Printed Electronic Devices in Human Spaceflight
Jack Bacon
NASA/JSC/OM3

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The space environment requires robust sensing, control, and automation, whether in support of human spaceflight or of robotic exploration. Spaceflight embodies the known extremes of temperature, radiation, shock, vibration, and static loads, and demands high reliability at the lowest possible mass. Because printed electronic circuits fulfill all these requirements, printed circuit technology and the exploration of space have been closely coupled throughout their short histories. In this presentation, we will explore the space (and space launch) environments as drivers of printed circuit design, a brief history of NASA's use of printed electronic circuits, and we will examine future requirements for such circuits in our continued exploration of space.
Printed Electronic Devices in Human Space Flight

Jack Bacon Ph.D P.E
NASA Johnson Space Center
Mail Code OM3
Houston, TX 77058
(281) 244-7086
john.bacon-1@nasa.gov
Agenda

• Part 1:
  – Why and how people go to space
• Part 2:
  – Challenges of the space environment
• Part 3:
  – Status, Challenges and Opportunities for Printed Electronics in Human Spaceflight
REVOLUTIONIZING SPACECRAFT MASS:
TOWARD A "SPACECRAFT ON A CHIP"

PAST  PRESENT  FUTURE

10 kg

100 kg

1000 kg

NASA

CASSINI

MARS PATHFINDER

MARS '98 LANDER

SSTI/ DISCOVERY

PLUTO FLYBY

"NEW MILLENIUM SPACECRAFT"
Pressure Containment

Thermal Protection

Internal heat rejection(!)

Computers, radios, gyros, engines, etc.

Electrical Power
Fluid behavior
in a propellant tank

Design Limit + Margin

Design Limit
Qualification Limit
Certification Limit
Operating Limit
Design Limit + Margin

Design Limit
Qualification Limit
Certification Limit
Operating Limit
INTERNATIONAL SPACE STATION
A New Star On the Horizon!
AO Erosion

Source: NASA Reference Publication 1390
Failures and Anomalies Attributed to the Natural Space Environment
Factors Affecting Space Systems

- High accelerations
  - Static/oscillating \(-3 \text{ G's}\)
  - Shock \(\approx 0.05 \text{G}^2/\text{Hz}\), up to 1000 G's peak load

- Highly competitive RF environment
  - Spacecraft in view of 98\% of world population
    - Every manmade source is line-of-sight
    - EMI field high: especially outside
    - IVA environment in a Faraday cage with hundreds of sensitive systems— including people

- 3-phase medium (gas, solids, liquids)

Factors Affecting Space Systems

- Severe materials limits
  - Flammability
  - Offgassing
  - Outgassing
  - Toxicity

- Dense packing
- Multi-layer assemblies & systems

- High radiation environment
- Large thermal extremes
Factors Affecting Space Systems

- Atomic Oxygen corrosion (LEO)
- Particulate erosion/puncture
- Vacuum
- Oscillating Temperatures

Future Issues

- Lunar and Martian Dust
  - Gums up any works...
- Higher radiation
- Longer durability
  - (years/decades)
- The Unknown....
Opportunities:

- **Inventory is critical**
  - Finding it can be a problem
- **Weight and performance are drivers**
  - Sensors
  - Effectors
  - Connectivity
- **Reliability and Durability**
  - If it moves, it can break
  - If it moves a lot, it can break faster
  - ...and it must not break....