3D Printed Electronics for Spaceflight Missions

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NASA Goddard Space Flight Center

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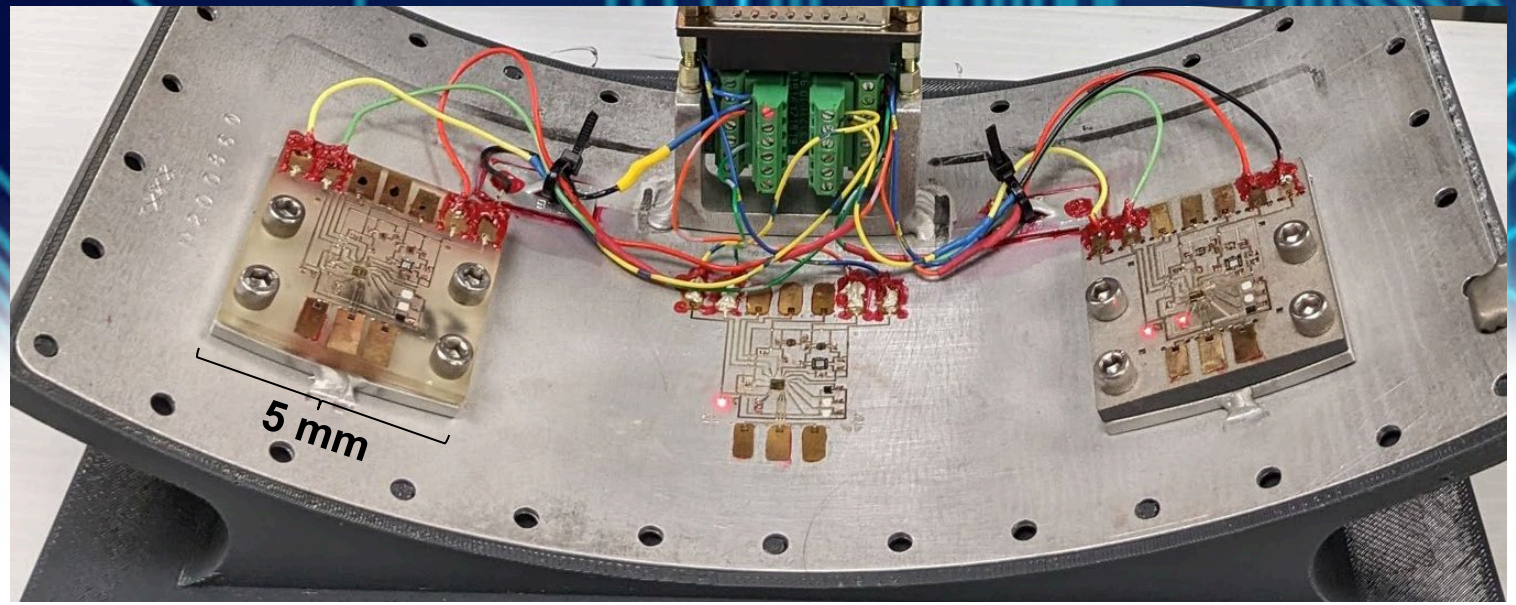
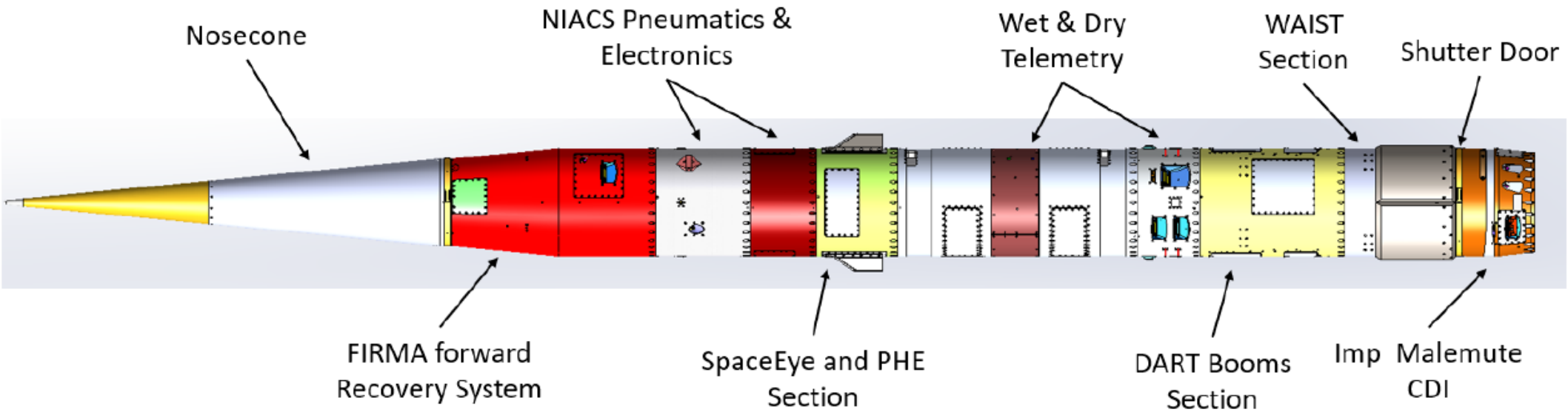
NASA GSFC 3D Printing Electronics Group

Overarching goal: Demonstrate capability for 3D Printing electronics to both **maximize customizati**on for unique needs of spaceflight missions while **minimizing cost and schedule.**

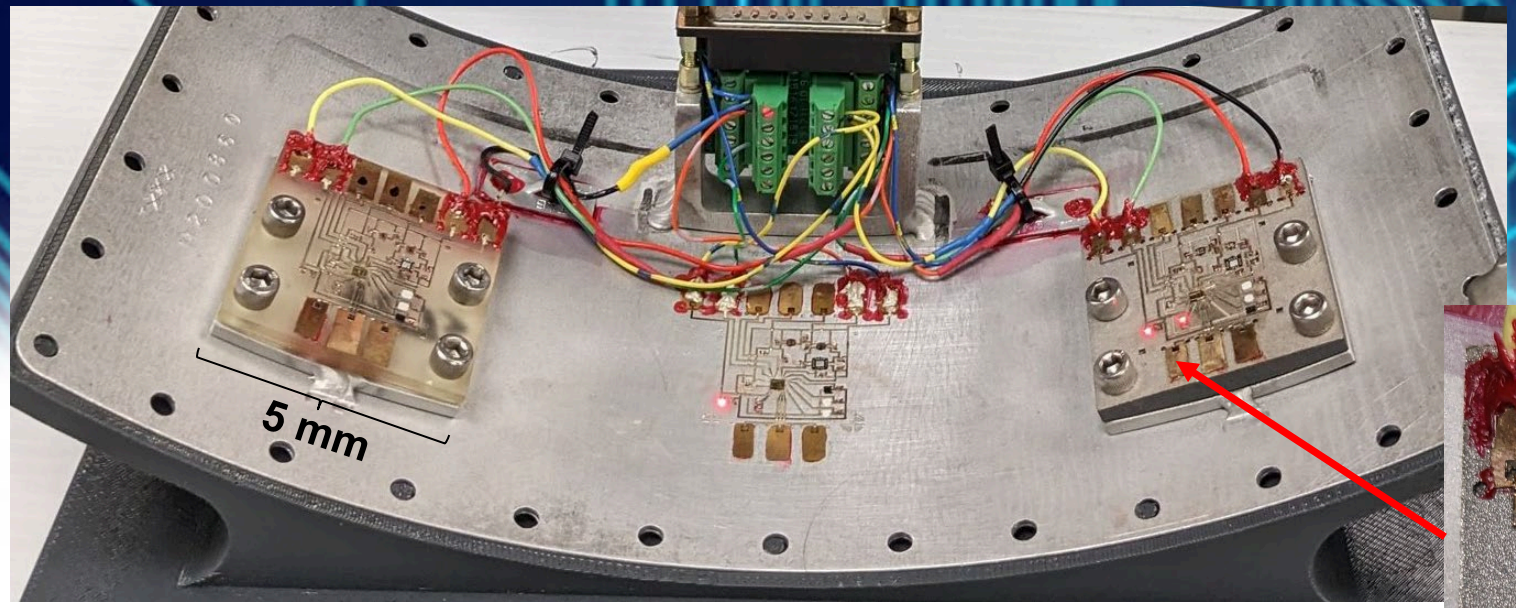
We plan to accomplish this via two prongs:

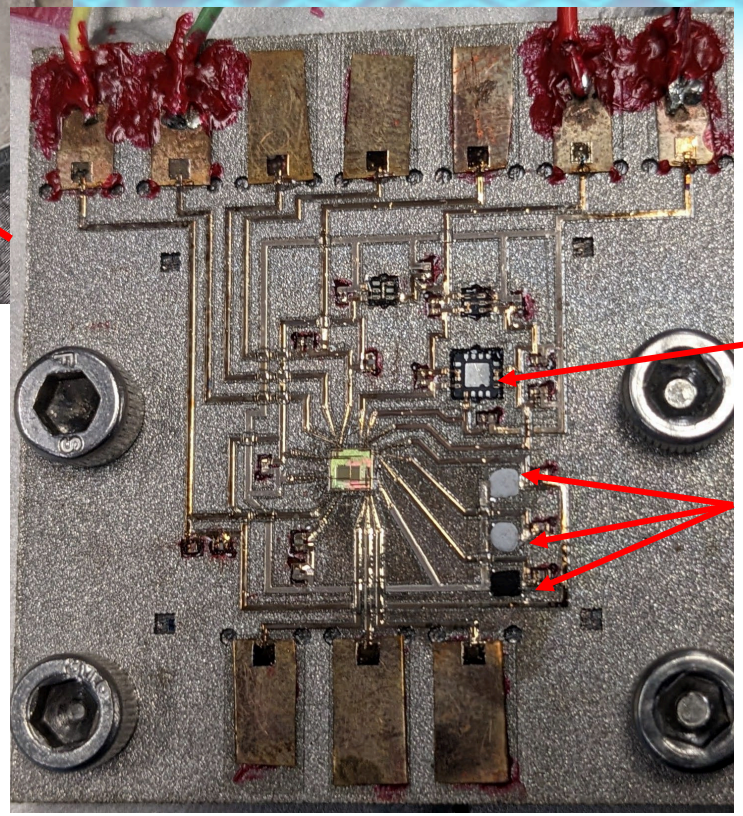
1. **Research:** applications for spaceflight projects with unique needs
2. **Rapid prototyping:** helping low-risk missions prototyping boards and other electronics early, enabling earlier testing and addressing design flaws

