

Advancements and Challenges in NASA Robotics: Expanding Horizons for Space Exploration

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Abstract- In NASA's exploration and research endeavours, robotics are vital. The space agency uses robotic systems and technology to carry out a variety of activities, from satellite maintenance and space exploration to building habitats and planetary rovers. Robots have been an integral part of NASA's space exploration and research, whether it be rovers, humanoid robots or robotic arms. These robots have been a critical part of many space projects done by NASA throughout the years. Technologies for satellite maintenance and repair missions have been developed by NASA. Examples of programmes designed to increase the lifespan of satellites include the Robotic Refuelling Mission (RRM) and the Restore-L mission. These programmes use robotic systems to refuel satellites or repair and upgrade its components. NASA has been working on the creation of lunar rovers as part of the Artemis programme. With the help of these rovers, humans will be able to explore the lunar surface, carry out experiments, and collect useful data on crewed trips to the Moon.

Robotic manufacturing in space is an idea that NASA has been looking into. Robots could be able to create tools, spare parts, and even dwellings using 3D printing technology on other celestial worlds like the Moon or Mars by exploiting locally accessible materials. Future trips to Mars and other celestial planets are being planned by NASA. Robotic systems will be necessary for the collection, storage, and ultimate return to Earth of these samples for in-depth scientific examination.

This Paper sheds light on the types of robots used in NASA's missions, their working, and their impact on space research along with various. This research highlights different types of robots which were part of NASA's missions through the years. The materials used to make these robots along with the tech which is used to make them one of a kind. The study focuses on how they revolutionised space exploration for mankind and also how it opened future possibilities for us, along with that we will see how these machines can be used in other fields like farming, medical and disaster management.

Keywords: Robots, equipment, space, explore, study, astronauts, tasks

INTRODUCTION

NASA has been using robotic automation since the start of 80's, since then for all mission

Robots have been a crucial component. These robots are being used for various tasks ranging from collecting data and samples to conducting complex experiments and repair work, Hubble Space Telescope and ISS are some popular examples of major space missions where robots are used.

Types of robots being used-

Rovers –

Robotic vehicles known as rovers are made to go around the surface of heavenly bodies like planets and moons. Rovers use scientific devices for data collecting and processing and have legs, tracks, or wheels for mobility. For examining the surface of the planet and carrying out scientific research, NASA has employed rovers like the Mars Pathfinder rover, Mars Exploration Rovers (Spirit and Opportunity) and the Mars Science Laboratory rover (Curiosity).

Orbital Robots –

Robots in orbit around heavenly bodies, such as planets or moons, are known as orbital robots. These robots have the ability of communicating, imaging, and doing remote sensing. The Lunar Reconnaissance Orbiter, which has been orbiting the Moon since the year 2009, and the Mars Reconnaissance Orbiter, which has been examining Mars since the year 2006, are two examples of orbital robots used by NASA.

Robotic arms –

On spacecraft and the International Space Station (ISS) robotic arms and manipulators are used for tasks like capturing and connecting spacecraft, managing objects, and carrying out repairs and maintenance. One well-known example of a robotic arm used by NASA for space operations is the Canadarm, which was created by the Canadian Space Agency and installed on the International Space Station.

Landers –

Robotic spacecraft called landers are made to land on celestial bodies like planets, moons, and asteroids. Landers have specialised equipment for examining the surface and running experiments. For example, NASA used the Phoenix Mars Lander to examine the Martian Arctic and look for evidence of water ice.

Humanoids –

Humanoid robots are robots designed to mimic human-like features and movements. These robots are used in research and technology demonstrations for tasks that require human-like dexterity and mobility. For example, NASA's Robonaut 2 (R2) is a humanoid robot that has been used on the ISS to assist with tasks such as maintenance and repairs.

Materials used to build these robots

NASA designs its robot to work in extreme conditions of space which require advanced materials which are built to handle high temperatures, vacuum, radiation etc.

Metals –

NASA uses lightweight metals such as titanium and aluminium to make the parts of these robots. These lightweight metals are known for their extreme strength for such less weight, which helps in reducing the overall weight of the spacecraft.

Ceramics –

Ceramics is a material known for its high strength and their resistance against high temperatures, making them useful in extreme conditions of space, NASA uses it for various components in robots such as thermal coating, heat shield and etc. to withstand high temperatures with good durability.

Plastics –

The lightweight, chemical resistance, and thermal stability of high-performance plastics like polyether ether ketone (PEEK) and polyimide make them ideal for use in NASA robots. These plastics are utilised in parts with low friction, high wear resistance, and long-term endurance, such as gears, bushings, and seals.

Electronics –

In order to control their motions, operate their sensors, and perform other tasks, NASA robots need complex electronic components, including microchips, sensors, and cabling. These electrical components are made to endure the harsh conditions found in space, such as exposure to radiation, high temperatures, and vacuum. Electronics are shielded from harmful environments and given specialised materials and coatings to ensure reliable functioning.

Thermal insulation –

Thermal insulation is important because NASA robots work in areas with significant temperature fluctuations, from frigid temperatures to scorching heat. For the purpose to protect delicate components from heat damage and ensure steady functioning, thermal insulation materials such as foams, blankets, and coatings are used.

Surface coatings and adhesive –

For corrosion, radiation damage, and other environmental threats, NASA robots may need special surface coatings. These coatings are used to improve the performance and endurance of many different components, such as structural parts, electronics, and sensors, in space environments. When assembling and connecting NASA robots, adhesives are crucial because they create a firm connection between different materials and parts. In order to resist the harsh conditions of space, such as vacuum, temperature changes, and radiation exposure, NASA utilises specialised adhesives.

