



Engineering, Test & Technology  
Boeing Research & Technology

# Applications of Flexible Hybrid Electronics (FHE) in Harsh/Extreme Environments

Robert Smith, PhD, TF  
Advanced Electromechanical Technologies  
Boeing Research & Technology  
[robert.a.smith8@boeing.com](mailto:robert.a.smith8@boeing.com)

# What is Boeing?



1925: Boeing Air Transport enables cargo transport in the emerging Air industry

2017: Boeing is World's Largest Aerospace Company



# Potential Applications For Electronics In Harsh Environments

- Aircraft Engine Control Electronics (300-600°C)
- Environment control systems
- Aircraft braking systems (~250°C)
- Embedded Sensors
- Hypersonic Vehicles
- Rocket Engines
- Space Based Radar Applications
- High Voltage Air/Spacecraft Bus Electronics
- Control Electronics For Harsh Environment Power Converters
- Terrestrial Vehicles Operating In Desert Environments
- Long Duration Space and CisLunar Missions
- Industrial Applications in the Factory (Autoclaves, etc..)



# What Are Harsh/Extreme Environments?

## Definition of Harsh Environments for Avionics

- Temperatures over 200°C
- High Radiation Flux Density > Mrad
- High Operating Voltages 10V – 1000V
- Mechanical vibrations



### Flight Altitudes:

Drops 2°C per 1000 ft, However, speed creates compressibility that raises temp, Rain, Lightning, Winds, etc...

Transition Time to Altitude: 10 to 20 minutes

Take-off/Landing

**Cold Desert Climate:**  
-50°C to 10°C, Very Dry, High Pressure, Dynamic Fronts



**MidWest Climate:**  
-20°C to 40°C, Rain, Fog, Snow, Varying Pressure



**Hot Desert Climate:**  
0°C to 50°C, Very Dry, High Pressure, Dynamic Fronts



**Temperature range:**  
-40°C to 85°C versus 0°C to 70°C for most commercially available solutions

# Variations for Military Applications

For Rotorcraft: The considered harsh environments are humidity, sand/dust, and salt spray fog mixed with various temperature levels



For Missiles: A harsh environments are humidity with various temperature levels and degradation of propellants



When systems are operating in these environments the removal of heat from electrical systems can be important



# For Space Exploration

Missions in the central (equatorial) regions of the Moon:

Limitations:

- Daylight temperatures at lunar “noon”  $380\text{K} = 107^\circ\text{C}$
- Temperatures at lunar “midnight”  $120\text{K} = -150^\circ\text{C}$

An Extreme Environment for rockets includes instrumentation that can operate at cryogenic temperatures, down to  $35\text{K} (-238^\circ\text{C})$

An Extreme Environment for Space Travel includes temperatures swings from  $120^\circ\text{C}$  to  $-150^\circ\text{C}$  depending on sun exposure



# Boeing Technology/Material Needs

Some of the Things Boeing is Seeking to Enhance with FHE:

- Knowledge of Corrosion Status in Materials
- High Conductivity Materials
- Fabrication of Large FHE Arrays/Systems
- Robust Interconnects
- Substrate Materials
- Component Integration



# Boeing's Interest in FHE

## Lighter Weight

- 1% weight reductions can equate to billions in operating cost savings to carriers.

## Less Complexity, Improved Maintenance, Higher Reliability

## Added Capability



Printed electronics is an enabler