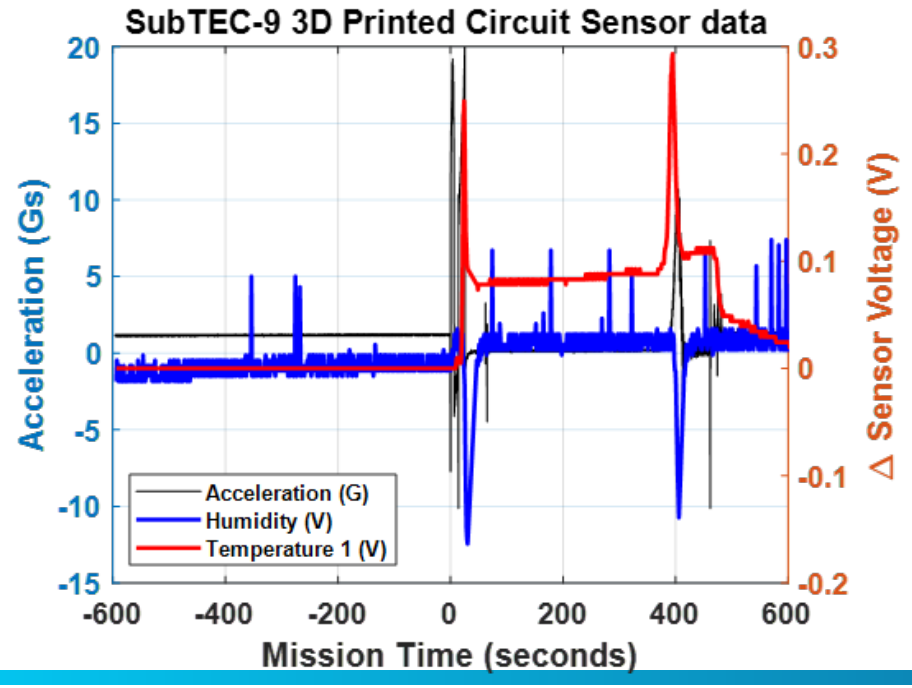




April 2023 SubTec-9 Sounding Rocket Demonstration

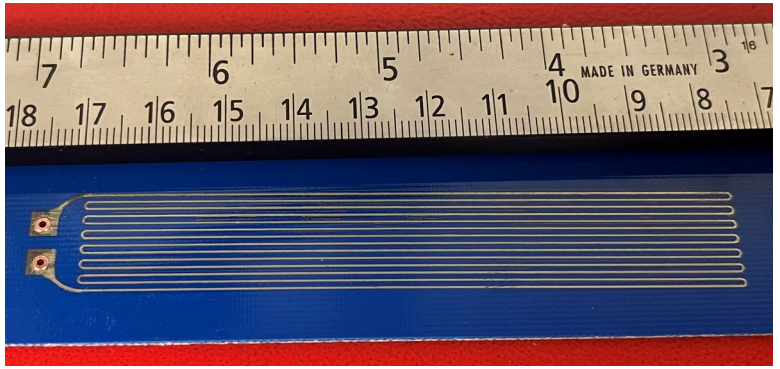


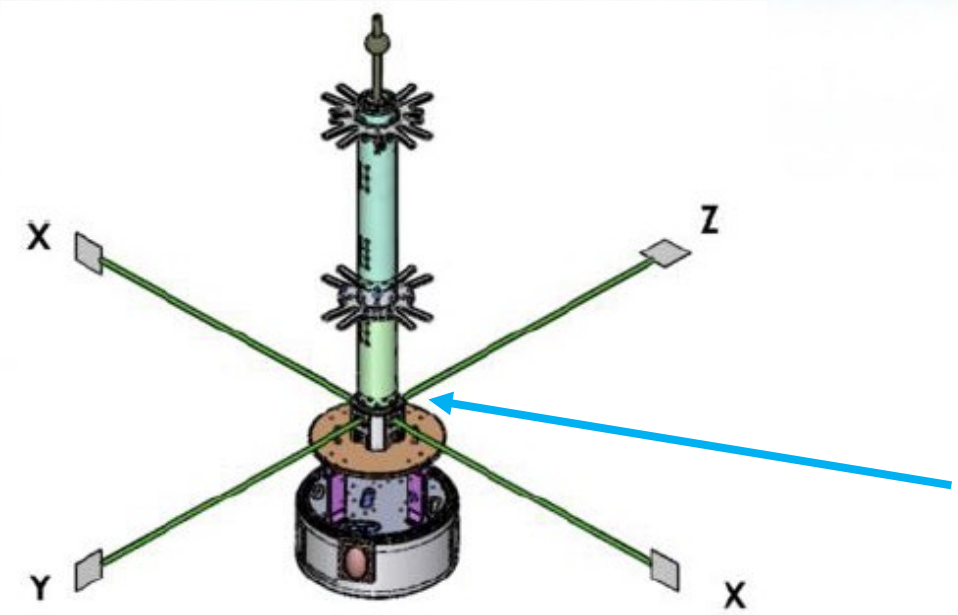




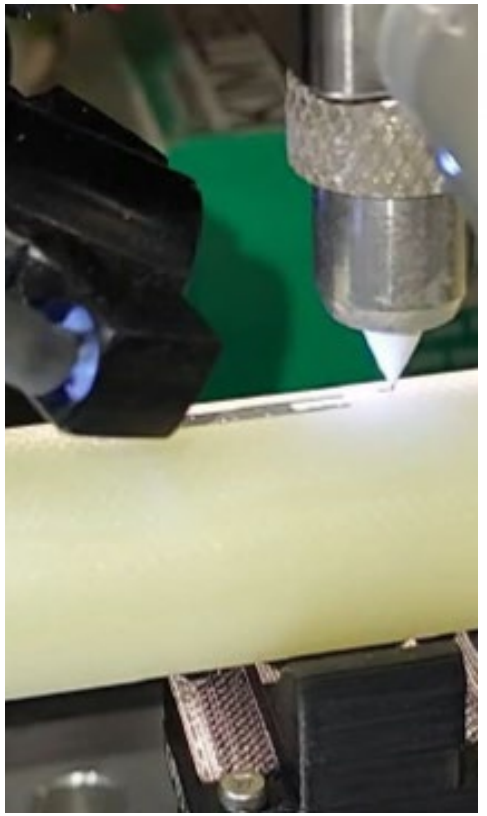
April 2023 SubTec-9 Sounding Rocket Demonstration

Strain gauges for sounding rocket wind velocity measurements





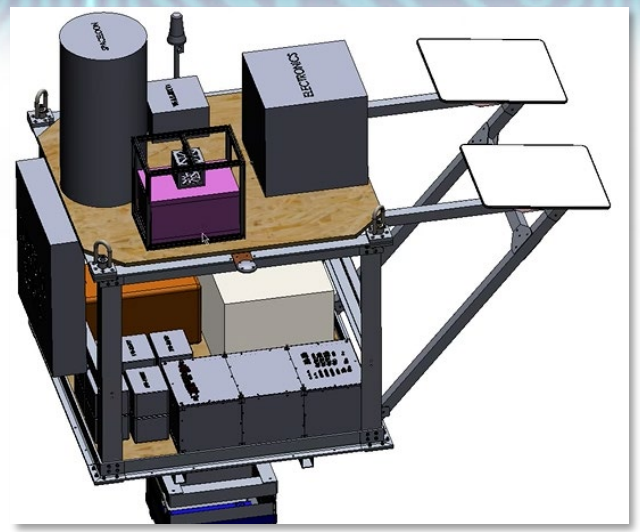
Need 1kΩ and 10^{-6} sensitivity



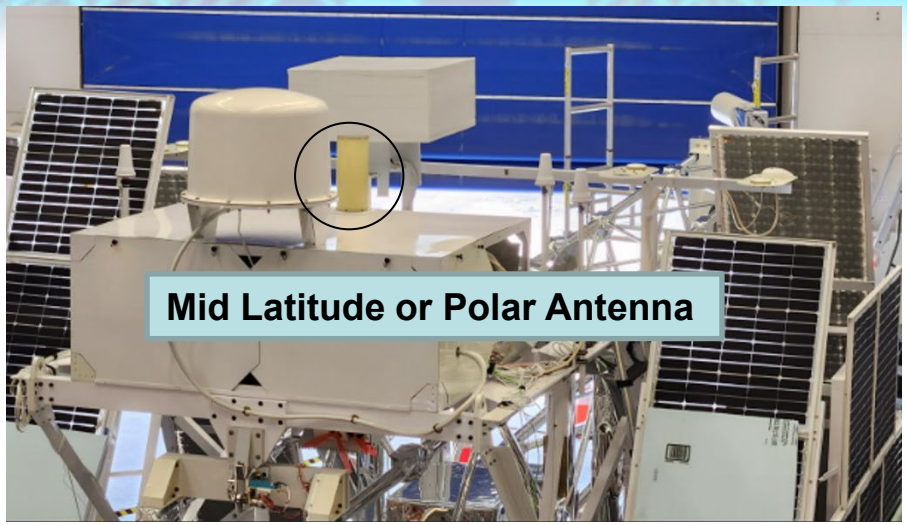
FY24 Printed Antenna on a Balloon Test Flight Project

Scientific Balloon Program
Salter Test Flight Payload Configuration

Balloon Deployment



Gondola for the Salter Test Flight



Antenna mounted on Gondola

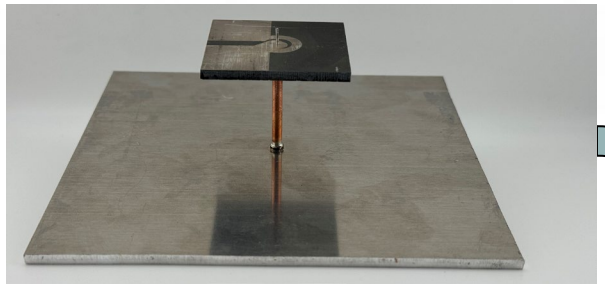
- Balloon program is run from NASA Goddard Wallops Flight Facility in Virginia
- 10 – 15 launches per year

