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# Autonomous Orbit Changing and Out-of-the Orbit to Interstellar Point Maneuvering: A Novel Concept

Sayak Subhra Bera*

Department of Automation and Robotics, Maulana Azad National Institute of Technology, Bhopal, India.

**Abstract:** A satellite, throughout its operational lifetime, typically follows a pre-defined orbit, which restricts its ability to observe only specific regions on Earth. This paper explores methods by which a satellite can modify its current orbit and transition to a newly defined trajectory to expand its coverage and increase the number of observable locations on Earth's surface. Furthermore, the paper describes how a satellite can temporarily depart from its orbital regime and travel into deep space for the purpose of observing astronomical events before returning to its designated orbit. To support these advanced maneuvers, a conceptual framework for trajectory planning is presented, detailing the sequence of operations required for seamless orbital changes and deep-space excursions. The entire process including transitioning to a new orbit, conducting interstellar observations, and autonomously returning to the original orbits designed to be executed automatically once an appropriate trigger or mission command is received. Additionally, the paper discusses the potential advantages, limitations, and technical challenges associated with such autonomous orbital and deep-space operations.

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## 1. Introduction

Modern space missions demand versatility, with satellites operating across diverse orbital regimes from Low Earth Orbit (LEO) to Lagrangian points and interplanetary trajectories. Boley and Byers highlight the challenges of satellite mega-constellations, noting the increased collision risks and environmental impacts in crowded orbits [1]. Concurrently, precise orbit determination and autonomous navigation, as explored by Guo et al. and Sirbu and Leonardi, are essential for enabling satellites to operate in complex environments such as halo orbits or interplanetary paths [7, 16]. Traditional mission designs rely on dedicated satellites for specific tasks, yet the operational similarities across Earth-orbiting and deep-space missions such as launching, trajectory tracking, and orbiting suggest potential for more flexible systems, as noted by Ma et al. for gravity-assist spacecraft [12]. This paper introduces a novel concept: a single satellite capable of autonomously adjusting its orbit and position to support multiple mission types. By integrating machine learning for spacecraft control, as surveyed by Shirobokov et al. [8], intelligent mission planning, as proposed by Hilton et al. [11], and resilient autonomous frameworks, as reviewed by Banerjee et al. [19], this approach aims to enhance mission efficiency, reduce orbital congestion, and pave the way for sustainable, multi-purpose space exploration. In this era of smart living, satellites play a vital role in communication and in monitoring parameters such as temperature, climate change, and land-use distribution. High-performance satellites typically remain in a single orbit to observe specific locations, which creates a need for deploying additional satellites for different purposes, in different orbits, and over different regions. For deep-space observation for example, missions to Lagrangian points or planetary orbits, a highly specialized space program and precisely defined orbit are required. For Earth-orbiting missions, the typical sequence includes launching, synchronizing, and orbiting; and for interplanetary missions, launching, following a trajectory to the target location or planet, and establishing orbit. In essence, scientists are conducting similar types of missions with only minor variations. This paper presents a concept in which a single satellite can be used for most of these mission types by autonomously adjusting its orbit and position as needed. Such a system could support both advanced space exploration and tactical Earth observation.

*Department of Automation and Robotics, Maulana Azad National Institute of Technology, Bhopal, India. **Corresponding Author:** sayaksubhra.in@gmail.com.
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## 2. Literature Review

The rapid advancement of space exploration and satellite technology has driven significant research into orbital dynamics, autonomous navigation, and mission planning for spacecraft. This literature review synthesizes key findings from recent studies, focusing on satellite orbit determination, autonomous navigation, mission planning, and the challenges posed by emerging space technologies such as mega-constellations. The reviewed works span a range of methodologies, from traditional orbital mechanics to modern machine learning and multi-agent systems reflecting the interdisciplinary nature of contemporary space research. Orbital dynamics remain a cornerstone of spacecraft operations, with studies addressing both natural and artificial perturbations. Boley and Byers highlight the environmental and operational risks posed by satellite mega-constellations in Low Earth Orbit (LEO). Their work emphasizes increased collision risks, atmospheric impacts, and ground-based interference caused by the proliferation of satellites, underscoring the need for robust orbit management strategies [1]. Similarly, Kalimeris et al. (1994) explore orbital period changes in contact binary star systems, offering insights into gravitational interactions that can inform satellite orbit stability models [2]. Their findings suggest that tidal interactions and mass transfer can significantly alter orbital parameters, a principle applicable to spacecraft in complex gravitational environments.

