SAND2024-01505C

Sandia National Laboratories

ADVANCED FUZING TECHNOLOGY

Microbeaded Encapsulants

93rd Shock & Vibration Symposium
Atlanta, GA 9/24-9/28

Presented By:

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Controlled by: Sandia National Laboratories, Alex Chen

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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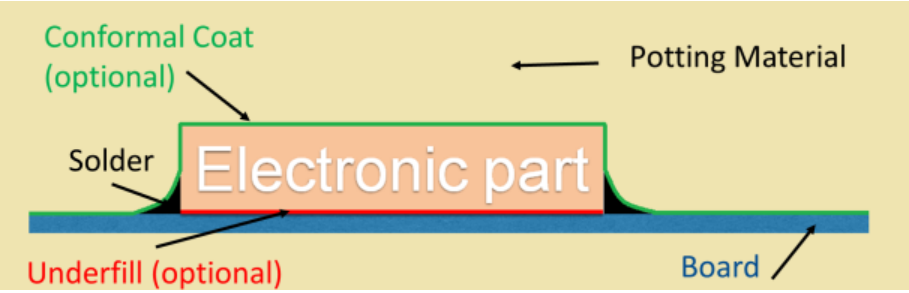
SAND2017-12745 PE

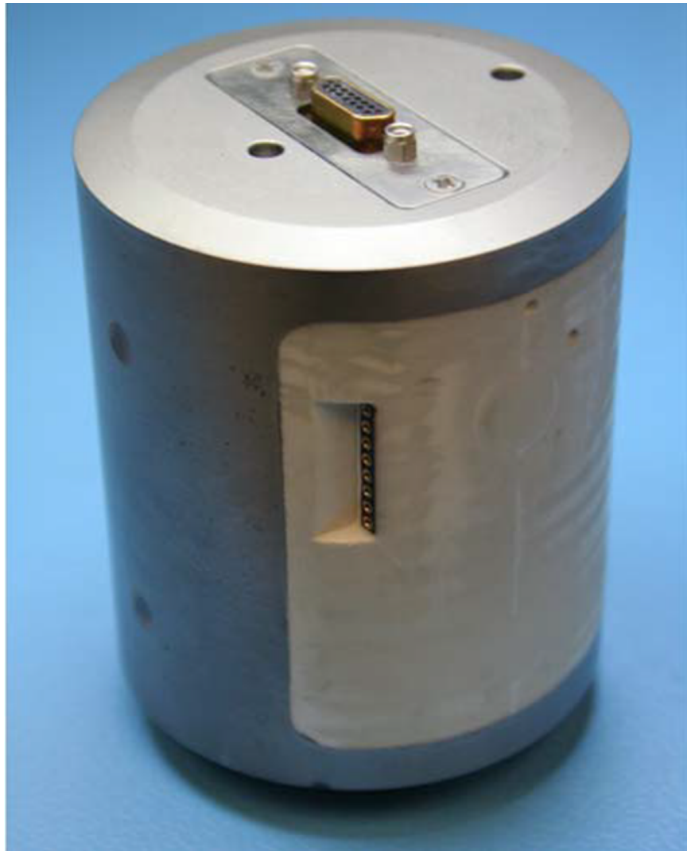
Background

Current Electronics Encapsulation

- Optional Fillers
- Physically supports electronics
- Prevents HV breakdown
- Proven shock performance



Current state-of-the-art component encapsulation method.

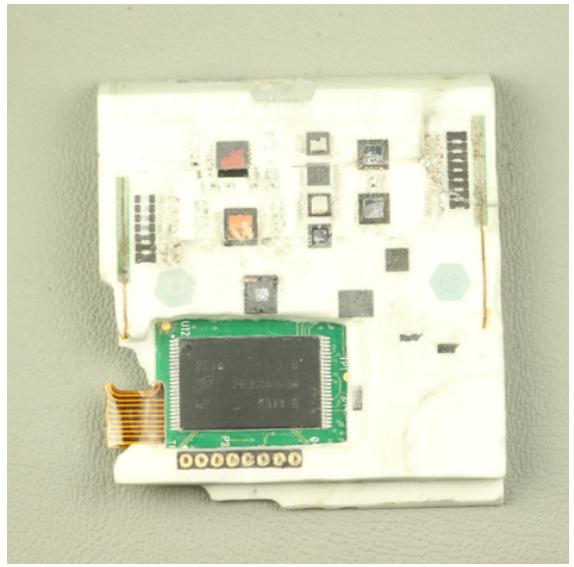


828/DEA/GMB encapsulated Data Recorder

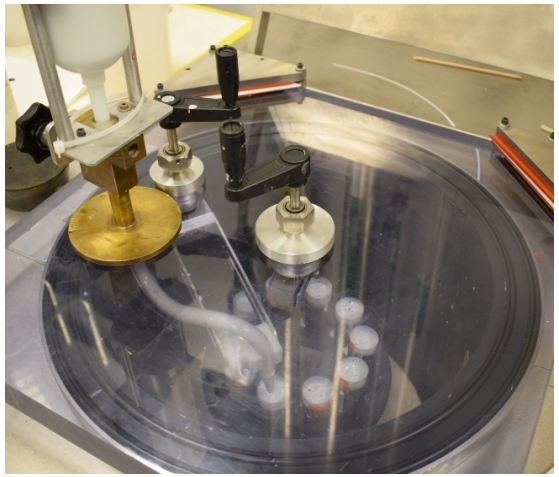
Background

Disadvantages

- Lengthy procedure with specialized processing
- Difficult/impossible to remove/rework
- CTE mismatch
  - residual stress after cure
  - stress during thermal cycling)



Removing a component from potted assembly



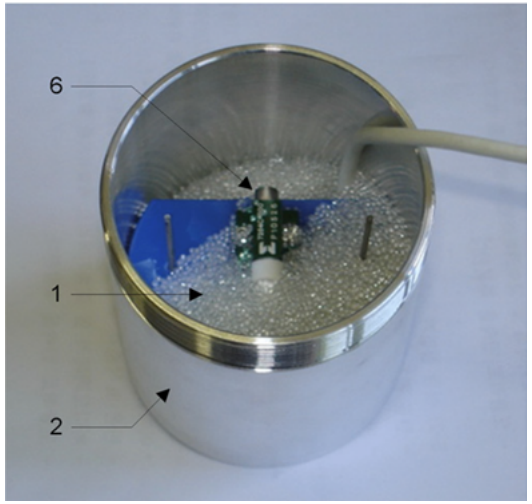
Pouring 828/DEA/GMB under vacuum

Thermally cure encapsulant (optionally elevated)

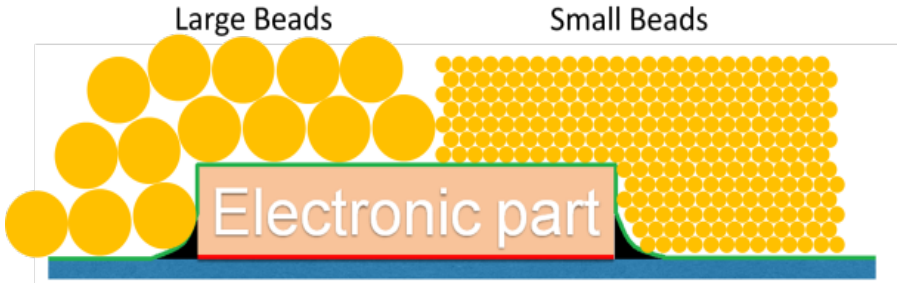
Microbeaded Encapsulation

Solution: Microbeaded encapsulation – using randomly packed solid beads to support electronics inside of a housing

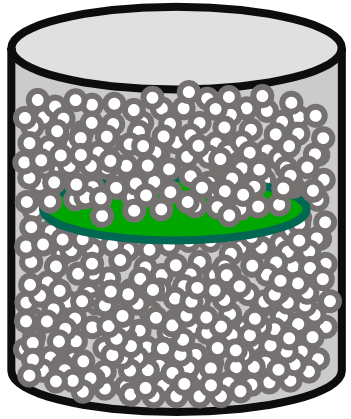
- Easily removable and components to be replaced
- No heating or vacuum required during packing
- CTE can be tailored based on bead material

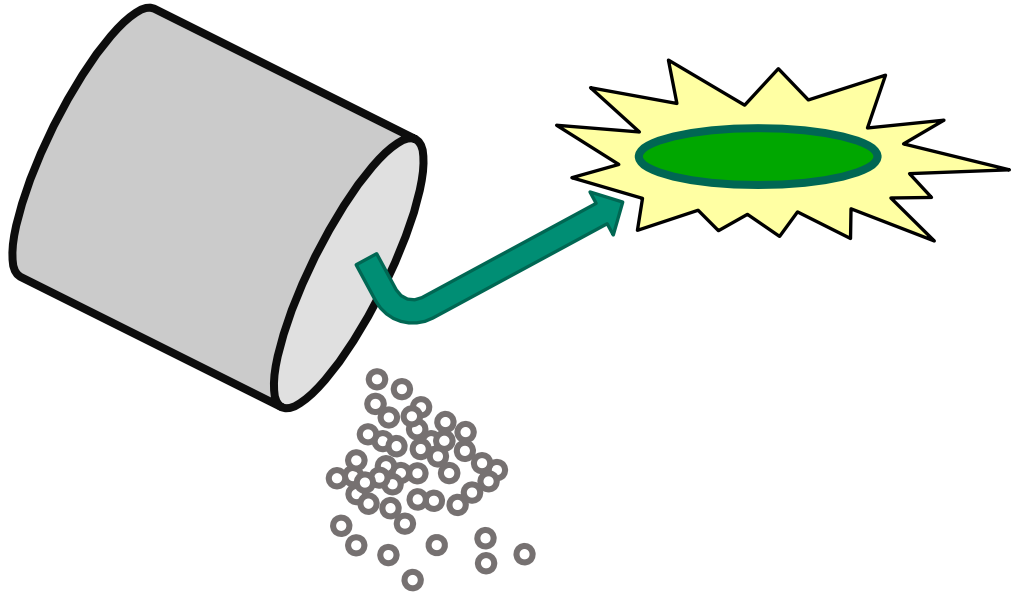


Yoon, Bioinsp. Biomim. 6 (2011) 016003



Proposed micro-beaded component encapsulation.



