, mapping of the impact or foresee the effects or damage of upcoming natural and manmade activities, and many more. All space observation activities on Earth and in space require a power (electricity) supply. Satellites, rockets, and all outer space activities require an uninterrupted electric supply for their operation. The Near-Earth spacecraft go for photovoltaic solar cells linked with chemical storage batteries for power supply. The satellites equipped with solar energy sources are dependent on the positioning of the Sun. Solar power is suitable for limited space missions only. Deep space explorations, discovering lunar or interplanetary bases, manned space missions, sustaining human survival in the foreign atmosphere of space all necessitate high thrust, efficient propulsion systems. Nuclear power is the most suitable

[13] ICJ REPORT, Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, [1996] ICJ Rep 226. https://www.icj-cij.org/en/case/95 (last visited on Dec. 31, 2020).

[14] For all areas of wellbeing and development, subject specific international organizations are created. For example, to monitor national and international developments in the field of nuclear technology, International Atomic Energy Agency (IAEA) is created. The outer space related activities are observed by the United Nations Office of Outer Space Affairs (UNOOSA), which has United Nations Committee on the Peaceful Uses of Outer Space (UNCOUPS).

[15] Under United Nations guidance there are many International treaties, Conventions, Protocols, Resolutions, etc.

option amongst all available power sources for conducting all such experimentation and explorations.

II. Outer Space Exploration

The outer space investigation is no more just for the human fantasy, but it is for better understanding our own Earth and Universe. Space investigation promotes Earth science research, and it helps to understand remote sensing data and information captured by satellite and converts/transfers that information ahead of time. There are many international collaborations and joint partnership endeavors in this domain. International cooperation is evident in many areas of technology sharing for assisting in information allocation.

A. Space Exploration Activities at Global Outlook

Many countries do have their national space agency like India has its ISRO[16] (Indian Space Research Organisation); Russian Federation has State Space Corporation (ROSCOSMOS[17]). NASA[18] has divided their space exploration missions into Earth missions[19] (these missions include atmosphere, climate, **Continental Drift and Geodynamics, Gravity, Hurricanes, Ice, Land and Vegetation, Oceans, Ozone, Sun and its Influence on Earth, Water Cycle, Weather, Wildfires), Humans in space missions**[20] **(**these missions **include International space station**[21]**, Commercial Resupply mission, Asteroid Redirect Initiative, Commercial Space, Orion Crew Vehicle, Space Launch**

[16] (last visited on Dec. 15, 2020), Details can be found on www.isro.gov.in.

[17] (last visited on Dec. 15, 2020), Details can be found on www.roscosmos.ru.

[18] National Aeronautics and Space Administration (NASA) a primer United States space agency.

[19] NASA'S Earth missions, (last visited on Dec. 15, 2020), https://www.nasa.gov/content/earth-missions-list.

[20]NASA'S human in space mission (last visited on Dec. 15, 2020), https://www.nasa.gov/content/human-missions-list.

[21] Marcia S. Smith, Congressional Research Service, "NASA's Space Station Program: Evolution of its Rationale and Expected Uses" (Testimony before the subcommittee on Science and Space Committee on Commerce, Sciences and Transportation United States Senate) 1-17 (April 20, 2005).

System, Apollo, Gemini, Mercury, Skylab, Space shuttle mission), Solar system missions[22] **(**these missions include Asteroid, comet, Jupiter, Mars, and all other planetary missions are in it), and Universe missions[23] (include Big Bang and cosmology mission, Black holes**, Gamma-Ray Bursts, Galaxies, Gravity, Interstellar Medium, Life in the Universe, Nebulae, Planets Beyond the Solar System, Stars, Supernovae).** There are also some regional space agencies got mentions at UNOOSA such as Asia Pacific Space Cooperation Organization[24] (APSCO), European Global Navigation Satellite System Agency (GSA), and European Space Agency[25] (ESA).

There are so many space-related activities and experiments going on all around the world. To maintain sustainable development and protect outer space from

[22] NASA'S **Solar system missions** (last visited on Dec. 15, 2020),https://www.nasa.gov/content/solar-missions-list.

[23] NASA missions (last visited on Dec. 15, 2020), https://www.nasa.gov/content/universe-missions-list.

[24] In 1988 China, Pakistan and Thailand came with an idea to have cooperation in that Asia Pacific region, then in 1992, they came up with MOU, in 2005 the APSCO convention was signed by three Countries. APSCO has 8 member States (Bangladesh, China, Iran, Magnolia, Pakistan, Peru, Thailand, and Turkey). (last visited on Dec. 15, 2020),APSCO details are available on www.apsco.int.Asia region has two space agencies one is APSCO and (last visited on Dec. 15, 2020) another is APRSAF (The Asia-Pacific Regional Space Agency Forum) https://www.aprsaf.org/. APRSAF was established in 1993 to enhance space activities in the Asia-Pacific region under Japan's leadership and APSCO was established in 2008 under China's leadership. India is not a member of APSCO but takes active participation in APRSAF activities. The very existence of two regional agencies in the space domain shows the division of power and the strong geopolitical environment in the Asian region. See, "Asia in Space: Cooperation or conflict?" (last visited on Dec. 15, 2020), https://www.orfonline.org/research/asia-in-space-cooperation-or-conflict-44890/
Also, read RajeswariRajagopalan, "the case for outer space cooperation in South Asia", *ORF* (Jan. 18, 2019) (last visited on Dec. 15, 2020), https://www.orfonline.org/research/the-case-for-outer-space-cooperation-in-south-asia-47460/.

[25] The ESA (est. in Paris, 1975) is an intergovernmental organization for space exploration with 22 member states.

hazardous activities, it is essential to have a log of all kinds of space activities. It is important to have data with maximum possible information about the goals/objectives of such missions with particulars of it. The United Nations maintains records and registration of objects launched into outer space since 1962. To date over 86% of all satellites, probes, landers, crewed spacecraft, and space station flight elements launched into Earth orbit and beyond have been registered with the Secretary-General of UNOOSA[26]. The information on unregistered space object needs to be monitored. The space exploration activities are not only booming at the individual national fronts but there are also joint space collaboration activities between multiple countries and international/regional space agencies. Worldwide, the last decade has shown tremendous development in the space exploration sector and the future has much brighter expansion opportunities in this sector. At present almost every country has a satellite or uses a space-based technology for communication, weather updates, navigating details, and remote sensing.

