Artificial Intelligence and Machine Learning in Space Sector

For Prelims: Indian Space Research Organisation, Artificial Intelligence, Machine Learning, Gaganyaan, NISAR, SPADEX Experiment, Bharatiya Antariksh Station.

For Mains: Role of AI and ML in Diverse Space Applications, ISRO's Future Endeavors

Source: PIB

Why in News?

Recently, the Government of India highlighted the substantial strides made by the **Indian Space Research Organisation (ISRO)** in **integrating** Artificial Intelligence (AI) **and** Machine Learning (ML) within the realm of space exploration.

- This transformation has been a **strategic response to the rapid technological advancements** in these domains over the past few years.
- ISRO's ongoing projects, including the **Gaganyaan Program** have integrated AI solutions.

How AI and ML Assist in Diverse Space Applications?

- **Space Exploration and Robotics: AI-driven robots and rovers can navigate,** make decisions, and explore distant planets or asteroids without constant human intervention.
    - ML helps in **identifying celestial objects, terrain, and hazards** in images captured by space probes or satellites.
- **Satellite Operations:** ML algorithms **analyze satellite images to monitor changes in Earth's surface,** weather patterns, and environmental changes.
    - AI helps anticipate satellite component failures by **analyzing telemetry data**, enhancing maintenance scheduling and reducing downtime.
- **Spacecraft Systems:** AI systems **monitor the health of spacecraft components,** predicting potential failures and allowing proactive maintenance.
    - **ML algorithms optimize power, fuel, and other resources** for spacecraft operations during missions.
- **Data Analysis and Pattern Recognition**: AI analyzes vast amounts of astronomical data to discover new celestial bodies, understand cosmic phenomena and identify space debris in space.
    - ML helps in processing signals from deep space, **distinguishing between noise and potential communication or scientific data.**
- **Mission Planning and Decision Making:** AI models assess mission risks, **aiding in decision-making processes** by considering various factors and scenarios.
    - ML enables spacecraft to adapt to changing environments or unexpected situations in real-time.
- **Optical Communications Optimization: AI and ML** models refine optical communication systems, adapting to changing space conditions and maximizing data transmission rates, crucial

for interplanetary missions.
- **Quantum Computing for Space Challenges:** AI has the potential to harness **quantum computing's potential to tackle complex calculations and cryptography**, enhancing security and computational capabilities for space missions requiring high-level encryption or intricate simulations.

What AI and ML Projects are Underway in India's Space Sector?

- **AI and ML Projects:**
  - There are various projects and programmes in the domains of AI and ML being undertaken by the **Department of Space** are at different stages of feasibility studies and implementation. Major ones include:
    - **Launch vehicle and spacecrafts mission** trajectory design and autonomous operations;
    - **Launch vehicle and satellites health monitoring** and prediction from the telemetry data;
    - **Satellite Data Processing** for Resource mapping, weather prediction, disaster prediction, **geo-intelligence (object and change detection),** Precision agriculture, Agroforestry etc.
    - **Humanoid robots and chatbots**
    - **Space Robotics** and smart manufacturing in space.
- **ISRO's Future Endeavors:**
  - **Chandrayaan-4 Mission**: Planned by ISRO to bring back samples from the Moon within four years.
  - Bharatiya Antariksh Station **(India's Space Station):** The first module, capable of conducting experiments with robots, will launch by 2028.
  - **SPADEX Experiment:** Demonstrates autonomous docking capability between two spacecraft.
    - Involves launching connected satellites that separate, travel a distance, and then reconnect.
  - NISAR**: NASA-ISRO SAR (NISAR)** is a **Low Earth Orbit (LEO) observatory** being jointly developed by NASA and ISRO.
  - **Gaganyaan:** Gaganyaan mission aims to **send humans to space and return them safely to Earth**. The mission will consist of two unmanned flights and one manned flight, using the GSLV Mk III launch vehicle and a human-rated orbital module.

Note

- During the past 9 months of the **financial year 2023-24**, the government stated that startups in the space sector within the country have garnered **private investments exceeding 1,000 crore rupees.**

What are Major Challenges Related to AI and ML in the Space Sector?

- **Computational Limitations:** Spacecraft have **limited computational power and memory, making it challenging to run complex AI algorithms**. ML models need to be optimized to run efficiently in these resource-constrained environments.
- **Robustness and Reliability:** Space environments are **harsh, with high levels of radiation and extreme temperatures,** which can affect the hardware and software components of AI systems. Ensuring the reliability and robustness of AI algorithms in such conditions is crucial.
- **Training Data Limitations**: Gathering training data for AI models specific to space missions can be challenging due to the **limited number of past missions or situations to learn from.**
- **Ethical and Legal Considerations**: As AI becomes more prevalent in space missions, ethical and legal concerns arise, such as the **responsibility for AI decisions, data privacy**, and **potential conflicts between AI-driven decisions and human judgment.**

Way Forward

- **Edge Computing and Onboard Processing:** Focus on **onboard processing and edge computing** to minimize data transmission delays and reliance on Earth-based computational resources.
    - This **allows spacecraft to process data and make decisions autonomously**, reducing dependency on constant communication with Earth.
- **Interdisciplinary Collaboration:** Encourage collaboration between **space agencies, researchers, and industries** to combine expertise from various fields such as astronomy, computer science, materials science, and robotics.
    - This interdisciplinary approach fosters innovation and comprehensive problem-solving.
- **Ethical Frameworks and Governance:** Developing **global ethical frameworks and governance guidelines specific to AI and ML in space that** address issues like AI decision-making, accountability, data privacy, and adherence to international space laws.

UPSC Civil Services Examination, Previous Year Question (PYQ)

Prelims

Q. Consider the following statements: (2016)

The Mangalyaan launched by ISRO

1. is also called the Mars Orbiter Mission
2. made India the second country to have a spacecraft orbit the Mars after USA
3. made India the only country to be successful in making its spacecraft orbit the Mars in its very first attempt

Which of the statements given above is/are correct?

(a) 1 only
(b) 2 and 3 only
(c) 1 and 3 only
(d) 1, 2 and 3

Ans: (c)

Mains

Q. What is India’s plan to have its own space station and how will it benefit our space programme? **(2019)**