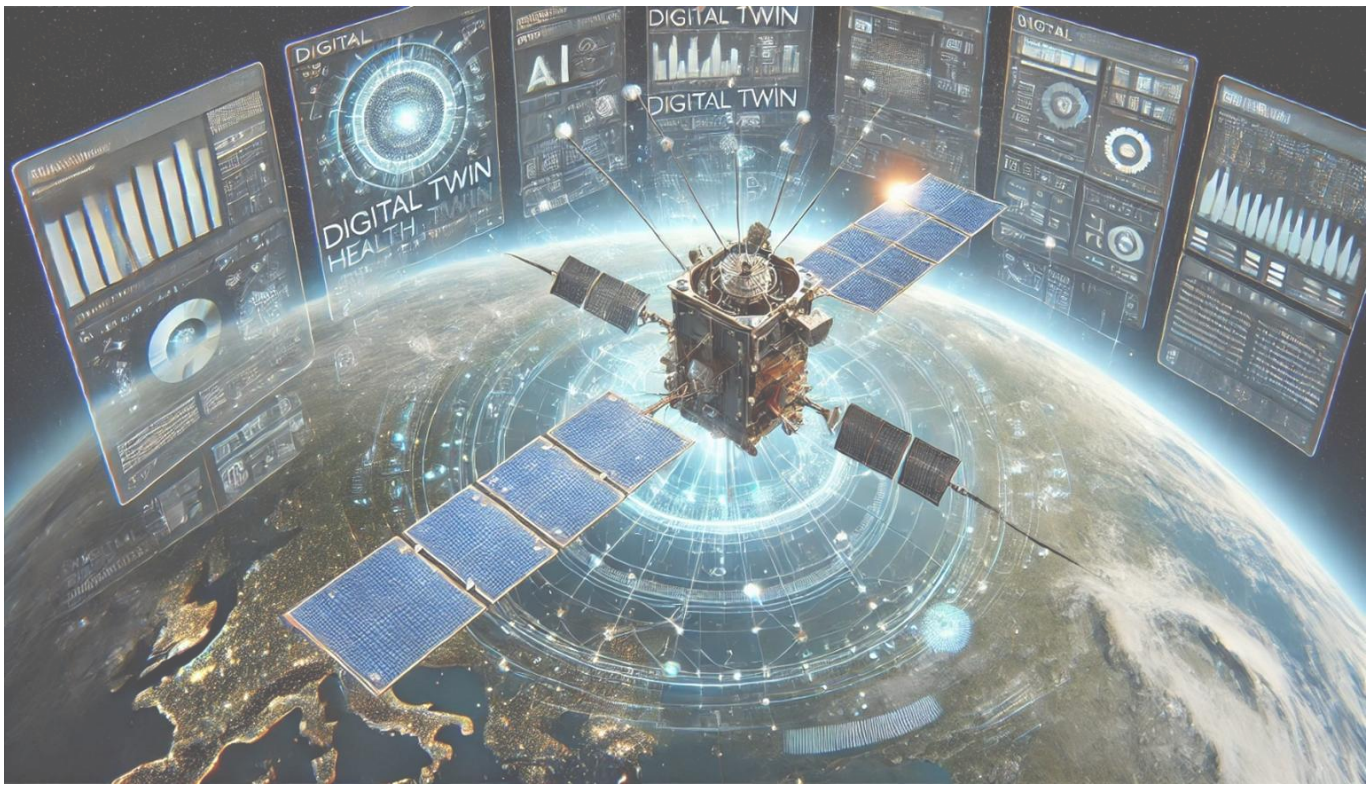
AI-POWERED DIGITAL TWIN PROTOTYPE FOR SATELLITE HEALTH MONITORING



- **Prepared by**

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AI-POWERED DIGITAL TWIN PROTOTYPE FOR SATELLITE HEALTH MONITORING

Project Overview:

This task involves developing a prototype of an AI-powered digital twin for satellite health monitoring. The digital twin will simulate real-time satellite conditions and predict potential issues using AI models trained on simulated satellite telemetry data.

- Real-time Satellite Health Monitoring
- Predictive Analytics for anomaly detection
- Interactive Dashboard (built with Streamlit)
- Automated Alert System
- Visualization of Satellite Metrics

Usage

- Launch the dashboard using Streamlit.
- View real-time telemetry data and health status of satellites.
- Receive alerts if anomalies are detected.
- Access the Digital Twin simulation for in-depth analysis.

