



GOMACTech-2024

Printed Hybrid Electronics (PHE) in a Flight Environment: 3D Printed Electronics on Suborbital Technology Experiment Carrier 9 (SubTEC-9)

March 19, 2024

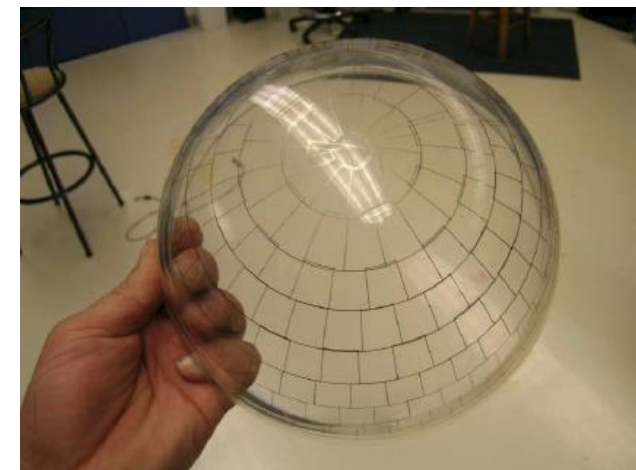
Beth Paquette/ NASA GSFC

Jason Fleischer/Laboratory for Physical Sciences



To be presented by Beth Paquette at GOMACTech, Charleston, SC, March 19-21, 2024

- Printed Hybrid Electronics (PHE) – additive manufacturing technique where electronic circuits are fabricated by depositing materials onto an existing substrate without the use of masking or etching, and using existing electrical components
- Advantages:
 - Fine feature sizes down to 20-30 microns
 - Variety of substrates – flexible, rigid, 3-dimensional non-planar
 - Demand for increased sensitivity and performance
 - Reduced size weight and power (SWaP)
 - Subsystem miniaturization can increase the SWaP available for instruments, thereby increasing the science return for a mission
- Applications:
 - Hard Energy X-Ray Photoelectric Polarimeter (HXPP) detector strips
 - Next Generation Microshutter Arrays (NGMSA) interconnects
 - Microcontroller Circuitry providing telemetry data

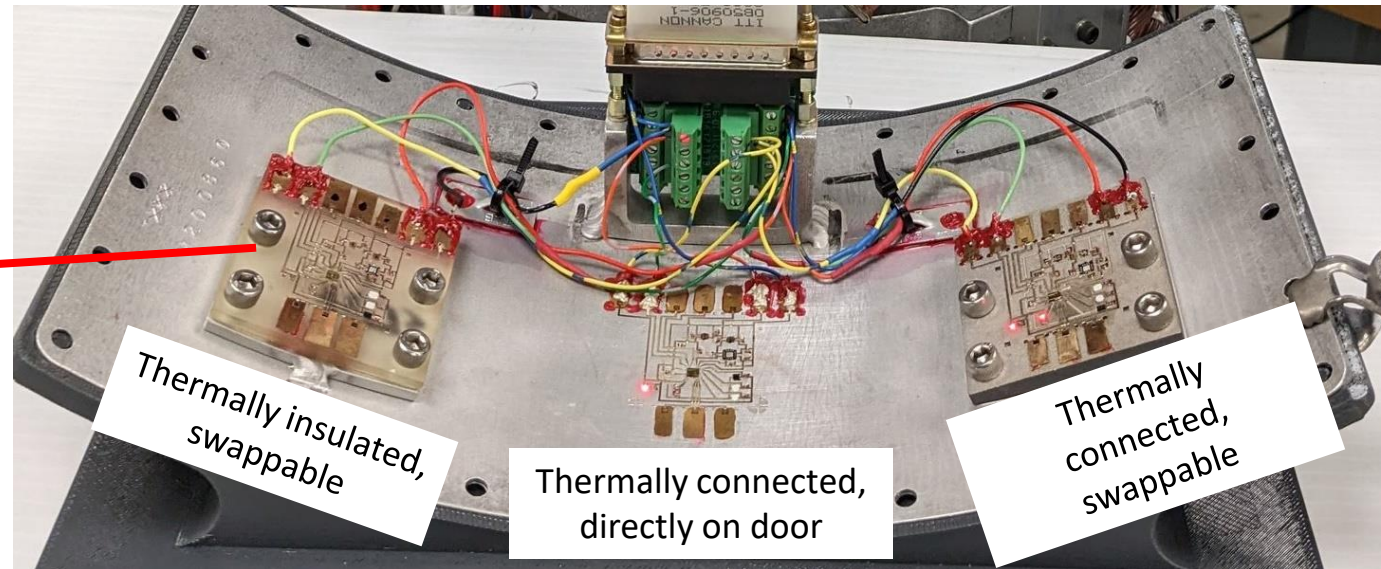
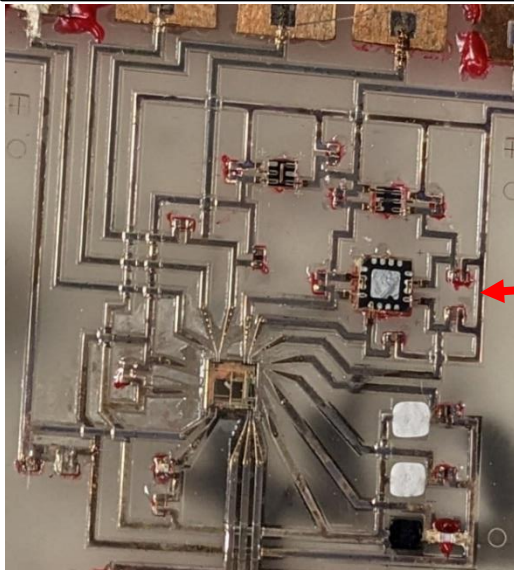


EMI shield [Optomec]

PHE Experiment Objective

- Additively Manufacture Arduino-type microcontroller Circuits, including temperature and Humidity sensors on the inside of a sounding rocket payload door in a waterproof section
- Collect data and recover circuits from experiment to evaluate performance over flight and robustness of the circuits