Some well-known robots used by NASA

Curiosity -

The Curiosity rover is a robotic vehicle sent by NASA to examine the surface of Mars in August 2012, weighing over 900 kg it was equipped with various sensors, robotic arms, cameras and other equipment. It also had a drill bit to examine the Martian soil. Its major discovery was the evidence of organic compounds like methane which forms the foundation of life, it also hinted the existence of ancient rivers and lakes stating the fact that Mars is the best alternative to Earth for supporting human life in solar system, initially Curiosity was made to work for roughly 2 Earth years but it still holds strong and continues to send crucial data regarding Mars to us for further research.

Robonaut 2 -

Robonaut 2 is the humanoid robot developed by NASA in collaboration with General Motors, It was designed to assist in space missions and perform complex tasks, it stands 3.7 ft tall and weighs around 150 kg's, It's equipped with human like features like limbs and a head. It has functioning fingers to replicate a human's delicate touch while working with fragile components. It's equipped with cameras, motion sensors, force sensors and touch sensors to interact with its surroundings in a human like manner, it has various attachments like drill, cameras and sensors to perform various functions. It was designed for the International Space Station and has been a significant part of it, since its deployment in 2011 it has been helping astronauts with complex work and research.

Canadarm-

Canadarm also known as shuttle remote manipulator system (SRMS), is the robotic arm developed by Canadian aerospace company SPAR aerospace and is currently used by NASA for various space missions, It is a significant part of the ISS. It was first launched to space shuttle Columbia in 1981 and since then has played a crucial role in satellite retrieval, assembly, repair work of ISS and astronaut extravehicular activities. It's a 50 ft long arm along with 7 motorised joints for flexibility of work. Its controlled by astronauts in ISS or from the mission centre on earth. It is also equipped with various attachments to perform a wide variety of tasks in space.

Astrobee-

Astrobee is a autonomous free-flying robot system which was developed by NASA for using It is onboard the ISS. It's made to help astronauts with daily tasks, scientific research, etc ISS. It consists of 3 cubic robotic systems about the size of a standard football each well equipped with cameras, sensors and a docking system. These robots are capable of navigating the ISS without any assistance. It easily performs tasks avoiding obstacles in a less gravity environment and is also able to move in all three directions. It helps in reducing the work of astronauts by performing quick daily tasks like picking up things, they act as the housekeeper of ISS. They work with an electric fan propulsion system.

RASSOR -

Regolith advanced surface systems operations robot is a robotic system designed by NASA for the purpose of mining and excavation on celestial bodies, It is designed to operate in a low gravity environment. It's equipped with cutting edge digging system that allows it to excavate

Through loose soil and rock easily. It consists of two rotating drums with in built blades to process the regolith it collects. It doesn't require any human intervention making it perfect for remote missions, it's equipped with LIDAR and stereo cameras to navigate through its environment and identify potential hazardous obstacles, It can be easily customised Depending on mission requirements, It has a lightweight and a compact design which helps it to move freely on rough surfaces and it also has low battery consumption which allows it to work for long hours without recharging it constantly.

FUTURE PROJECTS-**Dragonfly-**

NASA's dragonfly mission is lander that will explore Saturn's moon titan which has a thick atmosphere, dragonfly will be equipped with various scientific equipments to study Titan's surface and atmosphere. It being a rotorcraft, it will be able to fly to various locations on the moon to collect data and conduct experiments.

Mars ice mapper-

NASA is developing the ice mapper mission to study the distribution and the composition of water on the red planet, The mission will use a robotic spacecraft equipped with advance instruments to map the surface of the planet and the sub layers of it to identify crucial pockets of water resources which could be useful for future research.

Viper-

As part of a mission named VIPER, which stands for Volatiles Investigating Polar Exploration Rover, NASA plans to send a robotic rover to the south pole of the moon in 2023. Its objective is to depict how water ice is distributed across the lunar surface. The rover will be furnished with cutting-edge tools, such as a drill that can take soil samples and analyse them from depths of up to three feet. By analysing the distribution of water ice on the moon with VIPER, scientists will be better able to comprehend the history of water on the moon and its potential as a resource for eventual human exploration and occupation. Other fields where these robots can be used-

Farming-

These robots are equipped with tech which allows them to grow vegetation in space, such technology can be used for growing vegetation in places where agriculture is not supported like deserts and mountains.

Disasters-

NASA robots are made to assist astronauts in space, these robots can also be used in disaster management. They can be equipped with tools to assist people in need in times of emergency in unfavourable environments.

Medical Industry-

NASA robots have been equipped with advance health monitoring systems which can monitor SPO2, pulse, hydration levels and sugar levels of astronauts, same can be used in hospitals and in the military to keep a track of the health of patients.

Maintenance-

These robots can monitor our environment by checking pollution levels in air and water, they can help in planting seeds and watering plants along with cleaning trash and segregating it properly.

Delivery-

These robots can assist in quick delivery of essential goods in areas where transportation is not possible, they can deliver crucial medicines, blood and food, especially in undeveloped areas or areas of disaster.

Conclusion:

In conclusion, this research paper serves as a comprehensive exploration of NASA Robotics with insights into its current state and future potential. By leveraging robotic technology, NASA can continue to expand our understanding of the universe, overcome obstacles, and conduct scientific experiments in environments that are inaccessible or hazardous to humans. As advancements in robotics continue to evolve, it is clear that NASA Robotics will play a crucial role in future space missions, paving the way for groundbreaking discoveries and pushing the boundaries of human exploration.

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