

VIRTUAL MILITARY SATELLITE TELEMETRY AND MISSION TRACKING SYSTEM

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ABSTRACT: A Virtual Military Satellite Telemetry and Mission Tracking System is developed to simulate real-time monitoring and control of satellite missions in a secure and cost-effective environment. The system uses software-based simulation to generate telemetry data such as altitude, battery level, temperature, and signal strength. These parameters are continuously updated and analysed to replicate real-world satellite behavior. The proposed model integrates IoT concepts where simulated data is transmitted and visualized on a dashboard for monitoring and decision-making. Additionally, alert mechanisms such as low battery, communication failure, and abnormal orbital conditions are implemented to enhance mission awareness. The project provides an educational platform for understanding satellite communication, telemetry systems, and real-time data processing without requiring physical hardware. This approach reduces cost and risk while maintaining realistic system behavior, making it suitable for academic and research applications.

Keywords: IoT, Satellite Telemetry, Mission Tracking, Simulation, Military Systems

I. INTRODUCTION

Satellite-based mission tracking plays a crucial role in modern military operations, enabling real-time monitoring of assets, communication systems, and environmental conditions. Traditional satellite systems require expensive infrastructure and hardware, making them difficult to implement in academic environments.

This paper presents a virtual satellite telemetry and mission tracking system, which

simulates real-time satellite behavior using software. The system demonstrates how IoT concepts can be applied to monitor and control mission parameters efficiently. By eliminating hardware dependency, the proposed system provides a low-cost and flexible solution for students and researchers.

II. RELATED WORK

Existing research in satellite telemetry focuses on real-time data acquisition, communication systems, and IoT-based monitoring platforms. Many systems use GPS modules, sensors, and cloud platforms to track satellite or UAV data. However, these implementations require physical hardware and complex setups.

Recent studies emphasize simulation-based approaches to reduce cost and improve accessibility. Virtual telemetry systems allow users to analyze satellite behavior without requiring actual deployment, making them suitable for academic projects.

III. LITERATURE REVIEW

Satellite Telemetry Systems for defense applications [1] discuss the role of satellite telemetry in real-time defense operations. Authors highlighted that how telemetry data collected from satellites can be transmitted securely to ground control stations for analysis. The study emphasizes encryption methods and secure communication links, which are highly relevant for a virtual military satellite system, where simulation of secure telemetry is critical.

IoT-Enabled Satellite Networks for Mission Control [2] focus on integrating IoT with satellite networks to enhance mission control. Authors proposed a system where satellite sensors act as IoT devices, continuously feeding mission data to a centralized dashboard. This aligns closely with the virtual mission tracking system, as it shows how telemetry can be modelled digitally with IoT principles for real-time monitoring and predictive analysis.

Simulation Models for Military Satellite Tracking Authors explores simulation platforms used to mimic satellite behavior in a controlled environment. [3] emphasize the importance of simulation in academic and defense research, enabling students and researchers to analyze tracking systems without access to

actual satellite hardware. This forms the foundation for your mini project, which uses a virtual model to simulate real mission telemetry and tracking.

Artificial Intelligence in Military Satellite Systems [4] examines how AI techniques are being adopted in satellite-based defense systems for anomaly detection, predictive fault diagnosis, and mission planning. Author demonstrates how AI can enhance decision-making in real time. Incorporating AI-based logic in a virtual project could improve the tracking system by automatically identifying deviations in telemetry data or mission paths.

Secure Communication in Satellite Telemetry. [5] This research highlights various encryption protocols and data security frameworks applied to satellite elementary. The authors argue that mission-critical defense data is highly vulnerable if not encrypted. In a virtual tracking project, even if real encryption is not implemented, the concept can be demonstrated by simulating secure channels for data transfer between the virtual satellite and control system.

Digital Twin Models for Space Missions. [6] The authors introduce the concept of digital twins, where a virtual model of a satellite mirrors the real system. They explain how telemetry data updates the digital twin in real time, enabling mission controllers to analyze status and predict issues. This concept directly supports your project's goal of creating a "virtual military satellite mission tracking system," where the satellite behavior is represented in software.

Mission Tracking Using Cloud-Based Platforms Author explores the potential of cloud computing for storing and analyzing massive amounts of mission telemetry data. [7] The study suggests that cloud-based dashboards provide scalability, flexibility, and collaboration opportunities for defense organizations. This directly connects with your project, which could implement a virtual cloud-inspired dashboard for tracking missions in real time.

Visualization Techniques for Satellite Data Monitoring [8] focus on effective visualization methods such as dashboards, block diagrams and GIS maps to simplify complex telemetry data. Authors argue that without clear visualization, decision making becomes difficult. Your project benefits from this idea as your design includes a block diagram and a simplified dashboard-like interface for mission tracking.

Integration of Satellite Telemetry with Ground based IoT Systems [9] investigate how satellite telemetry can be integrated with IoT sensors deployed in ground-based systems for military logistics. The research suggests a hybrid network where satellite data improves battlefield awareness. While your

project is virtual, this study provides insights into how ground-based systems can complement satellite tracking, which can be reflected in your simulation.