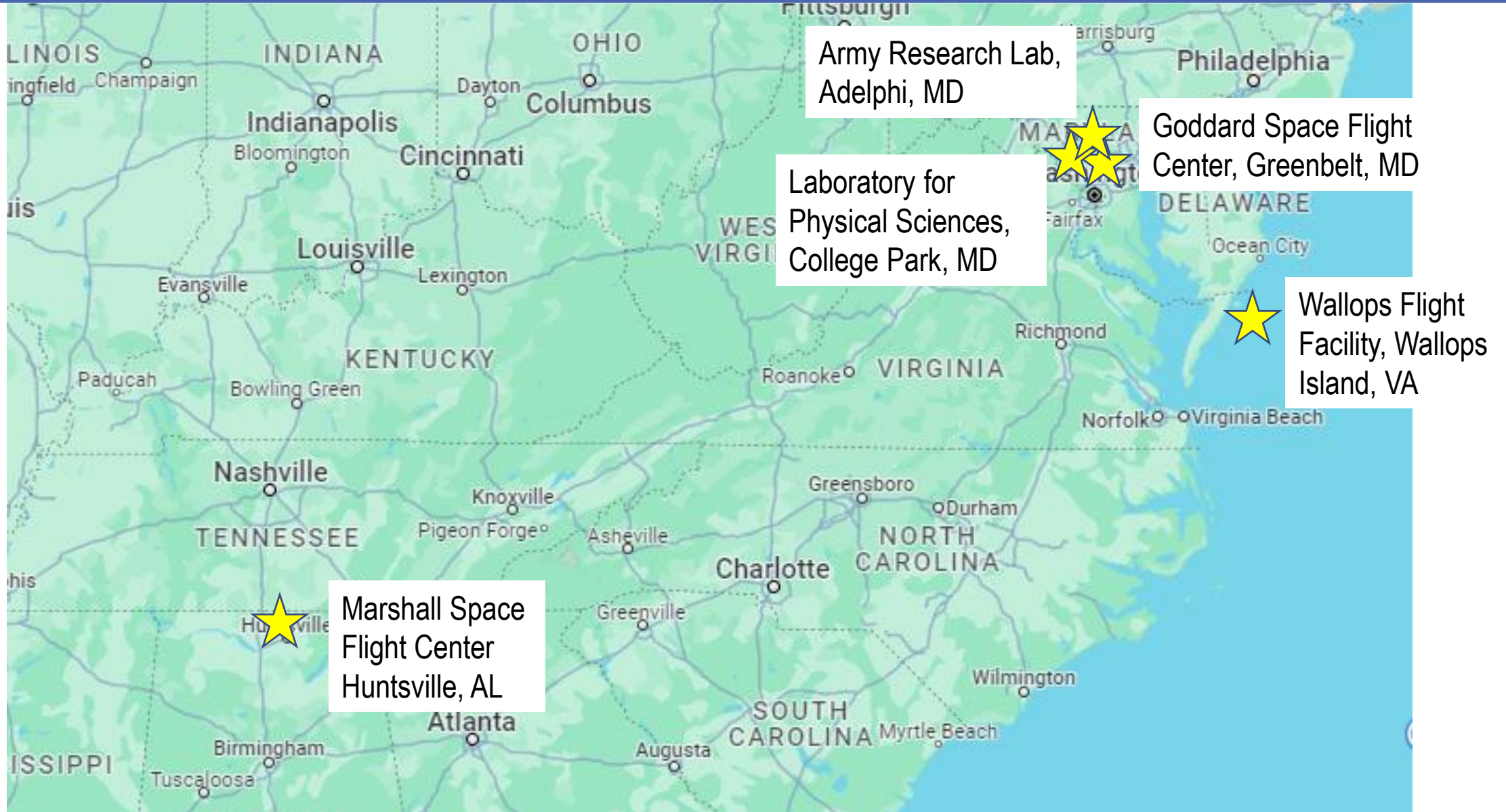
This experiment provides environmental data on the technology that we did not have before!



12 inch x 6 inch curved aluminum door panel

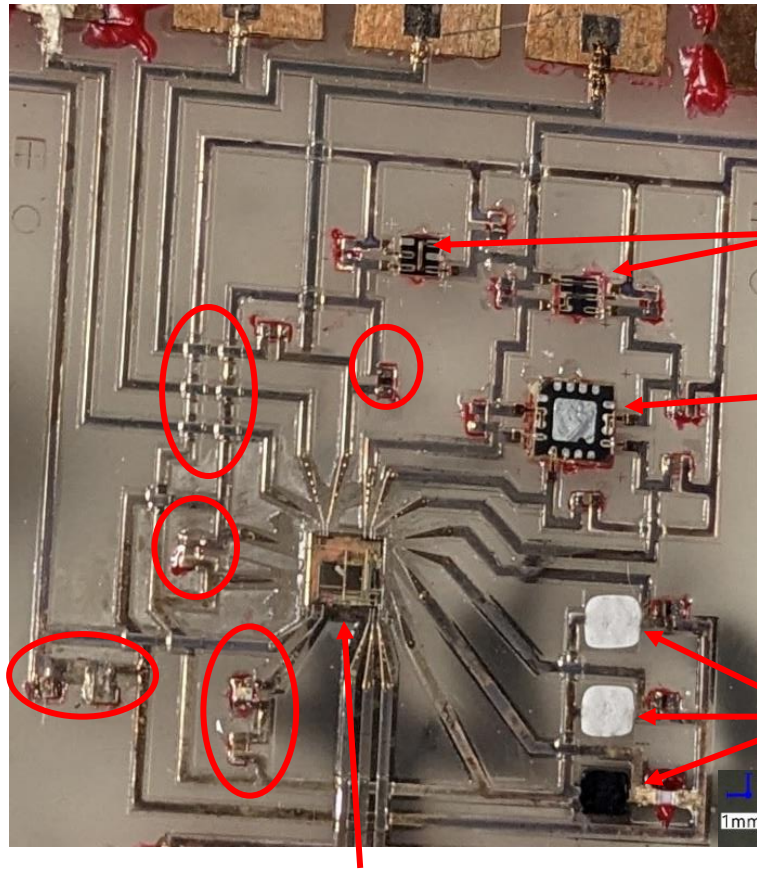


PHE Experiment Team



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- Cavities were milled out of or printed with the substrate
- Components were placed upside down in the cavities
- Insulating “moats” were added around the components
- Traces were printed to the pads on the components to complete the circuit – multiple layers



Voltage Regulators

Accelerometer

Passive
Components
(circled)

Syringe Printed
Temperature and
Humidity Sensors

Microcontroller bare die,
unencapsulated

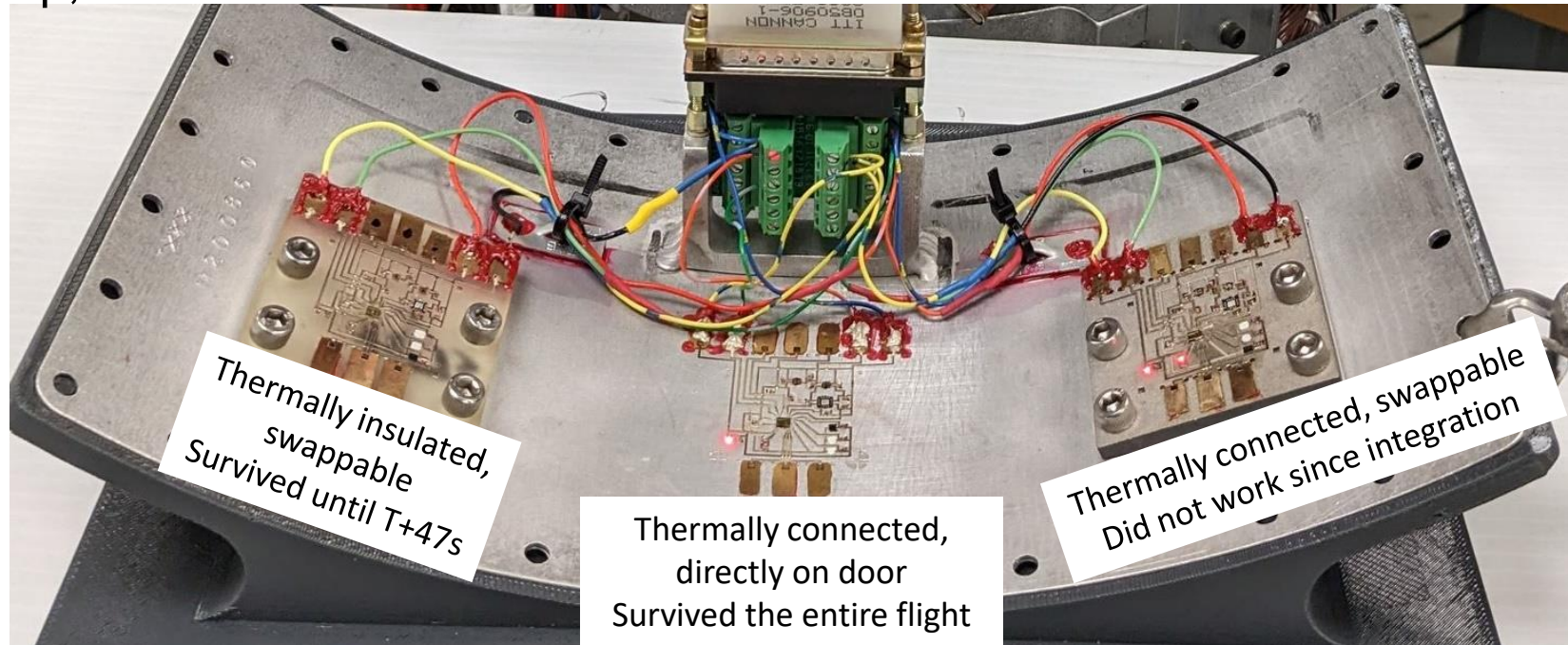
- Suborbital Technology Experiment Carrier 9 (SubTEC-9)
- 14 Experiments on board
- 20 ft long payload, Terrier-Improved Malemute Vehicle
- 181.5km altitude
- Launched from Wallops Island, VA April 25, 2023
- 12 minute flight