B. India and Outer Space Exploration

On Feb. 16th, 1962, the Department of Atomic Energy (DAE), the Government of India formulated the Indian National Committee for Space Research (INCOSPAR), and later it established Thumba Equatorial Rocket Launching Station (TERLS) started. Almost a year later, TERLS launched the First sounding rocket on Nov. 21th, 1963. In 1965 Space Science & Technology Centre (SSTC) was established in Thumba, and in 1967 Satellite Telecommunication Earth Station was set up in Ahmedabad. In the early days, INCOSPAR advised the government of India on space policy. TERLS was dedicated to the United Nations on 2nd February 1968. On the historic day of 15th August 1969, the Indian Space Research Organization (ISRO) was formed under the Department of Atomic Energy and in later years its administrative control was given to the Department of Space. For many areas, the administrative model for space activities was similar to the atomic energy in India. There was an Atomic energy commission, Department of Atomic energy, and the Atomic Energy Establishment Trombay later it was renamed as a

[26] (last visited on Dec. 15, 2020), https://www.unoosa.org/oosa/en/spaceobjectregister/index.html.

Bhabha Atomic Research Centre (BARC). Since the emergence of atomic energy, India has the Atomic Energy Act 1948 (amended in 1962). The Atomic Energy Act 1962 defined the role and responsibility of the government in the nuclear power sector. Contrary to this, India didn't have any specific space law since the start of these space establishments.

The mission and vision statements have guided ISRO for its aims and objects so far. Finally, on June 1st, 1972 Space Commission and Department of Space (DOS) was set up, and ISRO then brought under DOS[27]. On Apr 19th, 1975 'The *Aryabhata*[28] spacecraft' became India's first satellite[29]. In 1984, *Rakesh Sharma*[30]the first Indian Astronaut[31] flew in space on the Russian Space craft[32].

[27] ISRO timeline, (last visited on Dec. 15, 2020), https://www.isro.gov.in/about-isro/isros-timeline-1960s-to-today#7.

[28] *Aryabhata* was a famous Indian astronomer. The *Aryabhata* spacecraft was completely designed and fabricated in India and launched by a Soviet Kosmos-3M rocket from Kapustin Yar. (last visited on Dec. 31, 2020),https://www.isro.gov.in/Spacecraft/aryabhata-1.

[29] (last visited on Dec. 15, 2020), https://www.isro.gov.in/Spacecraft/aryabhata-1.

[30] To date Rakesh Sharma is the first and only Indian Citizen who went to space, spending 7 days, 21 hours, and 40 minutes aboard the Salyut 7 orbital station. There was another Indian, the Kirti Chakra recipient, Air Commodore (Retd.) Ravish Malhotra, who was trained along with Rakesh Sharma as his backup astronaut for the Indo-Soviet space mission.

[31] Two Indian origin astronauts have gone to space with NASA. *KalpanaChawala*who died onboard space shuttle *Columbia* (2003) was amongst the much-praised astronauts of NASA, she was born and raised in India but later she took US citizenship (last visited on Dec. 31, 2020), https://www.space.com/17056-kalpana-chawla-biography.html. Another astronaut, *Sunita**Williams***is t**he record holder of the longest spaceflight for a female space traveler along with the most spacewalking time by a woman. December 2020, NASA declared its upcoming Artemis Team for the next lunar missions and Raja Chari is going to be the 3rdIndian-Americanamong 18 astronaut's team for a manned mission to the Moon and beyond. (last visited on Dec. 31, 2020), https://indianexpress.com/article/technology/science/raja-chari-nasa-indian-astronauts-7102185/.

[32] On 3rdApril 1984, Rakesh Sharma along with two Soviet cosmonauts, YuryMalyshev and Gennady Strekalovtraveled to space to the space station Salyut 7. At present, the

The father of India's space program Dr. Vikram Sarabhai has said that India's space program is not for competing with the economically advanced nations but, we have the same purpose for this scientific advancement as they do have.To date India has 110 spacecraft missions, 78 Launch Missions, 10 students satellites, 328 Foreign satellites of 33 countries to its name; ranging its applications from Earth observation (LEO[33])experimentation, Communication (GSO[34]) satellites, *Chandrayaan*[35] (Moon exploration under Planetary observation), Mission Mars, Climate and Environment observation, Disaster Management systems, etc[36]. At present, India is preparing for its first manned space mission and ready to have many records to its name. So far, India has used three launch vehicles, 1) the ASLV[37], 2) the PSLV[38], and 3) GSLV[39] for

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Gaganyaan team (four Indian Air Force pilots) is undergoing intense training at Russia's Gagarin Cosmonaut Training Center for India's, ISRO's very first manned mission '*Gaganyaan'* (2021-2022).

[33] LEO (Low Earth Orbit), as per the International Academy of Astronautics (IAA) a simple definition is '*orbit below about 2000 km above Earth surface'*. As per Merriam-Webster Online Dictionary LEO '*usually is circular orbit from about 90 to 600 miles (about 140 to 970 kilometers) above the earth'*. See, a guide to Space Law terms by Space Policy Institute (SPI), George Washington University and Secured World Foundation, (SWF) Pp77 (1-145) Dec. 2012.About different zones of orbit there is no fixed agreement yet. Some of the experts have four different zones of orbits (LEO, MEO (Medium Earth Orbit), GSO, and HEO (High Elliptical Orbit) and few experts for commercial interest categorizes five orbit zones such as NEO (Near Earth Orbit), LEO, MEO, GSO and HEO.

[34] GSO (Geosynchronous Orbit) as per the International Academy of Astronautics (IAA) a simple definition is '*An orbit with a period equal to the period of rotation of the Earth (23h 56m 04s) about its axis'*. A Geosynchronous satellite is '*An earth satellite whose period of revolution is equal to the period of rotation of the Earth about its axis'* (ITU Radio Regulation 1.188).