London (1962) provides a foundational study on aerodynamic maneuvering for changing satellite orbit planes. By leveraging atmospheric drag, this approach offers a low-energy method for orbit adjustment, particularly relevant for satellites in LEO [3]. Haberle et al. (2003) extend the discussion to planetary atmospheres, using Mars general circulation models to study orbital changes [4]. Their experiments demonstrate how atmospheric variability affects spacecraft trajectories, highlighting the importance of environmental modeling for mission planning beyond Earth. Autonomous navigation is critical for reducing reliance on ground-based systems and enabling real-time decision-making. Guo et al. focus on precise orbit determination supported by time synchronization, emphasizing rapid orbit recovery techniques. Their methods leverage synchronized timing to enhance positioning accuracy, crucial for applications such as satellite constellations and interplanetary missions [7]. Similarly, Sirbu and Leonardi explore fully autonomous orbit determination for satellites in halo orbits, proposing synchronization techniques for navigation and communication systems [16]. Their work highlights the potential for autonomous systems to operate in complex orbital regimes, such as those around Lagrange points.

Ma et al. provide an overview of autonomous navigation for gravity-assist interplanetary spacecraft. Their study outlines techniques for onboard trajectory computation, emphasizing the need for robust algorithms to handle dynamic gravitational fields [12]. Du et al. further advances this field by addressing low-thrust trajectory planning in the Earth–Moon elliptic restricted three-body problem [18]. Their nonlinear dynamics approach demonstrates how low-thrust propulsion can achieve precise trajectory tracking, offering a framework for fuel-efficient interplanetary missions. The integration of machine learning (ML) and artificial intelligence (AI) into spacecraft control has gained traction in recent years. Shirobokov et al. survey ML techniques for spacecraft control design, highlighting applications in trajectory optimization, attitude control, and fault detection. Their findings suggest that ML can enhance autonomy by enabling adaptive responses to unforeseen conditions [8]. Yielding et al. explore multi-agent reinforcement learning for satellite guidance, focusing on triangulation of moving objects in relative orbit frames [9]. Their work demonstrates how collaborative algorithms can improve situational awareness in dynamic environments.

Brandonisio et al. investigate AI-aided image-based guidance, navigation, and control (GNC) for autonomous inspection of uncooperative space objects. Their closed-loop system leverages computer vision to enable precise maneuvering, a critical capability for debris removal and satellite servicing [13]. Tipaldi and Glielmo provide a broader perspective, surveying model-based mission planning and execution for autonomous spacecraft [14]. They emphasize the importance of integrating predictive models with real-time control to achieve mission objectives. Mission planning for autonomous spacecraft requires balancing efficiency, safety, and adaptability. Hilton et al. propose intelligent mission planning for distributed satellite systems, focusing on optimizing resource allocation and coordination in multi-satellite missions. Their framework leverages distributed computing to enhance scalability and robustness [11]. Truszkowski et al. introduce the concept of autonomous and autonomic systems, advocating for self-managing spacecraft capable of adapting to environmental changes and system failures [15]. This paradigm is particularly relevant for long-duration missions where ground intervention is limited. Banerjee et al. review resiliency in space autonomy, identifying key challenges such as fault tolerance, cybersecurity, and environmental adaptability. Their work underscores the need for redundant systems and adaptive algorithms to ensure mission success in hostile space environments [19]. Zhou et al. draw parallels with unmanned surface vehicles, exploring multi-modality constraint-based path planning [6]. Their findings on dynamic path optimization can be applied to spacecraft, particularly for collision avoidance in crowded orbits. Space situational awareness (SSA) is increasingly critical as orbital environments become more congested. Kazemi et al. survey orbit determination techniques for SSA, emphasizing the need for accurate tracking of both active satellites and space debris. Their work highlights advancements in sensor fusion and data processing to improve tracking precision [10]. Mansfield et al. address collaborative mission planning, introducing the concept of "evolving orbits" for group-based satellite operations [5]. Their process-oriented approach provides a framework for coordinating complex missions involving multiple stakeholders.