Sub-TEC 9 Launch [Youtube]

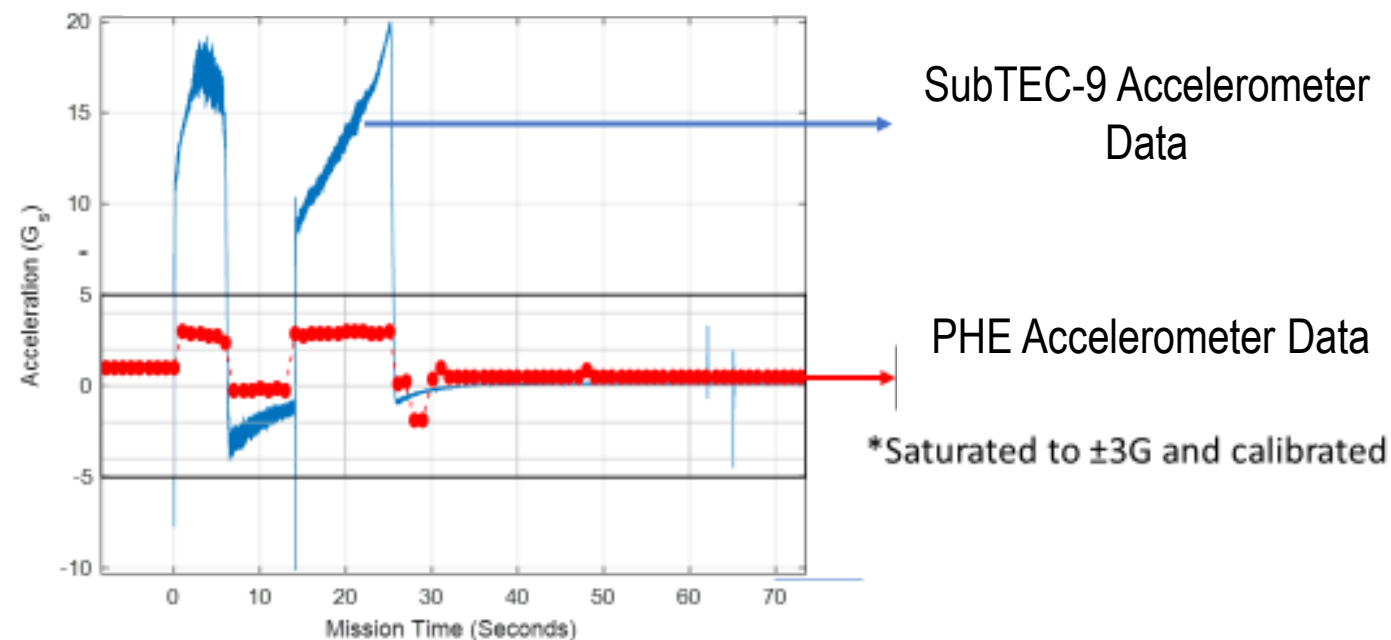
Post-Flight Analysis: Flight Data

- Monitored PHE circuit health during flight in real-time
- Received telemetry data recorded from flight
- Analyzing data from events leading up to flight, including vibration tests, payload buildup, and dress rehearsal



- T+47 seconds:
 - PHE current increases
 - Thermally Connected Circuit printed directly on door rebooted
 - Thermally insulated Swappable circuit stops functioning
- Acceleration and sensor data follows main payload data