Phase 1: Data Collection & Digital Twin setup

- Identify key satellite parameters to simulate (e.g., battery voltage, solar panel efficiency, thruster health, etc.).
- Generate or use **pre-existing satellite telemetry datasets** for training & simulation.
- Set up a basic **database** (MySQL) to store simulated satellite data.

Dataset: Sample_satellite_telemetry_data.csv

Satellite Telemetry Parameters:

- timestamp
- battery_voltage
- battery_current
- state_of_charge
- solar_panel_voltage
- solar_panel_current
- solar_panel_efficiency
- power_consumption
- internal_temp
- battery_temp
- solar_panel_temp
- radiator_temp
- radiator_efficiency
- thermal_gradient
- position
- velocity
- gyroscope
- magnetometer_rpm
- reaction_wheel_rpm
- thruster_status
- signal_strength
- data_rate
- packet_loss
- payload_power
- sensor_data_rate
- camera_temp
- data_quality
- error_flags
- latency
- bit_error_rate
- sensor_discrepancies
- thruster_malfunctions
- thruster_efficiency
- orientation
- throughput
- power_anomalies
- thermal_anomalies
- aocs_faults
- payload_failures

Phase 2: AI Model Development:

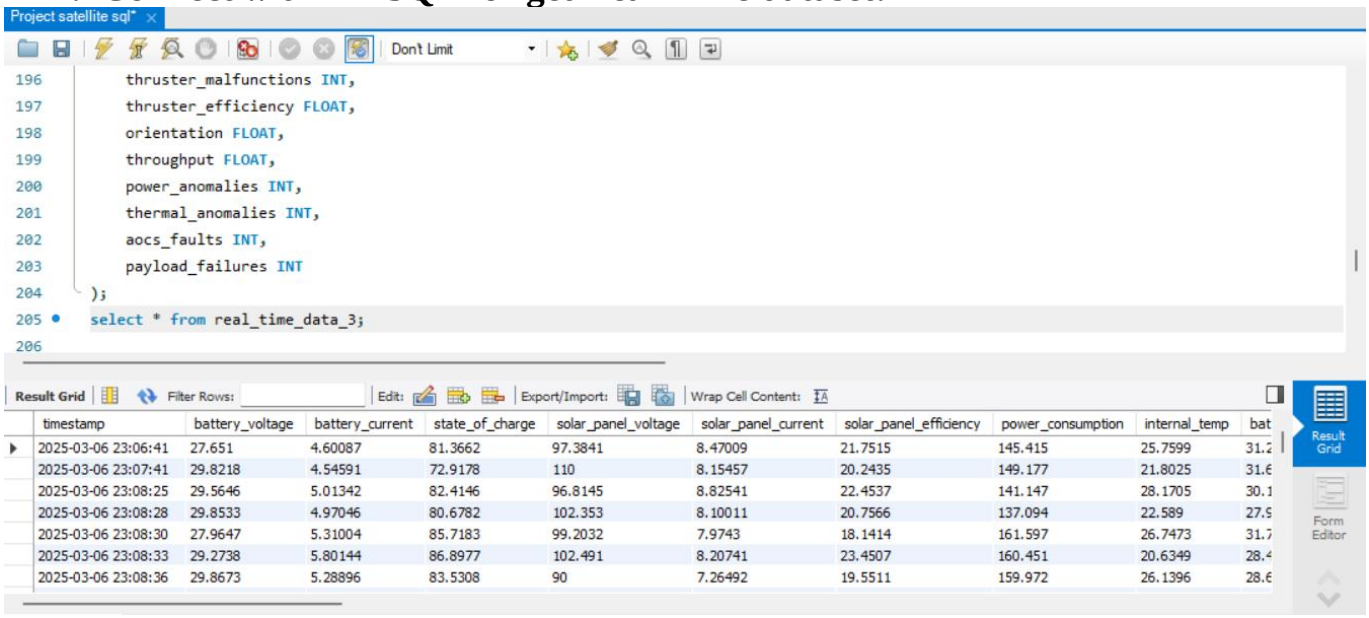
- Train an anomaly detection model (Isolation Forest) using historical telemetry data.
- Test AI predictions against simulated satellite failures.

