

Applicability of Artificial Intelligence in Space Activities

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Abstract:

Artificial intelligence plays a crucial role in the era of advance technology development for various space activities. Artificial intelligence based technology can perform any complicated task automatically which is very important for space exploration. Its application in various fields of space activities such as data collection and analysing, information of outer space terrain, removal of space debris and space mission operations are worthwhile. Infact, leading space agencies of the world are incorporating artificial intelligence based technology to assist in their space activity programs. The application of artificial intelligence in space activities has certain loophole as evident in the space law instruments regarding the question of liability in case of repercussion of artificial intelligence based systems. The analysis of this paper is based on secondary sources, particularly articles publish in journals and newsletters. The paper outlines the scope of provisions of space law instruments governing the applicability of artificial intelligence in space exploration and the domain of artificial intelligence technology in space activities.

Keywords: Artificial Intelligence, Application, Liability, Space Activities, Space Agencies.

Introduction:

It is a herculean task to define the broad concept of artificial intelligence. There is no standard definition of artificial intelligence in precise terms. Artificial intelligence (AI) refers to the technology of learning by systems which are programmed to mimic activities without intervention of any human. The basis of the concept of artificial intelligence is that a system is programmed in such a way to stimulate human intelligence and to justify the best opportunity through which the specific goal can be achieved. Artificial intelligence is regarded as the future of 21st century where programmed system would perform the day-to-day activities of humans from a simple task to complex one.

The applicability of artificial intelligence in space activities is not a new phenomenon but has undergone rapid changes from the system of basic automation to complex decision making. The role of artificial intelligence in outer space exploration has undergone incremental changes with the passage of time through the phases of Early Space Era (1950s-1970s), Shuttle Space era (1980s-2010s) and the current Space Era from 2010s onwards. The applications of artificial intelligence in space activities in the initial stages were of very simple standards which paved the way for the use of most advance technology artificial intelligence in the future. The first recorded use of artificial intelligence by National Aeronautics and Space Administration (NASA) was the Deep Space 1 mission in 1998.

Space 4.0 has paved way for artificial intelligence based technology with regard to various space activities. Space 4.0 refers to the new era of evolution of space sector with the participation of private players such

as SpaceX and Blue Origin in the domain of space activities. Space industry with a view to unlock the access to space based benefits is going through a phase of digital revolution with the use of technology. At this juncture, highly advance artificial intelligence based technology is the means to achieve sustainability and autonomy in space activities. The advent of 21st century has paved way for the use of artificial intelligence in various missions in outer space. Mars exploration and space rover system software are some of the areas where artificial intelligence has been used in recent times. SpaceX Robot and CIMON are two assistant robots where the technology of artificial intelligence has been use obtaining data for space exploration.

There is a tremendous scope for artificial intelligence based technologies to assist in exploration of outer space activities. A large area of the outer space is still unexplored by mankind as it involves a great potential of risks to carry out any activity. The risks ascertain may be related to the launching of space objects, space module placement and information regarding orbit of other celestial bodies. The problems of risk involved can be curtailed to a certain extent by the use of artificial intelligence technology in space exploration. Artificial intelligence can play an impetus role to ensure long term sustainability of outer space activities.

Artificial Intelligence in International Space Law Instruments:

The five United Nations international treaties on outer space along with five principles adopted by the General Assembly regarded as the space law instruments governs space activities of all States. The instruments on space law do not incorporate any specific provisions governing applicability of artificial intelligence technology in space activities. These instruments were adopted much before the development of modern artificial intelligence and contains general principles relating to outer space activities.

The basis of international space law is the Outer Space Treaty, 1967. It emphasizes inter-alia principles regarding non-appropriation of outer space by nations for the benefit of mankind, cast responsibility of States for national activities in outer space, imposes liability of States regarding damages caused by their space objects to other States and mandates jurisdiction of States in respect of activities regarding space objects. The Outer Space Treaty, 1967 may not directly incorporate provisions expressly relating to use of artificial intelligence technology in outer space related activities, but it can be implicitly assumed that it regulates matters concerning artificial intelligence through the principles of non-appropriation, responsibility, liability and jurisdiction.

The Liability Convention, 1972 forms the basis regarding regime of liability under the Outer Space Treaty, 1967. Its provisions inter-alia imposes the concept of fault and absolute liability upon the launching State for damaged caused by its space object on the surface of the Earth. The liability of the launching State is both jointly and severally which casts a responsibility to carry out space activities by mitigating the risks of damages. The Liability Convention, 1972 is very important regarding the application of artificial intelligence technology in space activities. The launching State must take into account the use of artificial intelligence, as it is solely liable for any damages and cannot shed away the responsibility to the non-government entities or private players.