[35]ISRO's first Indian Moon Mission, called Chandrayaan-1 was approved in Nov. 2003 and was launched successfully on Oct. 22, 2008; (both links last visited on Dec. 31, 2020),https://www.isro.gov.in/pslv-c11-chandrayaan-1and https://www.isro.gov.in/Spacecraft/chandrayaan-1.

[36] (last visited on Dec. 31, 2020), https://www.isro.gov.in/list-of-spacecrafts.

[37] India uses the ASLV launch vehicle is for the Low Earth orbits.

[38] India uses the PSLV launch vehicle is for the polar orbits.

launching space objects. In 2003, India invited countries to participate in its robotic spacecraft mission to the Moon (planned for 2007). India has many international tie-ups and in the initial days India took the help of foreign commercial space launch facilities and service providers.

Following India's nuclear weapons test (Pokharan-II[40]) in 1998 the United States had imposed sanctions on India. Those sanctions restricted resources and technology transfer in many scientific areas including nuclear and outer space[41]. Due to the pressure of international restrictions and US sanctions, the scientific and technical sector in India faced a crucial time in isolation and relied on their experimentations with limited resources[42]. This international non-cooperation impacted the speed and progress of India in these two vital areas of national interest. For decades India's space program has complete government control.

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[39] India uses the new GSLV launch vehicle for the launches to geostationary orbit. GSLV is India's hope to use to enter into the commercial market of the space industry.

[40] **Amitabh Sinha, *Nuclear scientist Anil Kakodkar explains: How Pokhran happened*, THE INDIAN EXPRESS (May 11, 2018) (last visited on Dec. 31, 2020),https://indianexpress.com/article/explained/how-pokhran-nuclear-tests-1998-happened-5172010/.**

[41] In the space sector particularly, after 1987 the Missile Technology Control Regime (MTCR), ISRO developed its launch vehicle technologies. ISRO faced sanctions by the United States in the early 1990s, after having an agreement with 'Glavkosmos' a Russian entity to acquire cryogenic engine technology. That time was so crucial with strict control on dual-use technology restricted access in many other areas. Gradually, in the space sector, India strengthened its export control mechanisms; leading ease on some of the sanctions on ISRO. Progressively, the situation changed in 2016 after India becoming a member of the MTCR, and later year the 'Wassenaar Arrangement' offered a bit of ease in business.

[42] Even during the international sanctions, India was determined on its commitments to protect its national territory and interest from external aggression, particularly from its neighborhood. During that time, then India's President APJ Kalam and Prime Minister Atal Bihari Vajpayee offered strong support, and motivated the Indian scientists working in the nuclear and space sector with a sense of responsibility. Both the leaders not only aimed for robotic Moon mission (Chandrayan-1) but also aimed for human space flight to Mars. At the same time, India came up with a draft of nuclear doctrine stating no first use of nuclear weapons in the war.

Internationally there are some ambitious private space companies and entrepreneurs who are working in this field[43]. India also wants to play an important role in the emerging commercialization of space. India is opening its doors for private players to work along with ISRO and the Department of Space. There are private players in the Indian space sector such as *TeamIndus*[44] and visible increase in participating commercialization of space is seen after establishment of *Antrix*[45] in 1992. To support these advancements India needs to have a robust legal framework and specific space law at the national level[46]. Though India doesn't have national space legislation yet[47], India has some policies in space-related areas[48]. Many industry experts feel that India lacks a comprehensive space policy[49]. Recently Government of India has decided to

[43] Internationally many private players are working for space exploration, such as Elon Musk's Space X, Virgin Galactic, Orbital, Blue Origin, Boeing, Astra, Rocket Lab, Skyrora, Onespace, etc.

[44] There were 15 Indian private startup applicants for the space Tech solutions award 2020. Out of this, Karnataka state has a maximum (7) start-up in the space sector. Amongst all Skyroot Aerospace Private Ltd. is the winner. The Dhruva Space Private Ltd. and Bellatrix Aerospace Private Ltd. both were the co-winners. There are other private companies and startups in India like Agnikul Cosmos, etc. (last visited on Dec. 31, 2020), https://www.startupindia.gov.in/content/dam/invest-india/nsa/National%20Startup%20Awards%202020.pdf, National Startup award 2020, https://www.startupindia.gov.in/nsa/.

[45]Antrix Corporation Ltd. is a wholly own government of India company under administrative control of Department of Space (GOI). It is known to be commercial wing of ISRO helping marketing ISRO's products and services, coordinates with private sector (last visited on Dec. 31, 2020), https://www.antrix.co.in/.

[46] Rakesh Sood, *An Indian Space Law: Long Overdue*, ORF Issue Brief No. 309, (August 2019).

[47]India proposed a space legislation draft in 2017 but it was lapsed. Almost 28 countries are having their space legislations. (last visited on Dec. 31, 2020), http://www.unoosa.org/oosa/en/ourwork/spacelaw/nationalspacelaw/schematicoverview.html.

[48] India has spacecom policy, remote sensing policy, telecom policy, etc.

[49]MunikrishnappaAnilkumar&ChetanSingai, *India needs a comprehensive space policy*, 118 (4) Current Science, 522-523 (Feb. 24, 2020) (last visited on July 17, 2019), https://www.researchgate.net/publication/339445886.

open the space sector to private companies. To allow the private players to take active participation in space exploration, the government decided to set-up IN-SPACe (Indian National Space Promotion and Authorization Centre). IN-SPACe will allow private companies to use India's (governmental) space infrastructure with ease of doing business and a friendly regulatory framework. This is seen as a boost to the private industry under make in India initiative and prevent Indian brain drain and encourage startups in India.