Phase 3: Real-Time Dashboard & Alerts

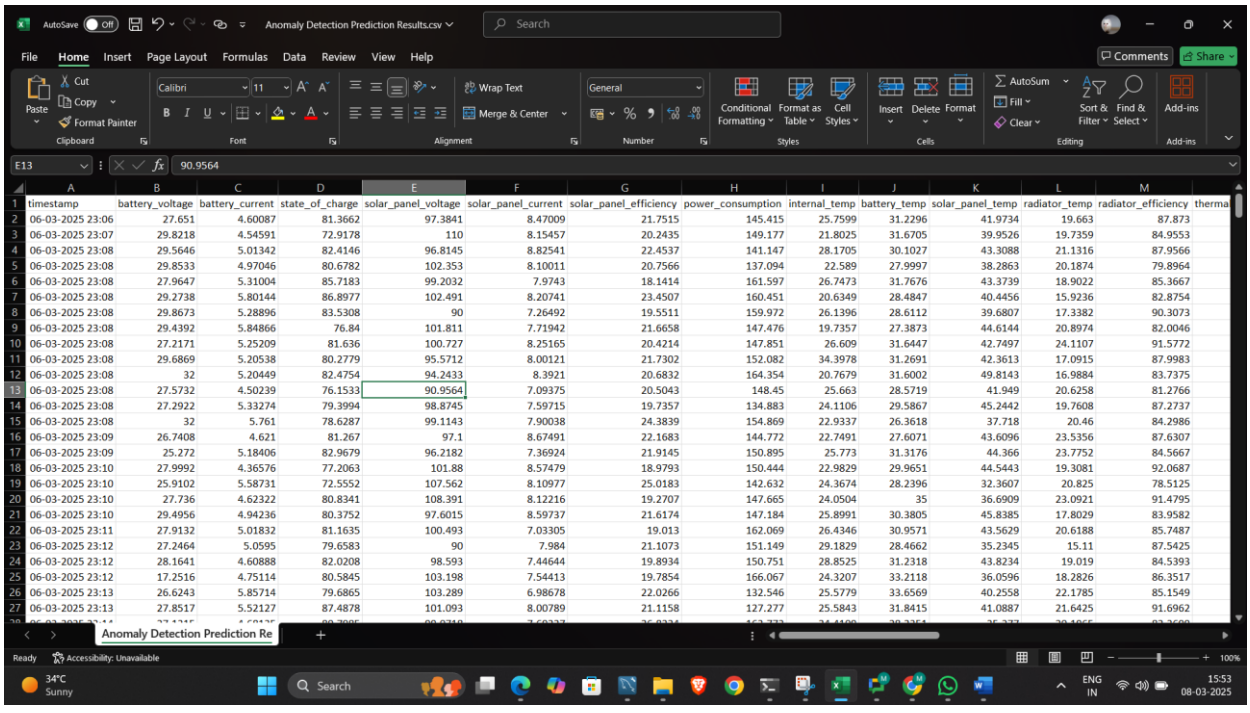
- Create an MYSQL to fetch Dataset and store the Predicted values.
- Implement an alert system (email) for detecting critical failures.
- Develop a dashboard (Streamlit) to visualize satellite status.

Screenshots:

1. Connect with MYSQL for get Real-Time dataset:



2. Dataset:



3. Alert System Output

13 of 7,048

SAT-2023-DT-001 Anomaly Alert - 2025-03-07 12:43:30.618386

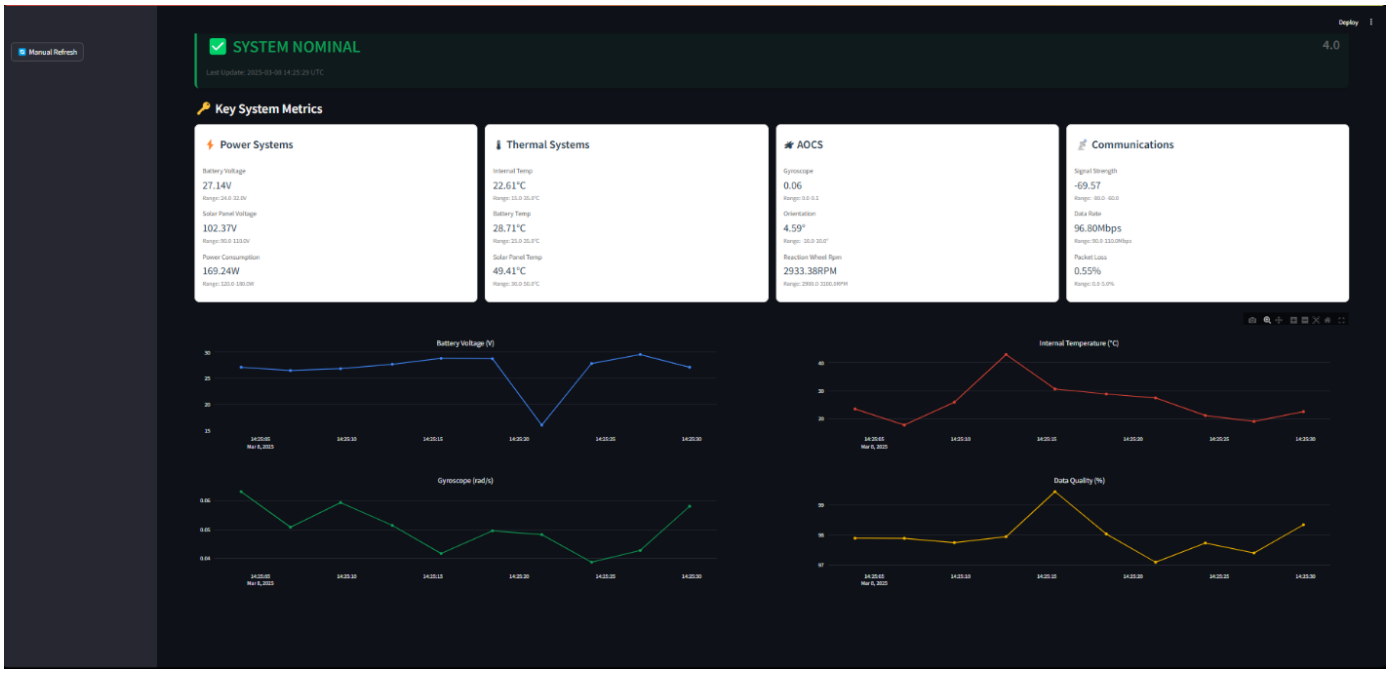
mass1441m2@gmail.com
to me

Fri, Mar 7, 12:43 PM (1 day ago)

CRITICAL ANOMALY DETECTED!
System: SAT-2023-DT-001
Timestamp: 2025-03-07 12:43:30.618386
Key Parameters:
- Battery Voltage: 29.19 V
- Internal Temperature: 21.5°C
- Gyroscope: 0.0420 rad/s
- Data Quality: 97.5%

Reply Forward

4. Streamlit Dashboard:



Using Libraries:

1. Database & Data Handling

- mysql.connector → Connects to MySQL databases.
- pandas → Handles dataframes and data manipulation.
- numpy → Supports numerical computations.

2. Machine Learning & Preprocessing

- joblib → Loads the Isolation Forest model.
- sklearn.preprocessing.MinMaxScaler → Normalizes/scales data.

3. Web Framework

- streamlit → Builds the interactive web dashboard.

4. Email Handling

- smtplib → Sends emails using SMTP.
- email.mime.multipart.MIMEMultipart → Structures email messages.
- email.mime.text.MIMEText → Handles email text content.

5. Visualization

- plotly.graph_objects → Creates charts and visualizations.
- plotly.subplots.make_subplots → Combines multiple charts in one figure.

6. Miscellaneous

- random → Generates random numbers for simulated data.
- time → Handles time-related operations.
- datetime → Deals with timestamps.
- timedelta → Manipulates date and time intervals.

Project GitHub link - https://github.com/madesh6554/AI-Powered-Digital-Twin-Prototype-for-Satellite-Health-Monitoring.git

Next Improvements

- Tune the dataset to improve the accuracy and reliability of telemetry data.
- Incorporate more realistic data to better simulate real satellite conditions.
- Enhance the dashboard for improved visualization and usability.
- Deploy the digital twin prototype on free-tier cloud hosting (Render/Supabase/Vercel).
- Conduct final testing & bug fixes.

Supporting Researches websites link:

- A Digital Twin-Based Approach for the Fault Diagnosis and Health Monitoring of a Complex Satellite System
- dasjaydeep2001/AI-Driven-Digital-Twin-for-Structural-Health-Monitoring-: This project aims to revolutionize structural health monitoring by leveraging Artificial Intelligence (AI), specifically Artificial Neural Networks (ANN), combined with Digital Twin technology. Our goal is to develop a fast-response surrogate model capable of providing real-time safety insights for critical infrastructure, such as bridges.
- data.nasa.gov/browse?sortBy=newest&pageSize=20&limitTo=datasets