The Registration Convention, 1975 provided for registration of any space object launched into Earth's orbit which must be furnished to the Secretary General of the United Nations. Its provisions inter-alia ensures for transparency and accountability of every object regarding space activities by providing every minute details. It is necessary for the peaceful use of outer space as non-transparency of information may pose a serious threat for unsophisticated use of artificial intelligence technology in near future.

The Moon Agreement, 1979 governs the activities of States on the Moon and other celestial bodies. Its provisions inter-alia emphasizes that the exploration and use of Moon by States must be for peaceful purpose in accordance with the United Nations Charter and norms of international law. It prohibits States to carry and place any mass destruction weapons, establishment of military bases and testing of weapons in and around the orbit of the Moon. The above provisions provide guidelines that there must be fair use of artificial intelligence technology in outer space activities, particularly Moon which is much accessible for space exploration by any State.

Arena of Artificial Intelligence in Space Activities:

Artificial intelligence has made advances in various disciplines of mankind in recent years. Its technology based on automation has delivered unbiased results eliminating human errors in a much faster way. The streamline data provided by artificial intelligence technology has provided the means to solve the critical and complex tasks. The justification for artificial intelligence based technology in outer space rests on the assumption that it is difficult for human being to explore and survive the hazardous environment in space. At this juncture, artificial intelligence based technology is best suited for various activities in outer space exploration. The active participation of private actors in the domain of space activities in the era of digitalization has paved way for the use of artificial intelligence. The realm of artificial intelligence in various space related operations can be analyzed as:

- **Planning and Designing of Space Missions**

- It is not an easy task to plan a mission to outer space based on limited information gathered from previous studies. The scheduling of a mission involves hours of work by various teams for accurate programming. Artificial intelligence technology through advanced algorithms and data analysis can help to address the constraints by providing information that is reliable and relevant. It thereby helps in planning and designing new space missions.

- **Assist Astronaut**

- Artificial intelligence based assistants and robots has played a key role to assist astronomers in long space journey by identifying the needs of the crew and pointing out the possible threats one may face with regard to exploration of outer space. CIMON (Crew Interactive Mobile Companion) a voice-based AI robot launched by International Space Station (ISS) into space provided assistance to astronauts regarding maintenance and repairing works of space crafts and other tasks of outer space activities.

- **Mission Operations**

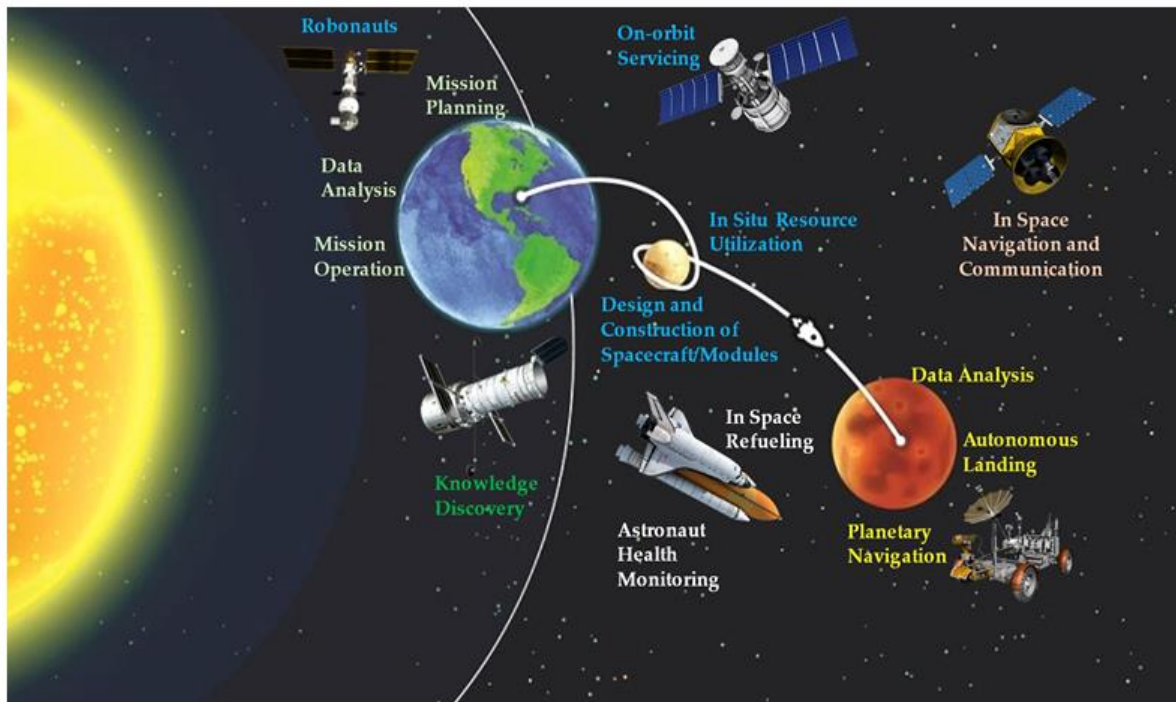
- Artificial intelligence can be applied to analyze operational risk associated with the mission. It can assess the safety of the mission by identifying the level of risk. Artificial intelligence can therefore ensure the successfulness of the mission through autonomous replanning without any control from the space station.

