Space Vehicle

Derived Requirements
System Configuration Requirements (1 Of 2)

- Few "Hard" Requirements
  - Early 1994 Initial Launch Capability
  - Enabling SDIO Technologies, e.g., Sensors, Composite Materials
  - Lunar Mapping & Asteroid Encounter

- Derived Requirements:
  - Medium Launch Vehicle (Titan II)
  - 8 Month Mission Duration In $\leq 20$ kRad (Si) Radiation Environment
  - Telemetry & Command Link Compatible With Deep Space Network (DSN)
  - Data Storage For Out-Of-View Sensor Image Data Using JPEG Compression
  - Selected Autonomy Level To Minimize Ground Support
  - Attitude Knowledge $0.03^\circ$ / Attitude Control $0.05^\circ$
Derived Requirements (2 of 2)

- Parts Program
  - Best Available With In Hermetically Sealed Packages
  - Controlled Processing Line (883B Or Better)
  - Acceptable SEU Rate; Non-Mission Critical
  - SEL Immune

- Minimum Documentation
  - Critical Item Specifications For Purchased Components; i.e. Transponder, Reaction Wheel, IMU, Solid State Recorder, Solar Array Drive Motor, Solar Arrays, & Nickel Battery
  - Formal Mission Sensor To Spacecraft Interfaace Control Documents (ICD's)
  - Environmental Test Plan
  - Subsystem/Component Level Drawings, Schematics, Assembly Drawings, Parts Lists, & Board Layouts
  - Software Requirements Documents & Top-Level Test Plans
  - Range Documentation
EEE Parts Program

- Provide The Highest Reliability Level Available Within Program & Schedule Limitations
- Hermetically Sealed Parts
- Radiation Hardness Characteristics Be Established, Implemented & Maintained
- Standard Parts Selected According To:
  - MIL-STD-975 Grade 1 & 2
  - JANS & JANB Microcircuits Per MIL-M-38510 Not Listed Within MIL-STD-975
  - JANTXV, JANTX, & JANS Semiconductor Devices
  - Passive Devices Procured Under Established Reliability Level Of "S" & "R"
  - NRL Qualified Parts List (SSD-D-AS139)
- All Other Parts Selection Are Considered Non-Standard
- Defined Waiver Process With SDIO Participation

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DSPSE Documentation Tree

- Only Program Essential Documents Are Planned
- 23 Documents Necessary For Procurement, Interface Control, & Launch Integration Are Released

DSPSE Documentation Tree 11/11/92
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DSPSE Test Philosophy

- Provide Flight Hardware With A High Probability To Meet Mission Objectives
  - Engineering Model For Structural Testing
  - Brassboard "Black Boxes" Prior To Flight Unit Delivery
  - Extensive Design Verification Testing
  - Rigorous Component Level Testing
  - Selected Non-Destructive Stress Tests
  - Test Flight Hardware With Simulated Launch & On-Orbit Flight Environments
  - Extensive Involvement Of Subsystem Engineers From Concept Development Through On-Orbit Operations
DSPSE Levels of Test

- **Acceptance:** Verify Component Performance Under Environmental Conditions Similar To Those Occurring During The DSPSE Mission
- **Qualification:** Verify Component & System Performance Under Environmental Conditions More Extreme Than Those Anticipated To Occur
- **Protoflight:** Verify Component & System Performance Under Environmental Conditions More Extreme Than Those Anticipated To Occur During the Mission But Less Extreme Than A Formal Qualification Environment

The DSPSE Test Program Emphasizes Protoflight Testing
Electromagnetic Compatibility (1 Of 3)


- Conducted Emission
- Meet The Conducted Emissions Levels
  - CE01 - As Specified In MIL-STD-461C
  - CE03 - Narrowband & Only As Specified In MIL-STD-461C
  - CE07 - As Specified In MIL-STD-461C With The Following Exception: Paragraph 5.2 b) Modified To Read: "DC Leads: +50 Percent, -50 Percent Of Nominal As Voltage."