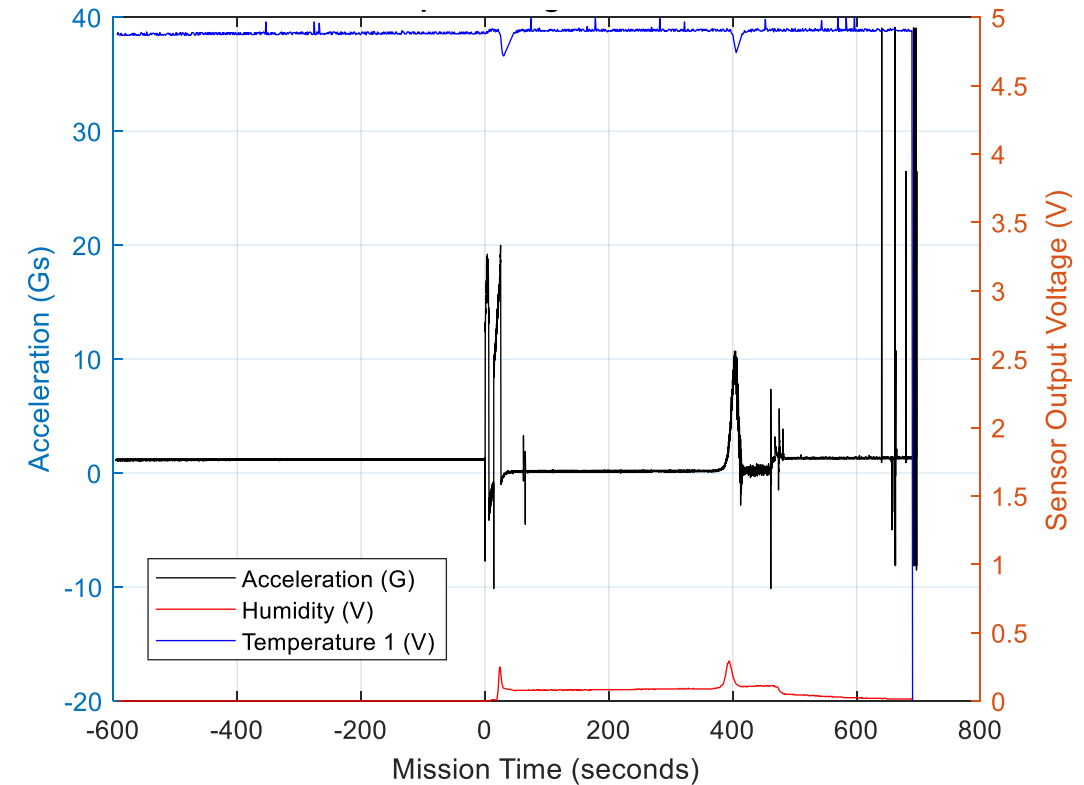
Accelerometer Data Comparison



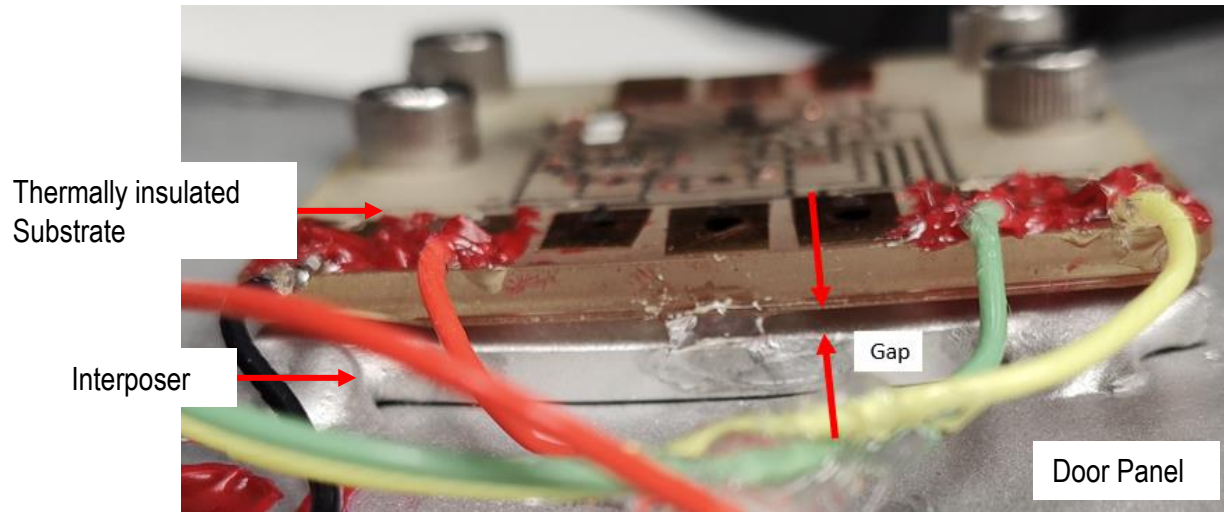
Post-Flight Analysis: Flight Data

- One sensor suffered from a voltage anomaly
- Remaining sensors showed responses to the launch and recovery events

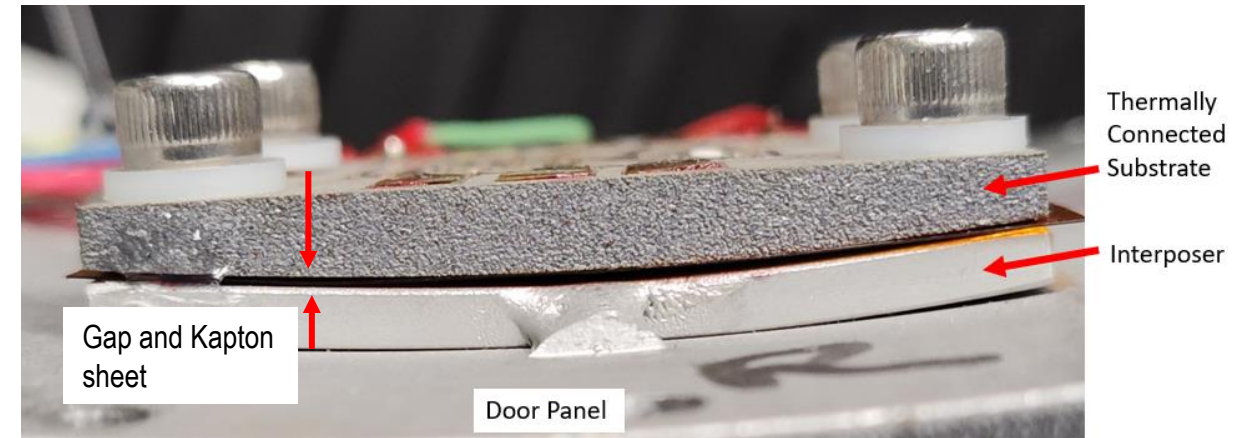
Sensor Voltages Compared to Acceleration Events of Flight



- Gaps between swappable substrates and door panel
- Creates additional stresses on substrates
- Leads to extra stresses in vibration



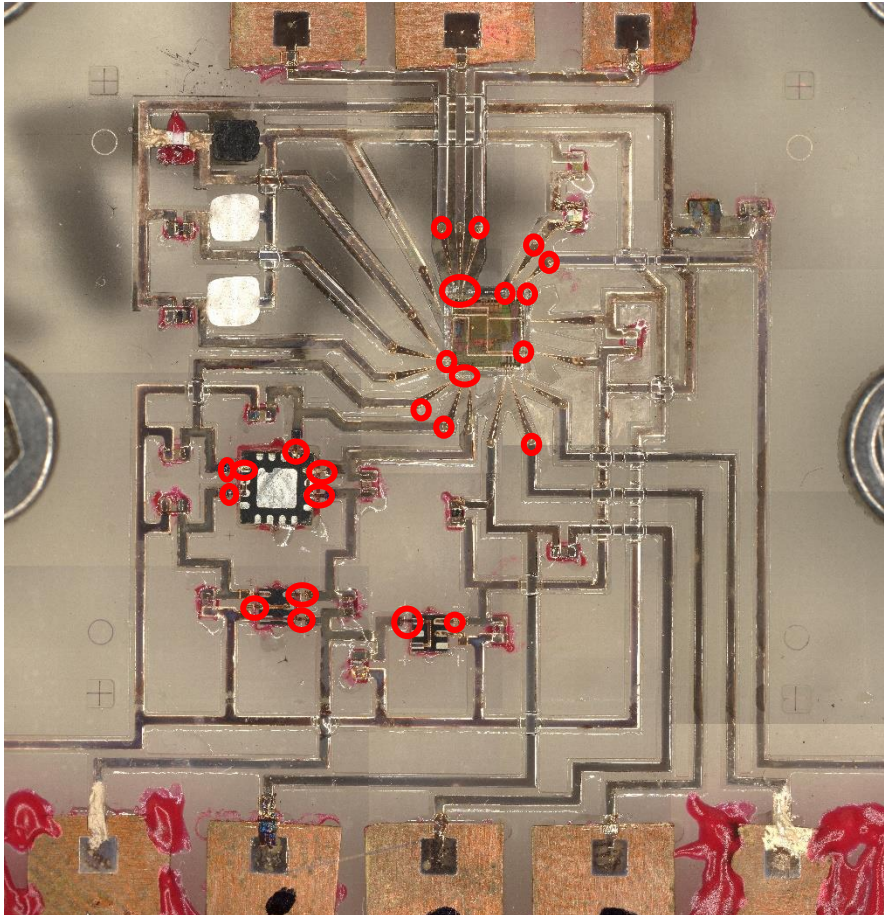
Thermally insulated, swappable circuit. Gap between substrate and door.



