Presenting a

New Attachment Technology for In-space attachment to Unprepared Surfaces

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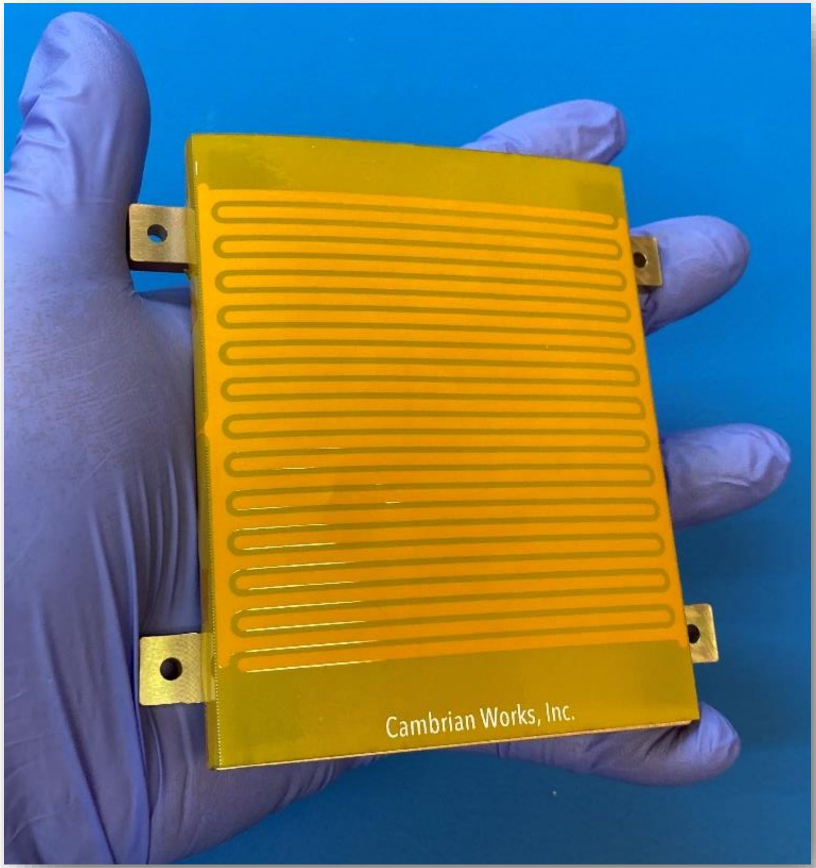
eTAP
General On-Orbit Attachment Technology

Features

- Uses the principle of electro adhesion
- Instant attachment
- Attaches to conductors and insulators
- Attaches to unprepared surfaces
- Conform to non-planar surfaces
- On/Off attachment
- Built with space rated materials



