

Drones in Space

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Abstract:

Drones are being utilized across the globe for various diverse uses by commercial, state, military, and individual users. In recent years, there has been a tendency to design and develop concepts of drones and robotic systems for planetary exploration. The integration of drones into space transportation and exploration represents a paradigm shift in how we approach the cosmos. Drones can make space more accessible, cost-effective, and efficient. Scientists use them to complement rovers and other observatory equipment to collect space data. Drones are expected to play a key role in the future of space exploration. This paper explores major applications, benefits, and challenges of drones in space exploration.

Keywords: drones, unmanned aircrafts, unmanned aerial vehicles (UAVs), space exploration, space drones.

INTRODUCTION

The vast expanse of outer space has long captured the imagination of humanity. Our solar system, including the sun and everything that orbits it (planets, asteroids, moons, comets, and meteoroids), has attracted more attention from various space agencies compared to other cosmological systems. Various space agencies have invested resources into exploring our solar system physically and through observation. There has been an interest in studying our neighboring planets and moons, such as Venus, Mars, and Titan. Progress in recent technologies has enabled space drones to be considered as valuable platforms for planetary exploration. Due to the advantages of drones

compared to other approaches in planetary exploration, ample research has been carried out by different space agencies in the world, including NASA, to apply drones in other solar bodies.

Drones are increasingly being used in space exploration, transportation, and other applications. They are reshaping our understanding of the universe and revolutionizing the space industry by making it more cost-effective, efficient, and accessible. Drones provide an unprecedented capability to traverse difficult terrains and access remote locations, enabling the exploration of regions that were previously inaccessible to surface rovers or landers.

WHAT IS A DRONE?

The FAA defines drones, also known as unmanned aerial vehicles (UAVs), as any aircraft system without a flight crew onboard. Drones include flying, floating, and other devices, including unmanned aerial vehicles (UAVs), that can fly independently along set routes using an onboard computer or follow commands transmitted remotely by a pilot on the ground. A typical drone is shown in Figure 1 [1]. A drone is usually controlled remotely by a human pilot on the ground, as typically shown in Figure 2 [2]. Drones can range in size from large military drones to smaller drones. Drones, previously used for military purposes, have started to be used for civilian purposes since the 2000s. Since then, drones have continued to be used in intelligence, aerial surveillance, search and rescue, reconnaissance, and offensive missions as part of the military Internet of things (IoT). Today, drones are used for different purposes such as aerial photography, surveillance, agriculture, entertainment, healthcare, transportation, law enforcement, etc.

Commercial drones have come a long way in the last decade. Drones work much like other modes of air transportation, such as helicopters and airplanes. When the engine is turned on, it starts up, and the propellers rotate to enable flight. The motors spin the propellers and the propellers push against the air molecules downward, which pulls the drone upwards. Once the drone is flying, it is able to move forward, back, left, and right by spinning each of the propellers at a different speed. Then, the pilot uses the remote control to direct its flight from the ground [3].

Drone laws exist to ensure a high level of safety in the skies, especially near sensitive areas like airports. They also aim to address privacy concerns that arise when camera drones fly in residential areas. These include the requirement to keep your drone within sight at all times when airborne. In the United States, drones weighing less than 250g are exempt from registration with civil aviation authorities. If your drone exceeds 250g in weight, you will also require a Flyer ID, which requires passing a test [5]. It is necessary to register as an operator, be trained as a pilot, and have civil liability insurance, in addition to complying with various flight regulations, and those of the places where their use is permitted.

Most drones have a limited payload, usually under 11 pounds. Drones are classified according to their size. Here are the different drone types:

- Nano Drone: 80-100 mm
- Micro Drone: 100-150 mm
- Small Drone: 150-250 mm
- Medium Drone: 250-400 mm
- Large Drone: 400+ mm

One of the emerging trends in drone use for factories is the utilization of LiDAR technology. LiDAR stands for Light Detection and Ranging. This technology provides accurate depth information essential for understanding the three-dimensional structure of the environment. LiDAR sensors emit laser beams to measure distances to objects, creating high-resolution 3D maps of the

surrounding terrain and objects. The ability to capture detailed data through LiDAR technology has opened up opportunities for better predictive maintenance, reduction in inspection times, and overall cost savings [5].

SPACE DRONES

Scientists need special tools and devices to explore space. Drones have emerged as useful tools, needed in space to observe and survey areas. Drones help scientists learn more about asteroids as well as other planets and moons. The advantage of using drones is they are cheaper than sending people and have better potential to fly over places the rovers cannot access. A standard drone cannot fly to space independently for many reasons. For the propellers to effectively lift the drone, there must be enough air in the atmosphere. As you move up the Earth's atmosphere, the air becomes thinner and the pressure drops. The reasons drones cannot fly in space include the following [6]:

- (1) Lack of air push.
- (2) Lack of movement.
- (3) Lack of powerful engine.
- (4) Drones cannot work in vacuum.
- (5) Propellers cannot work.