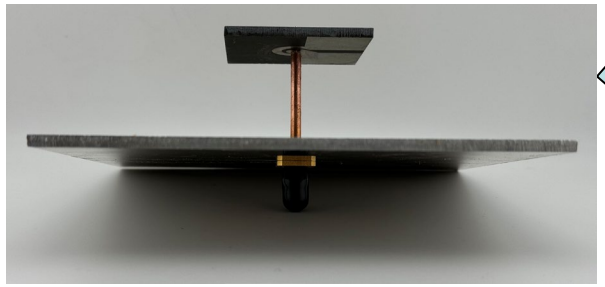
https://www.nasa.gov/scientificballoons/

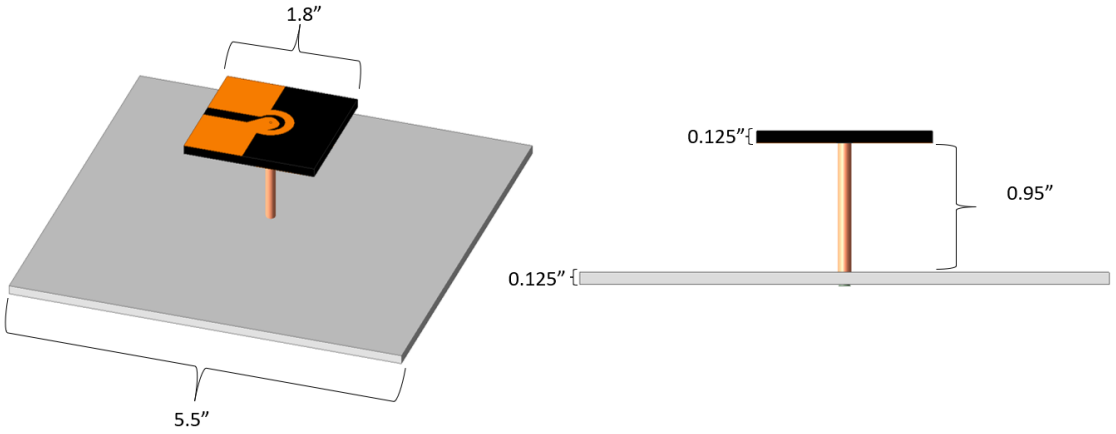
Antenna on Balloon Flight: project timeline

Time frame	Task	Location	Status
May 15	Funding approved	GSFC	-
May/June	Antenna design	Greenbelt, MD	Complete
June	Print prototypes	Greenbelt, MD	Complete
June	Adhesion testing	Greenbelt, MD	Complete
June	Drill holes in print	Greenbelt, MD	Complete
June 24	MIC/ORDM/ODR Design Review with BPO	WFF/GSFC	Complete
Early-Mid July	Iterate design and print if needed, otherwise, print extra for T-Vac and thermal tests	Greenbelt, MD	Complete
Early July	RF assembly	Greenbelt, MD	Complete
July 10	Pre-Integration Review with BPO	WFF/GSFC	Complete
Early-Mid July	Anechoic chamber testing	Greenbelt, MD	Complete
July 18, 19	Ground Testing	Palestine, TX	Complete
Late July	Instructions for mounting antenna plate and returning assembly	Greenbelt, MD	Complete
August	Integration and flight	Fort Sumner, NM	Flew Aug 22, 2024
September	Post-flight anechoic testing, inspection, data analysis	Greenbelt, MD	Late Sept – Early Oct

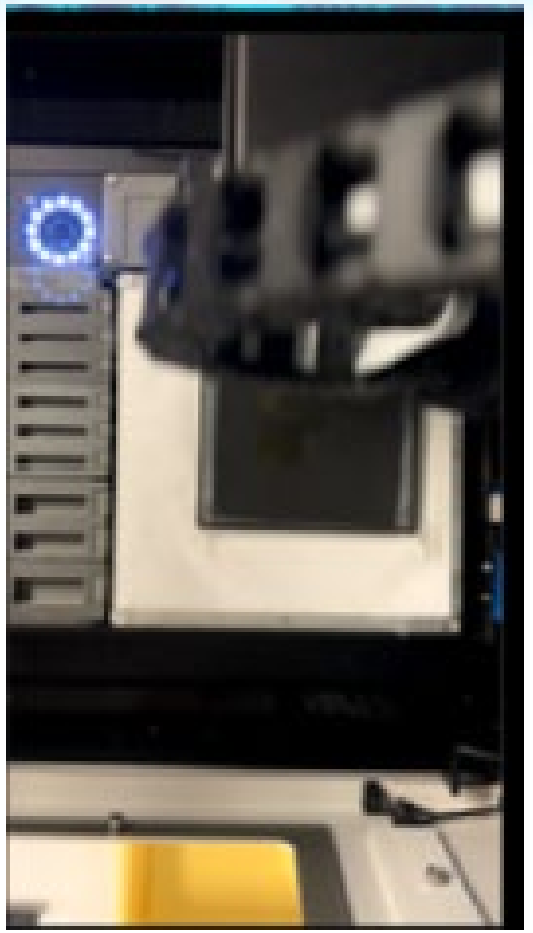
Antenna on Balloon Flight: magneto electric dipole design







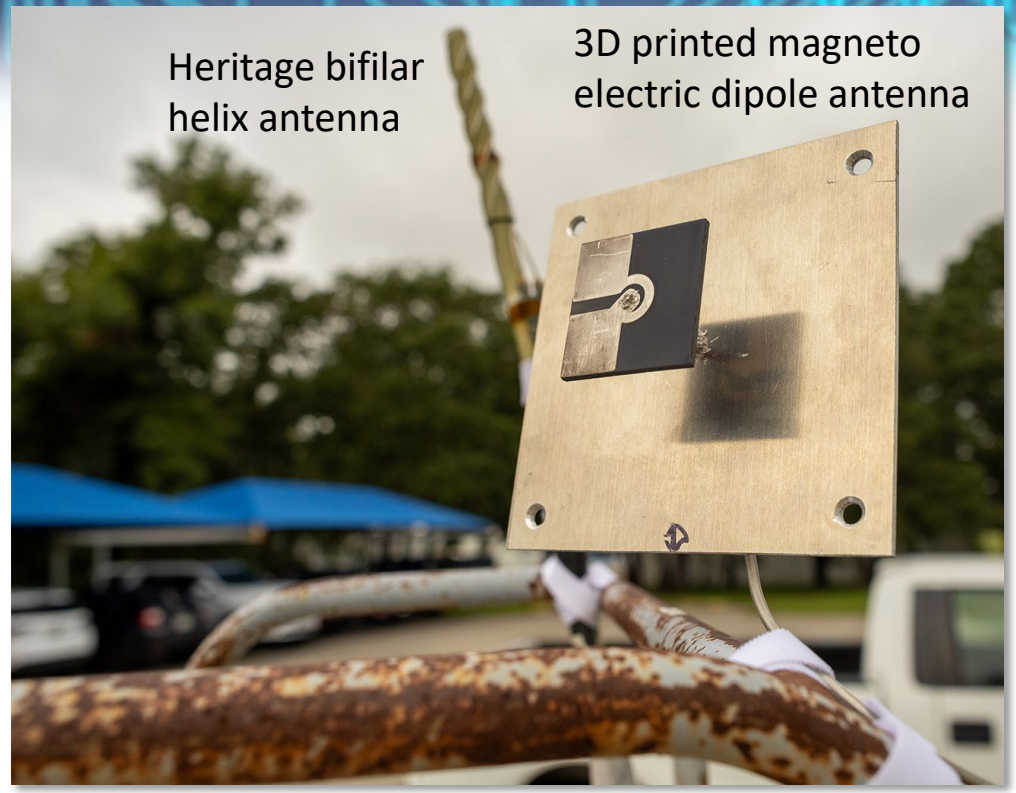
- Fly a printed TDRSS antenna, not transceiving
- Ground to satellite testing before flight
- Assessment of how printed materials hold up to elements of a balloon flight:
  - Pre- and post-flight testing



*Antenna design by Peter Moschetti/567
Printing by Tristan Epp Schmidt/562 Alexander Moricette/FAMU/FSU and Joshua Davey/FAMU/FSU

Antenna on Balloon Flight: TDRSS Uplink and Downlink Testing

Testing with satellite F6



Bifilar helix antenna strongest signal:

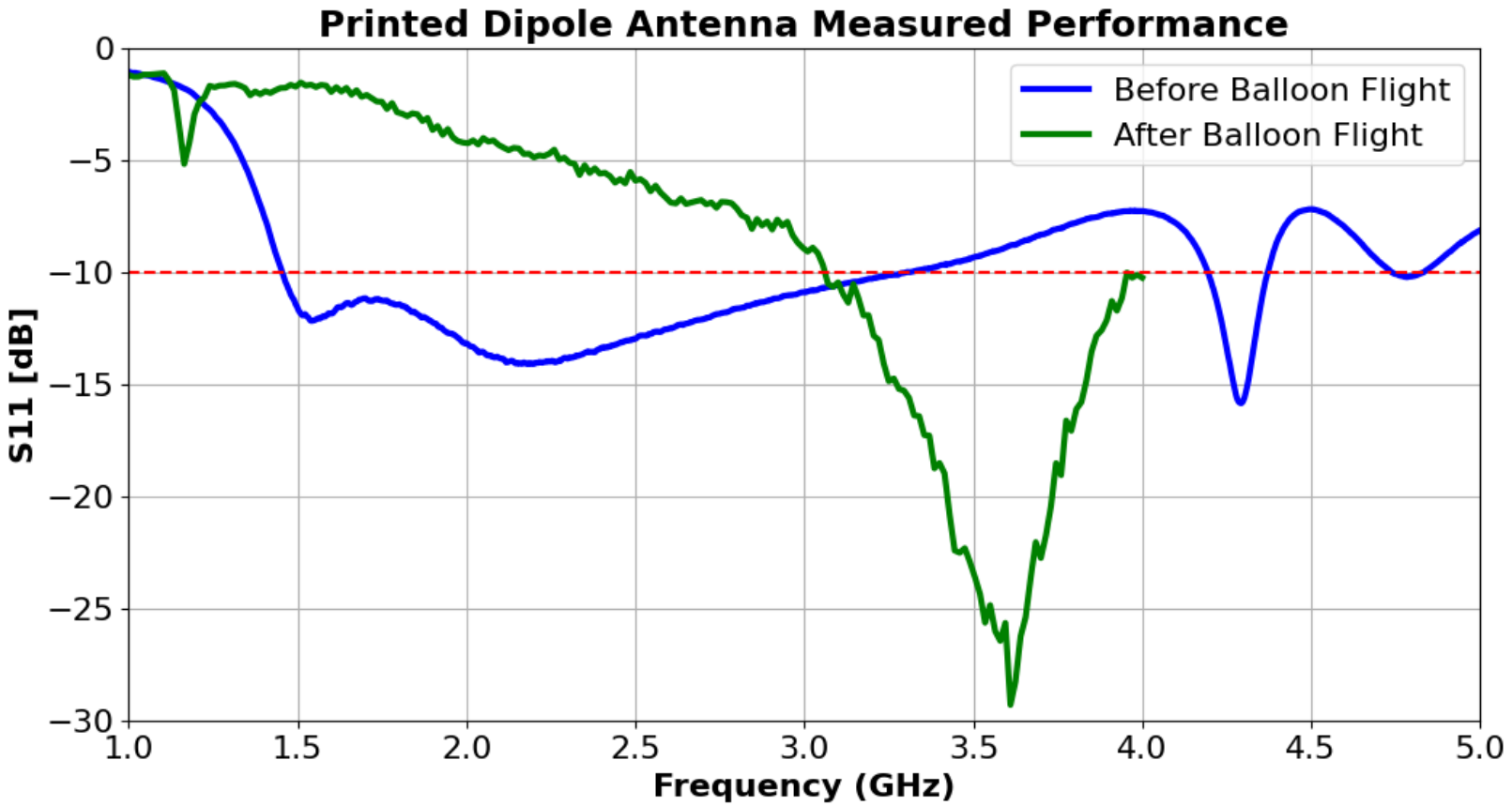
- Signal Strength at F6: 13.15 - 13.33 dB

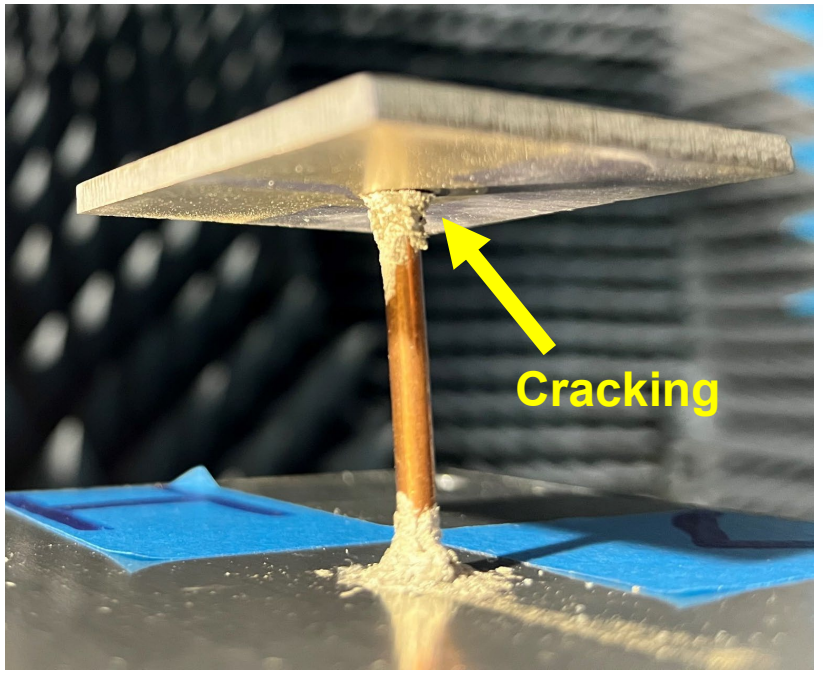
3DP ME Dipole strongest signal:

- **~45˚ from vertical and 100˚ azimuth**
- Signal Strength at F6: 15.54 - 16.01 dB

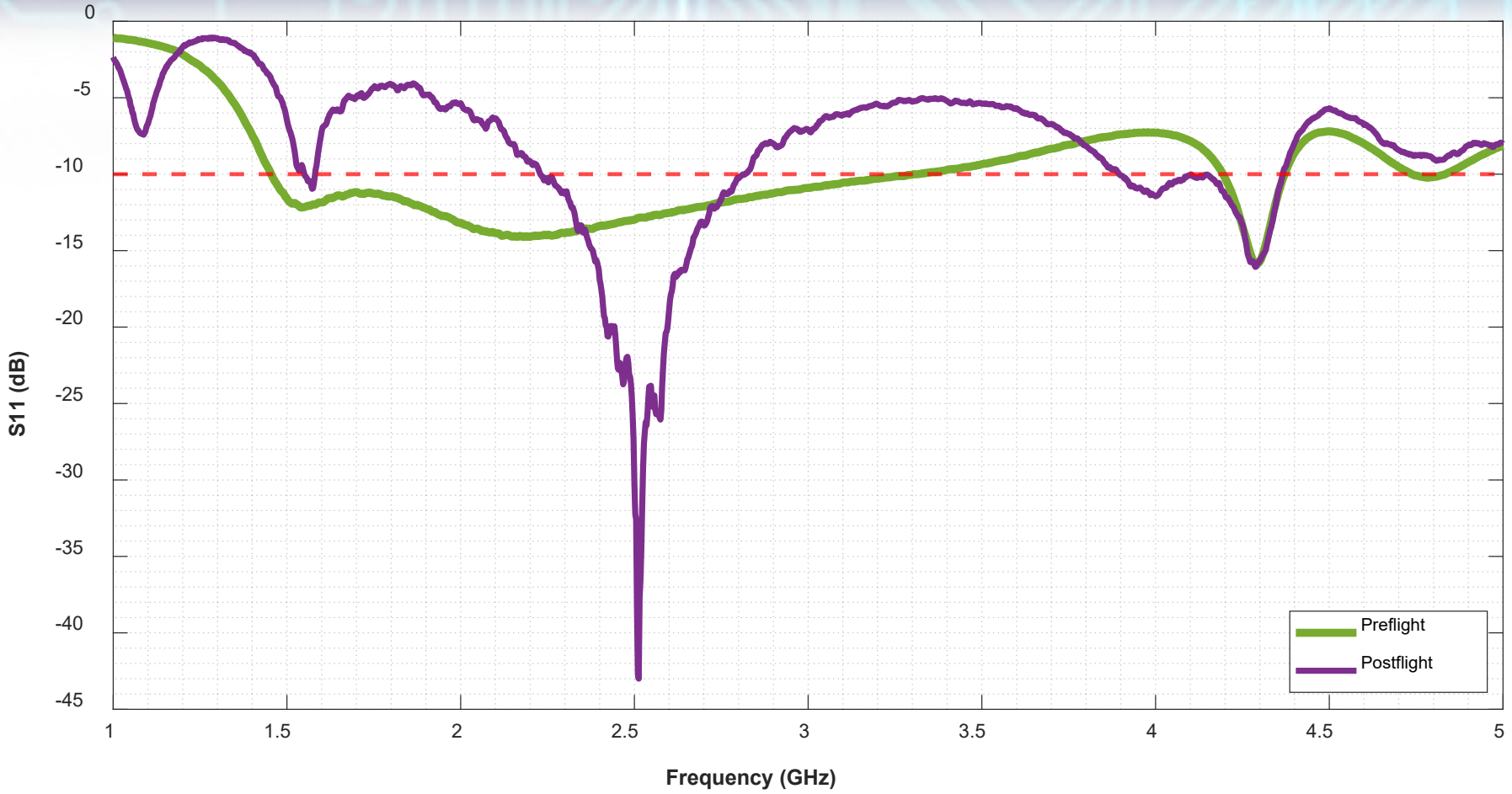
*Antenna testing performed by Peter Moschetti/567 and the Columbia Scientific Balloon Facility NASA personnel

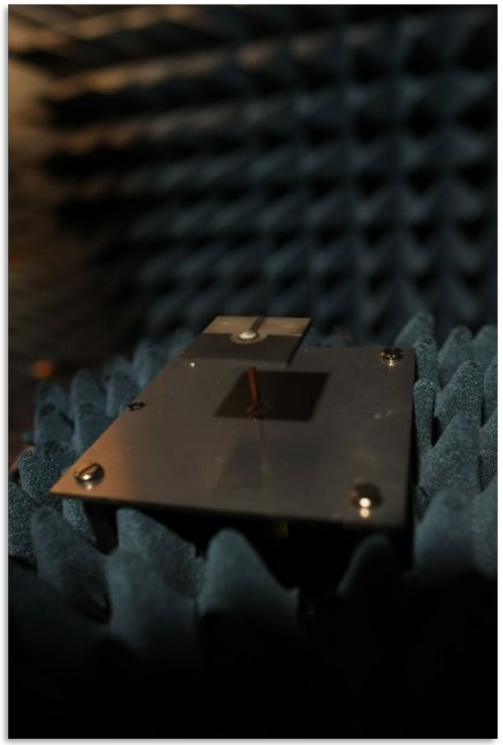
Antenna on Balloon Flight: Assessing antenna performance





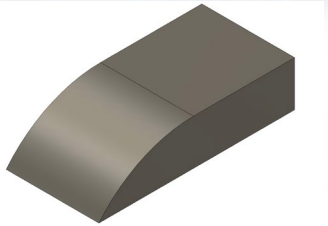
Antenna on Balloon Flight: Assessing antenna performance