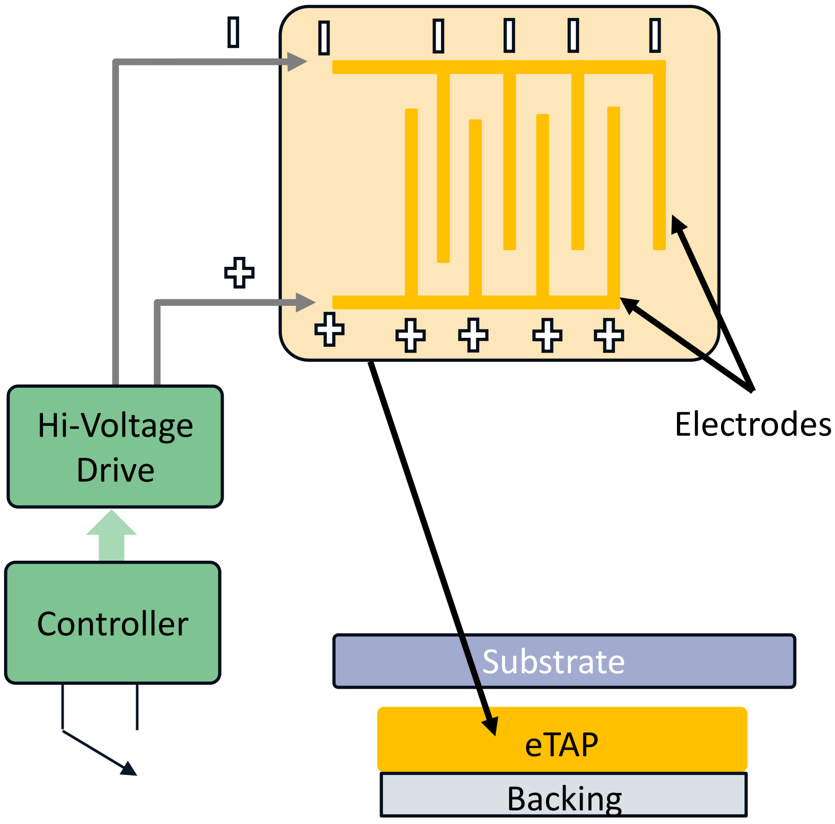
Demonstrated successfully with

Aluminum Alloys Anodized Al Steel Titanium	Glass Kapton Multi-Layer Insulation Carbon Fiber

How It Works

Electro-adhesion Anatomy

- **High Voltage Supply**
  - 1500V or higher
- **Electrodes**
  - High-voltage electrodes generate the electric fields
- **Dielectric**
  - Electrodes encapsulated within a dielectric for safe handling
  - Very thin package (<0.2mm)
- **Substrate**
  - Target surface for attachment

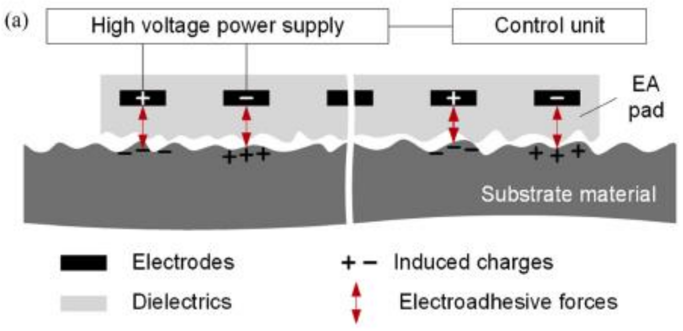


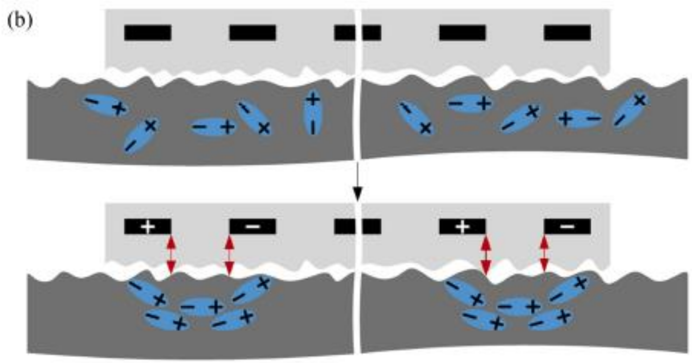
Electro-adhesion Operating Principles

- **Conducting Substrates**
  - eTAP field mirrors charges in a substrate opposing the fields imposed on the substrate surface. (Image courtesy Guo, et al. 2020)

- **Dielectric Substrates**
  - eTAP field affects the polarization of molecules within the opposing surface. (Image courtesy Guo, et al. 2020)

- **General Notes**
  - Adhesion force varies with material properties and surface contact
  - Attractive force scales with (eTAP) area and voltage
  - Shear attractive forces are particularly strong: about 10x normal forces
  - System-level power consumption (including high-power generation) is on the order of milliwatts
  - Fields penetrate only to a shallow “skin depth”: EMI/EMC concerns are minimal
  - Minimal impact to substrates (i.e. no residues)

