TITLE:- HIGH- FIDELITY FAULT MODELING CASUAL FAILURE TREES & AUTONOMOUS DETECTION ARCHITECTURE

AUTHOR:- ARJUN A.K.A HEET TRIVEDI
EMAIL:- heettrivedi02@gmail.com

Abstract:- Sensor Arrays from the Critical perception layer in autonomous orbital systems. In Project SOLIS , (Scenario 08) focuses on the failure modes of multi sensor input networks under high stress cosmic conditions. This Scenario investigates casual factors, fault Propagation Logic, and Real Time Failure Diagnostics for Multi sensor configuration in Dyson nodes Infrastructure, while simulating Intelligent Self Response via Redundancy checks, data Confidence scores, and emergency sensor isolation. The outcome is simulation framework that ensures Resilient perception, Autonomous fallback, and Diagnostic Traceability in deep space Nodes.

Introduction (Why Sensor Integrity Matters):- In complex orbital Infrastructure such as SOLIS, sensor array provide;

- ★ *Thermal flux Readings (Cooling/Heating Balance)*
- ★ *Gyroscopic orientation (Orbital Trajectory)*
- ★ *Magnetometers (Field Alignment Detection)*
- ★ *Solar flux meters (Energy Efficiency)*
- ★ *Environmental particle monitors (Radiations, Debris, Dust)*

Failure of these arrays Compromises;

- ★ *Navigation*
- ★ *Power Optimization*
- ★ *Thermal Stability*

★ *Communication Alignment*

Hence., a failure in Sensor layer = Cognitive Blindness for nodes

Root Causes of Sensor Failure (Space Context):-

Cause	*Description*	*Frequency*
Radiation Corruption	*Bit flip in Analog to digital converters*	*High*
Thermal Drift	*Sensor Drift beyond calibration Tolerance*	*Medium*
Data Bus Fault	*SPI/ I2C Line dropout, Ghost Readings*	*Medium*
EMI Pulse/ Noise	*External Solar/ Cosmic field spikes distort Readings*	*High*
Micrometeorite Damage	*Physical layer fracture or optical lens cracking*	*Rare*
Power Dip	*Under Voltage momentarily shuts sensor cluster*	*Common*

*Sensor Array Topology in SOLIS:- Each node contains a sensor grid of 3*3 matrix, with grouped redundancy.*

Node_ 000001 Sensor map;

[TEMP | RAD | MAG]
[ACC |GYRO| SOLR]
[IR | UV | VISL]

★ *Each group contributes to environmental model trust score*
★ *2 out of 3 Validation required per axis*
★ *System averages, then confidence-weighted checks for anomaly detection*

Simulation Model for fault Injection:- Sensor Confidence Score (SCS);

$$SCS_i = 1 / \sigma_i^2 + \epsilon$$

Where., σ_i *= Variance in the last 10 Readings*
ϵ *= Noise Constant to Avoid Division by zero*

Threshold., if $SCS_i < 0.6$ ↠ *Sensor Flagged*

System Recovery Logic:- If system enters sensor alert mode;

★ *Stop Control Logic using Faulty sensor data*
★ *Maintain previous stable reading for critical ops*
★ *Attempt Dynamics Recalibration or swap*

↓

$SensorIOutput_{corrected} = \alpha * mean_{history} + (1 - \alpha) * current$

Where., α *= 0.8 during sensor error fallback*

References:- ★ *ESA Sensor Failover Handbook (2022)*
★ *MIT Analog Sensor Drift Model*
★ *IEEE Aerospace Simulation Conference*
★ *NASA Johnson Sensor Calibration Archives*
★ *Trivedi Heet – SOLIS Protocol series Vol.3*