*Antenna testing performed by Justin Long/567 and Brian Banks/569

Additive manufacturing bottleneck: software for curved surface prints



3D Part

2D Circuit

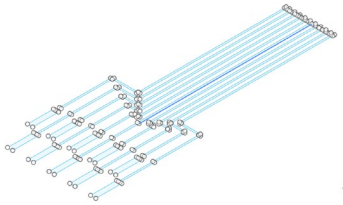
Projection

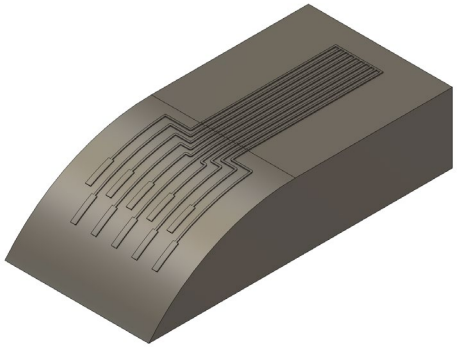
CAM toolpath

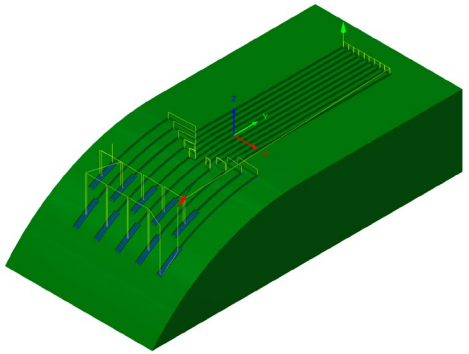
Machine code toolpath

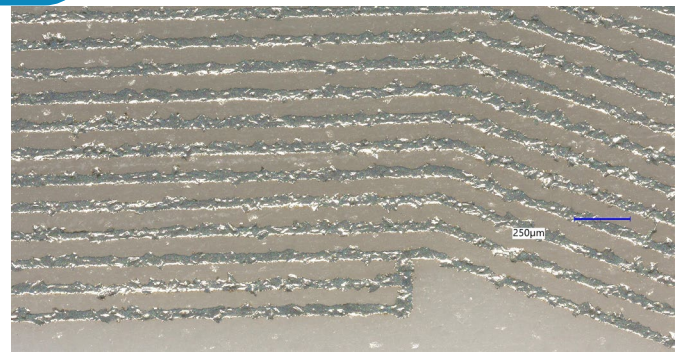
Print

G-code transpiler

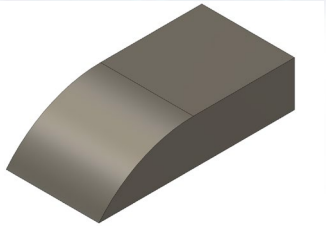








Additive manufacturing bottleneck: software for curved surface prints



3D Part

3D circuit design

Pr ction

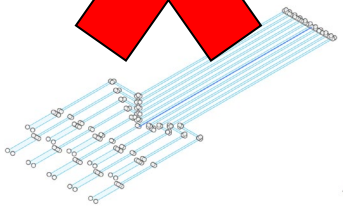
2D C uit

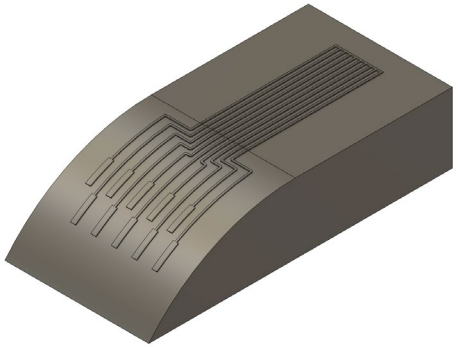
CAM toolpath

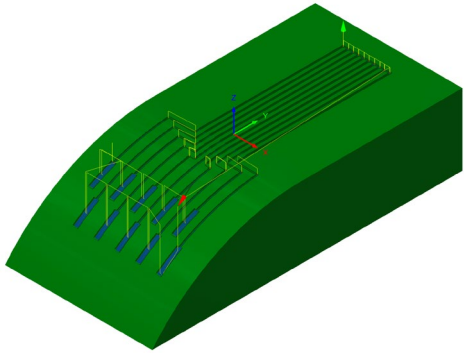
Machine code toolpath

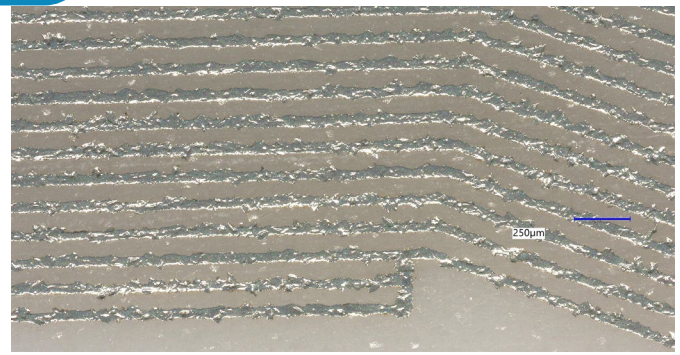
Print

G-code transpiler



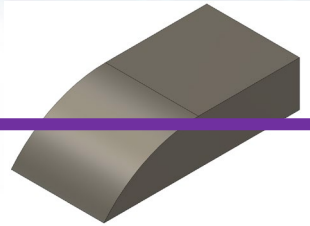






Additive manufacturing bottleneck: software for curved surface prints

Crowdplat, funded via
"Crowdsourcing Contenders"



3D Part

3D circuit design

Pr ction

2D C uit

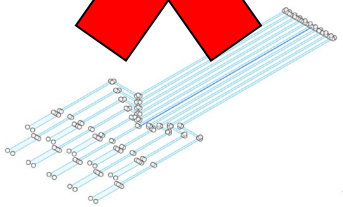
VA Tech Senior Software Engineering student team