Yang et al. draw inspiration from terrestrial autonomous systems, presenting a dynamic lane-changing model for automated vehicles [17]. While focused on ground transportation, their trajectory planning techniques offer insights into real-time path adjustment for spacecraft in dynamic environments. The reviewed literature reflects the multifaceted nature of orbital dynamics and autonomous spacecraft navigation. From traditional orbital mechanics to cutting-edge AI applications, researchers are addressing the challenges of precise orbit determination, autonomous navigation, and resilient mission planning. The rise of mega-constellations and crowded orbital regimes necessitates advanced SSA and collision avoidance strategies, while ML and AI offer promising tools for enhancing autonomy and adaptability. This study addresses these gaps by proposing a single spacecraft system that autonomously adjusts its orbit and position to support diverse missions. By integrating precise navigation (Guo et al. [7]), AI-driven control (Shirobokov et al. [8]), and resilient mission planning (Hilton et al. [11]; Banerjee et al. [19]), the proposed system offers a sustainable solution to reduce orbital congestion, lower costs, and enhance mission versatility, aligning with the evolving needs of space exploration.

## 3. Autonomous Orbit Changing and Out-of-the Orbit Maneuvering

It is discussed in two phases as follows

### 3.1 Autonomous Orbit change

A satellite orbits a path well its lifetime. The trajectory planning to change its orbit can happen in two phases one - out of plane maneuver, then - synchronization to new orbit. Followings steps can be taken:

i. **Selecting the position for triggering of out of orbit maneuver:** The selection of position to start the out of orbit maneuver depends on orbit orientation and characteristics. The point will be selected from such a position where the satellite will not face too much maneuvering difficulties for velocity direction, inclination to reach a certain position in space closer to the new orbit, may not be apogee, for smooth synchronization.
ii. **Out of plane maneuver:** After reaching the triggering position, out of orbit maneuver is in a straight direction starts, though effect of gravitational attraction, atmospheric drag needs to be considered because ultimately, the parabolic curve, the space craft will follow. For changing the orbit, altitude, and then inclination or vice-versa change can be considered or omitted as per requirements.
iii. **Synchronization maneuver:** After reaching the certain position in space, the synchronization maneuver starts to reach and align the new orbit. Align location in a new orbit may not apogee or perigee. Here also, the maneuver goes to straight direction, and all kind of space forces need to be considered, and it will result in a parabolic path.

### 3.2 Out-of-Orbit to Interstellar Maneuver

For going to interstellar space, another planet centered orbit, this kind of maneuver can be followed. Same like changing orbit, out of orbit maneuver will be done then bellow steps can be followed:

i. **Interstellar path:** After out of orbit maneuver, the space craft will follow a certain interstellar path to reach a certain position in space closer to the target planet centered orbit.
ii. **Synchronization phase:** From the interstellar point, the main objective of the spacecraft to synchronize to new orbit. In deep space, craft will face solar radiation, gravitational force etc., when it comes to planet, it will face the drag also, according to its gravitational field.

The craft should stay the deep space location like Lagrangian points etc., according to the mission requirements.