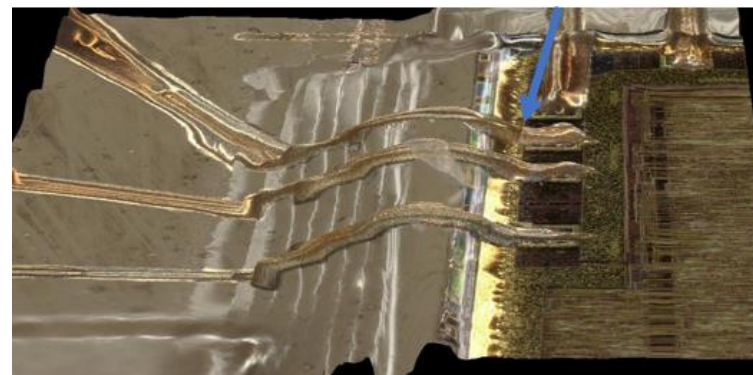
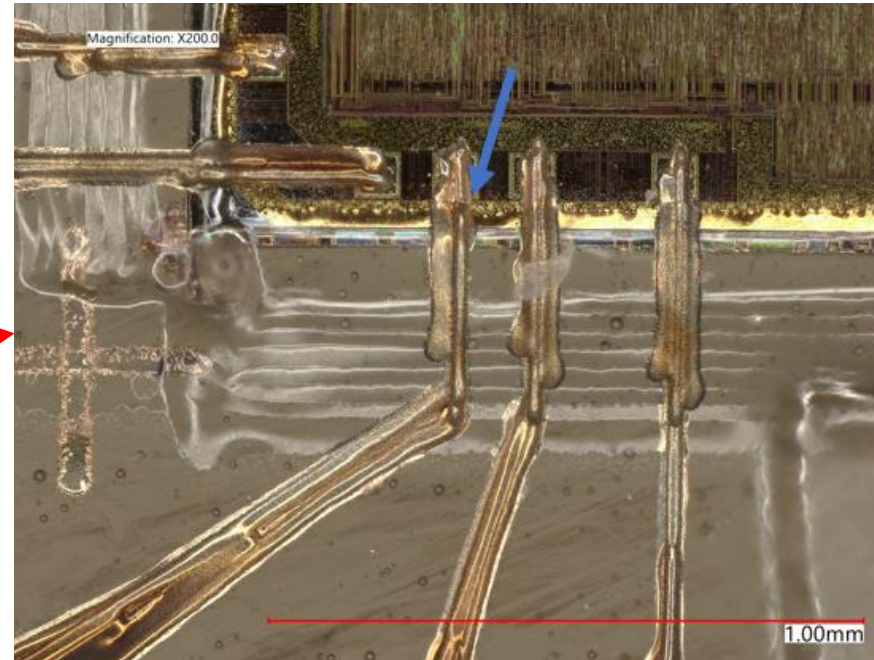
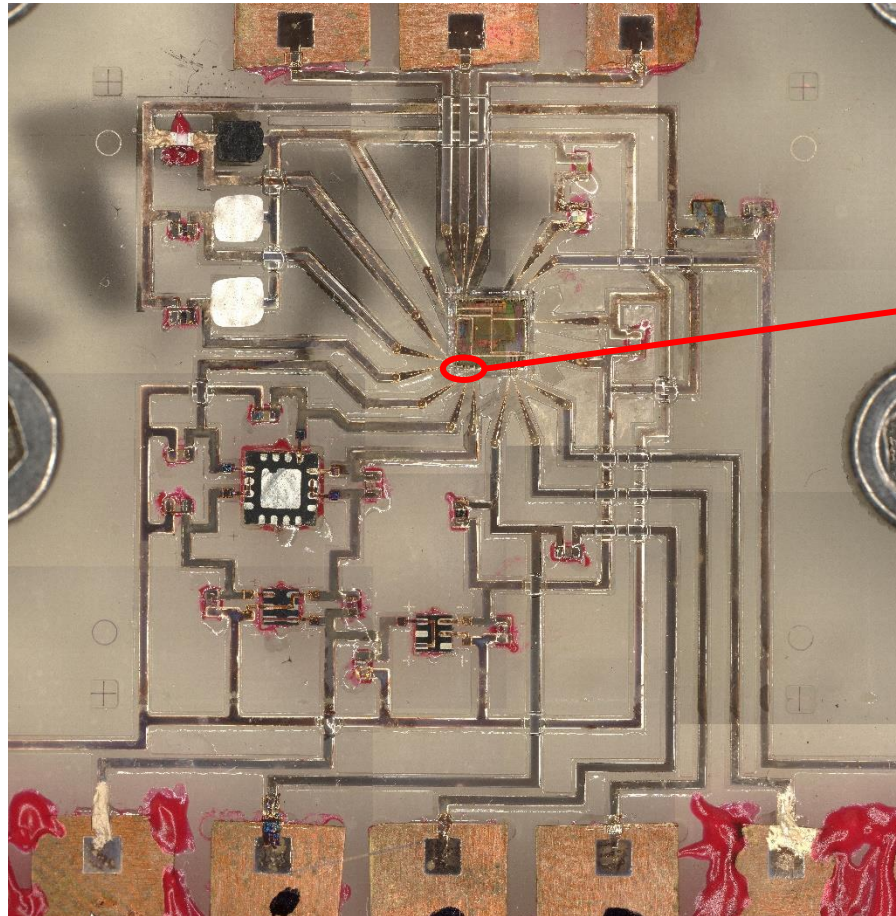
Thermally connected, swappable circuit. Gap and Kapton sheet between substrate and door.

Tightening the bolts holding the substrate to the interposer on the door panel creates stress in the substrate.