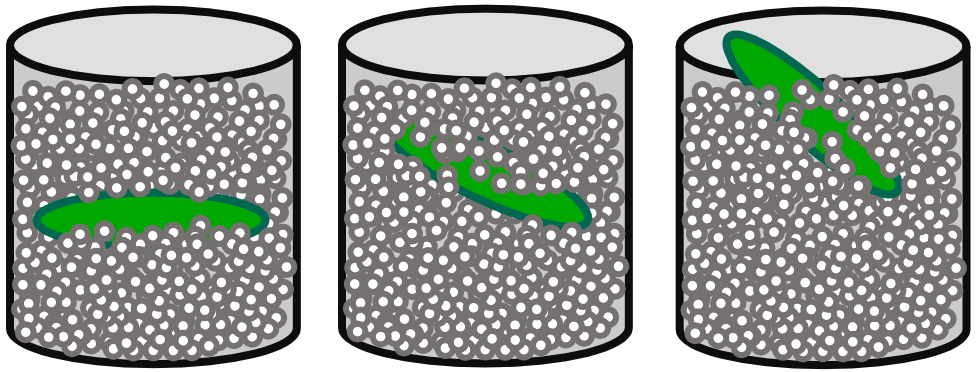


Microbeaded Encapsulation

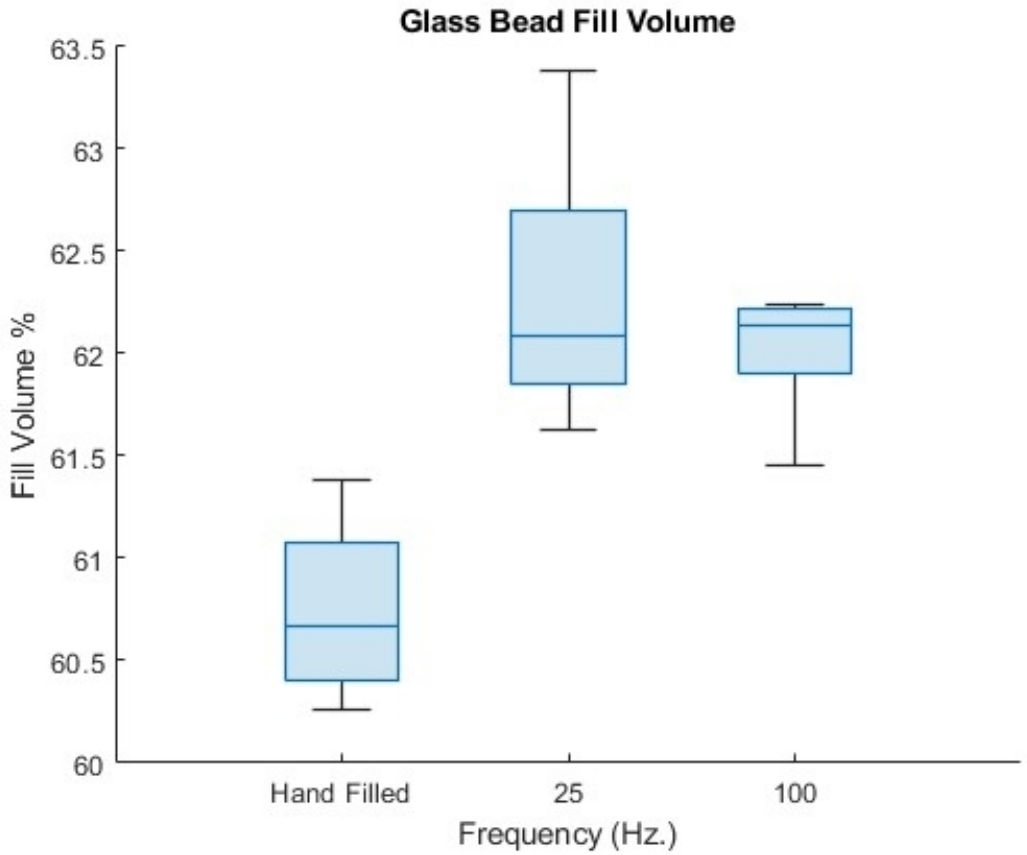
- Microbeads come in a variety of sizes and materials
  - Borosilicate Glass
  - Soda Lime Glass
  - 3M iM30K Micro balloons
  - Zirconia Microspheres
- Pictured to the right
  - 75-90 micron solid soda lime glass (top)
  - 600-710 micron solid soda lime glass (bottom)

Packaging

- Higher fill volume percentage while subjected to vibration
- Brazil nut effect
  - Creates requirement for fixturing for board



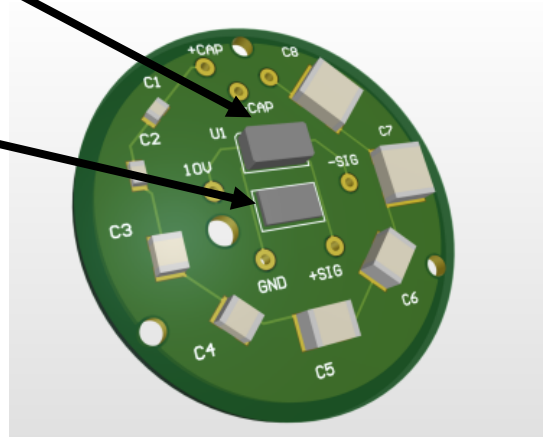
Board Rises + Shifts w/ Vibration



Test Setup

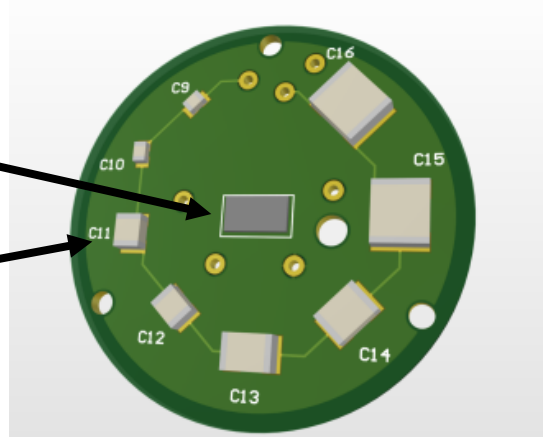
Accel/Tantalum Capacitor

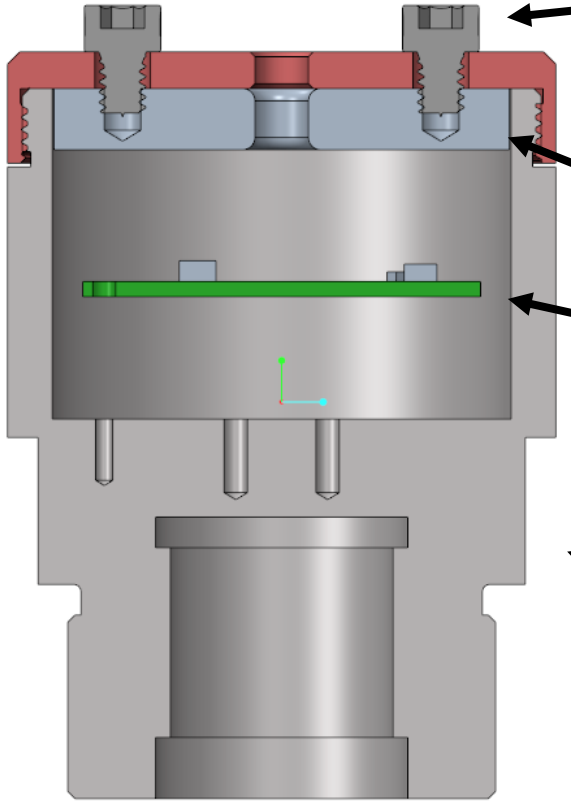
Top Strain Gauge



Bottom Strain Gauge

Ceramic Capacitors





Lid Screws

Titanium Lid

Preload Disk

PCB

Titanium Housing

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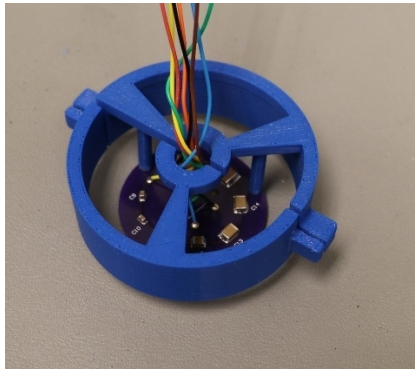
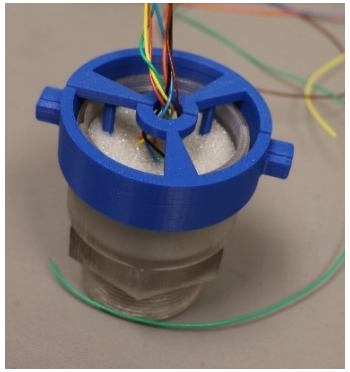
Packing Process

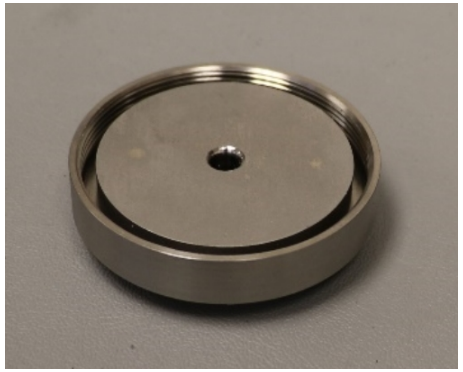
Initial Bead Pour



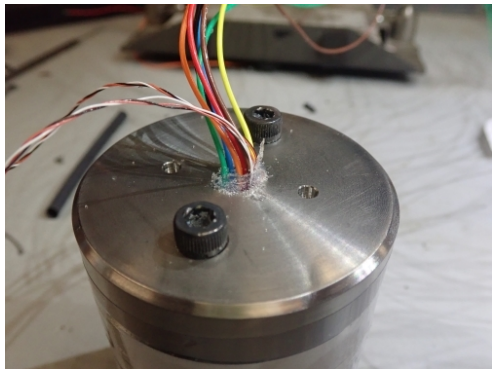
Board Fixture



Board Submerged

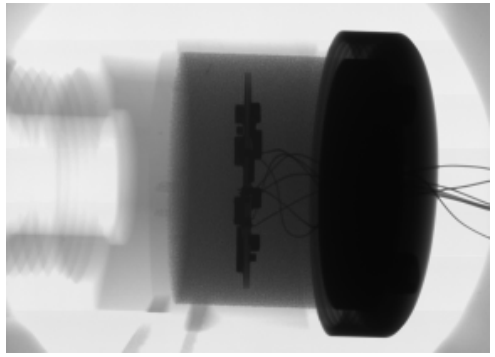


Lid Assembly

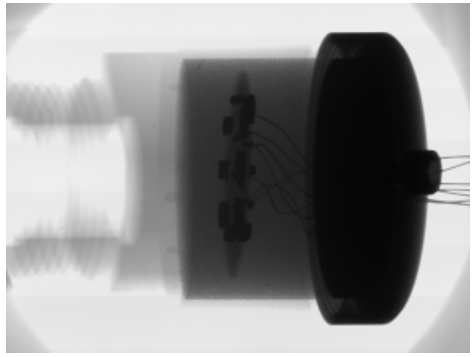


Wires sealed with RTV

All packing is done on a Bruel & Kjaer LDS V555 Low-Force Shaker (not shown)



