Essential Failure Modes and Effects Analysis (FMEA) and the Design Influence of Space Launch Vehicle Avionics Systems
Background

- Sophisticated electronics are prevalent in modern launch vehicle avionics system
  - Such as flight control computers and engine controllers
- Schedule, cost and safety risk constraints result in increased reliance on analysis over integrated testing
- Avionic system circuits use plenitude of passive and active electrical components
  - such as resistors, capacitors, inductors, transistors, amplifiers, etc.
- The cost of single electrical components is small compared to entire space exploration missions.
- FMEA can effectively influence design and reduce loss of mission risks
Our Solar System

The Sun

Mercury

Venus

Earth

Mars

Jupiter

Saturn

Uranus

Neptune

Pluto

Comets

Asteroids
Presentation Outline

• Background

• Electrical Component Review

• Electrical Diagram Tutorial

• Circuit-Level FMEA

• Design Solution
1. Electrical Component Review

- **Passive Components**
  - Does not require a power supply to perform its intended function
  - Includes resistors, capacitors, inductors, transformers, etc.
  - Includes RC, RL, and RLC filters

- **Active Components**
  - Requires a power supply to perform its function
  - Includes diodes, transistors, operational amplifiers, etc.
1.a Passive Components Cont.

• Resistors have several functionalities and can be utilized as:
  • Current Limiter
  • Voltage divider
  • Wheatstone Bridge Circuits (Gage Strain)
  • Heat-sense application (photoresistor)
  • Light brightness

• Capacitors store electric charge to be available the charge when needed for immediate use
  • The reactance nature of capacitors is utilized in signal noise filtering
Filters are used in circuits to be responsive to certain frequencies
- Very effective at filtering noise from signals

For instance, an RC filter can be designed for a specific cutoff frequency, and comes in two basic types:
- Low-pass filter (Filters AC signals)
- High Pass filter (Filters DC signals)
1.b Active Components

- Transistors are semiconductors doped with impurities to manipulate current flow
- Mostly used as electronic on/off switches and amplifiers
- They come in different types:
  - BJT (N-P-N and P-N-P)
  - FET
  - MOSFET
1. c Integrated Circuits

- A chip containing discrete electronic components (passive and active) functioning together as a larger circuit
2. Notional Vehicle Block Diagram

- Crew Capsule & Abort System
- Dual Abort Recommendation System
- Engine Sensors
2. Reading Electrical Diagrams
### 3. Circuit Level FMEA

<table>
<thead>
<tr>
<th>Component</th>
<th>Failure Mode</th>
<th>Immediate Effect</th>
<th>Next Effect</th>
<th>Final Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transistor 1</td>
<td>Fails short</td>
<td>Collector-to-emitter shunts (makes), allowing Vcc to supply power to R1</td>
<td>Load 1 energizes, as well as Load 2 due to common wiring. False-positive Abort recommendation is sent to crew</td>
<td>Loss of mission, vehicle and crew</td>
</tr>
<tr>
<td>Transistor 2</td>
<td>Fails short</td>
<td>Collector-to-emitter shunts (makes), allowing Vcc to supply power to R2</td>
<td>Load 2 energizes, as well as Load 1 due to common wiring. False-positive Abort recommendation is sent to crew</td>
<td>Loss of mission, vehicle and crew</td>
</tr>
<tr>
<td>FPGA - Pin1</td>
<td>Fails high</td>
<td>Pin1 supplies power to the base pin of Transistor1, collector-to-emitter</td>
<td>Load 1 energizes, as well as Load 2 due to common wiring. False-positive Abort recommendation is sent to crew</td>
<td>Loss of mission, vehicle and crew</td>
</tr>
</tbody>
</table>
4. Design Solution

![Diagram of a circuit solution involving ADC, FPGA, engine sensors, and load notifications.]
Questions

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