That is why NASA is working on a different propulsion system for the drones meant to fly to space. Thus, drones can fly in space but with customization to withstand low atmospheric pressure and weak gravity. A modified or assisted drone can fly to space, although the pilots have to add modified communication equipment to effectively control the drone. To fly in space, the drone needs some assistance in the form of a weather balloon, which allows the drone to get to the incredibly high altitude required in order to be able to see the circumference of planet earth. Once the weather balloon reaches a certain point, the balloon will pop, resulting in the drone falling back to earth.

Space drone is a spacecraft designed to dock with existing satellites that are running low on fuel but are otherwise operational. It uses electric propulsion to maneuver to its target satellite, attaching to the satellite's launch vehicle interface ring via robotic arms.

Solar panels and energy storage systems are helping space drones sustain longer missions. Drones are designed and fabricated with different shapes and sizes and hence various methods and materials for manufacturing. A typical space drone is shown in Figure 3 [7].

APPLICATIONS

In recent years, there has been a paradigm shift in the way we approach space transportation and exploration, with the integration of drones playing a pivotal role. Drone technology has multiple capabilities and applications. Space drones can assist in mapping, sample collection, and geological and atmospheric analysis. Common applications of drones in space exploration include the following [8]:

- **NASA:** NASA is using drone technology for a variety of reasons, such as aerial imagery, inspections, and mapping. Drones are used at NASA's Stennis Space Center to capture images and video and record data. NASA is developing a nuclear rotorcraft drone called Dragonfly that will explore the skies and surface of Titan. At NASA's Stennis Space Center at Mississippi, drones are becoming a go-to resource for use on difficult and potentially dangerous jobs, helping to save time and costs. As NASA integrates drone mapping operations into existing software, future scanning is expected to allow the creation of 2D or 3D real-time maps and models. A team of NASA engineers wants to put drones on Mars. NASA already uses drones in

many of their operations. Figure 4 shows an astronaut using a digital glove in space to control a drone on the moon [9].

- *Safety Inspection:* The safety of astronauts and the integrity of space vehicles are paramount. Drones can be used for safety inspections before and during launch. They can check for debris on the launchpad, ensuring a clean and safe departure. Drones equipped with high-resolution cameras and sensors can be used to inspect launch facilities. Additionally, drones can monitor the weather conditions, providing real-time data that helps in making critical launch decisions.
- *Autonomous Spacecraft Repairs:* Space exploration missions are often marred by the challenges of long distances and communication delays. Drones can be deployed to autonomously repair spacecraft, extending their operational lifetimes. In the future, autonomous drones could repair critical systems, such as solar panels or communication antennas, while the spacecraft is far from Earth. Autonomous drones could be equipped with tools and technology to handle routine maintenance and repairs.
- *Aerial Exploration:* On planets like Mars, drones are being used to conduct aerial exploration. For example, the Mars Helicopter has provided stunning imagery and data from the Martian surface, showcasing the potential for drones to reach areas that are inaccessible to traditional rovers.
- *Sample Collection:* Drones can also be used to collect samples from planets and moons. A drone can fly to a specific location, gather samples, and return to the main spacecraft, all while operating autonomously.
- *Resource Survey:* Drones can be deployed to conduct resource surveys on the Moon. They can explore the lunar surface, identify valuable resources like water ice, and even perform preliminary mining activities. This approach could significantly reduce the cost of lunar missions by utilizing local resources.

BENEFITS

Drones have the potential benefits in terms of cost-efficiency, versatility, and adaptability to different environments. Safety is a significant benefit of drone usage. Drones offer unique capabilities to get close views of potentially life-threatening situations. They can impact almost any business and provide a positive return-on-investment quickly. They are rapidly evolving beyond capturing data into major transportation vehicles and carrying us into their future.

CHALLENGES

There are challenges and limitations associated with drone technology in space exploration. These include issues related to power supply, materials, communication delays, thermal control, and the need for robust navigation systems in unfamiliar terrains.

Regulations in the industry have helped address safety and security concerns. Organizations like NASA have been trying their best to send drones at the heights, but there are many factors which pulled them down. Drones which are used on Earth cannot be used the same way in space, because we cannot push air over there. It is challenging for an astronaut to control a drone while outside of their ship on the moon's surface.

Further research and development in this field is needed to overcome these challenges.

CONCLUSION

As technology continues to advance, we can only expect the role of drones in space exploration to expand further. Drones have the potential to revolutionize future space missions, enabling greater understanding and exploration of the universe. They have proven to be indispensable tools in space

exploration and transportation. With their ability to access hard-to-reach areas, conduct autonomous repairs, and gather valuable data, drones are poised to continue transforming our dreams of exploring the cosmos into reality. Although only one drone has been sent to Mars, more research is underway to create better crafts for space exploration.

Drones are a transformative technology that will change in ways we likely never imagined. Much of the future of drones may seem like sci-fi but it is much closer than you may think. Using drones to explore the other planets or moons is one of the main priorities of space agencies. NASA already uses drones in many of their operations, and they hope to use drones widely in the future. More information about drones in space can be found in the books in [10-13] and in the following related journals:

- *Drones*
- *Vertical Space e-Magazine*
- *Progress in Aerospace Sciences*

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Figure 1 A typical drone [1].



Figure 2 A drone is usually controlled by operators on the ground [2].



Figure 3 A typical space drone [7].



Figure 4 A astronaut uses a digital glove in space to control a drone on the moon [9].