# Autonomous UAV Networks

v2.3

User Guide

## Overview

This guide introduces the Autonomous UAV Networks simulator — a research and educational tool designed to model real-world UAV networking behavior under aerospace-accurate conditions. It incorporates International Standard Atmosphere (ISA) physics, aerodynamic power equations, RF propagation (Two-Ray + Rician), and LTE-MCS throughput estimation to simulate resilient airborne mesh networks.

## Quick Start

1. Launch the app using: streamlit run app.py
2. Adjust parameters in the sidebar — area size, UAV count, frequency, and MAC scheme.
3. Click Run Simulation to begin the scenario.
4. Monitor the progress bar and live metrics in the dashboard.
5. View results via the 2D network plot or 3D Orbit View.
6. Export datasets using the available Download buttons (CSV, JSON, or ZIP).

## Key Features

- ISA-based atmosphere model for air density and temperature realism.
- Aerodynamic power computation combining induced, parasite, and climb loads.
- Two-Ray + Rician RF propagation for multipath ground reflection modeling.
- LTE-MCS PHY model or Shannon ideal channel for link throughput estimation.
- TDMA, NOMA, and RSMA MAC presets for multi-access performance benchmarking.
- Integrated jammer and eavesdropper modules for cyber-electromagnetic analysis.
- Dynamic 3D orbit visualization referencing LEO, MEO, and GEO orbital rings.
- Expanded export suite: metrics, trajectory, fleet, and configuration data.

## Simulation Workflow

Each simulation step calculates aerodynamic power draw, link capacity, and throughput for every UAV. Kinematic updates apply velocity vectors, climb rates, and heading perturbations. Signal-to-Interference-plus-Noise Ratio (SINR) is recalculated dynamically per link, while a directed capacity graph determines end-to-end throughput using a widest-path flow heuristic. This enables detailed evaluation of aerial network resilience, latency, and data relay efficiency under various environmental and operational conditions.

## Data Export and Analysis

Upon completion, exportable datasets include performance metrics (throughput, SoC, and energy), trajectory history, fleet configuration, and final UAV positions. The ZIP bundle consolidates all outputs with session metadata, ensuring reproducibility and cross-platform compatibility with analytical tools such as Python, MATLAB, and Excel.

## Troubleshooting & Best Practices

- Ensure Python ≥ 3.10 and Streamlit ≥ 1.30 are installed.
- For large fleets (> 25 UAVs), reduce the number of simulation steps or disable animations.
- If the simulation halts or crashes, click Reset Fleet & Reseed to restart with a new seed.
- Use fixed random seeds to reproduce identical conditions across multiple runs.
- Monitor the terminal for real-time progress and potential warning messages.

## Appendix: Mathematical Foundations

The simulator’s core algorithms utilize International Standard Atmosphere (ISA) equations for temperature and pressure, aerodynamic power models for induced and parasite drag, Two-Ray ground reflection and Rician fading for RF channel modeling, and LTE PHY Modulation and Coding Schemes for link-level performance estimation. These provide aerospace-grade fidelity suitable for advanced simulation and research contexts.