

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

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### What is Boeing?



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

2017: Boeing is World's Largest Aerospace Company









































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## 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

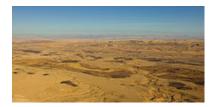
Cold Desert Climate: -50°C to 10°C, Very Dry, High Pressure, Dynamic Fronts



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



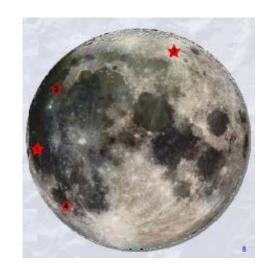
#### For Space Exploration

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

- Daylight temperatures at lunar "noon" 380K = 107°C
- Temperatures at lunar "midnight" 120K = -150°C

An Extreme Environment for rockets includes instrumentation that can operate at cryogenic temperatures, down to 35K (-238°C)

An Extreme Environment for Space Travel includes temperatures swings from 120°C to -150°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

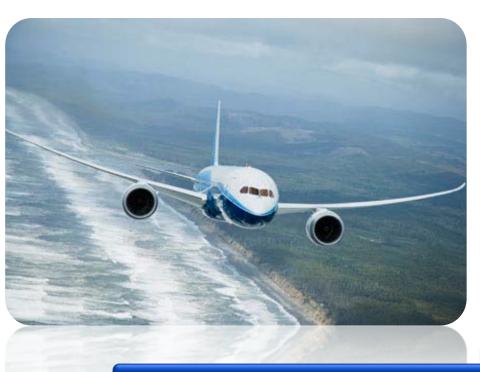


#### **Boeing's Interest in FHE**

#### **Lighter Weight**

 1% weight reductions can equate to <u>billions</u> in operating cost savings to carriers.

## Less Complexity, Improved Maintenance, Higher Reliability Added Capability





Printed electronics is an enabler