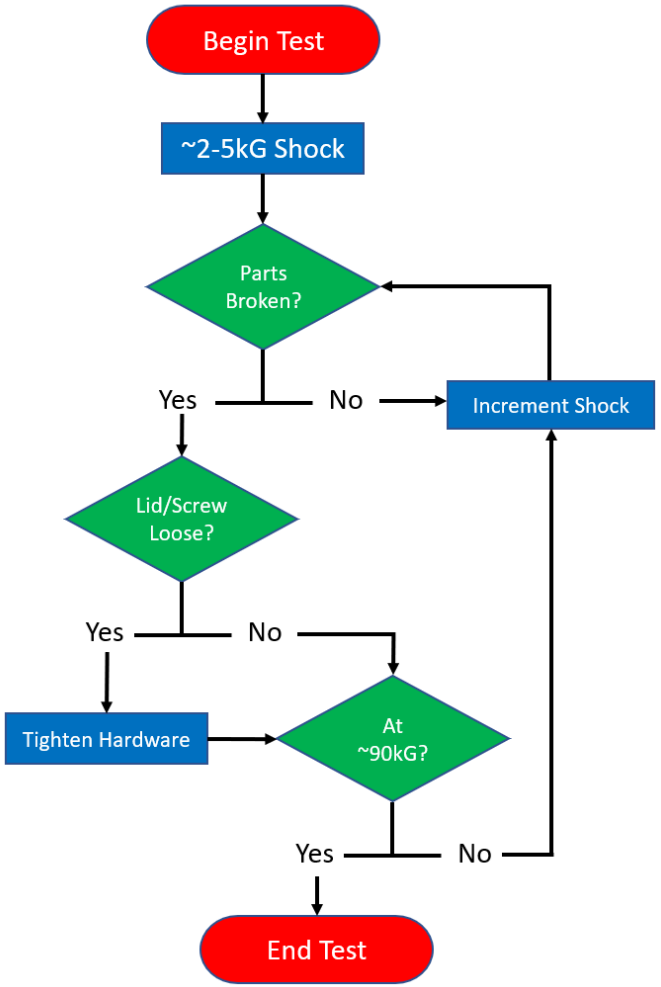
Before Random Vibration

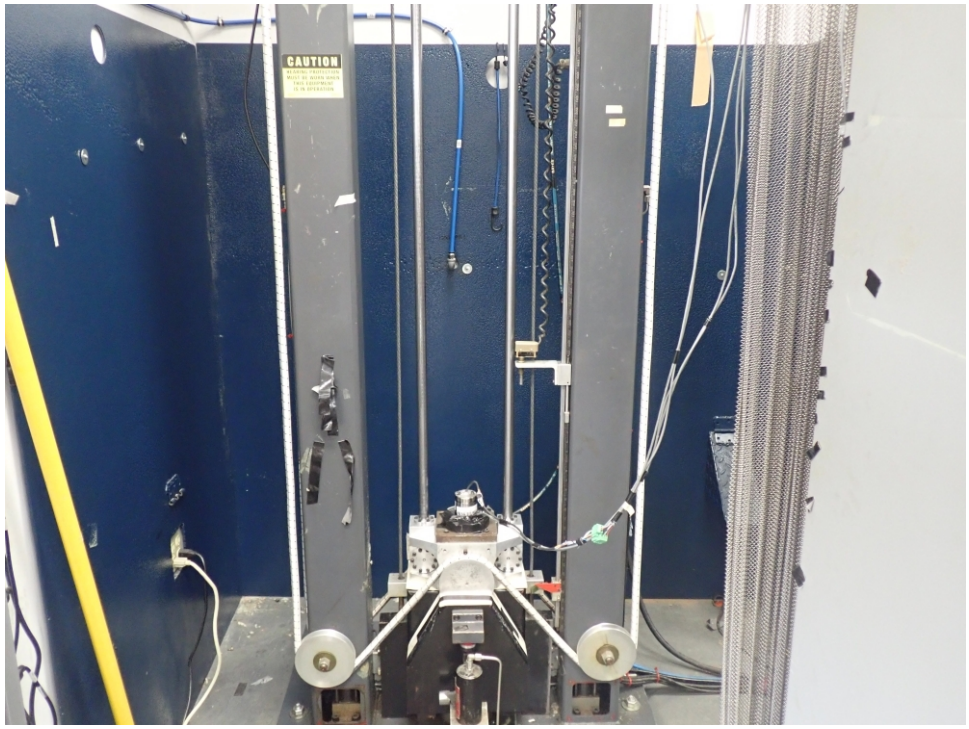


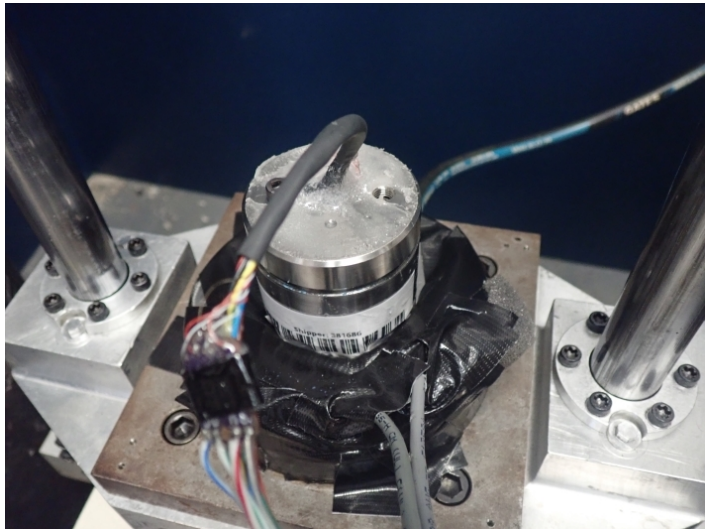
After Random Vibration

X-Ray Imaging on a 3D printed housing with a titanium lid

Test Setup