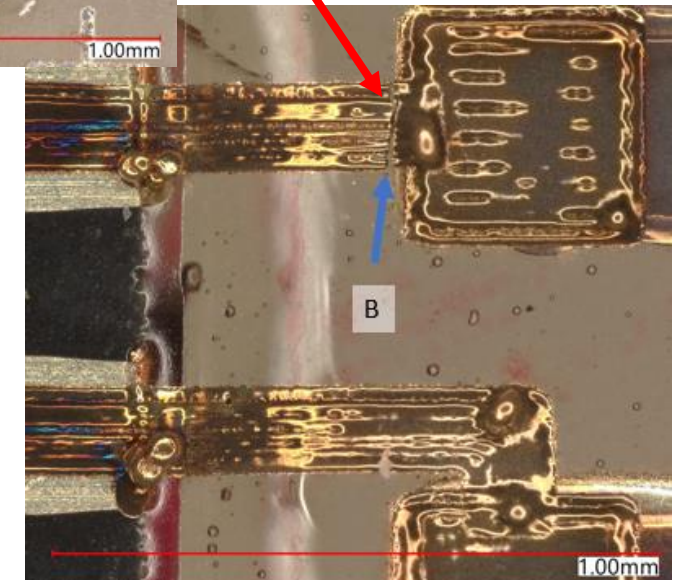
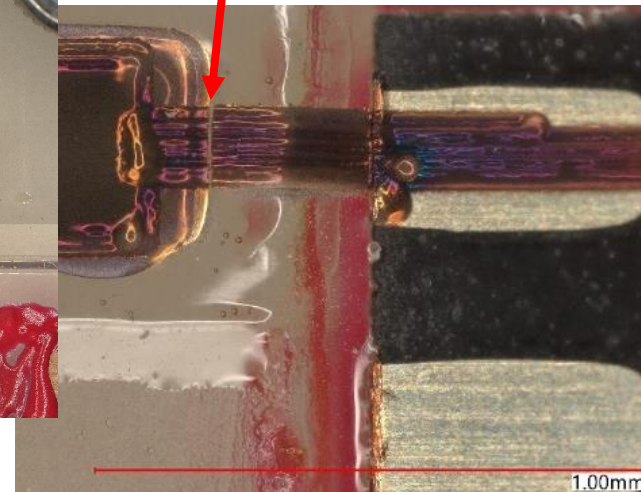
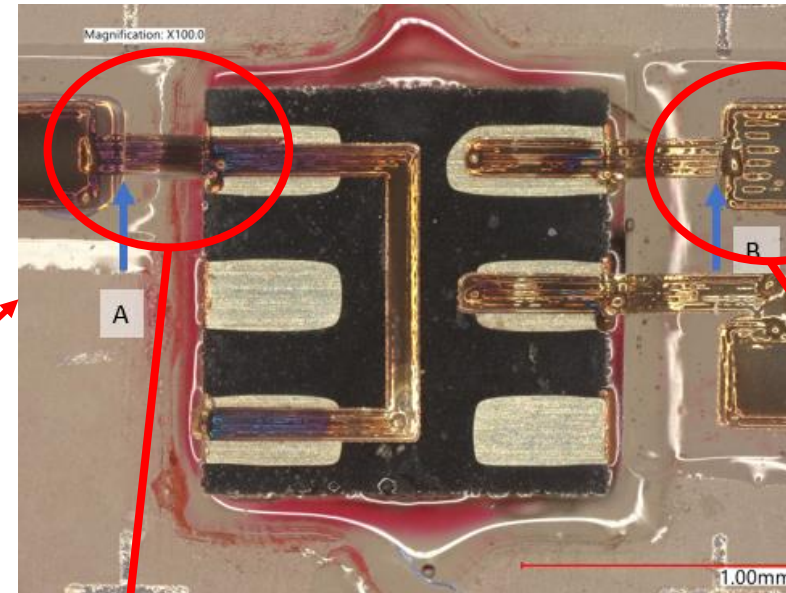
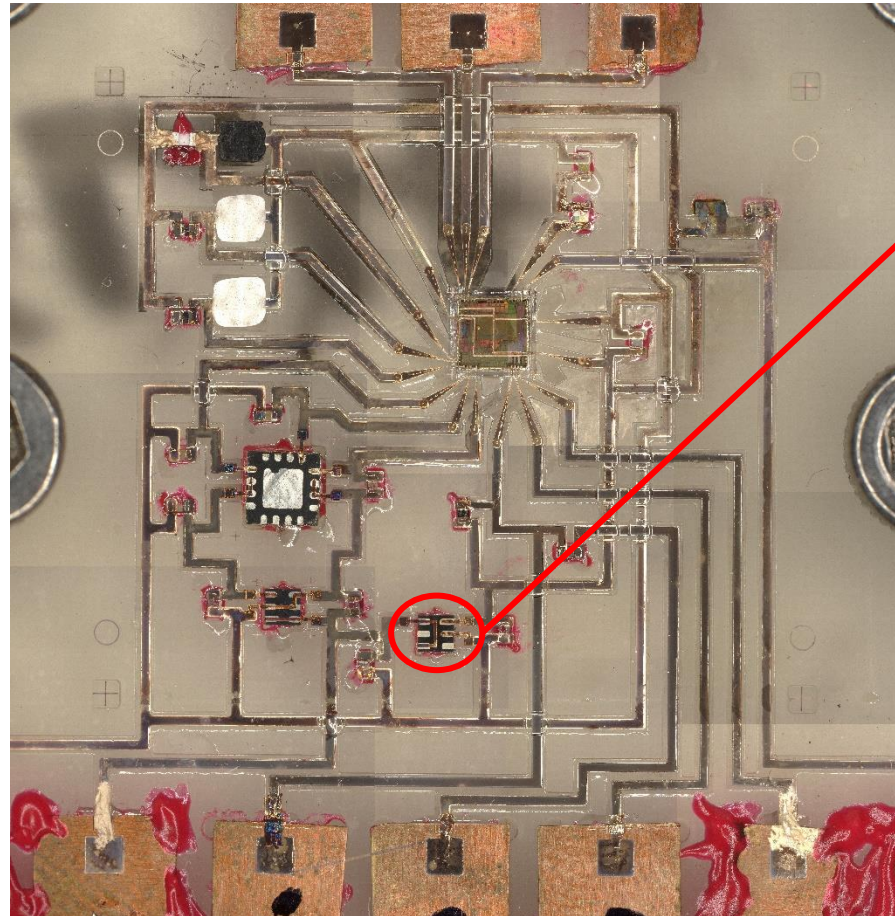
Thermally Insulated
Swappable Circuit
27 cracks/broken
printed traces
observed

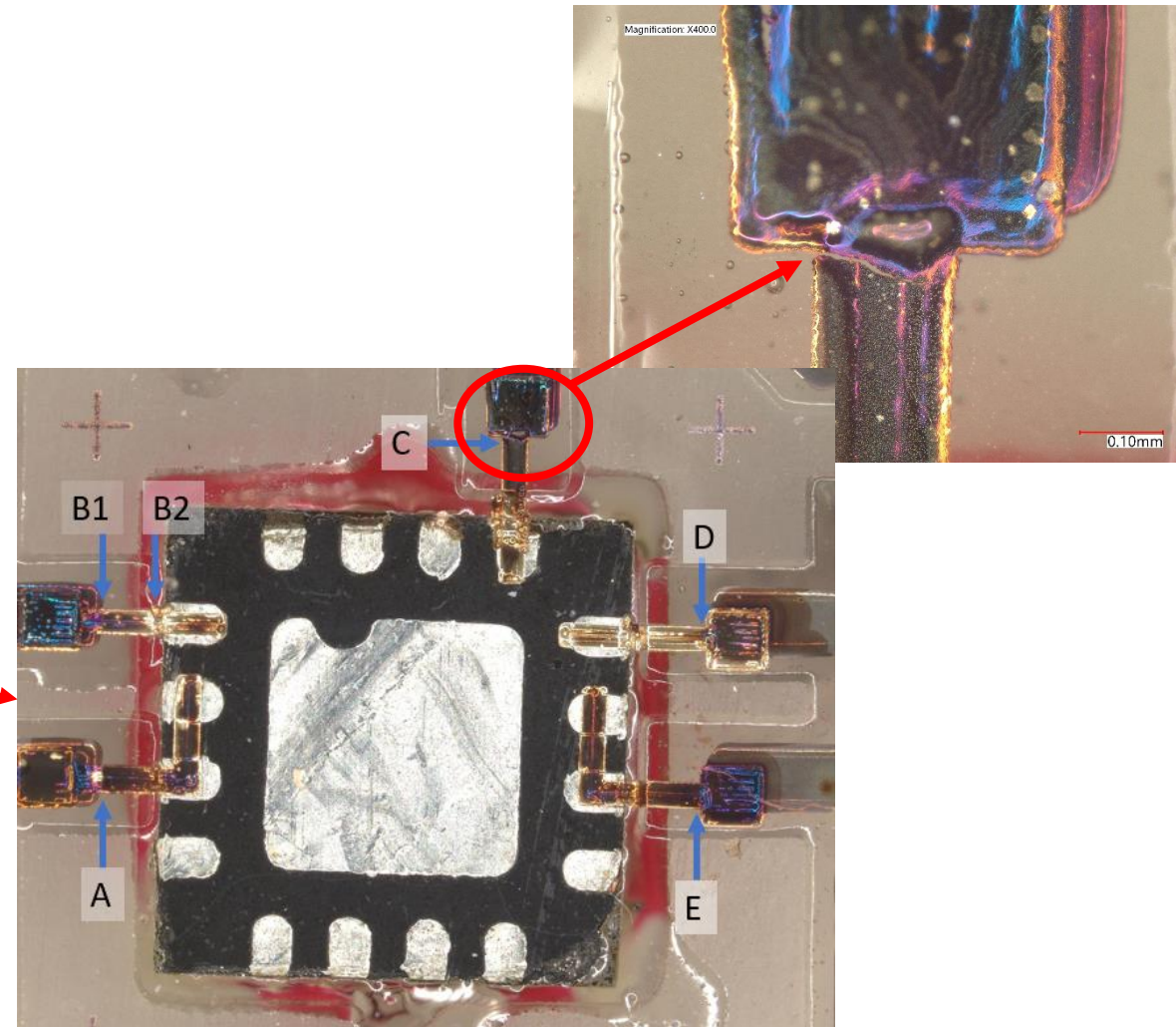
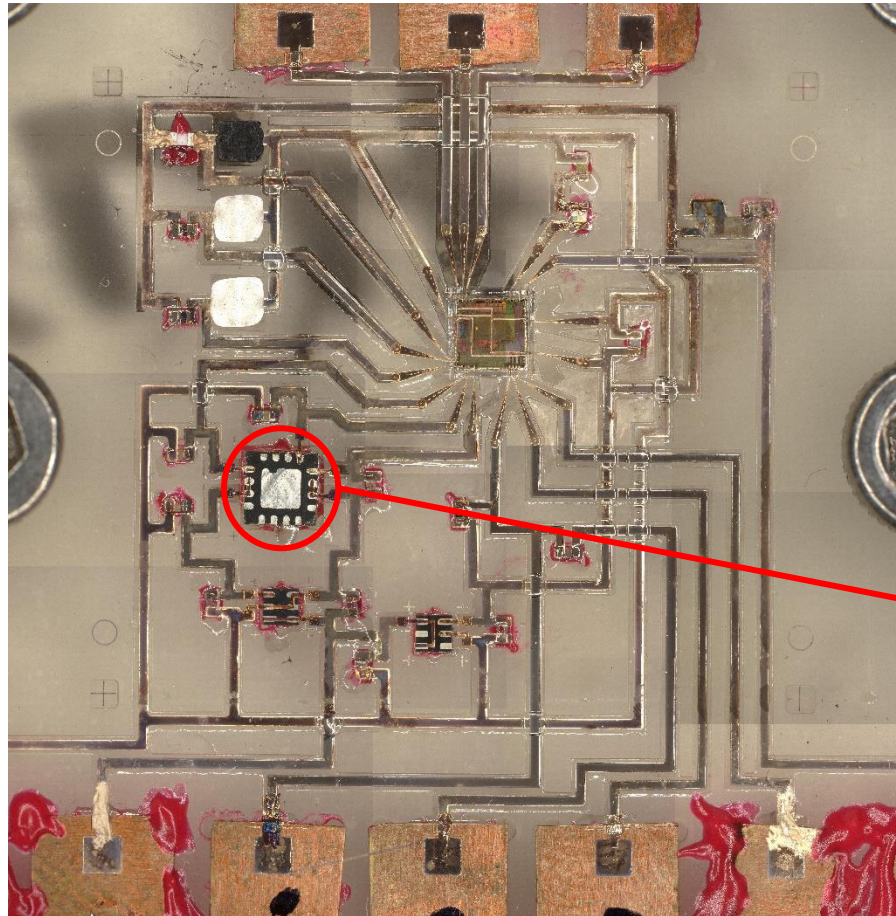


