IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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WINGS OVER VENUS: THE CONCEPT BEHIND V-FLARE

Abstract

Venus atmosphere presents significant challenges for aerial exploration, characterized by super-rotating winds, a carbon dioxide-rich composition, and corrosive sulfuric acid clouds. While the surface is extremely hostile, with pressures of approximtely 9.3 MPa and temperatures reaching approximtely 467°C, the 50–60 km altitude range offers a more favorable environment, with Earth-like pressures and moderate temperatures (0°C to 50°C). However, the dense, turbulent atmosphere limits the effectiveness of conventional aerial platforms, necessitating an alternative approach for sustained exploration.

This study introduces a biomimetic flapping-wing aerial system V-FLARE (Venus Flapping-wing Aerial Reconnaissance Explorer) optimized for efficient mobility within Venus' cloud layer. Inspired by biological flyers, the system employs flexible, high-temperature polymer-based wings that dynamically adjust stroke amplitude and frequency to optimize lift, thrust, and maneuverability in varying atmospheric conditions. The advanced metamaterial fuselage, coated with acid-resistant materials, ensures resilience against Venus harsh environment, while an articulated morphing tail enhances stability and aerodynamic control. Leveraging adaptive resonance-based flapping, the system synchronizes wing oscillations with prevailing air currents to minimize energy consumption, extending operational longevity. Additionally, the integration of solar and wind-energy harvesting enables prolonged autonomous flight, ensuring sustained data collection in Venus ever-changing atmospheric conditions.

Beyond its novel flight mechanics, this platform enables high-value scientific investigations, including atmospheric studies such as wind velocity profiling, turbulence characterization, and cloud chemistry analysis, along with geological exploration through subsurface radar mapping of Venus volcanic and tectonic features. Furthermore, its capability to conduct electromagnetic investigations, including lightning detection and ionospheric studies, enhances understanding of Venus' complex atmospheric dynamics. By bridging the gap between high-altitude balloons and orbital satellites, this system allows real-time data acquisition within Venus dense atmosphere. The concept extends beyond Venus, offering a blueprint for aerial explorers suited for Titan's thick nitrogen-rich atmosphere, exoplanets with dense gaseous envelopes, and even Earth's lower stratosphere for long-duration climate research. By integrating biomimicry, smart materials, and energy-efficient propulsion, this technology revolutionizes planetary aerial mobility, paving the way for sustained exploration in extreme atmospheric environments.