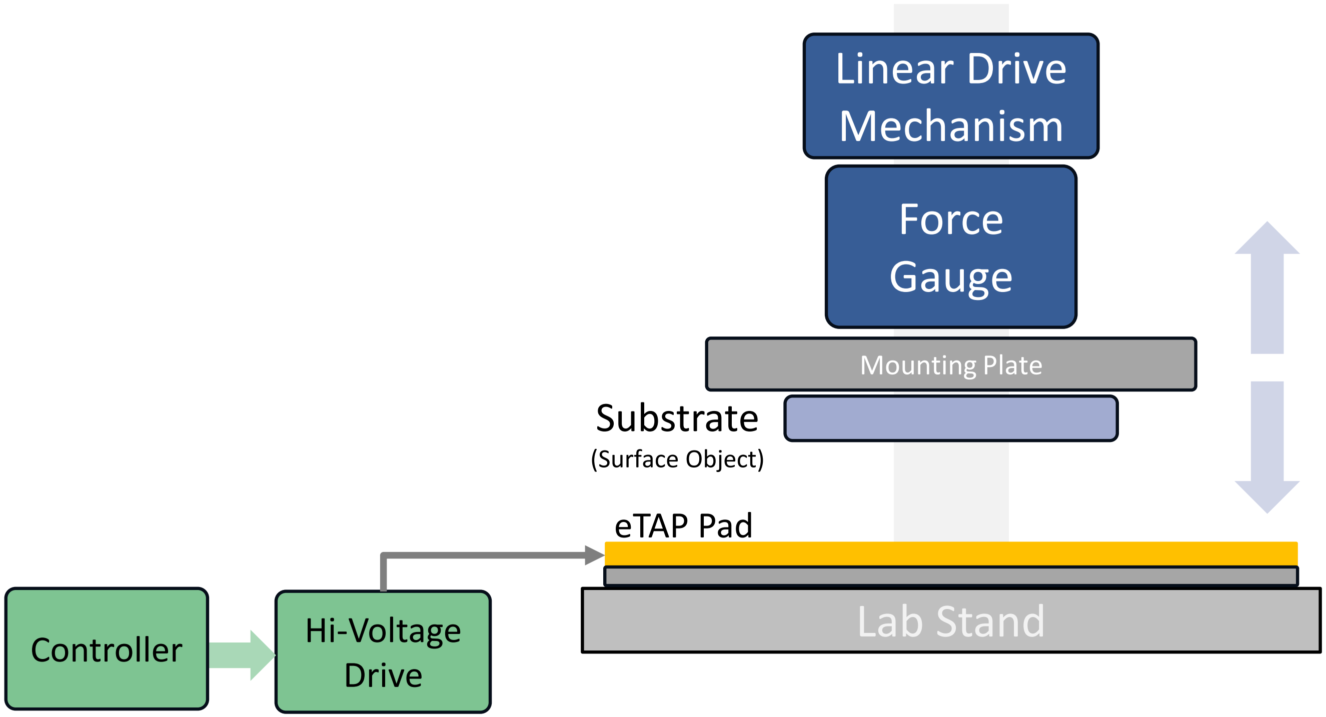


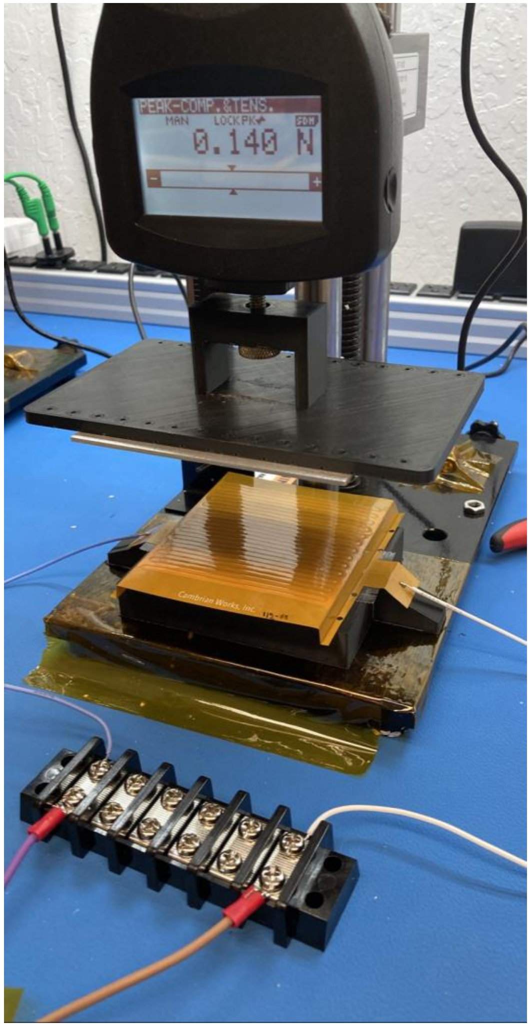


Demonstration Results

eTAP Normal Force Testing

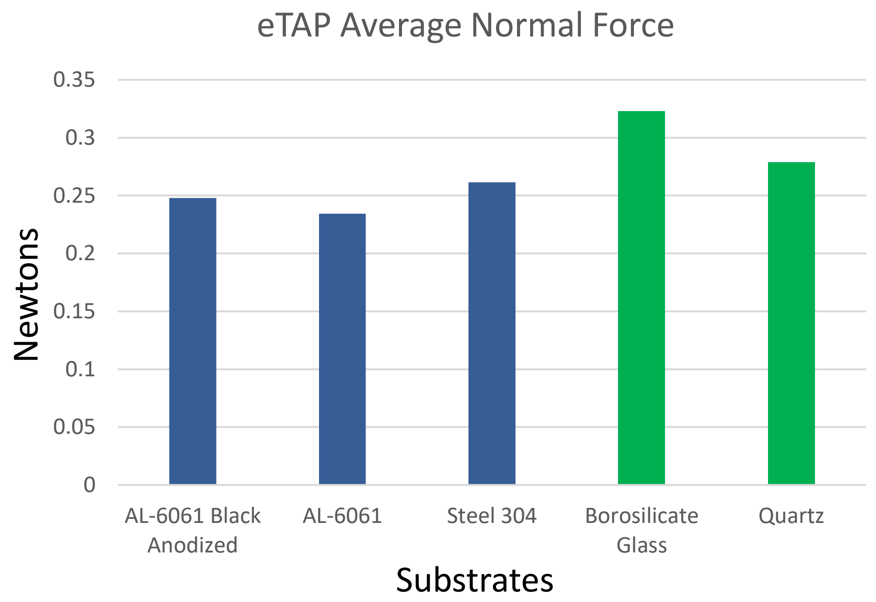
- Normal force testing setup allows for force measurement for different eTAP pad designs, material types, and voltage levels
- Different force gauges are used for different force level measurements.





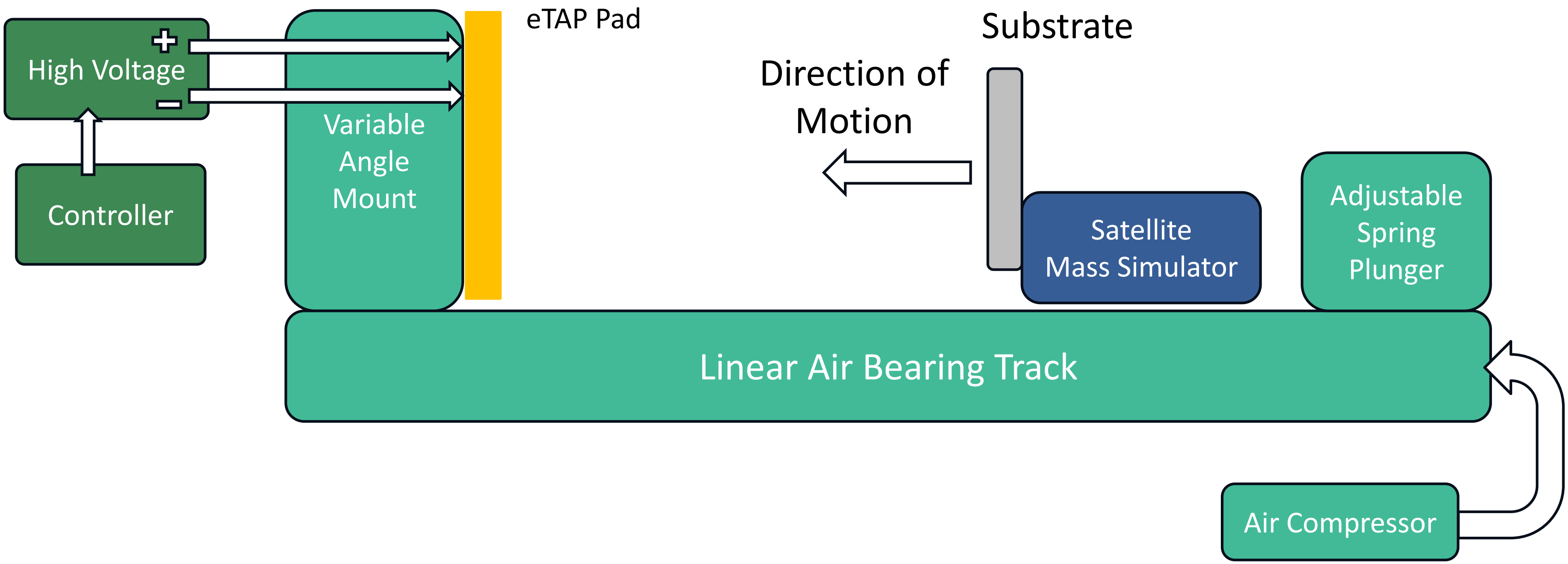
eTAP Testing Results

- Normal attractive forces are typically 15 mN/cm^2 at ambient pressure for a 4x4cm pad.
- Non-conductive coatings on conductive material do not affect attachment force.
- Insulator substrates have slightly higher normal attachment force than conductors.
- Normal force scales linearly with the attached area.
- Normal force attachment is significantly higher in vacuum than at ambient pressure.
- Mechanical design and mounting of the pads has a significant impact on the maximum attachment performance.