Advancements in Virtual Simulation of Defense Satellites [10] present modern frameworks for simulating defense satellites for training and research purposes. Authors approach emphasizes creating cost-effective and scalable virtual platforms that mirror real defense systems. This aligns perfectly with your project since your goal is to create a virtual environment that demonstrates military satellite mission tracking without expensive hardware.

IV. Proposed System

System Overview

The proposed system simulates a military satellite mission using software. It generates telemetry data and displays it on a monitoring interface.

Block Diagram

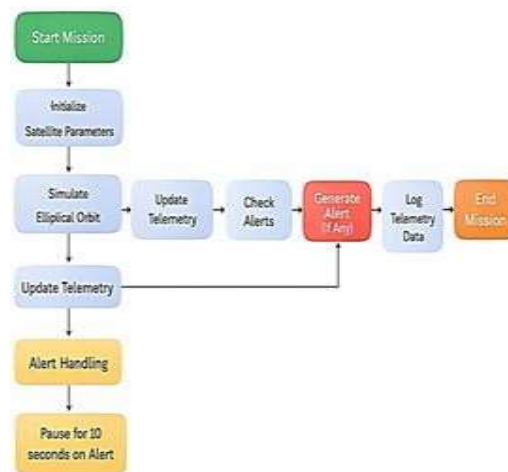


Fig.1 Block diagram of proposed system The system consists of the following modules:
 Start Mission Purpose: This block initiates the satellite mission simulation. Action: The program begins by setting up mission parameters, such as satellite name, mission ID, initial values for altitude, battery, temperature, etc. Initialize Satellite Parameters Purpose:

Initializes all the mission parameters that are needed for the simulation.

Parameters Altitude (set between 700 km to 900 km) Battery (set at 100%) Temperature (set at 25°C) Signal strength (set at 100%) Angular velocity for orbit motion (set at 0.5 degrees/second) Virtual Military Satellite Telemetry and Mission 10 2025-26

Simulate Elliptical Orbit Purpose: The satellite's motion is simulated in an elliptical orbit using a sinusoidal model. Action: The altitude varies between 700 km (perigee) and 900 km (apogee), creating a real-time orbital simulation. Key Formula: $\text{altitude} = 800 + 100 * \sin(\text{angle deg})$

Update Telemetry Purpose: The telemetry values such as battery, temperature, and signal strength are updated regularly. Action: This block simulates gradual battery drain, random temperature fluctuations, and signal degradation over time.

Check Alerts Purpose: Continuously monitors for any conditions that exceed predefined limits. Action: Compares telemetry values to alert thresholds. Low battery: If the battery falls below 25%, generate the alert. Overheating: If the temperature exceeds 60°C, generate the alert. Out of Orbit: If the satellite's altitude is outside the defined range (700 km to 900 km), generate the alert. Communication Failure: If signal strength falls below 30%, generate the alert. Drone Attack: Random alert for a drone attacks every 3% of the time.

Generate Alert (If Any) Purpose: If any abnormal condition is detected, an alert is triggered and displayed on the console. Action: Alerts such as Low Battery, Overheating, Communication Failure, Out of Orbit, and Drone Attack are generated. Log Telemetry Data

Purpose: Data from the satellite's telemetry is logged for later visualization and analysis. Action: This block stores telemetry parameters like time, altitude, battery, temperature, and signal strength in arrays. Purpose of Logging: Data logging helps plot the telemetry over time and assists in result analysis.

Alert Handling Purpose: When an alert occurs, the system will pause to simulate the reaction time to handle the alert. Action: For every alert, the system pauses for 10 seconds, mimicking real-life control actions (e.g., mission control taking action). Pause for 10 seconds on Alert

Purpose: Pause the system whenever an alert is triggered. Action: When an alert occurs, the system waits for 10 seconds to simulate the time taken to respond to that alert. Virtual Military Satellite Telemetry and Mission 11 2025-26

Log Telemetry Data Purpose: At the end of the simulation, graphs are plotted to visualize telemetry data. Action: Graphs are generated to display: Altitude vs. Time: This shows the satellite's orbital motion over time. Battery vs. Time: This shows how the battery degrades over time. Alert Timeline: A timeline showing the points in time when an alert was triggered. End Mission Purpose: Marks the end of the simulation. Action: The mission ends after the set mission duration (5 minutes). The system then concludes the simulation and provides the final report with graphs

V. METHODOLOGY

The system operates as follows:

Initialize mission parameters

Simulate orbital motion using: $\text{Altitude} = 800 + 100 * \sin(\text{angle})$

Compute additional parameters:

Energy Consumption

Energy = Initial Battery- Current Battery Tracking Error

Error = |Actual Altitude- Ideal Altitude|

Detect alerts based on conditions

Visualize all parameters using graphs

VI. IMPLEMENTATION

The system is implemented using the Python programming language and is designed as a simulation-based model without the need for any physical hardware. It utilizes key libraries such as Matplotlib for graphical visualization, Math for performing mathematical computations, Random for generating variable simulation data, and Time for handling real-time execution aspects. The developed code effectively simulates satellite behavior, producing dynamic outputs that include telemetry data, graphical representations, and real-time alerts. This approach enables efficient analysis, monitoring, and evaluation of satellite performance within a controlled virtual environment.