III. Genesis of Nuclear Power

Before going into the technicalities and challenges of using nuclear in space, it is important to understand the basic concept of nuclear power generation. A Physicist perspective to this field in simple words is nothing but the application of nuclear reactions[50] for various purposes. It is the form of nuclear reaction that naturally fuels the star including the Sun which supports the survival of life on an Earth. The study of nuclear (core an element) is the base for all kinds of research including the birth of a Universe. The major developments in this area occurred in the shadow of World War II starting from the Manhattan Project[51] of the USA. After the end of war application of nuclear technology was promoted for the benefit of human survival and not particularly for military purposes like creating nuclear/Atomic Bombs or weapons of mass destruction. There are various uses of nuclear technology for a variety of purposes of human life, such as the health sector[52], water purification techniques, deep-sea mining, advancements in food and agriculture, in environment protection like obtaining information of past and present conditions, mapping of the age of old

[50] The reaction consequent to the fission or fusion of atoms (particularly Uranium). Nuclear weapons have destructive/ explosive power derived from uncontrolled nuclear reactions.

[51] Manhattan Project was the code name for America's development of the atomic weapons program. It was the US response to the fear that German scientists were working on weapons creation using nuclear technology and Adolf Hitler was prepared to use that in the Second World War. https://www.history.com/topics/world-war-ii/the-manhattan-project and (last visited on Dec. 09, 2020), https://www.ushistory.org/us/51f.asp.

[52] Nuclear technologies are helpful in cancer treatments, radiation therapy, with the help of X-ray diagnostic technologies, are supported for MRI, CAT Scans, etc.

monuments, and many more[53]. A large amount of energy is generated through splitting (fissioning) the heavy nuclei of Uranium[54]. The same technique is used for generating nuclear energy at the nuclear power plant to produce billions of watts of electrical power by just consuming a few tons of Uranium in a year. On the other hand, to produce the same amount of electricity from other conventional (non-nuclear) sources, will require a huge amount of fuel like Coal.

Nuclear technology has many advantages and disadvantages. Nuclear energy provides a clean, reliable, and affordable source of electricity and also helps in mitigating the impacts of climate change. At present there are over 400 nuclear reactors working in 30 countries globally, providing about 11 percent of the world's electricity[55]. France is always cited as an example of a nuclear power generating country, which earlier has recorded more than 80 % of electricity supply through nuclear energy. Nuclear power plants were largely got momentum in 1970-the 1980s. This sector has always seen growth and decline with the changing social environment. Apart from the use of nuclear bombs on Hiroshima and Nagasaki nuclear power has shown harmful radiation effects in various nuclear power plant accidents[56]. The use of nuclear

[53] Benefits of nuclear energy, (last visited on Dec. 09, 2020), https://www.rusatom-overseas.com/nuclear-energy/benefits-of-nuclear-energy/. See, world Nuclear Association on "Many uses of nuclear technology" (last visited on Dec. 09, 2020), https://www.world-nuclear.org/information-library/non-power-nuclear-applications/overview/the-many-uses-of-nuclear-technology.aspx, also read "Nuclear power: pros and cons" (last visited on Dec. 09, 2020), https://www.power-technology.com/features/nuclear-power-pros-cons/.

[54]Uranium is a naturally radioactive element with an atomic number of 92 and is considered a heavy metal. Uranium-235 is the only isotope (an isotope is a version of the element with a differing number of neutrons in its nucleus) capable of sustaining a nuclear fission reaction. French physicist Henri Becquerel (1897) discovered some sort of emissions from the uranium salts while doing research this leads to him sharing a Noble Prize with Marie and Pierre Curie in 1903 for the discovery. (last visited on Dec. 09, 2020), https://www.livescience.com/39773-facts-about-uranium.html.

[55] (last visited on Dec. 09, 2020), https://www.iaea.org/topics/nuclear-power-reactors.

[56] The general public became aware of nuclear energy through nuclear bombings first and later discovered civilian use through nuclear power generation. The Three Mile

technology/fuel/resources/power sources is not as easy as compared to other ordinary energy sources like coal. The use of nuclear sources needs extra care and vigilance in handling. The use of nuclear for military purposes is a global worry, leading to the issue of proliferation of nuclear weapons and the acquisition of these weapons of mass destruction by the terrorist[57] groups. Nuclear is an important component of every State's national security policy to decide on the use of nuclear in defense or deterrence matters[58].

IV. Nuclear Power in Space- Facts and Prospects

As compared to other power sources, using nuclear power for deep space investigation is the most suitable option at present. Nuclear power allows having minimum weight and size of a power generating equipment, also has the ability to operate in high temperature and it can provide long term reliable power supply in a natural and perturbed environment of outer space. Space exploration is not possible without an uninterrupted power supply. Space power systems have three main patterns, 1) ground-based systems[59], 2) nonnuclear space power

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Island Accident (the USA in 1979), The Chernobyl Accident (Ukraine in earlier USSR in 1986), and the recent Fukushima nuclear plant (Japan in 2011) accident have shown long-lasting dangerous effects of radiation on human health and the environment.

[57] MATTHEW BUNN, MARTIN B. MALIN, et.al., *Preventing Nuclear Terrorism:* CONTINUOUS IMPROVEMENT OR DANGEROUS DECLINE?(Cambridge, MA: Project on Managing the Atom, BelferCenter for Science and International Affairs) Harvard Kennedy School (March 2016).

[58] For strategic decisions, India has come with Draft Indian Nuclear Doctrine in 1999. See, Rajesh Basrur, "Nuclear India at the Crossroads", 33 (7) *Arms Control Today* 7-11 (Sept. 2003). Draft report of National Security Advisory Board on Indian Nuclear Doctrine, Ministry of External Affairs, GOI (last visited on Dec. 09, 2020), https://mea.gov.in/in-focus article.htm?18916/Draft+Report+of+National+Security+Advisory+Board+on+Indian+Nuclear+Doctrine.

[59] Ground-based power systems require microwave beam to the Orbit and it includes utility grid, ground-based nuclear power (either by Fission considering military

systems[60], and 3) nuclear space power systems[61].The electrical power supply has certain operational requirements and similar are with the nuclear power supply. Many things such as controlling nuclear reactions, safe heat transfer or rejection, power conversion by using nuclear source, electricity/energy storage, power transmission, etc. need to be considered while operating nuclear power plants on Earth or on the ground. All the scientific-technological equipment require power to allow them smooth working. All over the world scientist are working on options for developing advanced high-power systems to support space-based studies. Solar power-based systems are used for many civilian space activities[62].