- Conducted Susceptibility
  - CS01 - As Specified In MIL-STD-461C Tailored By Figure A
  - CS02 - As Specified In MIL-STD-461C With The Following Exception: Paragraph 7.2 Modified To read: "...When Subjected To 0.5 Volt From A 50-Ohm Source."
  - CS06 - Section 11.2 a. Only & As Modified To Read: "E1 = ± 30 Volts Peak"
Electromagnetic Compatibility (2 Of 3)

- Radiated Emissions
  - RE02 - Broadband As Specified In MIL-STD-461C. Narrowband & As Tailored By Figure B

- Radiated Susceptibility
  - RS03 - As Specified In MIL-STD-461C With The Following Modifications:

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>E-Field (Volts/Meter)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 KHz To 30 MHz</td>
<td>1</td>
</tr>
<tr>
<td>30 MHz To 10 GHz</td>
<td>5</td>
</tr>
<tr>
<td>Above 10 GHz</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Electromagnetic Compatibility (3 Of 3)

Figure A
Limit For CS01 Susceptibility

Figure B
Limit For RE02 Narrowband Emissions
Space Vehicle

Radiation Environment
Agenda

- Introduction To the Earth Space Environment
- Solar Flares
- Radiation Effects
  - Dosage Effects
  - Single Event Effects
  - Examples From 1989 Storms
- Radiation Effects Panel
  - Charter
  - Screening Procedures
Solar Flares

August 1972 Al flare

Solar-flare proton fluences (vertical lines) superimposed on the sunspot cycle (continuous curve).

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Time Scale For Solar Flare Effects

- X-RAY EMISSION
- Sunlit Ionospheric Disturbance
- RADIO NOISE EMISSION
- HF Interference
- PROTON ARRIVAL AT EARTH
- Major Ionospheric Disturbance
- PCA Event
- SOLAR PLASMA
- Magnetic Storm

Energy (MeV)

- 1000
- 100
- 10
- 1
- 0.1

Time Scale:
- 1 MIN
- 10 MIN
- 1 DAY
- 10 DAYS
- 27 DAYS

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Comparison Of The 3/89 & 10/89 Solar Proton Events (E >10 MEV) With The 8/72 Event
The Earth's radiation belts in idealized dispute space, according to the AF and ABE models. Average omnidirectional integral fluxes above energy thresholds are shown.
Earth's Radiation Belts (Idealized Dispute Space) (2 of 2)
Variations In E >2 MEV Electrons & Kp Index At Midnight (Geosynchronous Orbit) (1 of 2)
Variations In E >2 MEV Electrons & Kp Index
At Midnight (Geosynchronous Orbit) (2 of 2)

PROBABILITY OF EXCEEDING GIVEN LEVELS OF FLUENCE ENERGY > 10 MeV
ACTIVE YEARS OF SOLAR CYCLE

PROTON FLUENCE >10 MeV 1956-1985 (ACTIVE YEARS)
Total Dose Effects On Microelectronics

\[ \Delta L_B \text{ vs Total Dose for LM108 Amplifiers} \]
Schematic Representation Of Sensitive Region In A Single Memory Cell

SURFACE OF SILICON CHIP, GREATLY ENLARGED

\[ \approx 25 \mu \]

SENSITIVE REGION

CHARGE CLOUD

COSMIC RAY TRACK

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Proton Mechanism

Primary Protons

Overlayer in Chip

Sensitive Volume

Proton Direct Ionization

Spallation-Caused SEU

Proton LET Curve

Proton Range Curve

Let $E_P$

Range $E_P$

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Integral Proton Energy Spectra, Solar Flare Particle Events

HEAVY ION COUNTER + protons

- D DOUBLE
- T TRIPLE
- P HOSP
- N HDPE

+ PROTONS > 10 MeV
+ PROTONS > 50 MeV
o PROTONS > 100 MeV

FLUX (cm$^{-2}$s$^{-1}$sr$^{-1}$)

TIME (DAY 1989)

GOES proton flux and HIC ion flux

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GOES Proton Flux

HEAVY ION COUNTER + protons

Flux (cm$^{-2}$s$^{-1}$)

Time (Day 1989)

O DOUBLE
T TRIPLE
P HOISP
N HOOPEN

+ PROTONS > 10 MeV
+ PROTONS > 50 MeV
+ PROTONS > 100 MeV

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5 shielding configurations considered in the NOVICE code for calculating dosage. Note that examples 3 and 4 are doubled by the code.