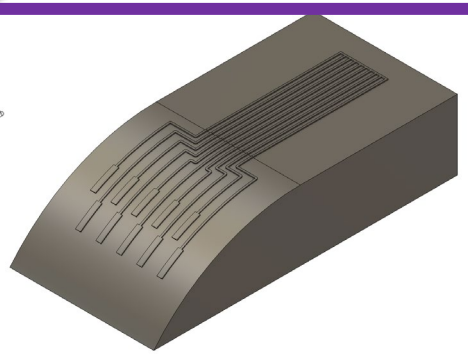
CAM toolpath

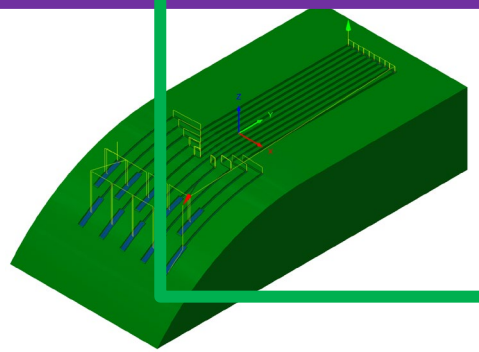
Machine code toolpath

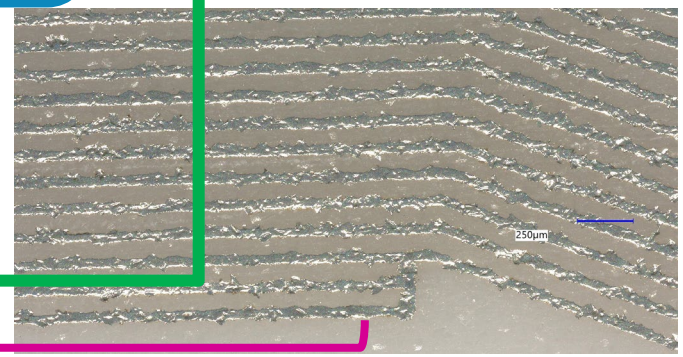
Print

G-code transpiler



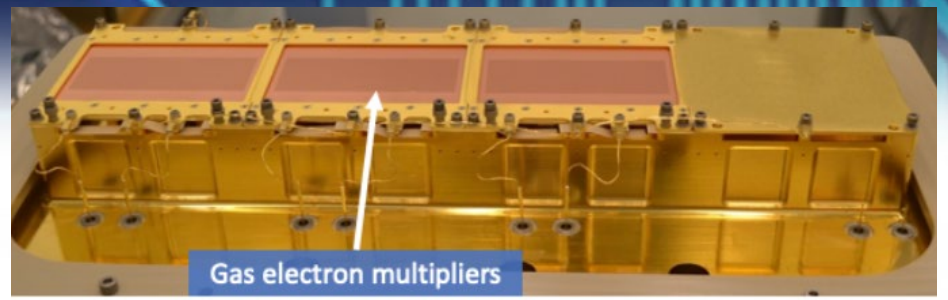


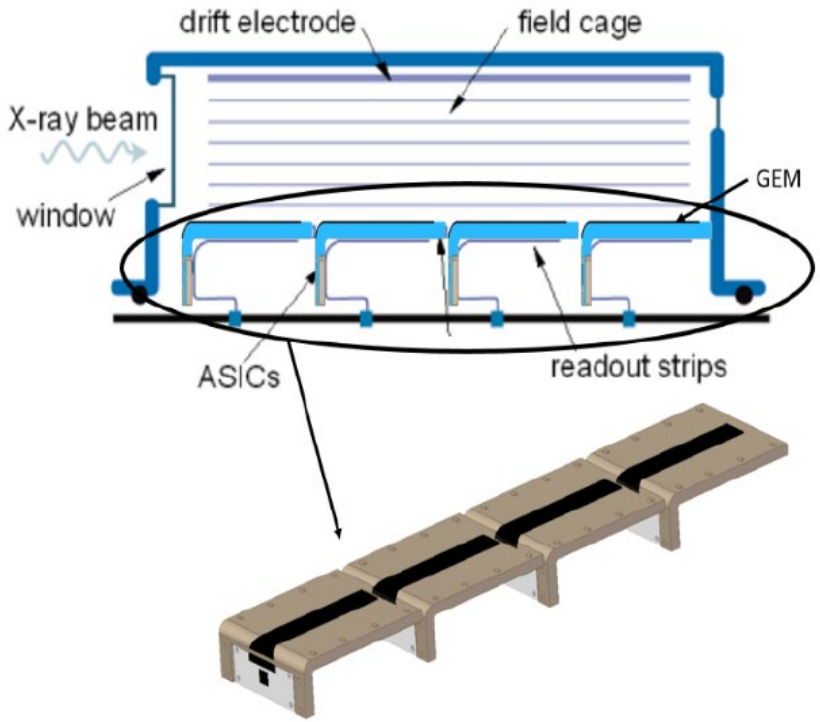


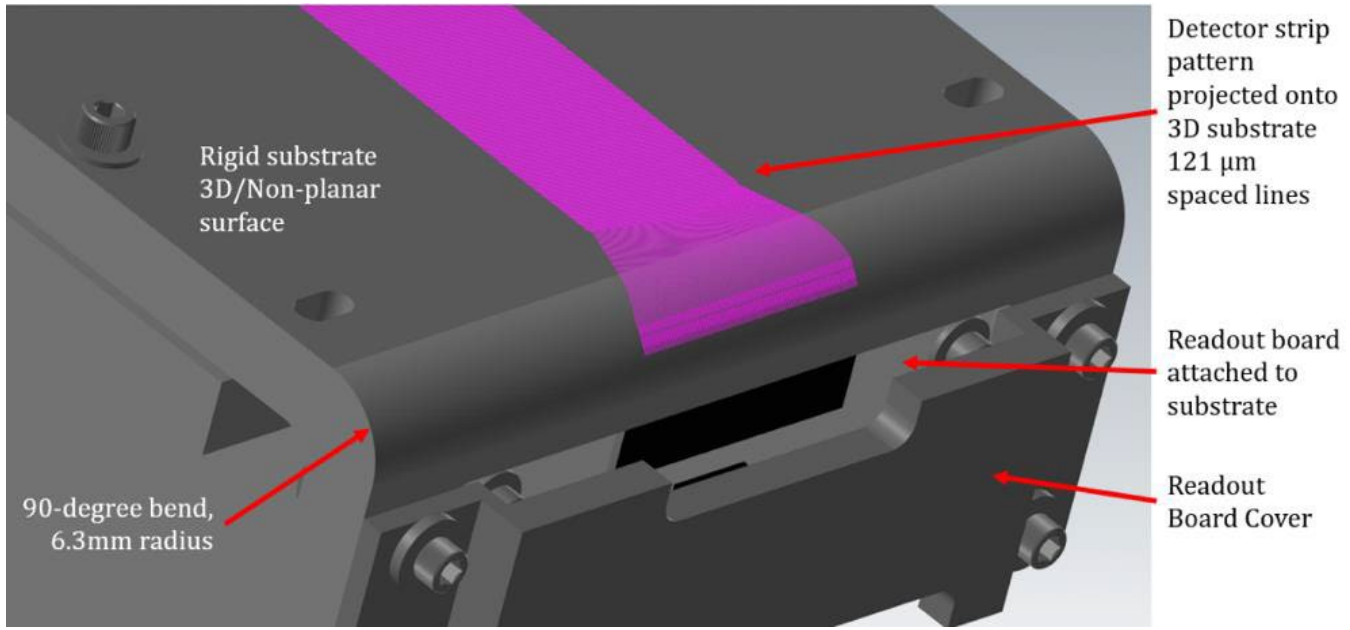


Process sketched and ACSPL transpiler begun by Jesse Trutna, OSTEM summer intern

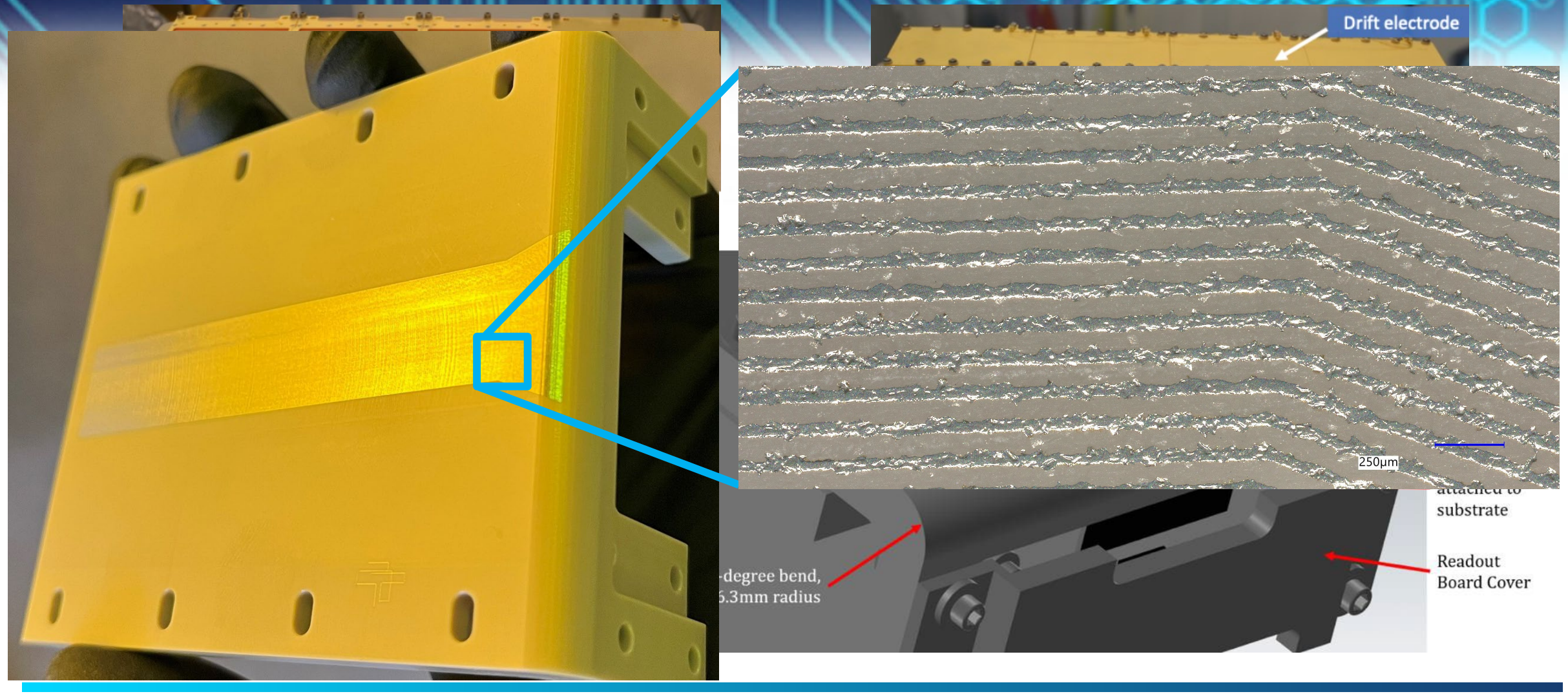
Hard X-ray Photoelectric Polarimeter (HXPP) Detector Strips for Astrophysics







Hard X-ray Photoelectric Polarimeter (HXPP) Detector Strips for Astrophysics



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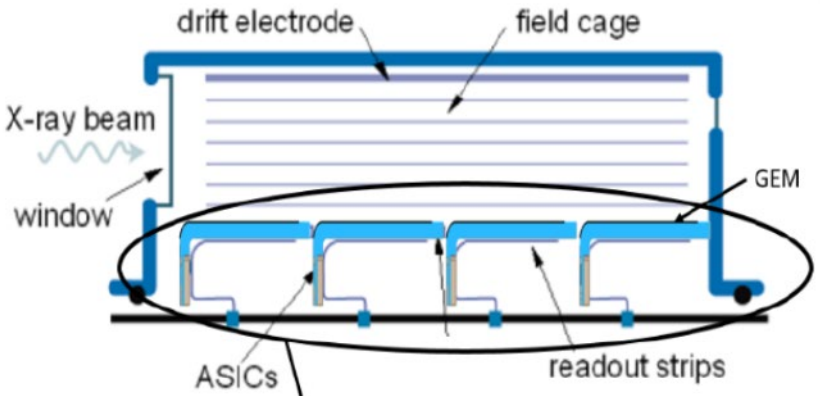
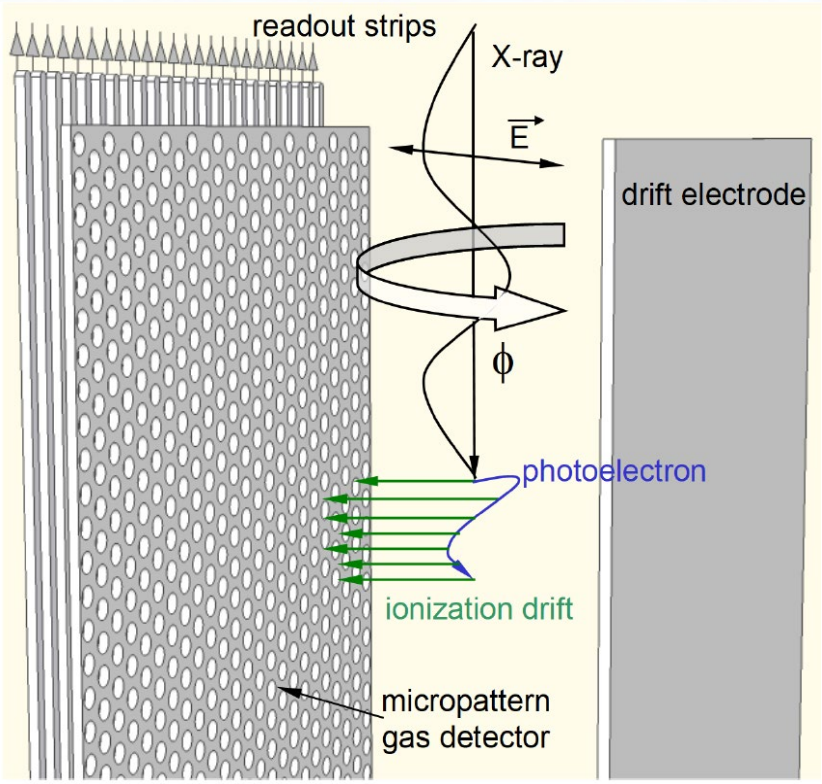
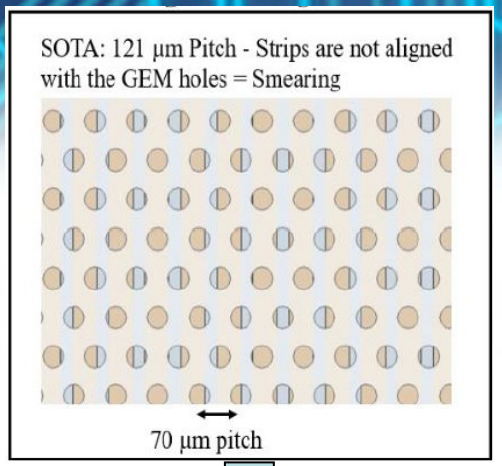
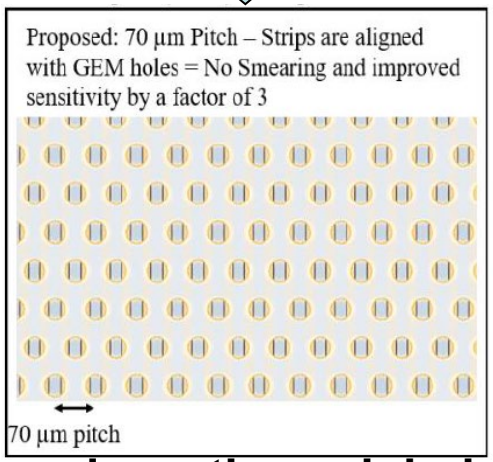