Near-Earth Orbit[63] missions generally get sufficient power through solar energy. But many long-term space missions such as establishing and maintaining Space Station, establishing Lunar base, Mars mission, deep-space exploration, or interplanetary missions requires a huge power supply, and space nuclear reactor is the probable solution for it. It is not a feasible and economic option to take orbital material back on Earth and do its processing and analysis. NASA decided to have space-based material processing facility in the near future. All these objectives are not achievable without an uninterrupted power supply in stormy conditions of space. Since 1965, the United States is using Radioisotope Thermoelectric Generators (RTGs) in space exploration and it has not used nuclear reactors except for some short-term tests/projects[64]. The former USSR

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requirements or fusion), Conventional power systems like Coal, gas; oil and chemical (non-nuclear MHD) power options.

[60] Non-nuclear space power systems include solar photovoltaic (conversion of solar radiation into electric power) systems, solar dynamic systems, and chemical systems (including magneto-hydrodynamic).

[61] For orbital nuclear power systems require a high-end inbuilt safety mechanisms and they include Radioisotope Thermoelectric Generators (RTGs), Dynamic Isotope Power Sources (DIPS), and nuclear reactor systems.

[62] Solar Power Satellites convert solar energy into electricity and then transmitting it to Earth.

[63] Near-Earth Orbit (NEO) is another different category of orbit. As per *Sa'idMosteshar,* NEO is between 150-450 kilometers above the Earth.

[64] By 2010, USA had almost 21 satellite launches involving nuclear power sources, out of these three launches faced problems and ended in a crash. These failures are proving that it is not easy to handle radioactive sources in space exploration. In 1978,

has successfully developed and deployed nuclear fission reactor systems in various space assets like satellites and space craft's. During the early days of drafting the Outer Space Treaty (OST), there was so much concern about adding provisions prohibiting the use of nuclear in space for military purposes. Many United States Senators were skeptical of Moscow's approach and their adherence to International law. At the threshold of the Cold War Deputy Secretary of State *Cyrus Vance* assured that '*whilst the Soviets could orbit a small number of nuclear weapons without American knowledge, such a small contingent of weapons would not constitute a significant threat*[65]'.The United States in 1963-1965 launched 12 Vela satellites designed to detect nuclear detonations. Recently NASA's Mars rover was equipped with nuclear power induced technology, which allowed the Mars rover detectors to analyze the composition of Martian rocks.

All these aspects of electricity are extra challenging when we have to operate in completely unfamiliar surroundings of outer space. Nuclear on board of a spacecraft is a challenge especially for radiation safety, controlling reactor (nuclear) fuels, shielding, and protecting nuclear substances/sources in turbulent conditions of space. These concerns are not new and experts from all corners of the world have already raised issues, concerning legality and challenges associated with the use of nuclear power sources in space exploration. The prominent subject expert *Gorbiel*[66] had identified four areas associated with this subject and they are, 1) information concerning the use of nuclear sources, 2) notification prior to re-entry, 3) assistance to states in an emergency, 4)

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the Russian (then USSR) satellite COSMOS-954 was crashed into the Canadian spreading radiation. This incident leads the discussions at the forum of UNCOPOUS. The use of nuclear power sources was also discussed earlier at the UN platform while discussing/negotiating the convention on liability for damages caused by space objects.

[65] STEPHEN BUONO, "MERELY A 'SCRAP OF PAPER'? THE OUTER SPACE TREATY IN HISTORICAL PERSPECTIVE", 31:2 Diplomacy & Statecraft, 364, 350-372 (June 2020) https://doi.org/10.1080/09592296.2020.1760038.

[66] A. GORBIEL, SOME COMMENTS ON THE PROPOSAL CONCERNING THE ELABORATION OF NEW LEGAL NORMS GOVERNING NUCLEAR POWER SOURCES USE IN OUTER SPACE, 131-139 Proceedings 22nd Colloquium (Munich, 1979). Also refer, I.H.Ph. DIEDERICKS-VERSCHOOR and V. KOPAL, AN INTRODUCTION TO SPACE LAW, 101 (Kluwer Law International, 3rd end. 2010).

Radiation exposure levels. These are the broader areas of concern that still need deep deliberations.

V. Assessment of Legal Framework

This domain of work needs the approval of two legal systems, one is domestic and another is international. Any kind of space activity in the State (Country) needs to have clearance from the national/local government and regulatory authority. At the same time, the government needs to assure that, their approval or authorization for conducting any kind of space activity should not violate any international standard or norms. The silent feature of space law as a whole is that it generally referrer the conventional law, includes international treaties, conventions, etc. The international space law expert '*Kopal'* mentions in his work that, '*national laws as well as activities of private entities performing them under the jurisdiction of individual states, should remain in full harmony with international obligations arising from the international law of outer space which should be respected as the base of all space law*[67]*'*.

A. National Legal Framework

The space exploration activities are governed by United Nations Treaties, Conventions, and resolutions. At the national level State has to adhere to international norms while conducting any space-related activity. To have uniformity throughout the world, there are international guiding documents on framing national space legislation[68].The need for national space law is very much immediate as it impacts the growth in the sector. The regulatory framework is an essential part of progress in every field. National law is essential to have sustainable development and promote private players (non-governmental entities) participation. India is a party to significant space law treaties and conventions. India is a member of the UN Committee on Peaceful Uses of Outer Space (UNCOPUOS) of the United Nations Office of Outer

[67] "Workshop of Space Law in the Twenty-first Century" 11-19 UNISPACE III Technical Forum (July 1999) [Doc. A/CONF 194/7].

[68] Many countries have referred to the "Sofia guidelines for a Model Law on National Space Legislation" (2013) while drafting national space legislation. (last visited on Dec. 02, 2021), https://www.unoosa.org/pdf/limited/c2/AC105_C2_2013_CRP06E.pdf .

Space Affairs (UNOOSA) set up by UNGA to govern the peaceful exploration of outer space for the benefit of all.

