TITLE:- AUTONOMOUS NODE RESPONSE TO SOLAR FLARE- INDUCED RADIATION EVENTS IN SIMULATED DYSON FRAMEWORK

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Abstract:- Solar flares represent one of the most sudden, Unshielded and Violent Natural phenomena capable of affecting orbital Infrastructure. These spikes generate Electromagnetic Interference Energetic particle showers, and Cumulative radiation exposure, leading to Physical Damage and Digital Corruption across on board electronic Subsystems. This Paper presents a detailed research analysis, mathematical radiation models, failure thresholds for space grade electronics, and an Executable Simulation protocols Implemented as a fallback Strategy in Autonomous Orbital nodes. The Primary aim to Build Resilient space system, that only detect such threats but also Initiate Autonomous Recovery and Logging procedures in Real Time.

Introduction:- Solar Flares are classified as Intense Bursts of Electromagnetic radiation originating from the Sun's Outer Atmosphere. When a Solar Flare Occurs, it Release vast Quantities of;

- ★ *X-rays and gamma Radiation*
- ★ *Energetic Protons and Electrons*
- ★ *Coronal Mass Ejection (CMEs)*

Context with SOLIS Project;

- ★ *Sudden Spike Event (X-Class flares, Proton Storms)*
- ★ *Radiation Induced failure of Digital Hardware*

★ *Fallback System Response Subsystem Shutdown, memory Snapshotting*

★ *Automatic logging and past- Events Diagnostic*

Physics Behind the Radiation spikes:-

<u>Solar Flare: Scientific Breakdown</u>

A solar flare events may involve;

- ★ *Class: C, M, or X*
- ★ *Typical Energy Range: 10 KeV - 100 KeV+*
- ★ *Time of Arrival: 30 seconds - 10 minutes*
- ★ *Total flux: up to* 10^7 *particles/* cm^2

The energy and particle count is sufficient to;

- ★ *Penetrate Shielding*
- ★ *Cause ionization in semiconductor gates*
- ★ *Generate single Event Effects (SEE).,*

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- ★ *SEUs - > Single Event Upsets (Bit Flips)*
- ★ *SELs - > Single Event Latch-ups (Thermal Lock)*
- ★ *SEFIs - > Single Event Functional Interrupts*

Biology & Electronic Sensitivity:-

Parameter	*Human Impact*	*Electronic Impact*
10 rad	*Safe*	*No Effect*
100 rad	*Mild Impact*	*Memory instability*
10000 rad (100 Krad)	*Lethal Dose*	*Permanent Logic corruption*

Vulnerable Subsystems in SOLIS:-

Subsystem	*Failure Mode*	*Mitigation Strategy*
CPU	*Logic Unit Corruption*	*Triple Modular Robusting (TMR)*
RAM	*Bit flips/loss*	*ECC+ Refresh*
Flash	*Permanent bit write Errors*	*Read only Fallback*
Power Convertors	*Regulator Instability*	*Voltage Clamping*
Communication Bus	*Random Noise/ Loss*	*Auto-Retry/ Timeout Handling*
Thermal Sensors	*Sensor Hallucination*	*Redundant Sensor -Comparison*

Actuators	*Latch-up State / Burnout*	*Overcurrent Breakers*

Radiation Dose Modeling (Mathematical Simulation):- Let's define a Simulated Dose Function D(c) per cycle;

$$D(c) = D_{base} + D_{flare}(c) + N(c)$$

Where., D_{base} is background Radiation (Random from 0.01 to 0.05 Krad/cycle)

D_{flare} is spike modeled as a Gaussian Burst;

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$$F(c) = A * e^{-(c-\mu)^2/2\sigma^2}$$

Where., A = Amplitude in Krad(e.g., 5 - 100 Krad)

μ = Centered cycle of flares

σ = Spread Window (~ 25 - 50 Cycles)

N(c) = Random Fluctuations (Uniform noise: $\pm\, 0.01\ Krad$)

Fallback Trigger Model:- Fallback model is Triggered if;

★ $\Sigma D(c) > D_{critical}$

★ *Critical System flag: memory_ corrption = true.*

★ *Subsystem Count failed > 3*

Trigger Protocol;

(i) Pause Sensor Polling

(ii) Snapshot last state

(iii) Enter minimal power loop

(iv) Log all values

(v) Await Manual or Autonomous Reboot Signal

References:- ★ *IEEE Transactions or Nuclear Science*

★ *NASA: Space Radiation Analysis group (SRAG)*

★ *ESA SOHO Data Analysis Toolkit*

★ *MIT Radiation Resilience study (2022)*

★ *Trivedi Heet – SOLIS Fallback Intelligence, Vol.1*