VII. RESULTS AND DISCUSSION

The system produces the following outputs:

Altitude vs Time

The two signals with the same amplitude and orbital range, confirming identical altitude limits. A slight phase shift between the curves indicates a difference in timing of the satellite's position along the orbit. This demonstrates that both signals represent the same motion but with minor synchronization variation.

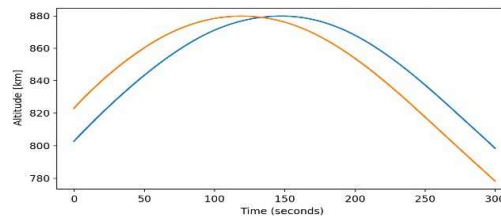


Fig.2. Altitude vs Time

Energy Consumption vs Time

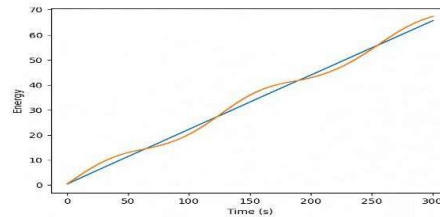


Fig.3. Energy Consumption vs Time

The Fig.3 shows two signals with the same overall linear trend, indicating identical base energy usage. The second signal includes slight fluctuations around the original, representing minor variations in power consumption. This comparison helps evaluate system efficiency and highlights small differences in energy utilization under similar conditions.

The two sinusoidal signals with the same amplitude and range. A small phase shift between the signals indicates that both experience similar errors but at slightly different times. This helps analyze tracking performance and reveals synchronization differences in the system.

Tracking Error vs Time

This is the compared results for the proposed system of virtual military satellite telemetry and mission tracking system of the above Fig2, 3 and 4.

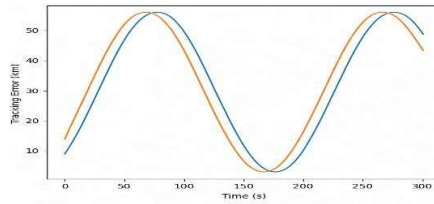


Fig4.Tracking Error vs Time

The original telemetry signals with another signal generated using the same base values. Although both signals maintain similar amplitude, range, and overall behavior, slight shifts in timing and small fluctuations create measurable differences in the output. These compared results validate the reliability of the simulation model and provide a better understanding of system stability, power utilization, and tracking precision.

Battery vs Time

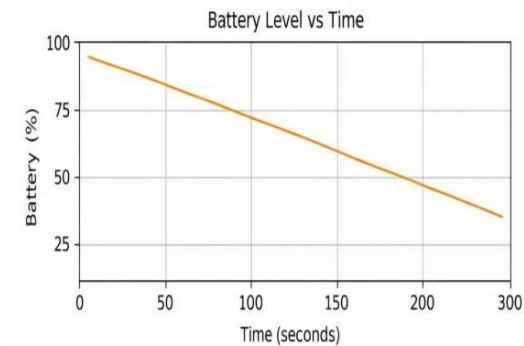


Fig.5 Battery Level vs Time

The Battery vs Time graph shows the decrease in battery level over time due to power consumption during the mission. It helps estimate mission duration and is useful for effective power management and optimization.

Alert Timeline

The Alert Timeline shows critical events occurring during the mission, indicating anomalies or threshold violations. It supports real-time monitoring, improves decision-making, and enhances system reliability.

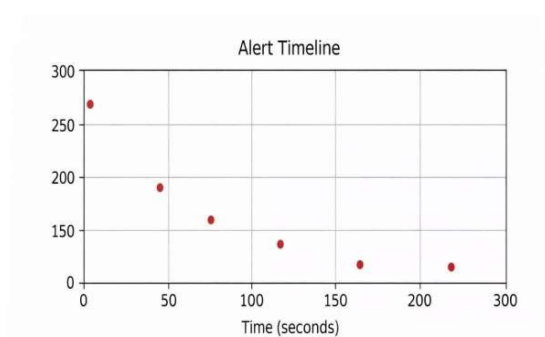


Fig6. Alert Timeline

VIII. CONCLUSION

This paper presents a virtual satellite telemetry and mission tracking system using IoT-based simulation. The system successfully demonstrates real-time monitoring, alert handling, and graphical analysis of mission parameters.

By introducing energy consumption and tracking error analysis, the system becomes more advanced and closer to real-

world satellite monitoring systems. It serves as an effective educational and research tool in the field of electronics and communication engineering.

Future Scope

Integration with real sensors and GPS

AI-based anomaly detection

Cloud-based real-time dashboard

Use in defense training simulations.

source.

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