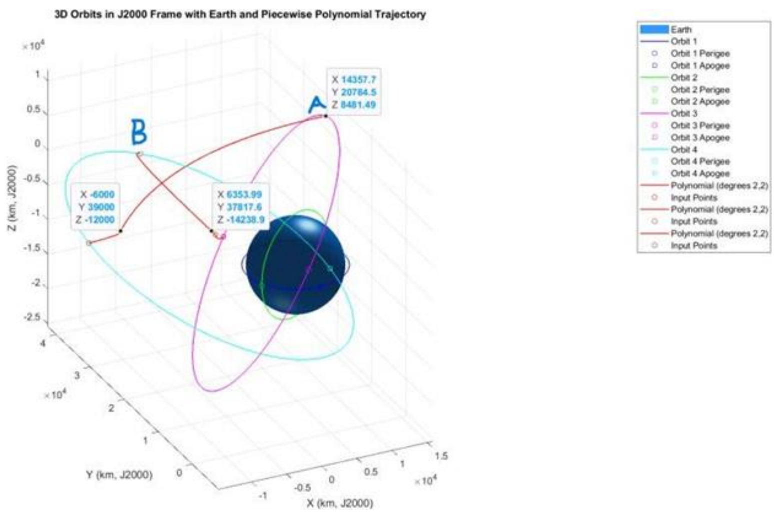


**Fig 1; Possible Two Molniya orbits transfer path, starts from point A, B**

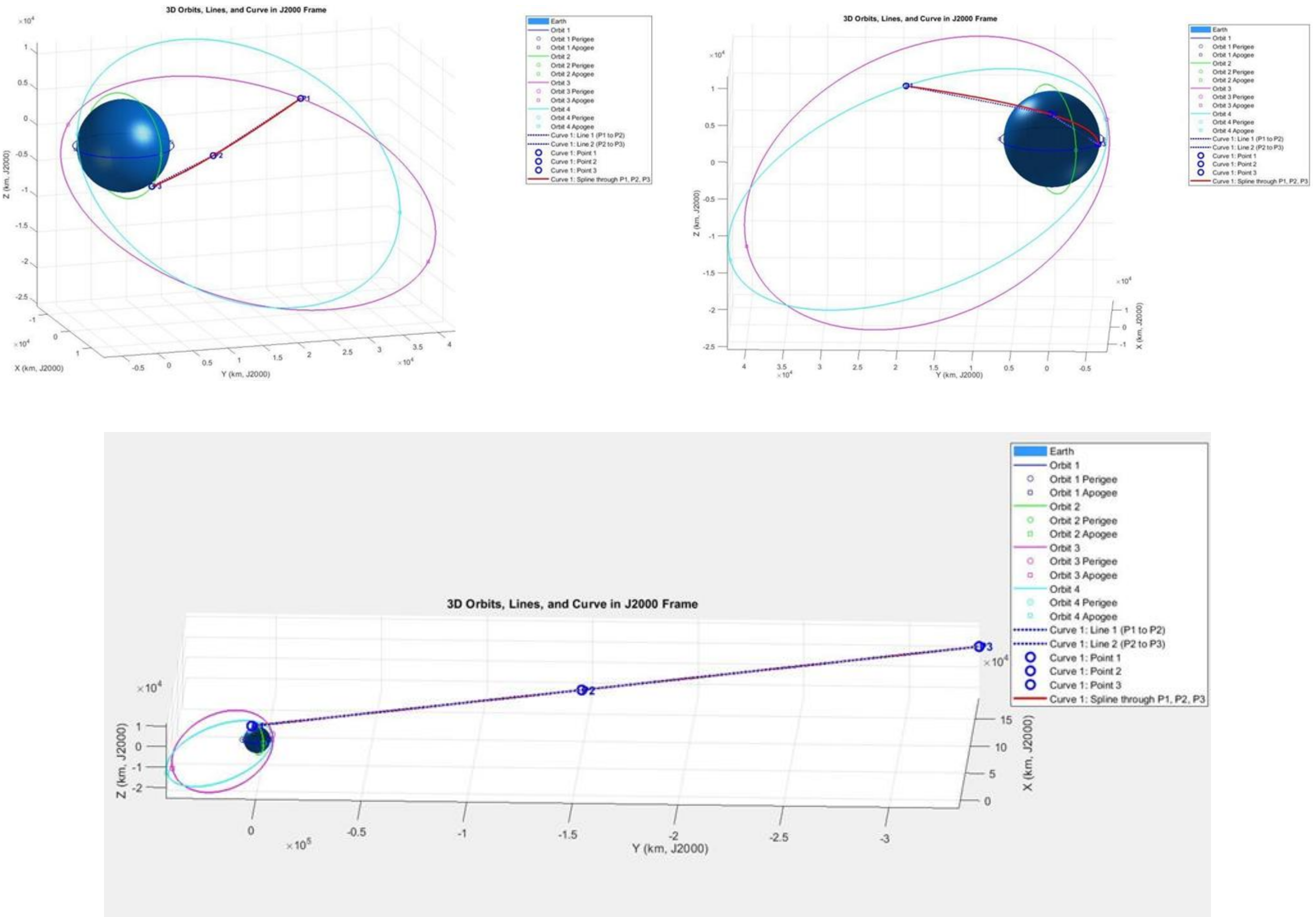


**Fig 2: Possible a) Molniya to Polar Orbit, b) Molniya to GEO, c) Molniya orbit to L5 point transfer Path**

**** All paths are changeable according to mission**

## 4. Advantages and Disadvantages

The advantages and disadvantages of this space operation are discussed as follows:

### Advantages

i. A single satellite can execute similar stypes of space missions.
ii. This approach can help reduce the budget required for repeated mission types, enabling the development of higher-quality satellites with longer operational lifetimes.
iii. Countries with limited budgets will gain access to their own independent space missions.
iv. A satellite can change its orbit to remain disguised or less detectable.
v. To observe an astronomical event, asteroid, or similar target, there is no need to plan a separate dedicated mission.
vi. Observation opportunities for target planets or their satellites will increase significantly.

### Disadvantages

i. For navigation or communication, this concept may not be useful.
ii. Required enough lifetime, will make to focus on nuclear or electric propulsion
iii. Trajectory planning will be complex. If the space system can reach a proper position in space closer to new orbit, synchronization will be with multiple maneuvers.
iv. Required enough thrust to follow optimum short trajectory, or the spacecraft needs to follow multiple intermediate orbits to reach target position or new orbit.