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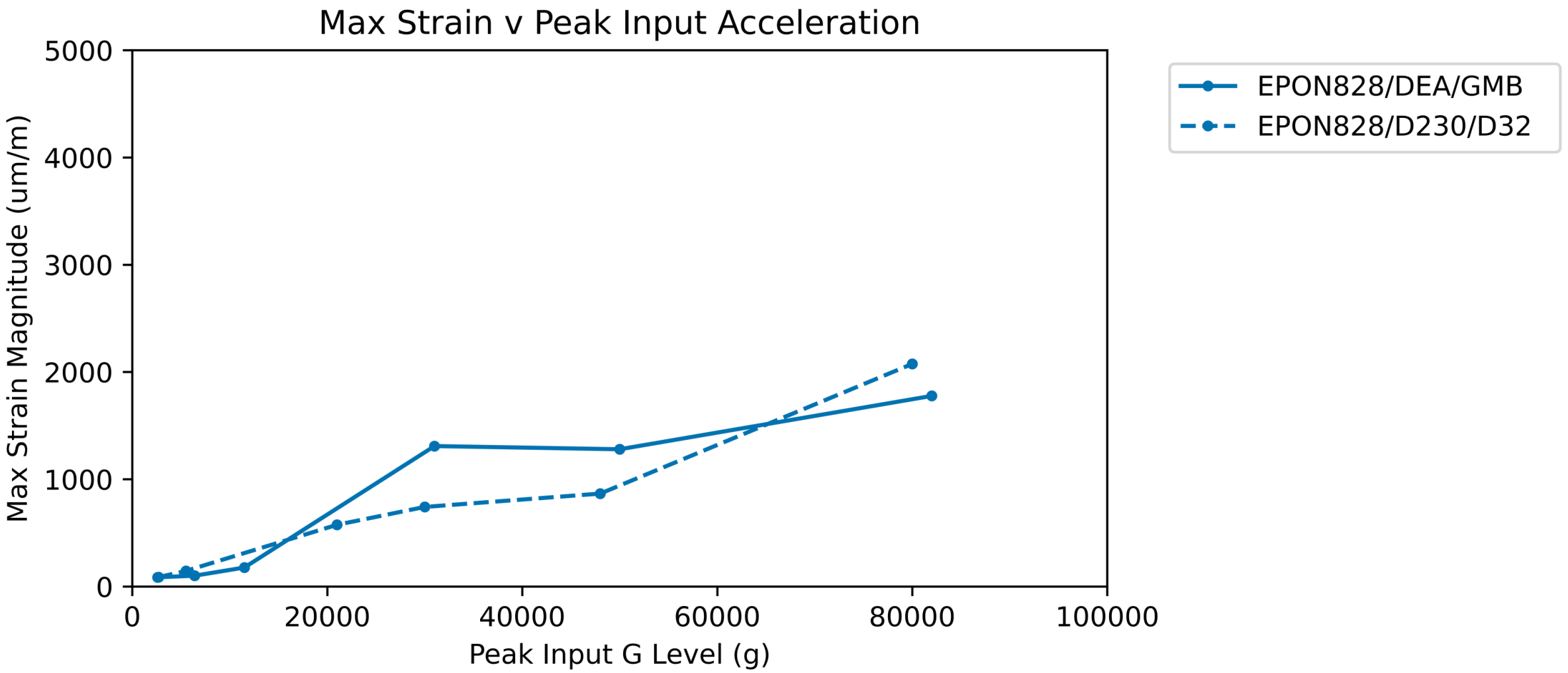
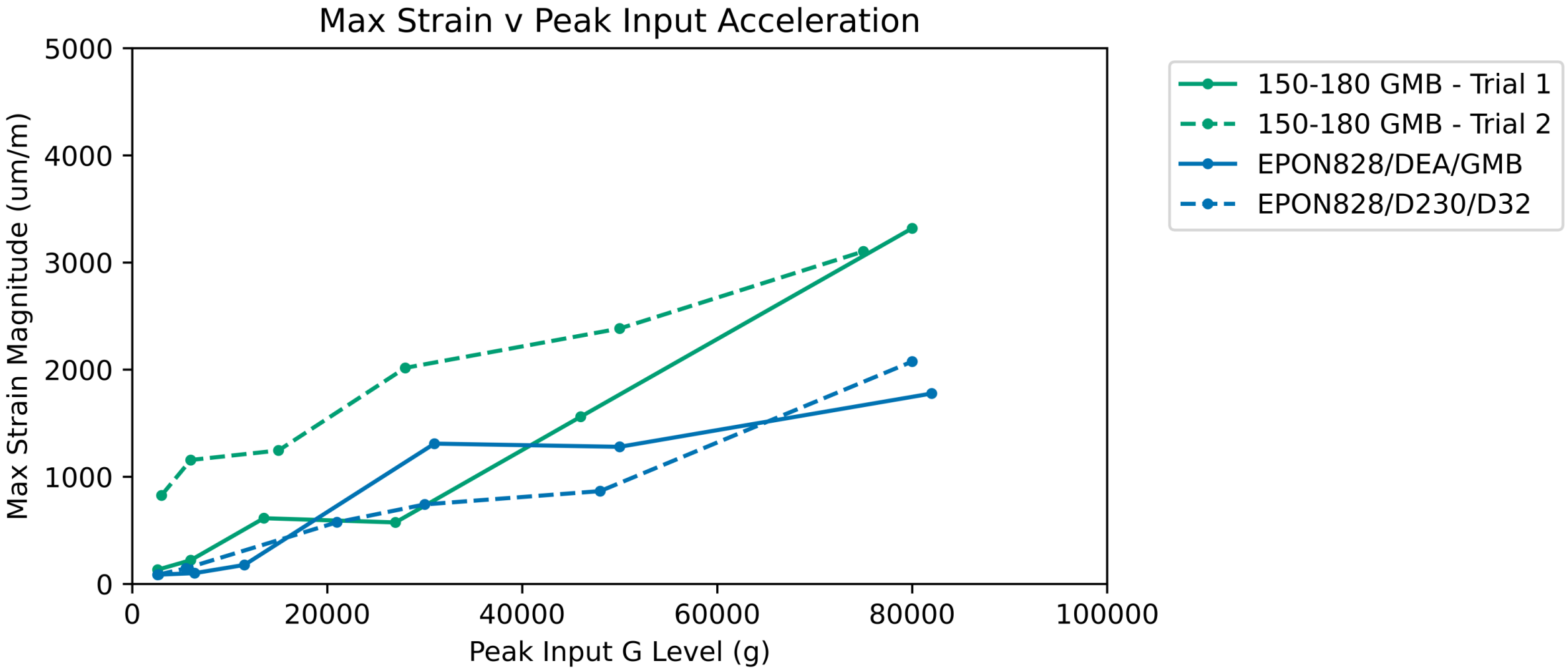
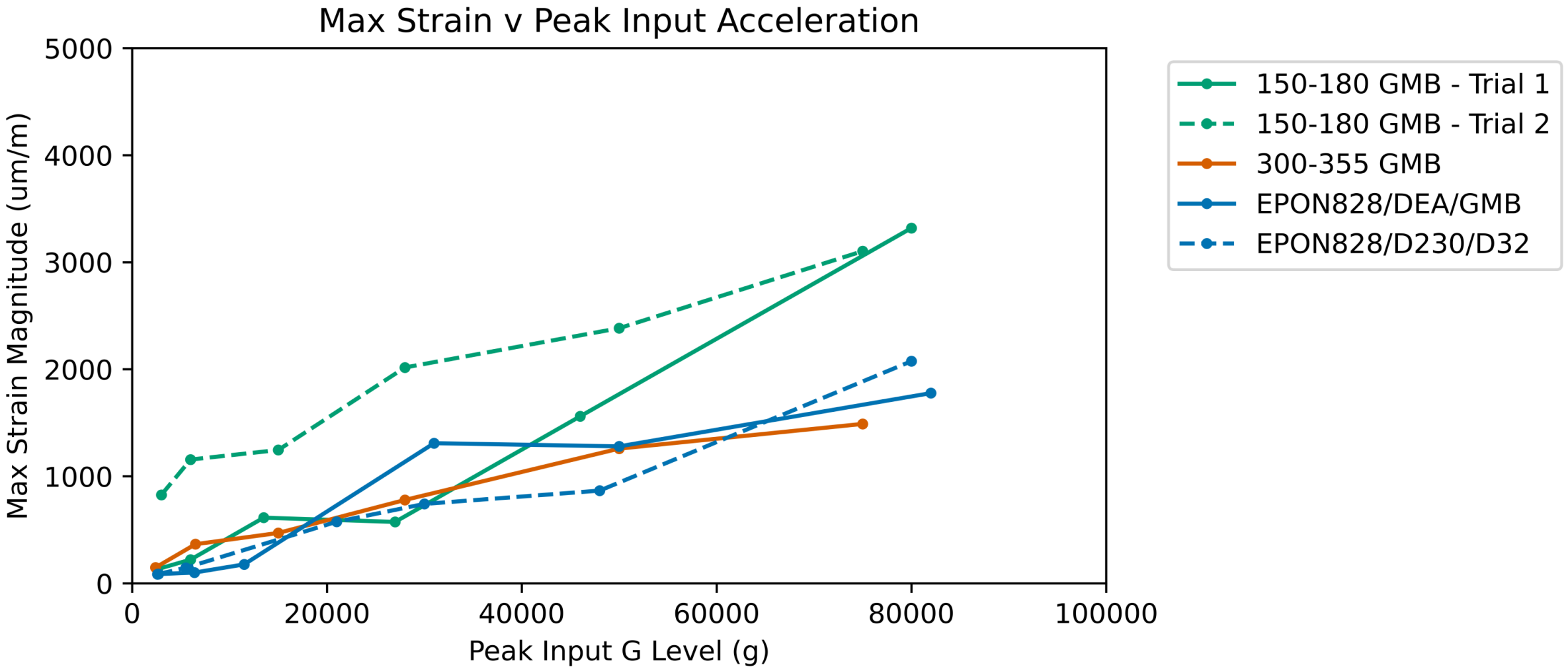
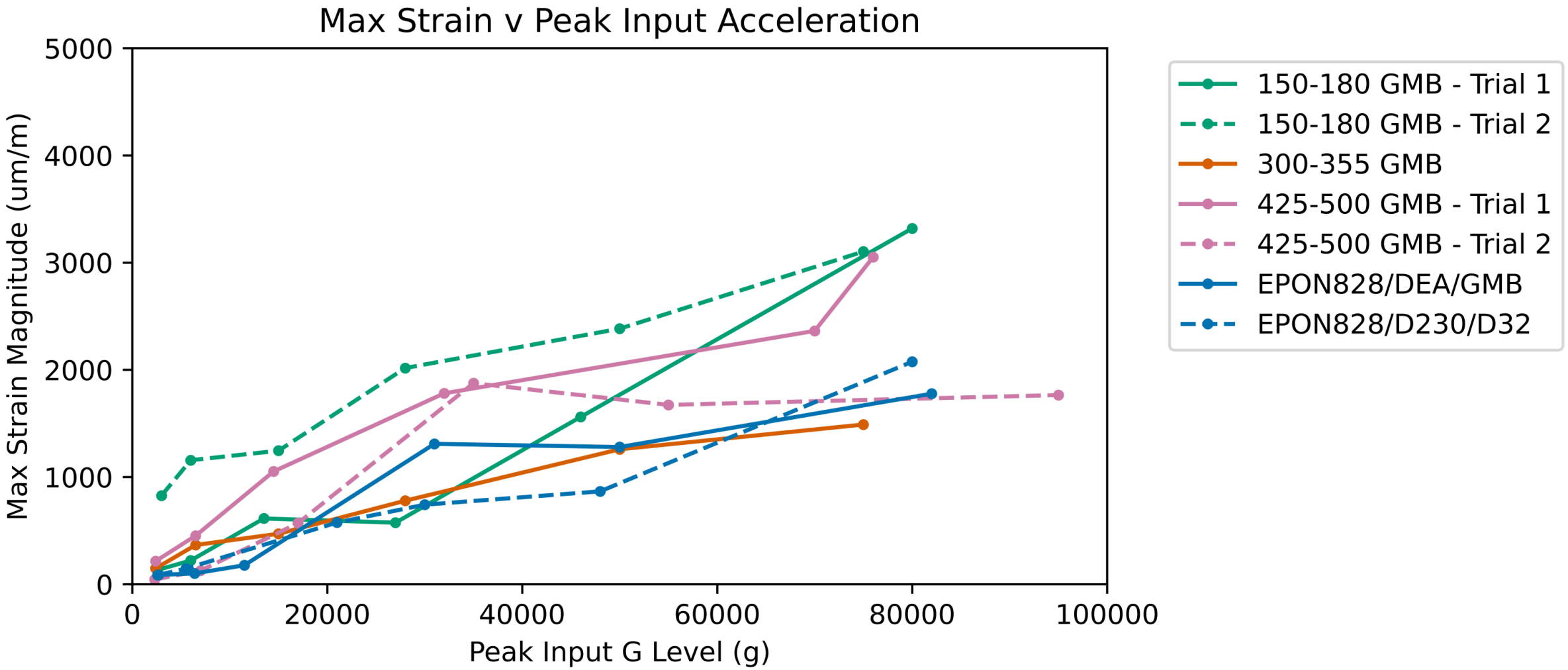
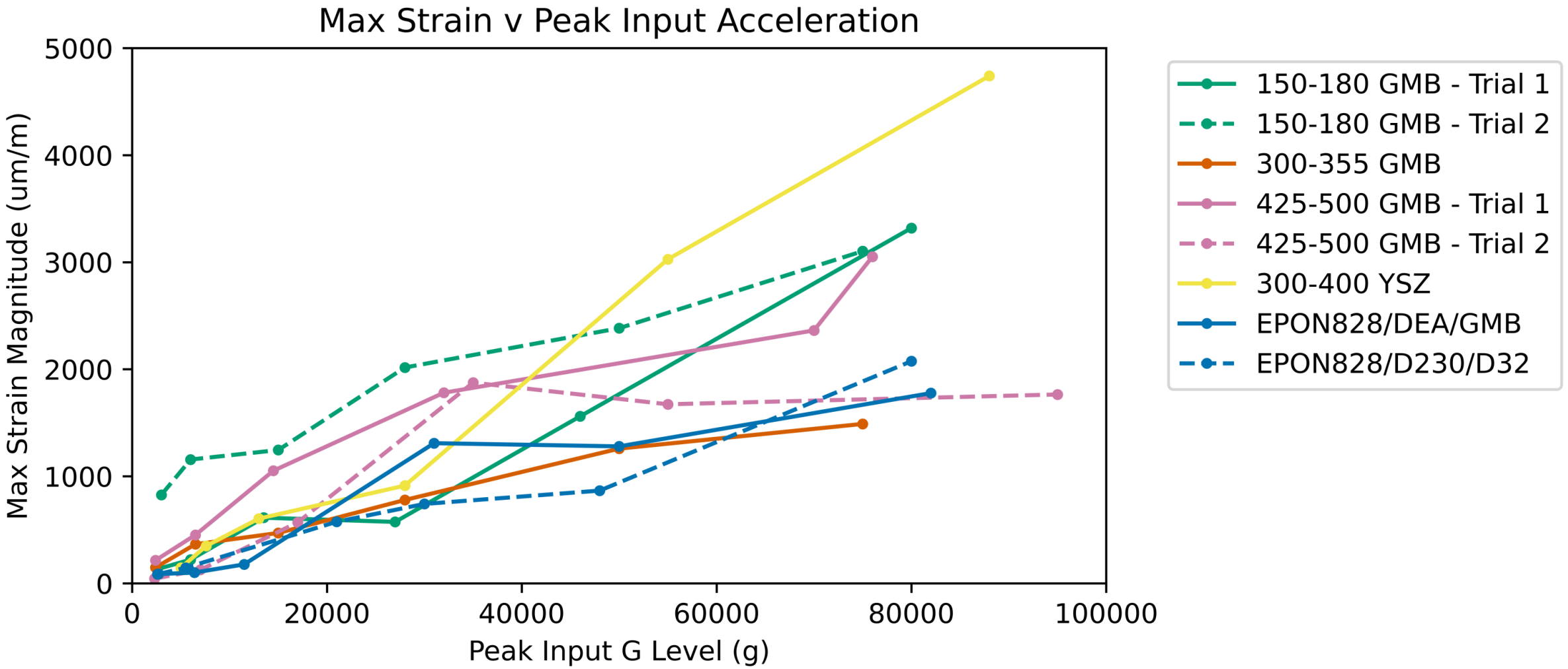
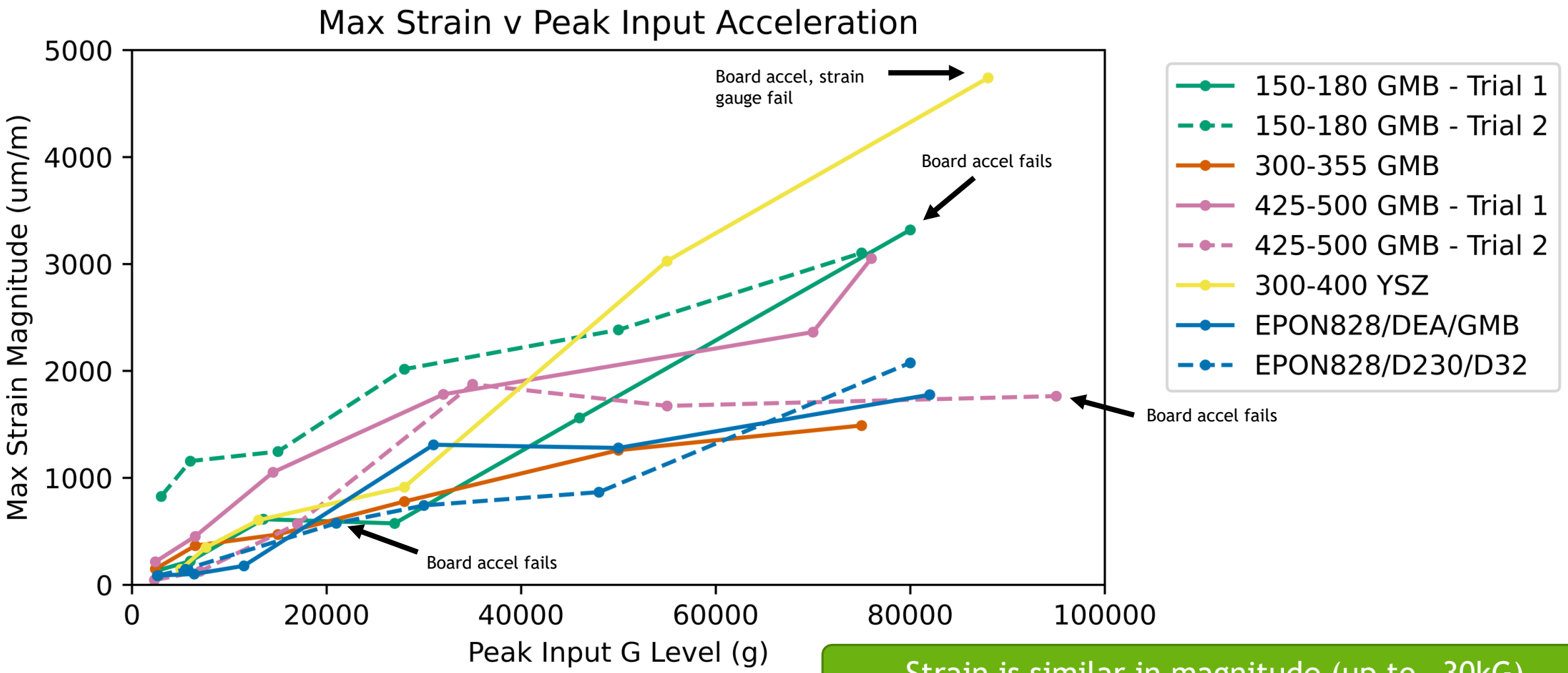