Looking down through holes on Gas Electron Multiplier (GEM)

HXPP: Print trials with diluted ink

DOWA AgNP
C_p = 80%

+ Distilled Water

Ultrasonication (45kHz, 1 hour)

Smooth Ink Consistency

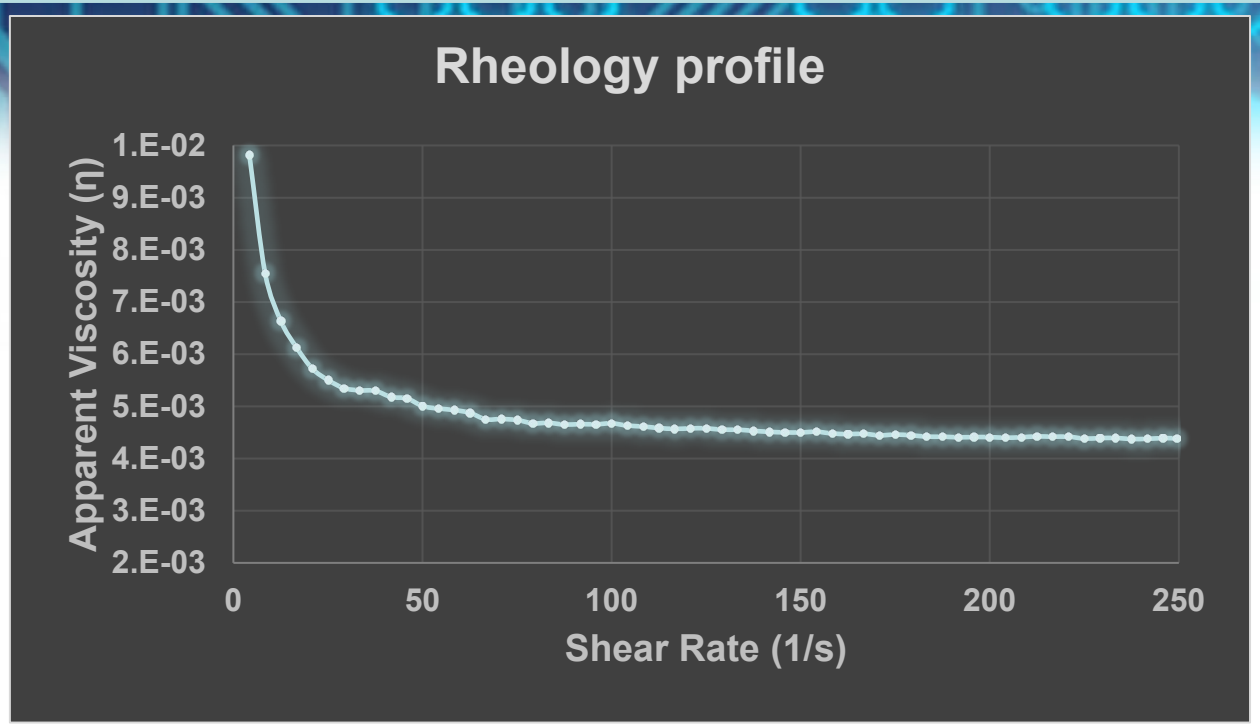
Filtration (Grade 413, 4um pore)

DOWA AgNP Ink
C_p = 50%; $d_{p,max}$ = 4µm

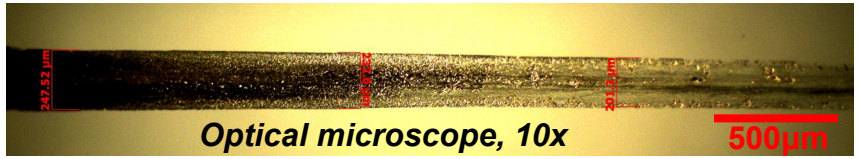
Print Trials (d_{noz} = 75µm)

Heated Magnetic Stirring (40°C, 500rpm, var time)