- **Collection and Processing of Data**

- Data collection and its processing is indispensable part of any space programme. Data obtained in a raw form needs to be analyzed by multiple users for its end results. It involves a very complex process and requires considerable time. Artificial intelligence has the ability for optimizing the sheer of data automatically and transmits the same after processing to the end user. Its application in the field of meteorological data and health monitoring system are worthwhile to mention.

- **Navigation**
 - It is not possible to monitor continuously the operation of spacecraft in real time due to communication lag in outer space. It may result in certain cases lead to failure in the operation of the mission. The use of artificial intelligence can facilitate guidance to the spacecraft without waiting for any command from the Earth. Artificial intelligence has been successfully used to develop a navigation system for exploring planets.
- **Spacecraft Maintenance on Orbit**
 - A successful space mission depends on how a spacecraft is maintained while orbiting around the outer space. A spacecraft launch for routine assistance needs to be refuel, hardware upgradation and system restoration. Artificial intelligence technology can play a pivotal role for maintenance of spacecraft in orbit and thereby execute the task with precise execution of assignments.
- **Space Debris**
 - A major concern of the space industry is the problem of space debris. Its collision in space may cause a serious damage to various satellites orbiting round the Earth and may result in more space debris. Artificial intelligence using innovative debris removal technology is the only means to achieve space sustainability for removal of space debris.
- **Autonomous Rovers**
 - The use of artificial intelligence can be seen in the field of autonomous rovers developed by NASA with regard to explorations in Mars. Autonomous rovers using artificial intelligence is designed to make decision for determining the best route while roaming over the surface of planets.

Figure 1: Artificial Intelligence - Augmented Space Activities



Source: - New Challenges for International Space Law: Artificial Intelligence and Liability

Applications of Artificial Intelligence by Space Agencies:

National Aeronautics and Space Administration (NASA) use of artificial intelligence in space activity missions:

- **Autonomous Exploration and Navigation**
- AEGIS (Autonomous Exploration for Gathering Increased Science): AI-powered programme for planetary exploration designed to collect scientific data independently.
- ML Nav (Machine Learning Navigation): AI-driven navigation device to enhance movement across difficult terrains.
- Perseverance Rover on Mars – Terrain Relative Navigation: AI technology to improve accuracy by supporting navigation of rover across Mars in unknown terrains.
- **Mission Planning and Management**
- ASPEN Mission Planner: AI equipped device for space mission to simplify optimizing planning and scheduling for mission efficiency.
- AWARE (Autonomous Waiting Room Evaluation): AI device design to manages operational delays, improve mission scheduling and resource allocation.
- CLASP (Coverage Planning & Scheduling): AI tools design for resource allocation and scheduling to enable smooth and continuous space mission.
- Onboard Planner for Mars 2020 Rover: AI equipped programme to help tasks planning and scheduling of the Perseverance Rover automatically.
- **Environmental Monitoring and Analysis**
- Sensor Web for Environmental Monitoring: AI equipped device to monitor environmental factors relating to volcanoes, floods and wildfires on Earth and beyond.
- Volcano Sensor Web: AI equipped tool specifically design with advance technology to monitor volcanic activity.
- Global, Seasonal Mars Frost Maps: AI-generated maps to study the atmosphere and surface conditions of Mars emphasizing the seasonal variations.
- **Data Management and Automation**
- NASA OCIO STI Concept Tagging Service: AI tools to organize and text NASA’s scientific data for easier accessing and analysing.
- Purchase Card Management System (PCMS): AI-equipped system design to streamline procurement processes and improve financial operations.
- **Aerospace and Air Traffic Control**
- NextGen Methods for Air Traffic Control: AI aided device to optimize control systems of air traffic, enhance efficiency and reduce operational costs.
- NextGen Data Analytics: Letters of Agreement: AI-driven equipment to analyse agreements of air traffic control systems, improve management and operational decision-making.
- **Space Exploration**
- Mars 2020 Rover (Perseverance): AI equipped device embedded within the Perseverance Rover to support mission for Mars exploration.
- SPOC (Soil Property and Object Classification): AI-based classification device design for Mars exploration to analyse its soil and environmental features.
- Indian Space Research Organisation (ISRO) use of artificial intelligence in space activities:

- Chandrayaan-2 (2019) and Chandrayaan-3 (2023): AI-powered Pragyan rover and Vikram lander help to control robotic spacecraft on the Moon surface and to communicate with the lander for facilitating landing and navigation on the lunar surface.
- Gaganyaan Mission (2026): An AI-enabled half-humanoid, Vyommitra will be launched into space to test the Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mk III) rocket for tracking changes in the crew module during spaceflight and return.
- Dhruva Space: A private sector space agency in India is integrating artificial intelligence in space operations to conduct data analysis to reduce the downlinking of large data.
- **European Space Agency (ESA) use of artificial intelligence in space activities:**
- Rosetta Mission (2004): Artificial intelligence was used for autonomously land on a comet and to collect scientific data.
- Clear Space-1: An AI powered camera to determine space debris and burn it in outer space is design by the European Space Agency (ESA).
- OPS-SAT Projects: It uses AI technique deep learning to control the position of spacecrafts and detect features on Earth's surface.
- Hera Mission (2024): It uses artificial intelligence to study the impact of NASA Double Asteroid Redirection Test (DART) on Didymos asteroid.
- PROBA-3 Mission (2024): It uses artificial intelligence technology to create artificial eclipse for studying the Sun's corona.
- Φsat-2 Satellite: It is an artificial intelligence satellite to detect and discard clouds obstruct images for innovative Earth observation.
- ESA_Lab@DFKI: A technology transfer lab working on artificial intelligence to address issues relating to satellite autonomy and collision avoidance capabilities.

Discussion:

The technology of artificial intelligence has entered the field of space industry. The use of artificial intelligence as a part of activities of space industry can be traced to beginning of the era of outer space exploration. The use of artificial intelligence is evident in various outer space missions in a simple form since the beginning of the space race. Deep Space 1 mission, NASA, New Millennium Program (1998) was the step towards testing advance use of artificial intelligence technology for space activities. Artificial intelligence equipped device has now become an indispensable part of technology in various missions of space activities. NASA, ISRO, ESA and other space agencies have applied artificial intelligence based technology in various key areas of their missions.

The nexus between the space law instruments governing space activities and artificial intelligence is a point of conundrum. There is no specific provisions governing the use of artificial intelligence in space related activities. The Outer Space Treaty, 1967 and the Liability Convention, 1972 both regarded as two major space law instruments lack the intricacies to deal with artificial intelligence technology. The space law instruments do not lay down explicit provisions regarding use of artificial intelligence in space activities but casts responsibility and liability upon States for fair use of outer space without affirming sovereignty for the benefit of mankind. The Liability Convention, 1972 read with the Outer Space Treaty, 1967 imposes accountability of liability upon the launching State for any damages caused by space object along with authorization and supervision of activities carried out by government agencies or non-

government entities. There is a legal lacuna regarding liability concept as artificial intelligence based autonomous system may have repercussions during space activities.

Conclusion:

Outer space is an unpredictable terrain out of human being predictions due to harsh conditions. The application of artificial intelligence based technology will strengthen the future of outer space activities. Artificial intelligence is the means to assist exploration of outer space activities. Artificial intelligence equipped device has the ability to automatic decision making capacity to adapt itself to unpredictable situations. Further, it gathers and provides data which can be beyond human capabilities in a very short period of time which is essential for any research. Artificial intelligence on experimental basis can help to predict various hazards which may be crucial for survival for human beings in outer space. It has indeed open up a new horizon for deep exploration of outer space.

Nevertheless, inspite of having positive impacts regarding space activities, the use of artificial intelligence also has certain loopholes. There may be source of wrong data and information due to technical fault of artificial intelligence based space activity system. The burden of liability in such situation cannot be brought to the domain of the States for no fault on their part. It is necessary for the world community particularly the United Nations Office for Outer Space Affairs (UNOOSA) and the Committee on the Peaceful Uses of Outer Space (COPUOS) to lay down principles regarding application of artificial intelligence technology in space activities. It may be concluded that use of artificial intelligence technology is vital for studying the phenomenal structure of outer space and to venture out outer space exploration.

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