Max Strain v Peak Input Acceleration
Max Strain Magnitude (um/m)
5000
4000
3000
2000
1000
0
0
20000
40000
60000
80000
100000
Peak Input G Level (g)
EPON828/DEA/GMB
EPON828/D230/D32


Max Strain v Peak Input Acceleration
Max Strain Magnitude (um/m)
5000
4000
3000
2000
1000
0
0
20000
40000
60000
80000
100000
Peak Input G Level (g)
150-180 GMB - Trial 1
150-180 GMB - Trial 2
EPON828/DEA/GMB
EPON828/D230/D32


Max Strain v Peak Input Acceleration
Max Strain Magnitude (um/m)
Peak Input G Level (g)
0
1000
2000
3000
4000
5000
0
20000
40000
60000
80000
100000
150-180 GMB - Trial 1
150-180 GMB - Trial 2
300-355 GMB
EPON828/DEA/GMB
EPON828/D230/D32


Max Strain v Peak Input Acceleration
Max Strain Magnitude (um/m)
Peak Input G Level (g)
0
1000
2000
3000
4000
5000
0
20000
40000
60000
80000
100000
150-180 GMB - Trial 1
150-180 GMB - Trial 2
300-355 GMB
425-500 GMB - Trial 1
425-500 GMB - Trial 2
EPON828/DEA/GMB
EPON828/D230/D32


Max Strain v Peak Input Acceleration
Max Strain Magnitude (um/m)
Peak Input G Level (g)
0
1000
2000
3000
4000
5000
0
20000
40000
60000
80000
100000
150-180 GMB - Trial 1
150-180 GMB - Trial 2
300-355 GMB
425-500 GMB - Trial 1
425-500 GMB - Trial 2
300-400 YSZ
EPON828/DEA/GMB
EPON828/D230/D32



Strain is similar in magnitude (up to ~30kG)

YSZ Accel removed, nominally works (tap test)

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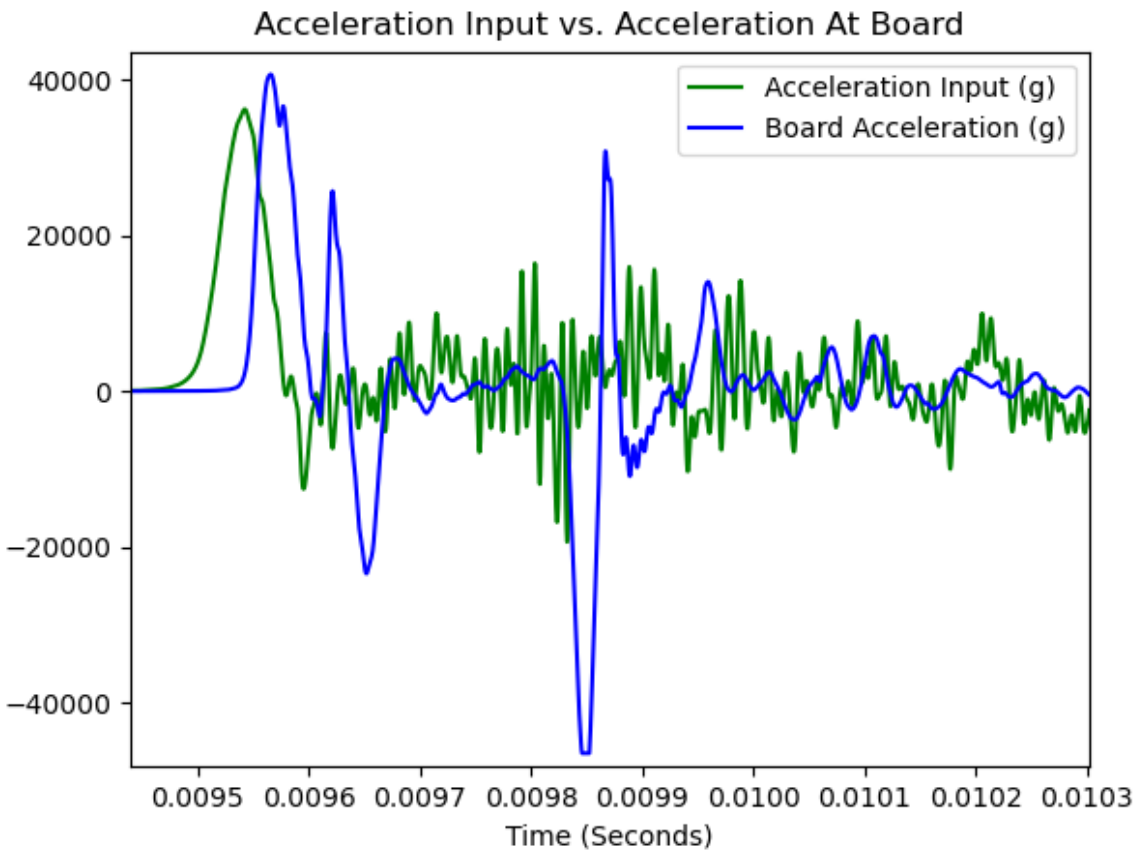
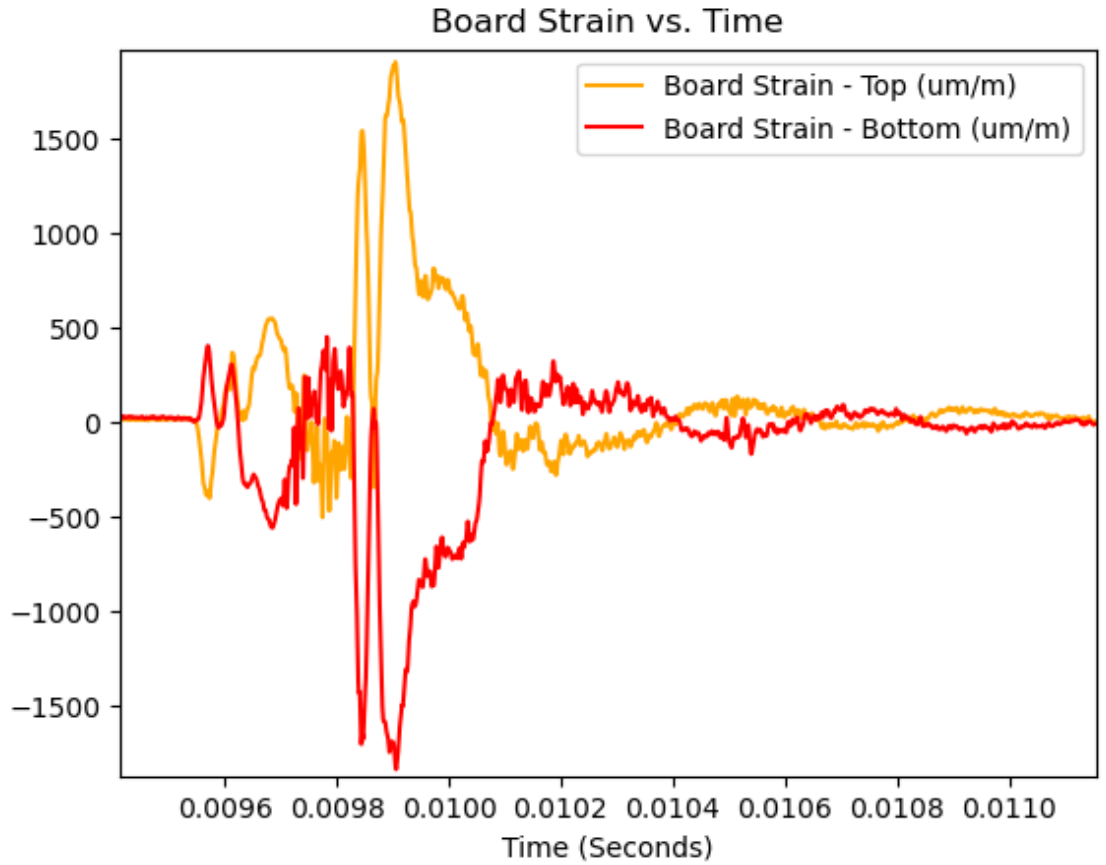
Typical Acceleration & Strain Results