Data from example pads of 16 cm^2 area.

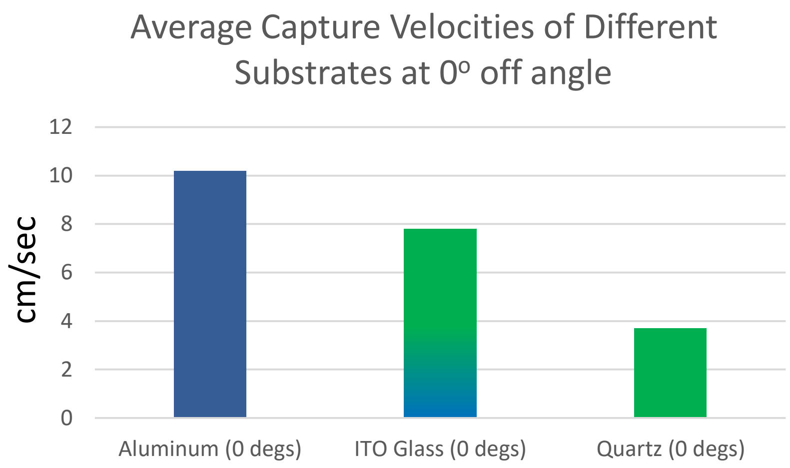
Linear Velocity Capture Testing

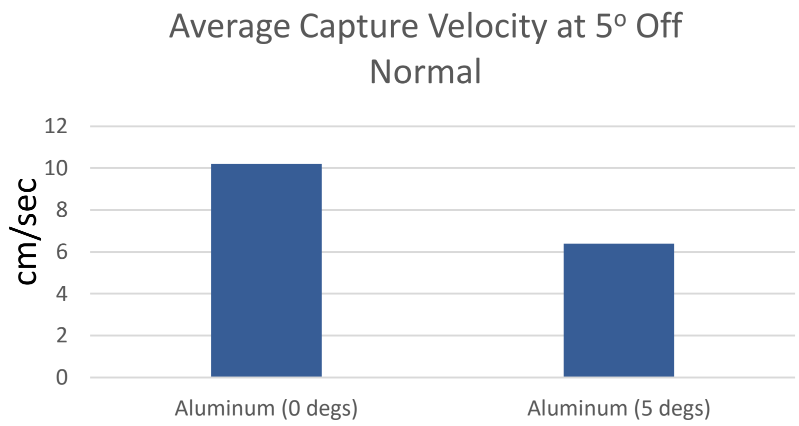


- Evaluate collision dynamics
- Repeatable impulsive docking at several velocities and angles
- Substrates can be swapped out
- Accommodates a satellite mass of 0.2kg

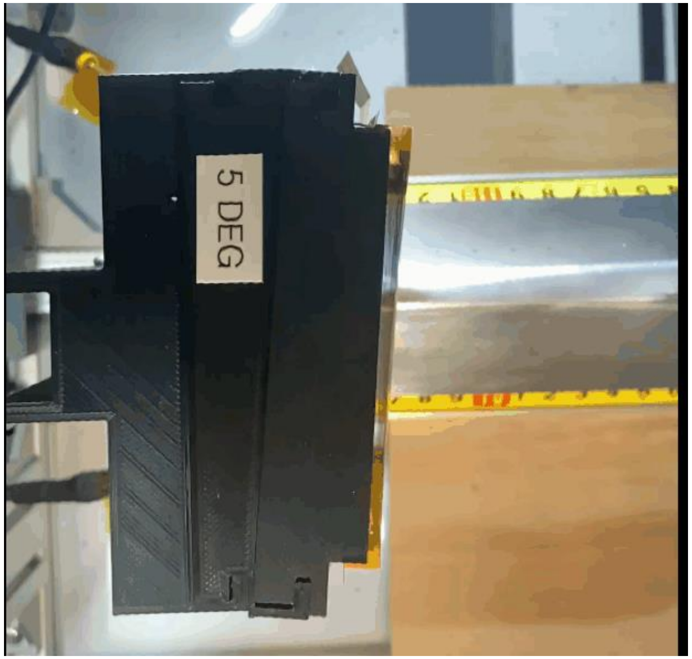
Linear Velocity Capture Results

- Conductive substrates have a faster electrical response time (0.02sec) compared to dielectric materials, and a resulting ability to capture objects with a higher velocity.
- Dielectric substrates coated with a resistive layer (≤15ohm/sq, 135nm thickness) behave more like conductive materials and allow capture at higher velocities
- 5 degrees off normal reduces the capture velocity