## 5. Conclusion

This paper presents a novel concept in which a single spacecraft can autonomously modify its orbit or depart from Earth orbit entirely to conduct deep-space observations before returning to its operational trajectory. By integrating advanced trajectory planning, autonomous decision-making, and potentially non-conventional propulsion technologies, such a system can significantly expand the functional versatility of future satellites. The approach addresses long-standing limitations in traditional mission architectures, where each mission is restricted to a fixed orbit and a single purpose throughout its lifetime. The findings suggest that autonomous orbit-changing and interstellar-point maneuvering are technically feasible, provided the spacecraft incorporates high-efficiency propulsion systems such as nuclear or electric propulsion, along with intelligent onboard navigation and control frameworks. This capability enables a single satellite to undertake multiple mission profiles Earth observation, planetary science, astronomical event monitoring, or reconnaissance thereby reducing the need for numerous dedicated spacecraft and alleviating orbital congestion. While the concept introduces challenges in trajectory complexity, thrust requirements, and mission planning, the advantages outweigh the limitations. The proposed system has the potential to reduce mission costs, increase accessibility for nations with limited resources, enhance scientific return, and improve operational flexibility across both near-Earth and deep-space environments. Ultimately, this vision represents a step toward a more adaptable, autonomous, and sustainable model of space exploration, where multipurpose spacecraft can dynamically respond to evolving mission needs and scientific opportunities.

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## 8. Conflict of Interest

The author declares no competing conflict of interest.

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