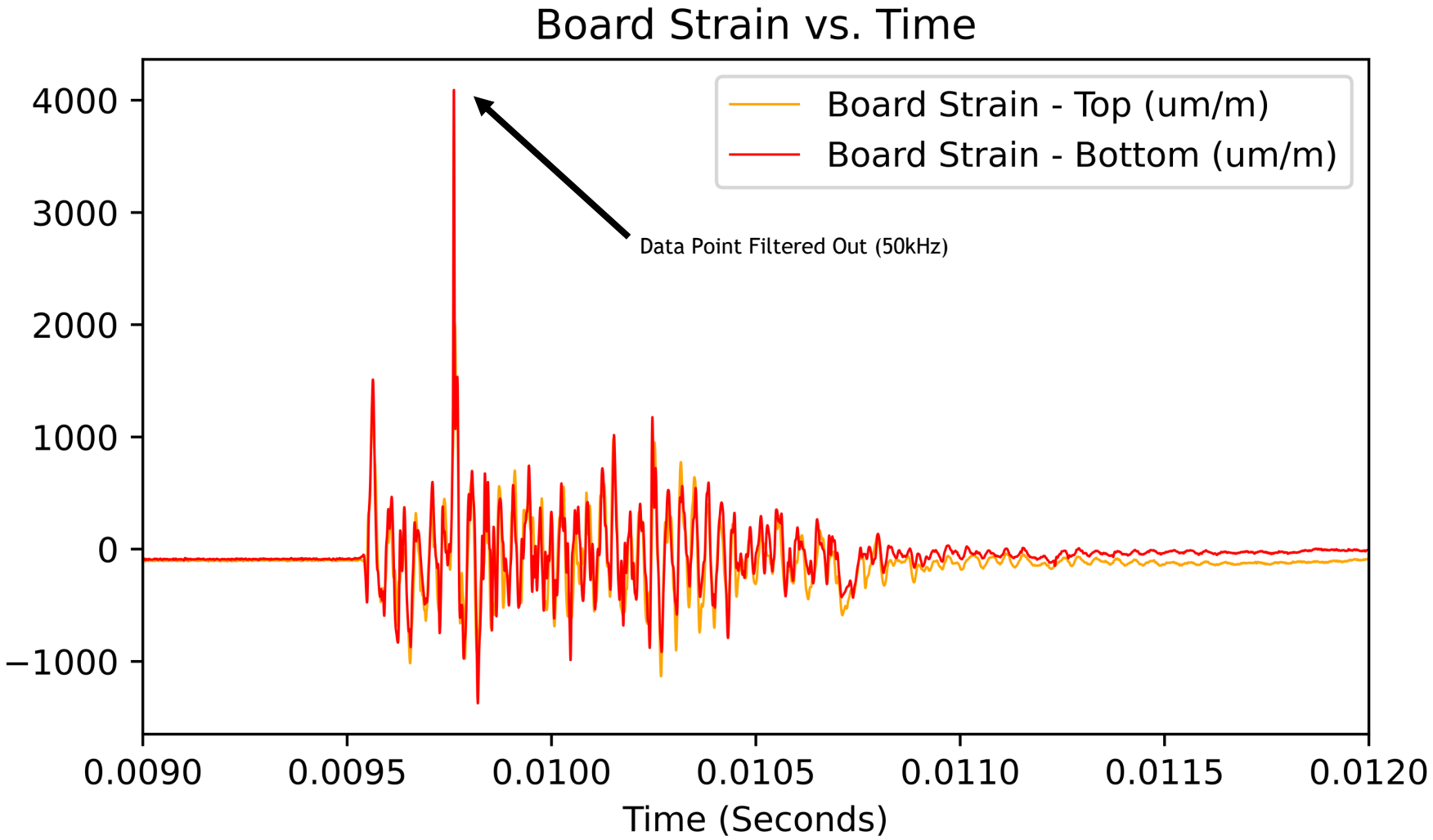




GMB provide filtering effect.
GMB experiences additional peaks.

PCB is experiencing strain in bending.

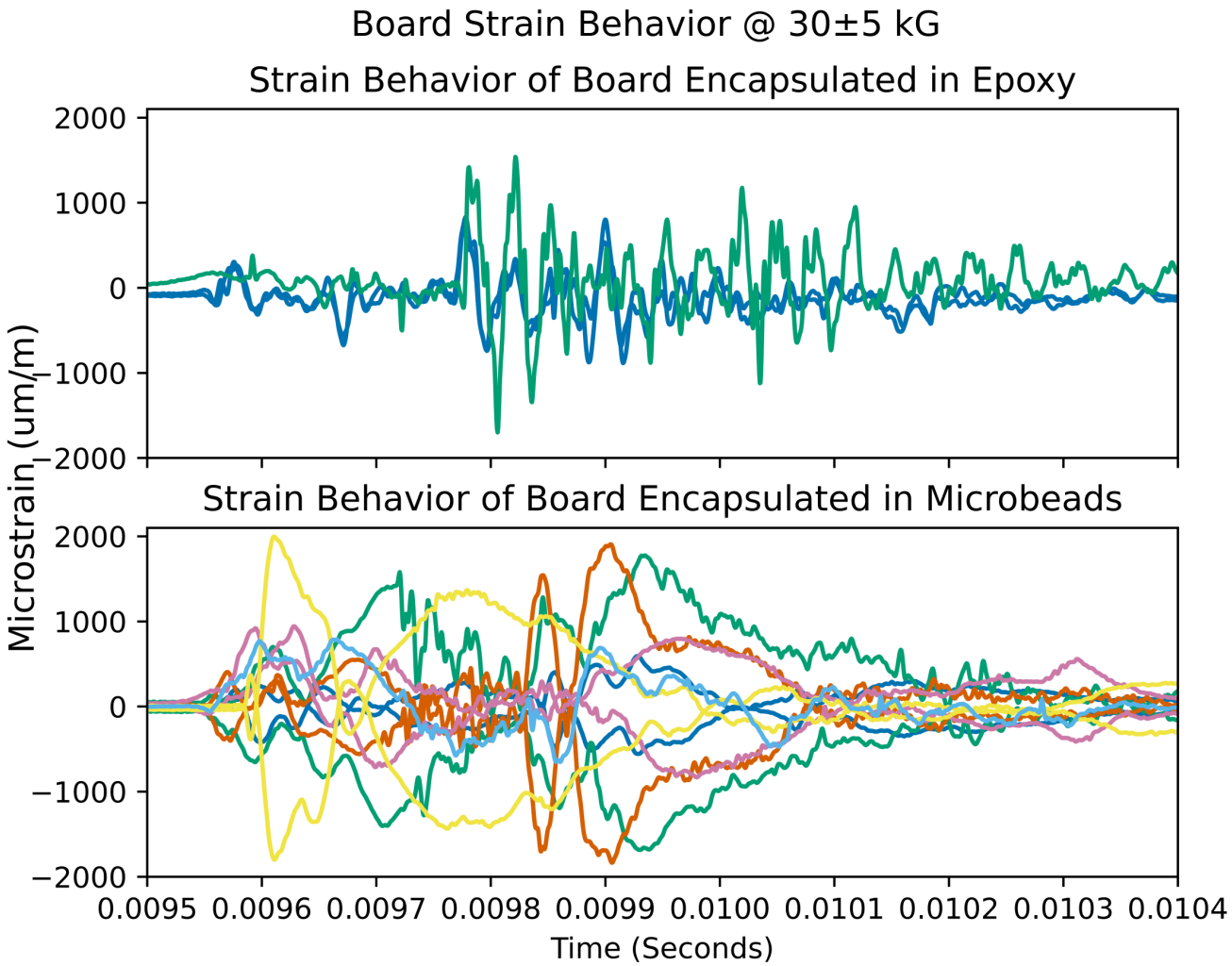
Epoxy Strain Data



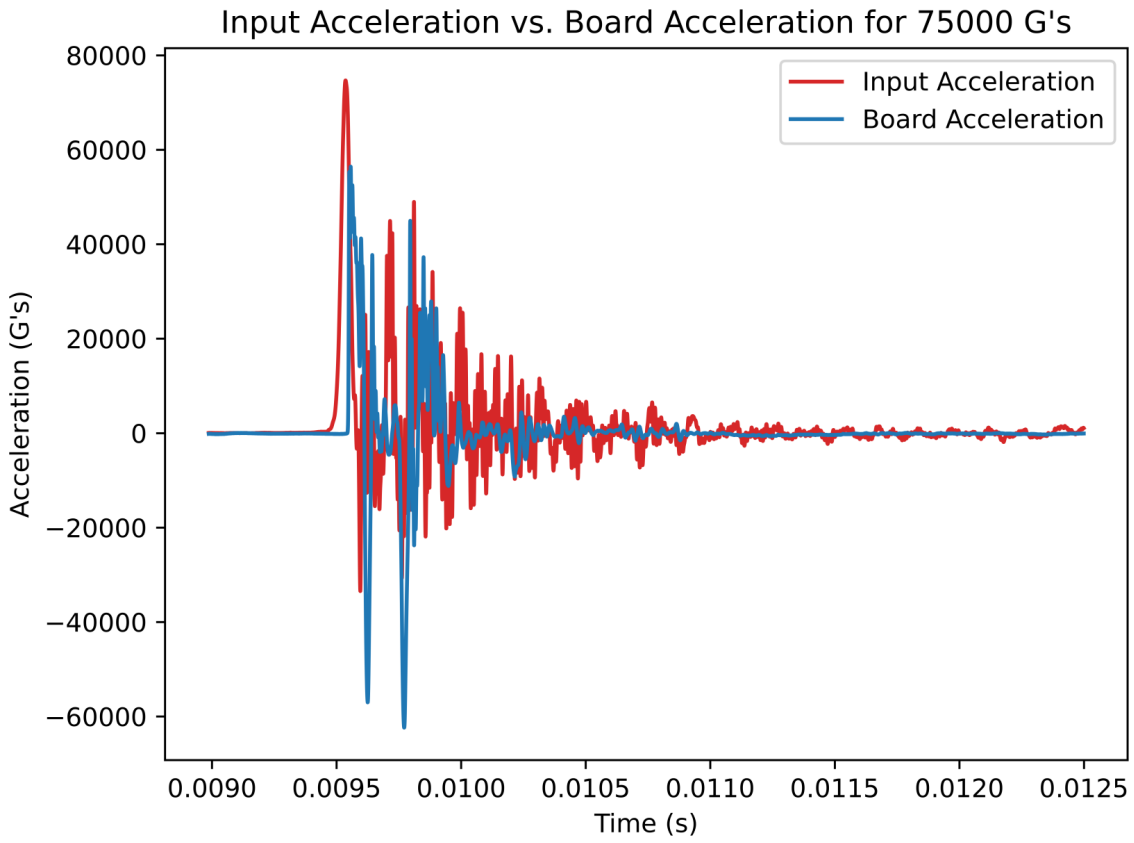
PCB is experiencing in-plane strain.