Articles 51 and 253 of the Constitution of India have laid down the responsibility to implement international treaties at the national level. Since 1960 with the initiation of space program India has space-related policies in tune with the international norms as and when necessary. The Department of Space (DOS), Government of India (GOI) is the main policy-making and administrative body to take decisions in this domain[69]. The Department of Space, GOI along with ISRO has formulated many policies and standard operating procedures (SOPs) for this sector. The majority of the policy framework is on the areas of satellite communication (1997), remote sensing data policy (2011), using space-based assets for disaster management and security purposes, and so on. In 2017, the Department of Space, GOI came up with the Draft Space Activities Bill 2017[70] but nothing happened ahead. For effective and efficient working DOS came with draft spacecom policy 2020 and soon we can expect concrete policy framework in this area. To participate at the international level, get the maximum benefit out of space exploration, regulate private players, and promote growth and competitive environment in this area India needs to have a robust legal framework. Industry experts demand speedy decision-making in matters relating to registration and authorization in this sector and steps to overcome this hurdle are already taken into consideration by the governmental agencies.

B. International Legal Framework

The fundamental principles of International law guarantee the peaceful development of all nations. All States do have the right to development irrespective of their social-economic limitation or not so good geopolitical situations. The United Nations treaties and conventions provide a basic legal

[69] The Government of India (Allocation of Business) Rules (1961) gives powers to the Department of Space (DOS), Government of India in matters relating to space exploration. (last visited on Jan 02, 2021), https://cabsec.gov.in/writereaddata/allocationbusinessrule/completeaobrules/english/1_Upload_1800.pdf.

[70] (last visited on Jan 02, 2021), https://www.prsindia.org/billtrack/draft-space-activities-bill-2017.

framework for all the areas of national and international coexistence. The United Nations has provided an international legal framework which is also applicable to outer space. As per Article 2 (4) of the UN Charter[71] the use of force is prohibited in outer space. For peaceful uses and exploration of outer space the United Nations General Assembly (UNGA) under the leadership and guidance of specialized agency United Nations Office of Outer Space Affairs (UNOOSA) has passed more than a hundred resolutions since 1958[72]. The international space law consists of five basic fundamental United Nations treaties[73] and has five important principles[74] adopted by the General Assembly of the UN. The legal subcommittee of UNCOPOUS has discussed this area on many occasions.

There are concerns on notification of nuclear incidents, re-entry of nuclear power sources in the earth's environment/ maybe in a different territory than the launching State has been long discussed on many UN platforms. The two conventions were adopted by the UN in 1986 namely[75], 1) the Convention on Early Notification of a Nuclear Accident and 2) the Convention on the

[71] UN Charter, 1945, (last visited on Jan 02, 2021), https://www.un.org/en/sections/un-charter/un-charter-full-text/.

[72] (last visited on Jan 02, 2021), https://www.unoosa.org/oosa/en/ourwork/spacelaw/resolutions.html.

[73] Five Fundamental Treaties are, 1) The Outer Space Treaty (1967), 2) Agreement on the Rescue of Astronauts, the return of Astronauts and the return of Objects Launched into Outer Space (Rescue Agreement 1968), 3) Convention on International Liability for Damage Caused by Space Objects (Liability Convention 1972), 4) Convention on Registration of Objects Launched into Outer Space (Registration Convention 1975), 5) Agreement governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement 1979).

[74]The five principles are,1) Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space(1963), 2) Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting (1982), 3) Principles Relating to Remote Sensing of the Earth from Outer Space (1986), 4) Principles Relevant to the Use of Nuclear Power Sources in Outer Space (1992), 5) Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries (1996).

[75] Doc. INFCIRG/335-336 (1986).

assistance in the case of a nuclear accident or radiological emergency. The concern of radiation protection while using nuclear power sources (NPS) has always received much discussion. NPS in space should be only in priority missions where other power sources are not feasible. The International Commission on Radiological Protection has also given directions on radiation protection in space exposure.

Outer Space Treaty (OST)

Treaty (OST[76]) obligates signatory States to proceed for the peaceful purposes[77]and beneficial uses of the space. OST solicit to avoid military or non-peaceful conduct in the space environment. The Outer Space Treaty laid down a legal regime on celestial bodies by declaring them a demilitarized zone, and bans the stationing of weapons of mass destruction in outer space. The Outer Space Treaty (OST) is the first formal international diplomatic agreement that prohibited nuclear weapons in outer space as well as forbidden military purposes and nuclear weapons installations on the moon and other celestial bodies' declaring the cosmos a special zone of the common heritage of mankind free for all.

Despite some inadequacies in OST, many have seen it as a durable and successful tool for controlling the arms race in outer space[78]. In absence of a concrete legal framework on explicit prohibitions on military uses of outer space, we can take the help of customary international rules to protect the environment and space environment/biosphere[79]. The OST in its Article IV

[76]Treaty on Principles governing the activities of State in the exploration and Use of Outer Space, Including the moon and other celestial Bodies (The Outer Space Treaty), 1967.

[77] MARTINA SMUCLEROVA, USE OF OUTER SPACE FOR PEACEFUL PURPOSES, the Oxford Research Encyclopedia, Planetary Science (oxfordre.com/planetaryscience). (DOI: 10.1093/acrefore/9780190647926.013.38) Oxford University Press, USA, 2019.

[78] Stephen Buono, *Merely a 'Scrap of Paper'? The Outer Space Treaty in Historical Perspective,* 31:2 Diplomacy & Statecraf*t* 350-372 (June 2020), https://doi.org/10.1080/09592296.2020.1760038.

[79] Tare Brisibe, *Customary International law, arms control and the environment in Outer space*, 8 (2) Chinese JIL 375–393 (2009).

deals with the deployment of weapons in outer space. The provision laid down under Article IV mentioned that, none of the States Parties to the Treaty should '*place in orbit around the earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner*'. This provision has its basis in the, 'Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, 1963'. This treaty prohibits and put restrictions on nuclear weapons testing, its explosions or any other explosions at any place under State's or control, or within its jurisdiction under the atmosphere, and beyond its limits including outer space. The OST in its Article IV also clarifies that, the moon and other celestial bodies shall be exclusively used only for the peaceful purposes. This provision also forbids the establishment of military bases, installations and fortifications, the testing of any type of weapons and the conduct of military maneuvers on celestial bodies. But the treaty is silent on the prohibition of use of any equipment or facility or deployment of military personnel for scientific research or any other peaceful purposes.