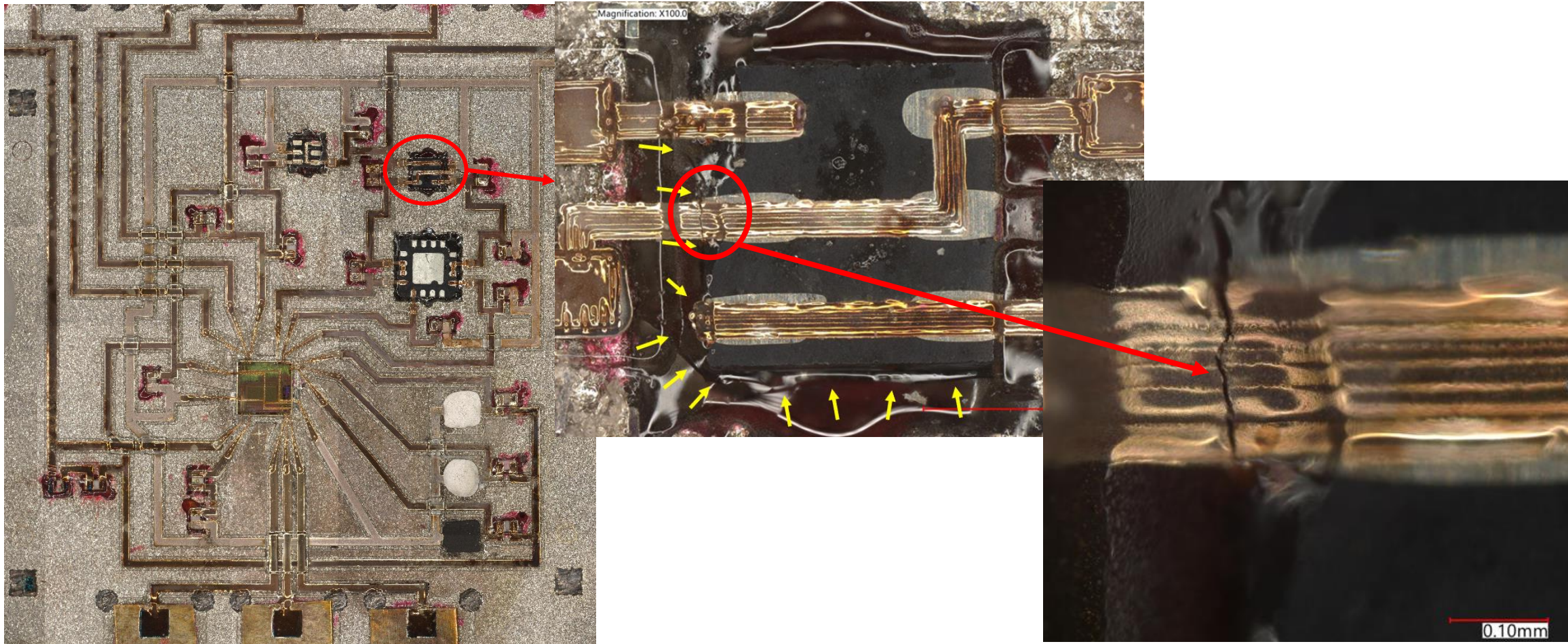
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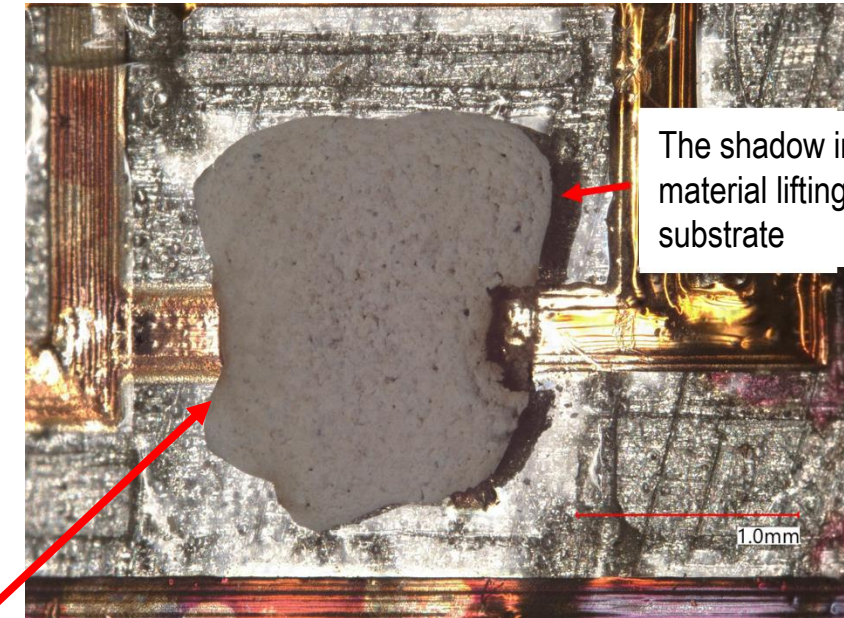
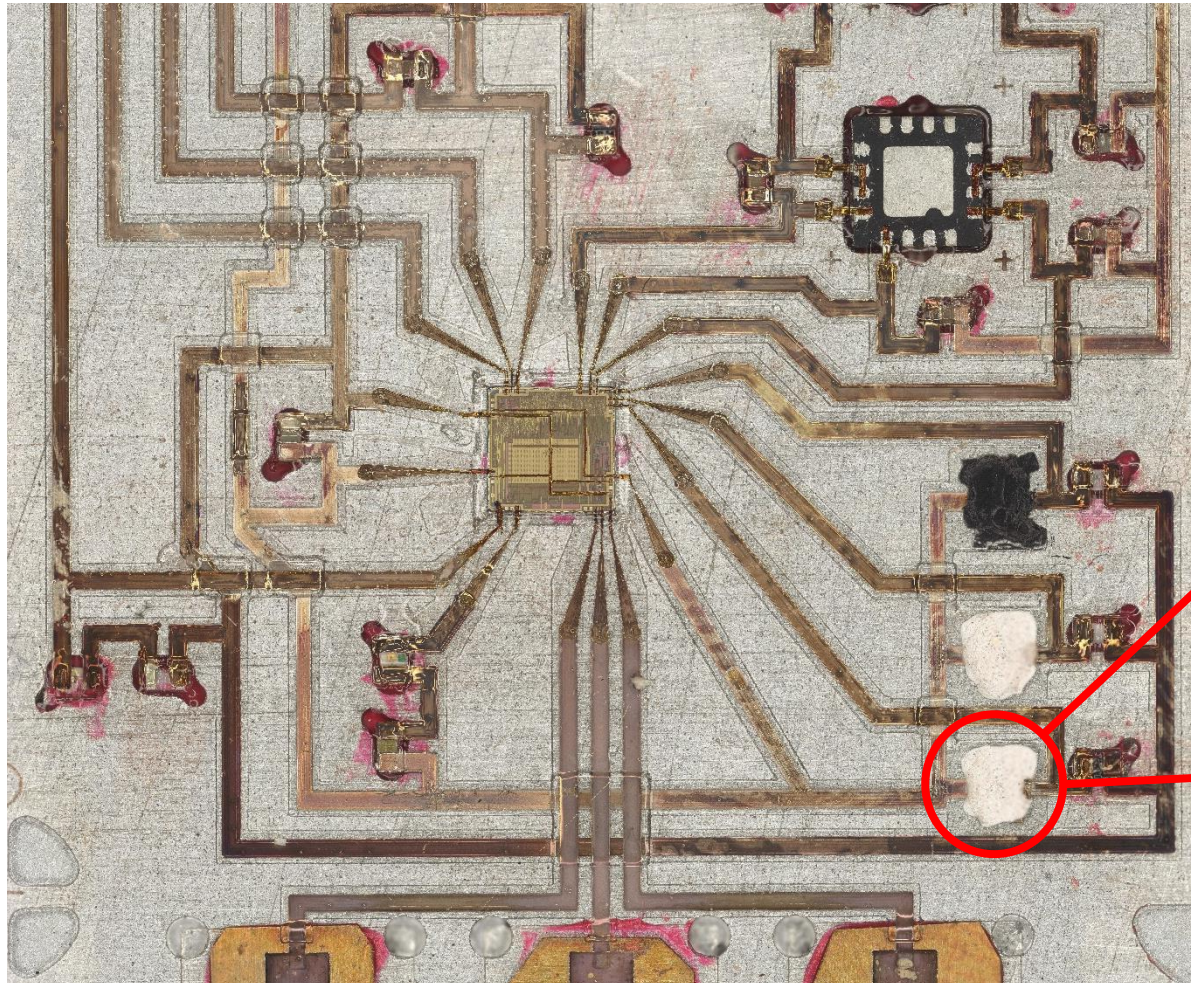