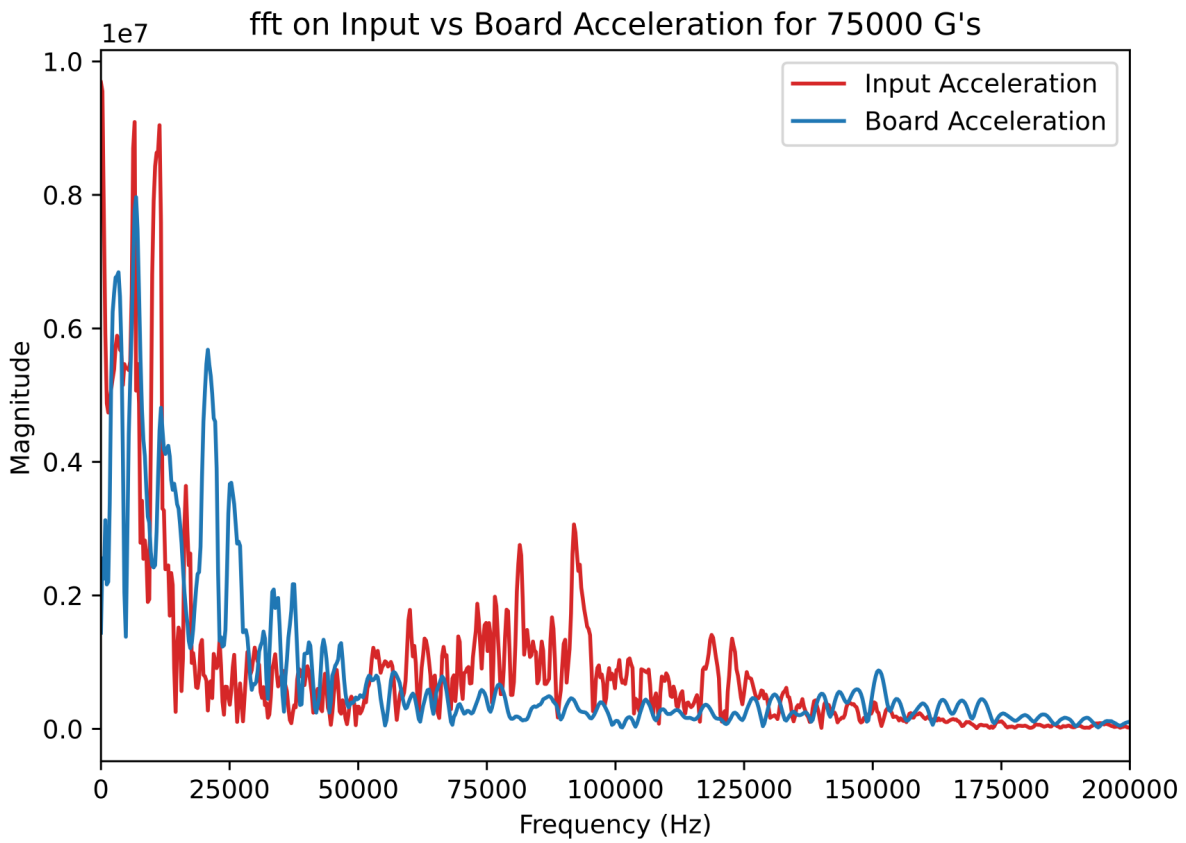
All Strain Data for 30kG Shock Input

- Strain behavior tends to oscillate in beaded encapsulants more
- Strains in the same order of magnitude
- Wires could be contributing to the bending behavior
- Variations in packing could contribute to strain differences



300-355 GMB,75kG Input





GMB filters certain frequencies out.

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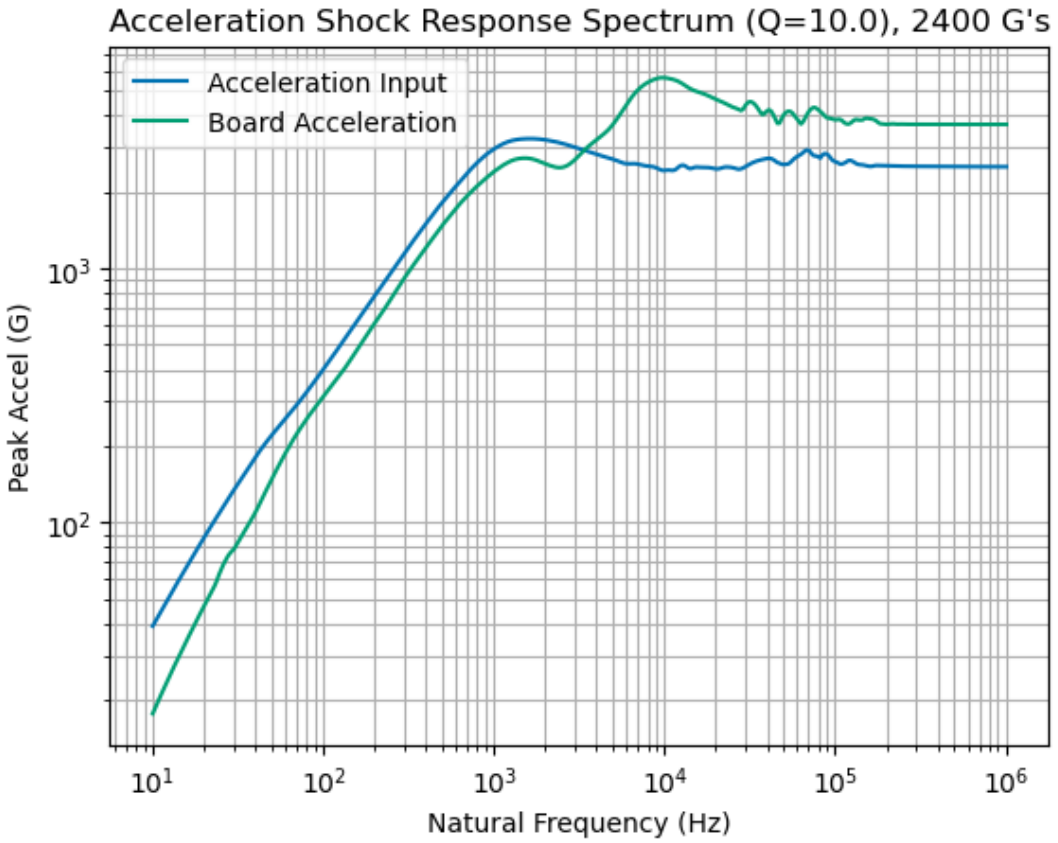
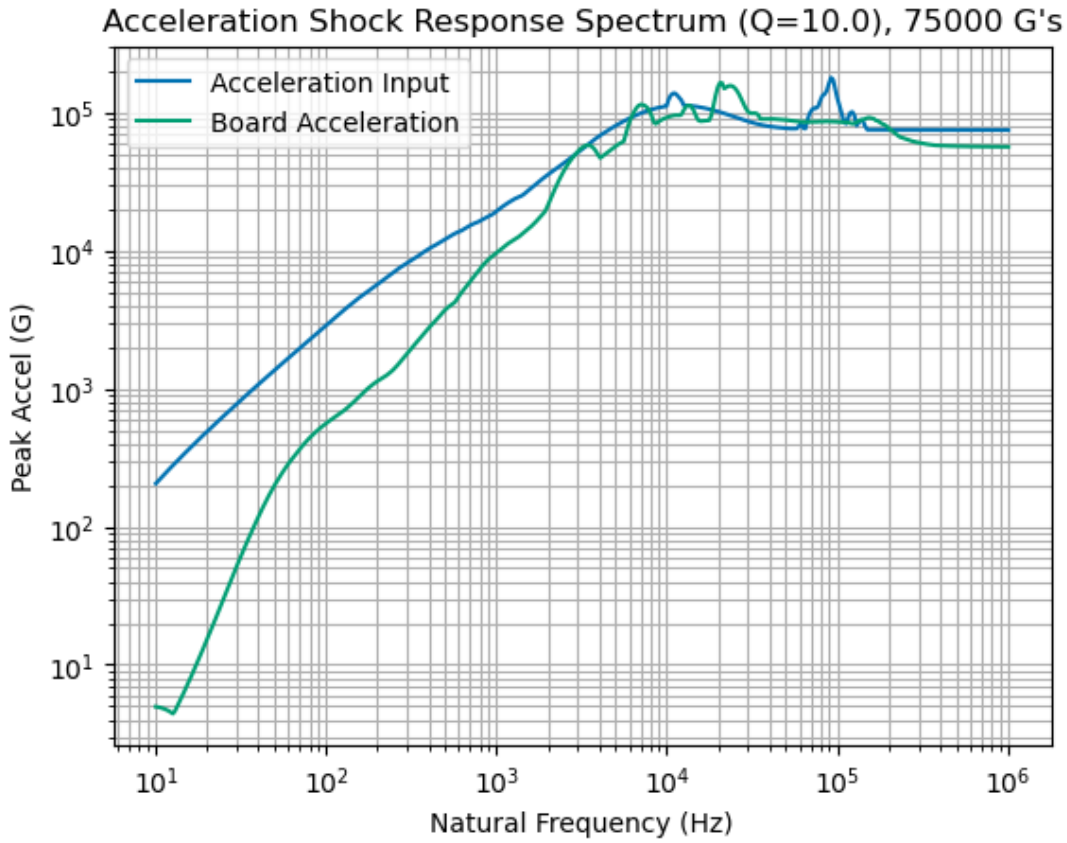
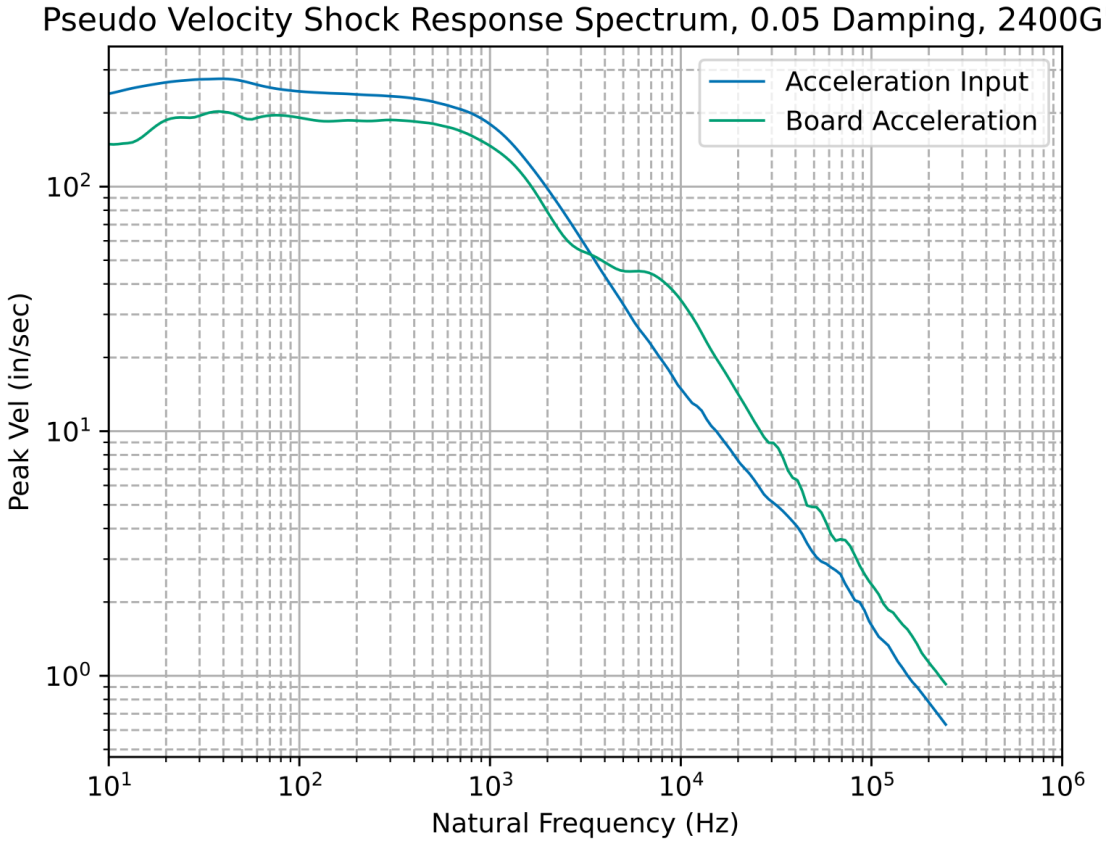
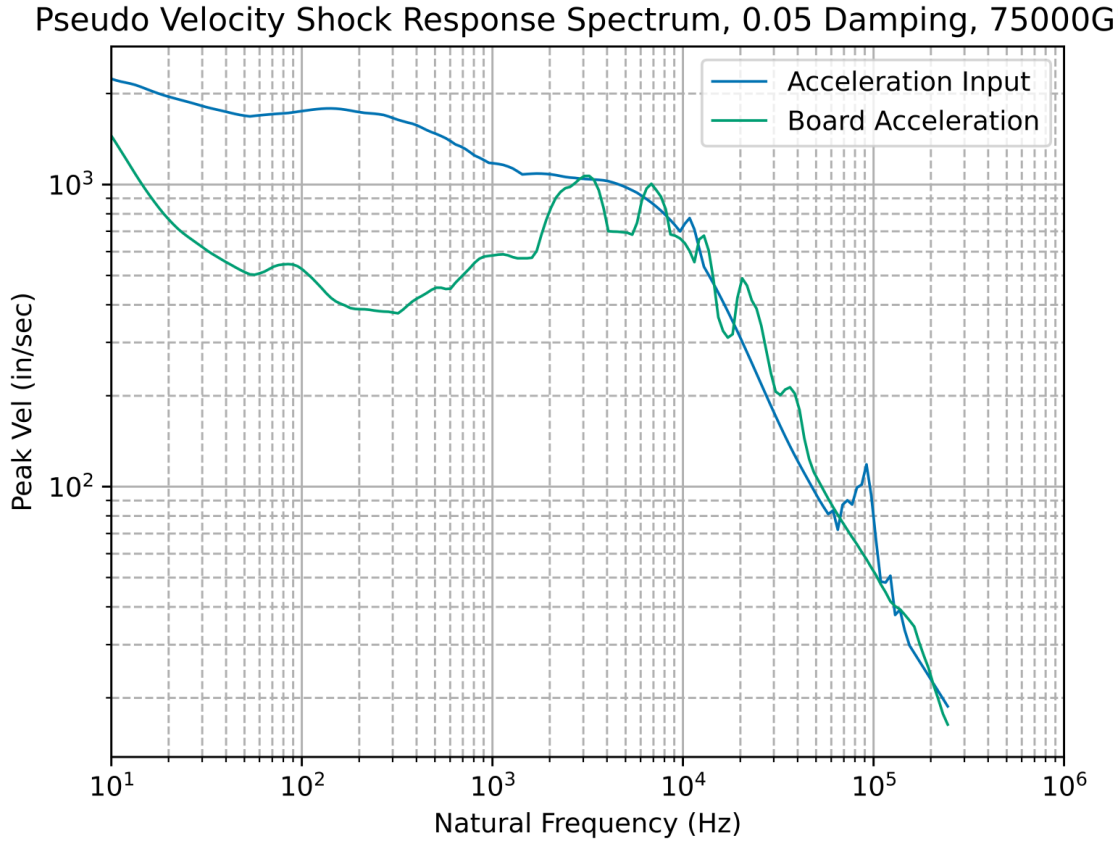
300-355 GMB SRS