This process can be extended to increase the particle loading of the final ink



Print



Min trace width*: 200-247 µm

Issues
- **High porosity**
- **Low viscosity (large print widths)**

HXPP: Print trials with HPS-FG77

Trials with a 50µm nozzle w/ 85% Ag content

Discontinuous lines

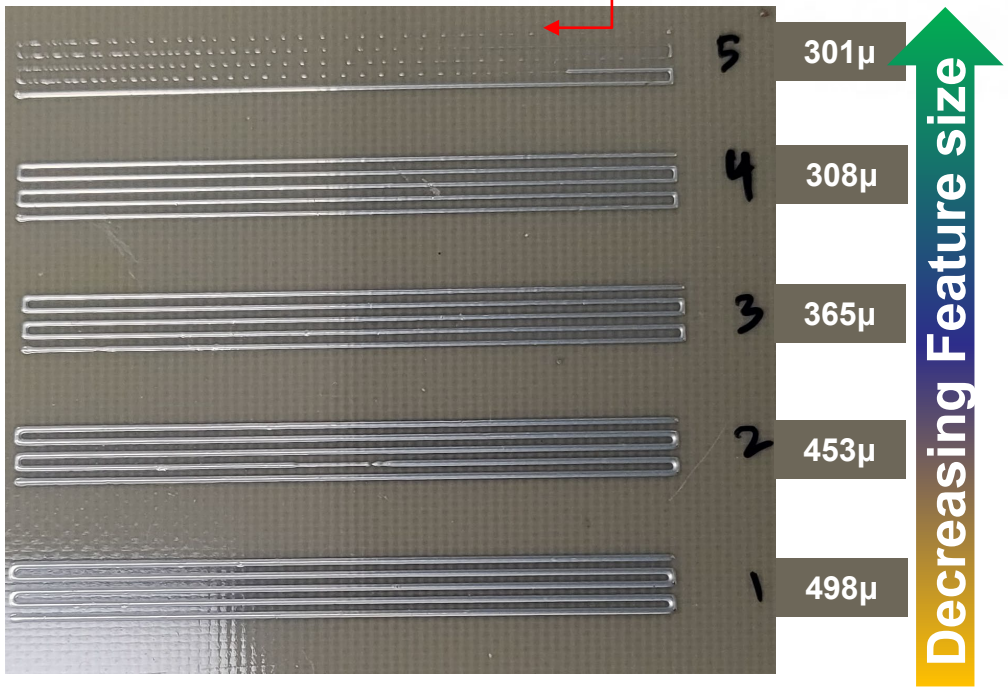
20mm/s | 30psi |Z80µm

20mm/s | 30psi |Z80µm

20mm/s | 35psi |Z80µm

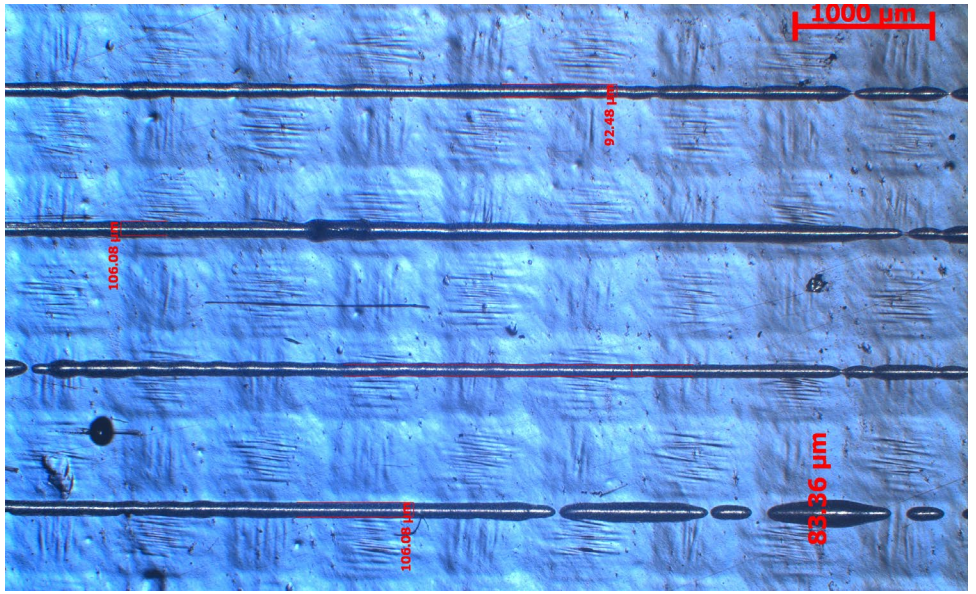
10mm/s | 35psi |Z80µm

10mm/s | 40psi |Z80µm



HPS-FG77 w/ 70% Ag content

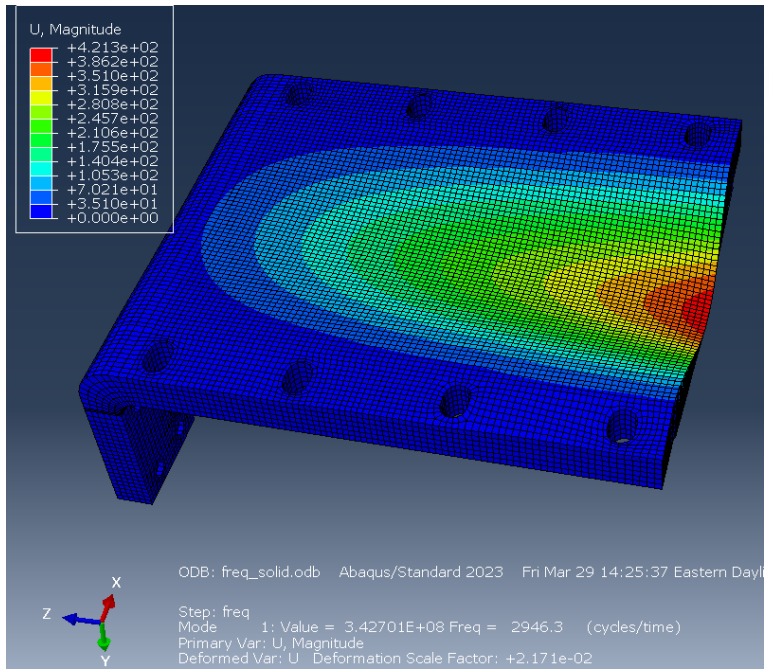
Avg. linewidth: 97 µm



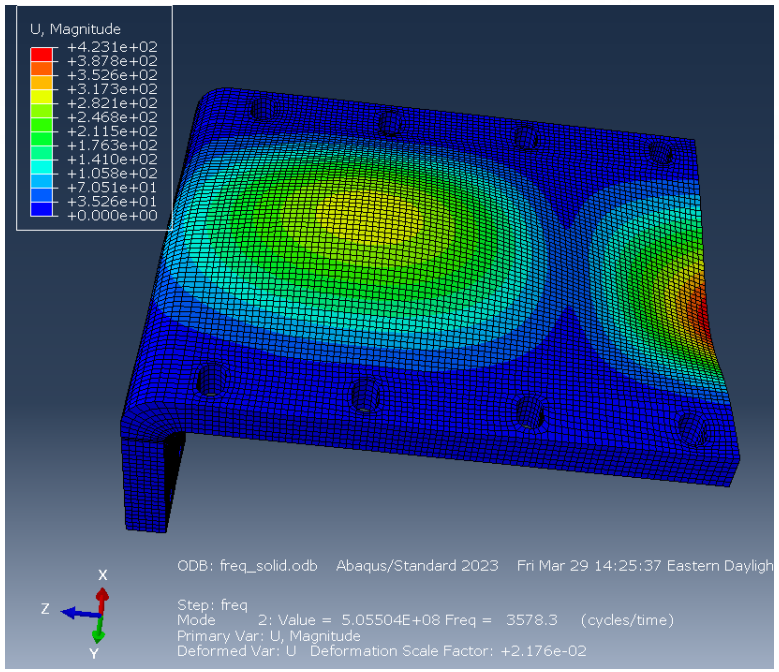
U_p = 25mm/s
P_{air} = 35psi

D_{noz} = 50µm
Z_{off} = 50µm

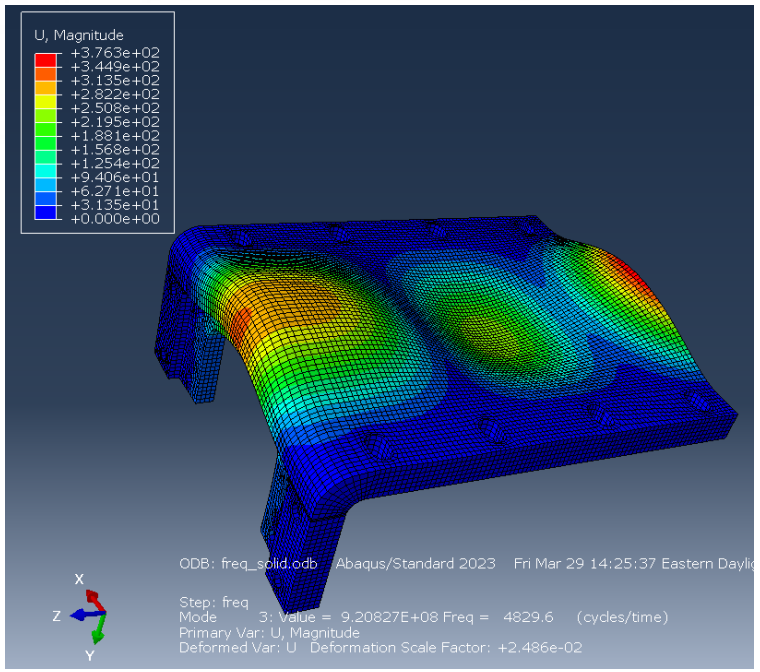
HXPP: substrate frequencies and mode shapes



Mode 1: 2946.3Hz



Mode 2: 3578.3Hz

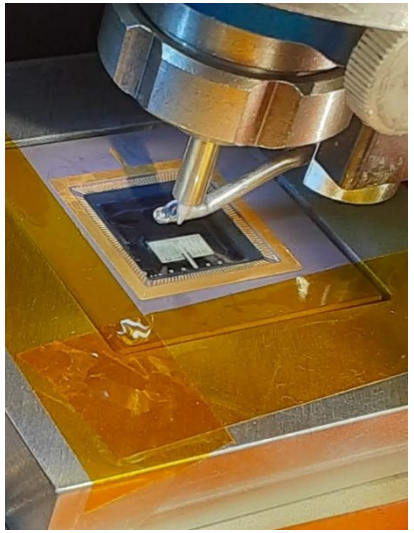


Mode 3: 4829.6Hz

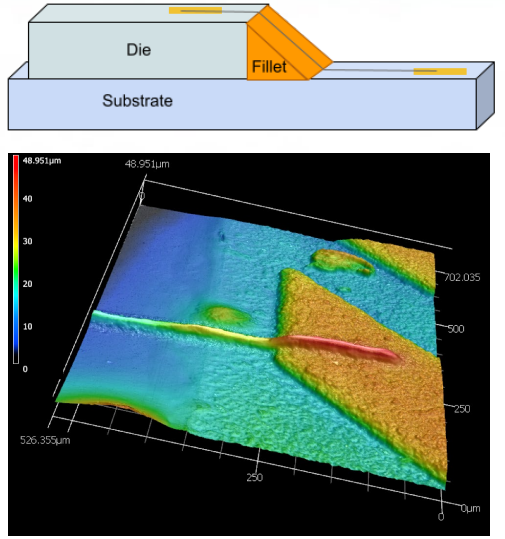
Upcoming applications and opportunities for collaboration

Summer 2025 projects:

- BOOP test flight
  - GPS antennas receiving signal during flight
- LEMS A3 conductive plane
  - Lunar environment testing
- Strain gauges:
  - Sounding rocket deflection measurements
  - Sounding rocket structural design ground testing



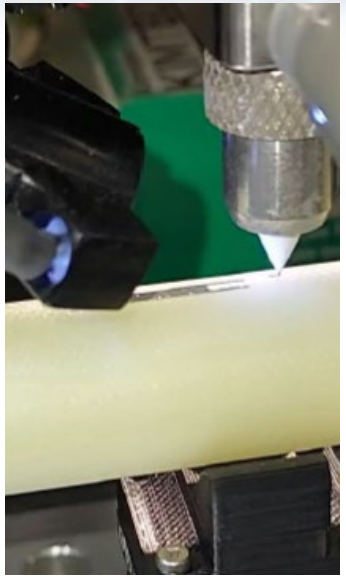
Printing antennas to minimize losses



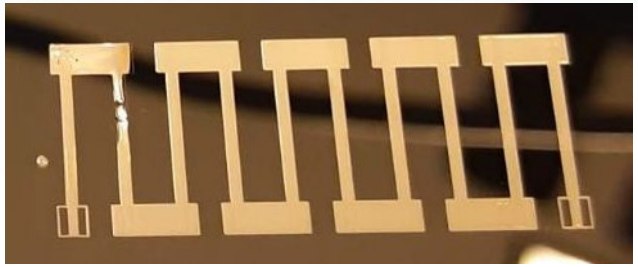
Printing interconnects and large interconnect arrays

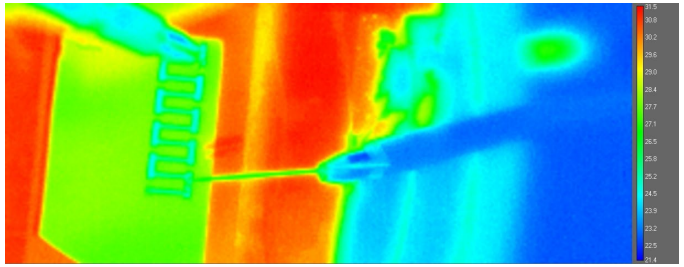
*RF patch antenna designed by Wei-chung Huang/567 for Multifunctional Sensor Platform (MFSP) Project led by Mahmooda Sultana/699

Upcoming applications and opportunities for collaboration



Curved surface print applications





Localized heaters for sensor outgassing; cryo interface temp control

Future opportunities for collaboration:

- Fine structured ceramics for high voltage applications
- Magnetometers
- Miniaturized electronics for CubeSats
- Localized EMI shielding
- Localized heaters
- Curved surface antennas

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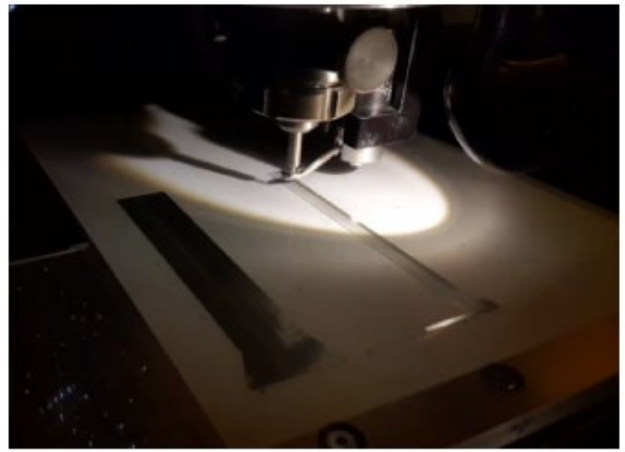
Current partners



Aerosol Jet Printing Detector Strip Pattern on Liquid Crystal Polymer [M. Samuels/562, LPS]

Acronym Table

Acronym	Definition
APRA	Astrophysics Research Analysis
ASTM	American Society for Testing and Materials
CAD	Computer aided design
CAM	Computer aided manufacturing
IRAD	Internal Research and Development
TDRSS	Tracking and Data Relay Satellite System
RF	Radio frequency
BPO	Balloon Program Office
MIC	Mission Initiation Consultation
ORDM	Operations Requirements Design Meeting
ODR	Operations Design Review
LHCP	Left hand circular polarized