So far in many space exploration activities and manned space flights, military personnel were chosen. Many equipment's which has dual use of technology (technology can be used for dual purposes like civilian and military, either or both) are employed on moon and other celestial bodies and there are no clear-cut restrictions on such uses is found. The most important provision Article III of the Outer Space Treaty provides that to maintain international cooperation, peace and security, States should carry on all the activities in outer space including the moon and other celestial bodies, per the international law (by following Charter of the United Nations).

OST is main legal document, considered as a hard law principle. It is quite easy to convince world leaders to follow treaty obligations and respect the international norms. It is always possible to achieve objectives as treaties are backed by signature and ratification by the States. Adherence to international space law is possible only when maximum States will become party to maximum treaties/Conventions. This will be bring uniformity in exploration and will assure common heritage of mankind will be preserved for generations.

Principles Relevant to the Use of Nuclear Power Sources in Outer Space (1992)

The NPS (Nuclear Power Sources) Principle[80] has eleven Principles. The Principles on NPS are addressed to all the states irrespective of their status with Outer Space Treaty (OST). The most important Principle 3 gives guidelines and criteria for the safe use of NPSs. Principle 3 stressed that it intends to minimize the quantity of the radioactive material in space and the risk associated with it, the use of NPS should only be allowed in those missions who are not possible with non-nuclear energy sources. The nuclear reactors may be used in space mission particularly in interplanetary mission, in high orbits, in low earth orbit if they are stored in high orbit after an operational part of the mission[81].

This NPS Principle in its various provisions deals with the regulatory obligation of the State, notification/communication of re-entry of such space object, consultation, and additional information for the States. The use of NPS in a spacecraft attracts the provisions of Article VII of the Outer Space Treaty concerning responsibility, liability, and compensation. The allocation of Compensation should be as per the Liability Convention. NPS Principle 10 also speaks about negotiation and peaceful settlement of the dispute.

These Principles are like guidelines to be followed by the States, while conducting any Space activity. These are like soft law. States may not take it seriously in their conduct as they are not compulsory and the State is not duty bound to follow such principles. Non adherence to such principles is no where clear signal as a breach of international space law, so it lacks deterrence. With advancements in the science and technology, these principles should be updated from time to time.

IAEA and Scientific and Technical Sub-committee (STSC)

During the 1992 NPS Principles preparation, it was decided to discuss this topic first in the Scientific and Technical Subcommittee (STSC) of UNCOPUS. Finally, from 2003 to 2007 a plan was prepared with a working group on this area. In 2007 they submitted a report which was then endorsed by the

[80] 47/68, Principles Relevant to The Use of Nuclear Power Sources in Outer Space (1992), (last visited on Jan. 02, 2021), https://www.unoosa.org/oosa/en/ourwork/spacelaw/principles/nps-principles.html.

[81] Principle 3, Principles Relevant to the Use of Nuclear Power Sources in Outer Space (1992),

subcommittee[82]. The report suggested a partnership between International Atomic Energy Agency (IAEA) and STSC to prepare and publish a safety framework[83] for NPS application in space[84]. The safety framework has discussed vital areas such as safety, guidance to the governments on safety policy, justifications for space NPS applications, mission launch authorization issues, emergency preparedness, and response. Technical guidance is provided by the governments on using NPS for space activities, especially for safety in designing and development, risk assessment, accident consequence mitigation, and so on.

VI. Dimensions and Challenges

A. Environment and Biosphere Risk

Construction of nuclear power plants and use of nuclear energy for power generation is still a hot topic of debate on Earth and at the same time choosing nuclear power as an energy source in outer space activities poses an altogether different argument. Irrespective of location (Earth or space) nuclear power generation necessitates significant safety framework and poses a multifold risk. The radiation hazards in the atmosphere are beyond human control. The concerns of the regulatory framework, waste fuel management; spent fuel management at the nuclear power plant on Earth is still a major challenge for the nuclear industry. Setting up a Nuclear power plant on the moon or on any other celestial body raises similar concerns; even it may be for a future human colony. The re-entry of the satellite with nuclear on its board is a worry for all the nations. You cannot immediately guess where exactly the radiation may spread and how much area it might contaminate. All we can do is, respond to the nuclear emergency. Considering the use of nuclear power sources in space

[82] Draft Report of the legal subcommittee on its 2007 session, UN Doc. A/AC.105/C.2/L.268/Add. 4, pp. 9-10.

[83] Safety Framework for Nuclear Power Source Applications in Outer Space, UN COPOUS STSC, and IAEA, Vienna, 2009 A/AC.105/934, (last visited on Jan. 02, 2021), https://www.unoosa.org/pdf/publications/iaea-nps-sfrmwrkE.pdf.

[84] (last visited on Jan. 02, 2021), https://www.unoosa.org/oosa/en/ourwork/copuos/stsc/nps/index.html.

exploration or any orbital services we should revisit the National Environmental Policies and time and again.

B. Public Acceptance

The use of nuclear in space exploration not only has scientific and technical challenges but also has socio-legal-economic issues. The operator of a spacecraft with NPS onboard has to reassure paramount safety mechanism and assure that even in case of misfortune or an accident in the space biosphere, it will be at extremely low risk of radioactive contamination. This kind of practice and approach is not the sole condition to have public acceptance but it will at least minimize the opposition. The general public is not open-heartedly ready to accept nuclear power plants on Earth. By showing commercial benefits, we can't expect public consent on space exploration with NPS in space. Another major concern is about finance. Space exploration demands more funds.

The use of NPS for space exploration needs more concrete study and understanding which demands more investment of money and best minds to work on these projects. The socialist believes that if such a huge amount is utilized for the basic needs and welfare of the common people then it is more beneficial than the fulfilling the fantasy of the modern competitive world of politics. Day by day all countries are investing in space exploration with a huge financial budget. It should be kept in mind that; money should be utilized for the righteous purpose. This field of study needs more research for developing safer, efficient, reliable, and cost-effective materials and techniques. More investments are required for R&D (Research and Development) in this area.