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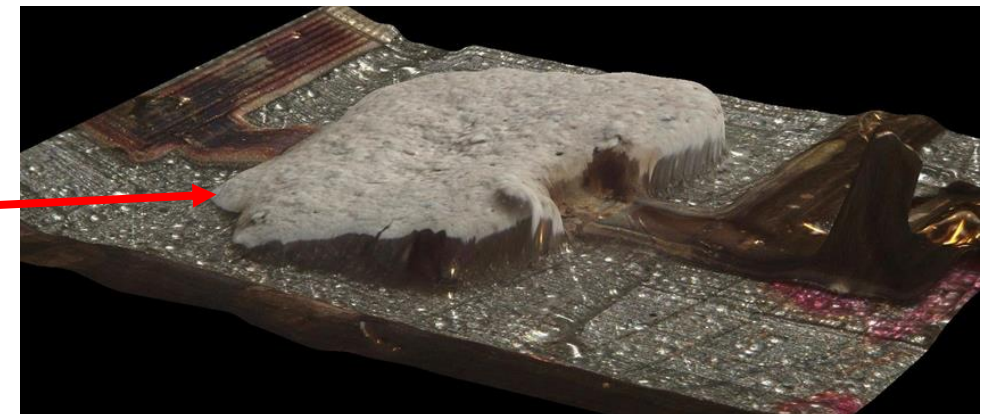








The shadow indicates material lifting from substrate





PHE Future Work



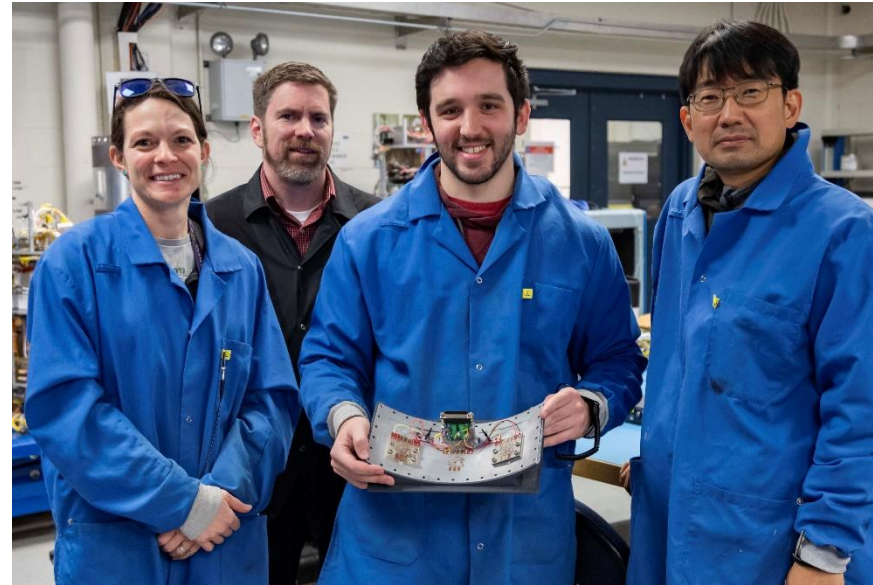
- Future concepts:
 - Antennas
 - Strain Gages
 - Temperature Sensors
 - Detectors
 - Interconnects
 - Conformal printing on shape-optimized 3D printed parts



Special Thanks



- Goddard Space Flight Center
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 - Chris Greenwell
 - Wes Powell
 - Margaret Samuels
 - Joshua Yacobucci
- Laboratory for Physical Sciences
 - Donghun Park
 - Dan Hines
 - Edwin Quinn
- Marshall Space Flight Center
 - Curtis Hill
 - Ian Small
 - Jennifer Jones
- Army Research Lab
 - Harvey Tsang
 - Sami Hawasli



Printed Hybrid Electronics Team: From left to right: Beth Paquette/GSFC, Brian Banks/GSFC, Jason Fleischer/Laboratory for Physical Sciences (LPS), Donghun Park/LPS. Photo by Berit Bland

Questions?

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Acronyms



Acronym	Definition
PHE	Printed Hybrid Electronics
PCB	Printed Circuit Board
SEM	Scanning Electron Microscope
SWaP	Size Weight and Power
SubTEC	Suborbital Technology Experiment Carrier