Velocity Capture Video



- Direction of motion is linear, allow us to understand the behavior of the flexible pads when it approaches with off-normal angles (e.g. 2° and 5°)

- Image shows eTAP pad conformance at an off-normal angle of 5.

Applications

eTAP™ Useful for a Wide Variety of Applications

- **Unprepared / Non-Cooperative Docking**
  - First soft capture
  - Repeatable release and redock
- **Generalized Workspace Management**
  - Tool and component management (eTAP wall™)
  - Workspace augmentation (camera mounts, anchor points, etc.)
- **Tele-Robotic and Servicing Assistance**
  - Attractive "touch" – pull objects in, and absorb incoming momentum
  - Augment existing mechanical graspers for in-space assembly

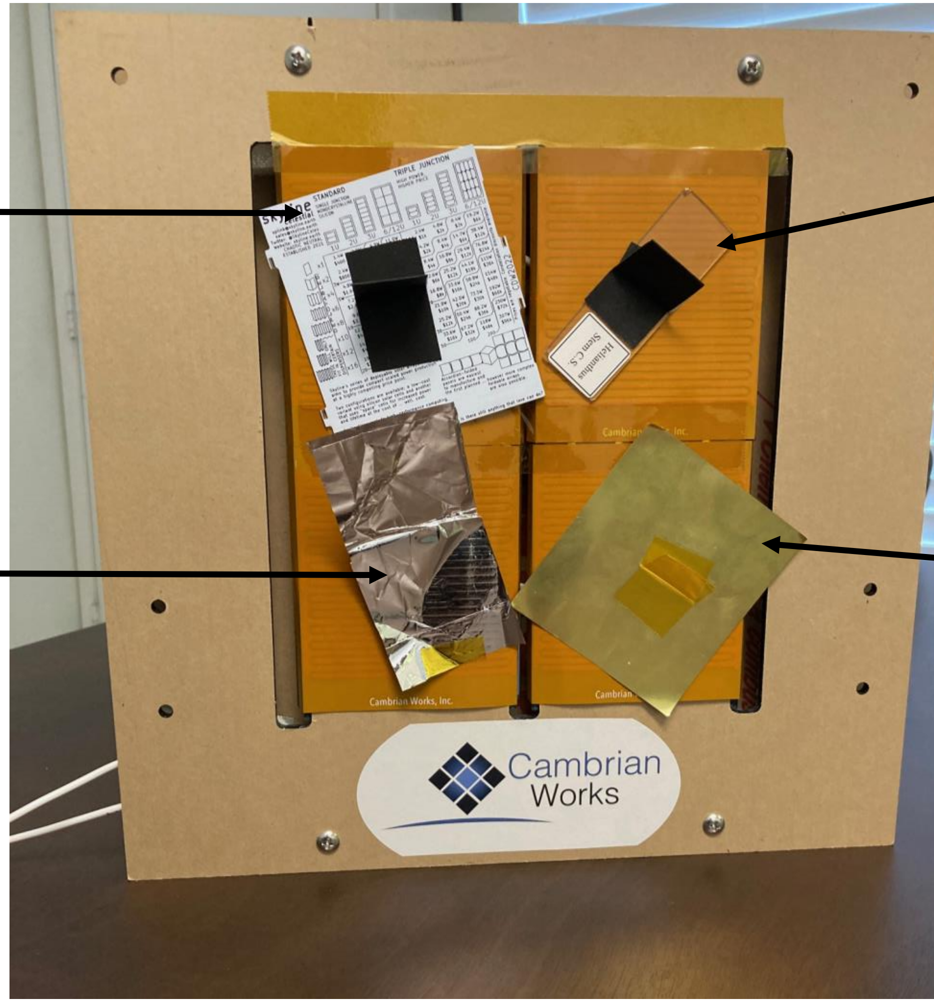
eTAP™ Wall – Come Try It Out!

PCB

Glass

Aluminized-Mylar

Brass



A Micro-Gravity Workspace

Questions?

Thank you!

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