C. Defense and Security

In 2020, the US government announced to have a space force, an armed force wing for space-based defensive measures. For decades superpowers are working on finding ways to achieve the power requirements of the space-based Strategic Defense Initiative (SDI). Not only SDI missions but civil space missions of NASA[85] also faced this challenge of power supply for longer duration missions.

Under security perspective, space-based defensive assets have the capability to operate with beam weapons which are also referred to as a direct energy

[85] National Aeronautics and Space Administration (NASA)

weapon. Such weapons have unprecedented power requirements for the preparation of war and during the actual war[86]. There are two potential energy sources for SDIs include chemical and nuclear. In space-based defensive assets[87] there are alert modes and bust mode. In alert mode technologies solar and chemical power sources can be used but for the bust mode, nuclear (nuclear reactor power system) is the potential option to supply multi-megawatt space power. Utmost care is a must in all space endeavors. Technology should not be deployed with an objective of destruction and deterrence. Technology should be used for sustainable development. World leaders should give priority to have a safe and vigilant regulatory framework in this domain.

D. Disarmament

Article IV of the Outer Space Treaty, based on the philosophy of 'Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water[88]' (Test Ban Treaty). The OST bans only a few forms of weapons, particularly those of mass destruction. Ballistic missiles and rockets are not banned in the treaty. The Moon agreement says that the celestial body should be explored for peaceful purposes by all the countries. The term peaceful purposes have another interpretation, which is non-military or non-aggressive. The verification process of a spacecraft assures the safety and the possible use of it for peaceful purposes. Nowadays, verification of the spacecraft has become a concern; States are hesitant in declaring their intention of launching a space mission.

Verification and registration leads to transparency, which help restrict misuse of space object for military purpose. Article 12 of the Anti- Ballistic Missile

[86]National Research Council, "Advanced Power Sources for Space Missions", the National Academies Press, Washington, DC. (1989) https://doi.org/10.17226/1320.

[87] Space-based defensive assets not only focus on SDI but it includes sensor systems, weapon systems, ground-based free-electron lasers, space-based lasers, chemical lasers, radar systems, light, weight and length detecting measure systems, etc. All this equipment requires a continuous power supply and every time solar power cannot supply it.

[88] (last visited on Jan. 02, 2021), https://treaties.un.org/pages/showDetails.aspx?objid=08000002801313d9.

Treaty[89] (1972) assures compliance with the verification provision. Prohibition of the militarization of outer space is one of the aims of the space law framework. Disarmament at the national and international level is most important for human survival. Arms race in outer space must be restricted at any cost.

E. Health Hazard

For lengthier space missions like going to Mars and beyond needs an appropriate power supply and conventional power sources are inadequate to support it. Nuclear technology is a must for longer space missions, and to reduce the weight of a spacecraft. Outer space already has radiation, and astronaut's exposure to such radiation is already a concern. NASA considers a 3% increased risk of fatal cancer as an acceptable career limit for its astronauts currently operating in Low-Earth orbit (LEO). As per the assessment of the *Curiosity rover*[90], the rover was exposed to an average of 1.8 mSv of radiation per day. Considering this data, the astronaut traveling in conventional spacecraft would receive a dose of about 660 mSv during a round-trip to the planet, which is nearby to the current limit specified by NASA. It means the accumulated radiation dose is like getting a whole-body CT scan once every five or six days. The nuclear power source may be an economic and feasible option but it certainly raises health concerns for the manned space missions.

F. Legality

Already astronauts are dealing with various levels of radiation exposure during the space mission as outer space itself has radiation and in addition to it, the nuclear rocket doubled such exposure from inside out. The International Court of Justice (ICJ) in the Nuclear Weapons Advisory Opinion Case gave paramount importance to the various aspects of human life and also advised to protect the environment in all possible manners as a sacrosanct duty even during military activities or in case of war. We cannot find a single legal text or international Treaty or Convention which allows or permits the use of nuclear

[89] (last visited on Jan. 02, 2021), https://treaties.un.org/doc/Publication/UNTS/Volume%20944/volume-944-I-13446-English.pdf.

[90] The Curiosity rover is a mission of a 36-week journey to Mars.

for military purposes (not on space nor Earth). All the permitted fields of using nuclear energy are for the betterment of mankind. World leaders are considering nuclear as a tool for demonstrating strength in the geopolitical environment. The USA has announced to have a space force soon. In the name of progress, we should not lead our world towards insecurity. Even India conducted ASAT test (*Mission Shakti*), while many considered it as a mean for self defence to guards India's assets in space, while some blame it for creation of space debris. Though government of India justified the testing and said that India has not violated any international space law, everyone has equal right of exploration and India is a responsible State. Globalization has allowed us to get connected and come closer but at the same time world is becoming more and more insecure and spending a lot on militarization. It's a conscious responsible of all to follow rule of law and conduct each and every activity by adhering to legal, moral and ethical norms.

VII. Concluding Remark

With advancements in this sector, serious attention requires in: reducing radiation risk in outer space, analyzing the environmental impact on the earth and in orbit, improve systems reliability in minimizing chances of nuclear accidents and find out long-term sustainable options that are cost-effective. Space exploration must adhere to all the fundamental principles of sustainable development goals (SDGs). The use of NPS in space exploration needs more financial support to develop a full proof safety mechanism. Without the government's support and systematic plan of an investment, the NPS for space exploration won't be an easy/affordable option for powering the spacecraft. Increased curiosity in the commercialization of space attracts more private players in this sector. Business-minded/profit-making attitude should be controlled by following ethical guidelines and a robust regulatory framework. The dual-use techniques are inbuilt in some equipment's and it's completely on the willingness of a State/operator, to decide what objective is to be achieved. It is difficult to hold State's and world leader's accountable merely on moral and ethical grounds. Strong regulation backed by hard law sources is must. International cooperation and commitment for peaceful exploration of outer space is an absolute need to avoid uncontrolled, unethical, unorganized, commercial activities, and expansion in space. At the national and international level, there should be awareness programs on scientific development for the

general public. Public should be made aware of the choices of using NPS for space exploration and related matters. The well-informed public will lead to more transparency and will make the State governments more accountable.