1. HOLLOW SPHERE

2. SOLID SPHERE

3. SINGLE SLAB

4. BACK SLAB

5. DOUBLE SLAB
Radiation Dose From Trapped Electrons

![Graph showing radiation dose from trapped electrons vs. shielding thickness. The graph compares the dose for different shielding configurations: sphere, spherical shell, double slab, and back slab. The x-axis represents shielding thickness in mils of aluminum, and the y-axis represents dose in Rads.](Image)
Solar Flare Proton Dosage (Rad (Si)) For A 90% Probable Maximum Dose

Solar Proton Dose
90% level of certainty

10^6
10^5
10^4
10^3
10^2
10^1

1
10
100
1000

TOTAL DOSE (Rads Si)

THICKNESS of ALUMINUM SHIELDING (Mils)

CDR/DR

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"Worst Case" Solar Proton Dosage Predictions
≈1 Year DSPSE Mission

<table>
<thead>
<tr>
<th>Probability Dose</th>
<th>Maximum Dose</th>
<th>Rad (Si)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Does Not Exceed:</td>
<td>5.8 mils</td>
<td>58 mils</td>
</tr>
<tr>
<td>50%</td>
<td>8,710</td>
<td>466</td>
</tr>
<tr>
<td>90%</td>
<td>33,500</td>
<td>2,750</td>
</tr>
<tr>
<td>95%</td>
<td>51,400</td>
<td>4,640</td>
</tr>
<tr>
<td>99%</td>
<td>138,000</td>
<td>12,700</td>
</tr>
</tbody>
</table>

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The DSPSE Environment

- Trapped Radiation (No RDM)
  - Dose For First 6 Months Of Current Mission:
    
    $0.04 \text{ G/CM}^2$  
    $\approx 6 \text{ Mil} \quad 4.85E4 \text{ Rad \ (IC EXPS)}$
    
    $0.40 \text{ G/CM}^2$  
    $\approx 60 \text{ Mil} \quad 1.06E3 \text{ Rad \ (Sensors)}$

- Solar Flare (Assume Active Part Of Cycle/No RDM)
  - Total 1 Year Solar Flare Dose (90% Probability That total Dose Will Be Equal To Or Less Than):
    
    $0.04 \text{ G/CM}^2$  
    $\approx 6 \text{ Mil} \quad 3.35E4 \text{ Rad \ (IC EXPS)}$
    
    $0.40 \text{ G/CM}^2$  
    $\approx 60 \text{ Mil} \quad 2.75E3 \text{ Rad \ (Sensors)}$

- Space Plasma
  - Will See Geosynchronous Charging Environment & Radiation Belts $\approx 7 - 8$ Times. Exposed To Surface ($V \leq 20 \text{ KV}$) & Buried Charge Effects.

- Solar EUV/Contamination
  - Exposed For 1 Year To Solar UV/EUV & Spacecraft Contamination
DSPSE Radiation Design Guideline Total Dose

60 MILS  7.6 KRAD (Si)*
6 MILS  167 KRAD (Si)*

* INCLUDES RDM OF 2
Radiation Effects Panel Charter

- Develop Mission Electronic Parts Screening Procedures Document
- Panel Will Represent Project & Program Offices In Reviewing Compliance With The Screening Procedures
- Maintain Cognizance Of All Electronic Parts That Do Not Meet Mission Design Requirements
- Maintain Electronics Parts Waiver Request Database