300-355 GMB PVSS

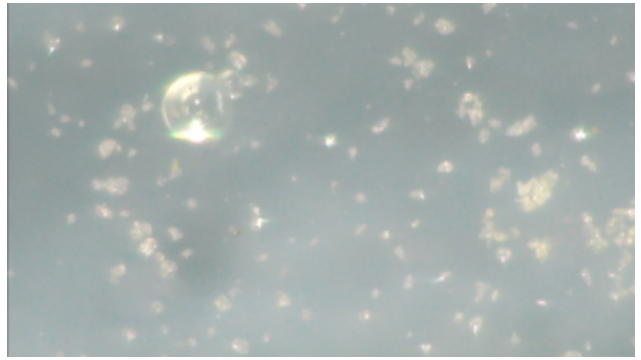




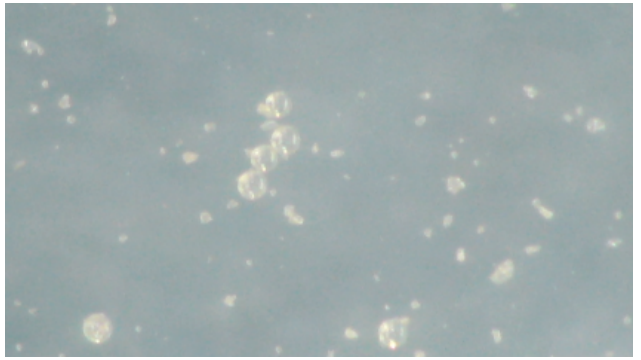
Board experiences lower peak velocity than the input.

Beads Post Test

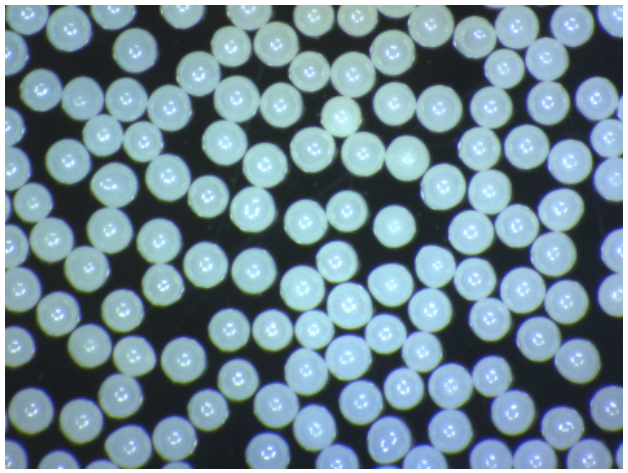
- Glass Beads fragment
  - Could be contributing to volume decrease
- YSZ Beads stay intact



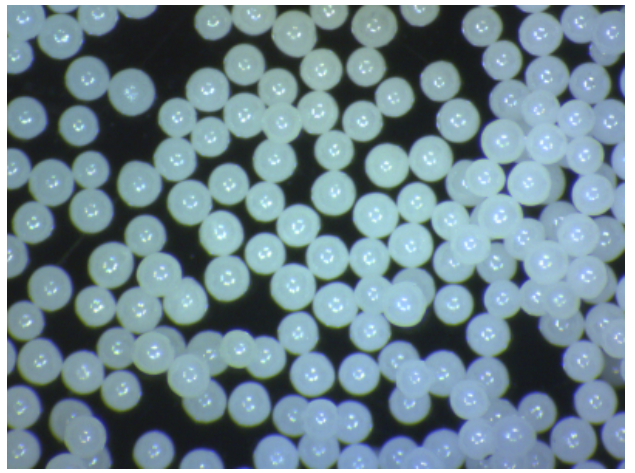
300-355 Micron Glass Beads Post Test



300-355 Micron Glass Beads Post Test



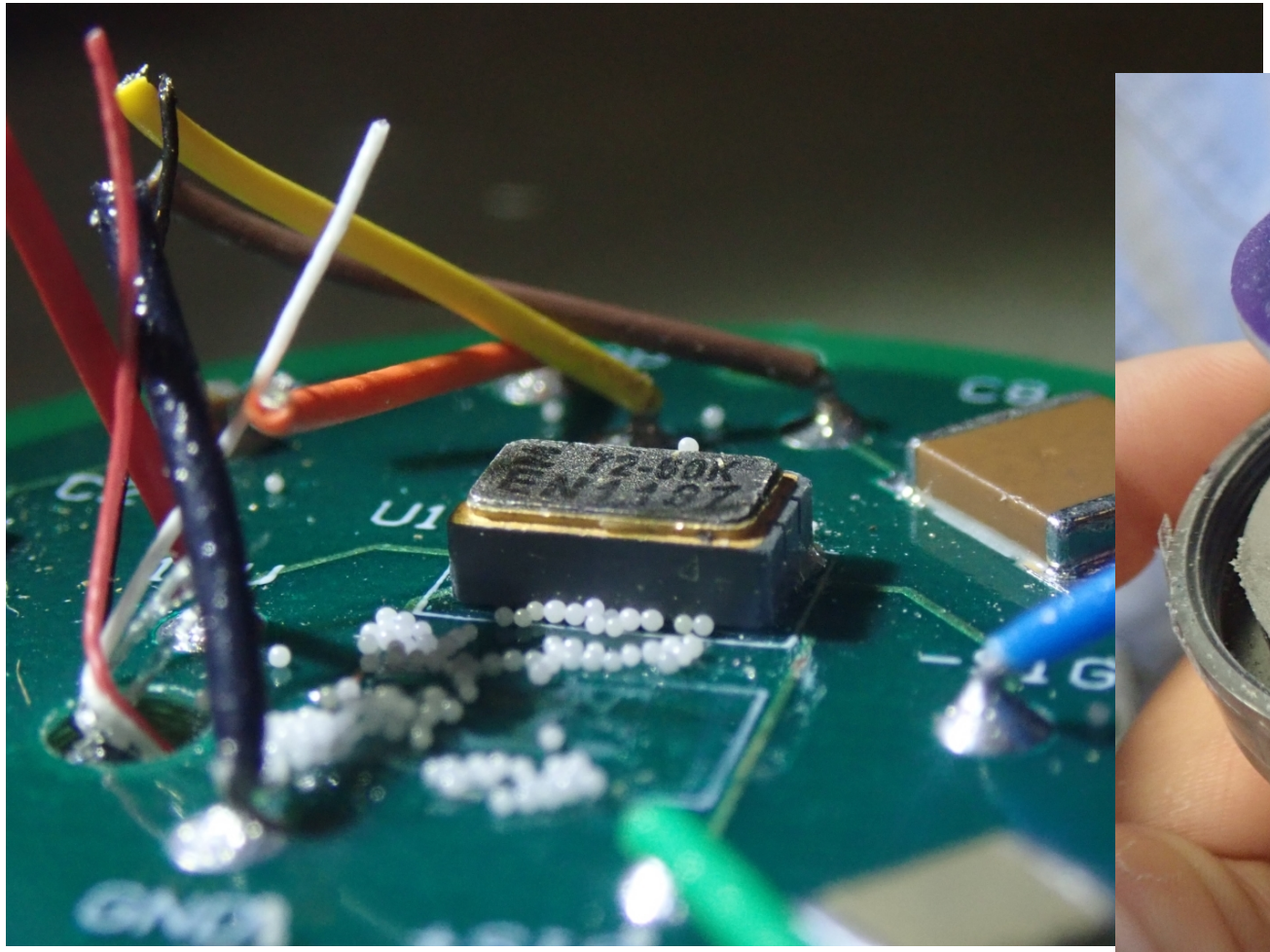
YSZ Beads Pre Test



YSZ Beads Post Test

YSZ beads don’t break.

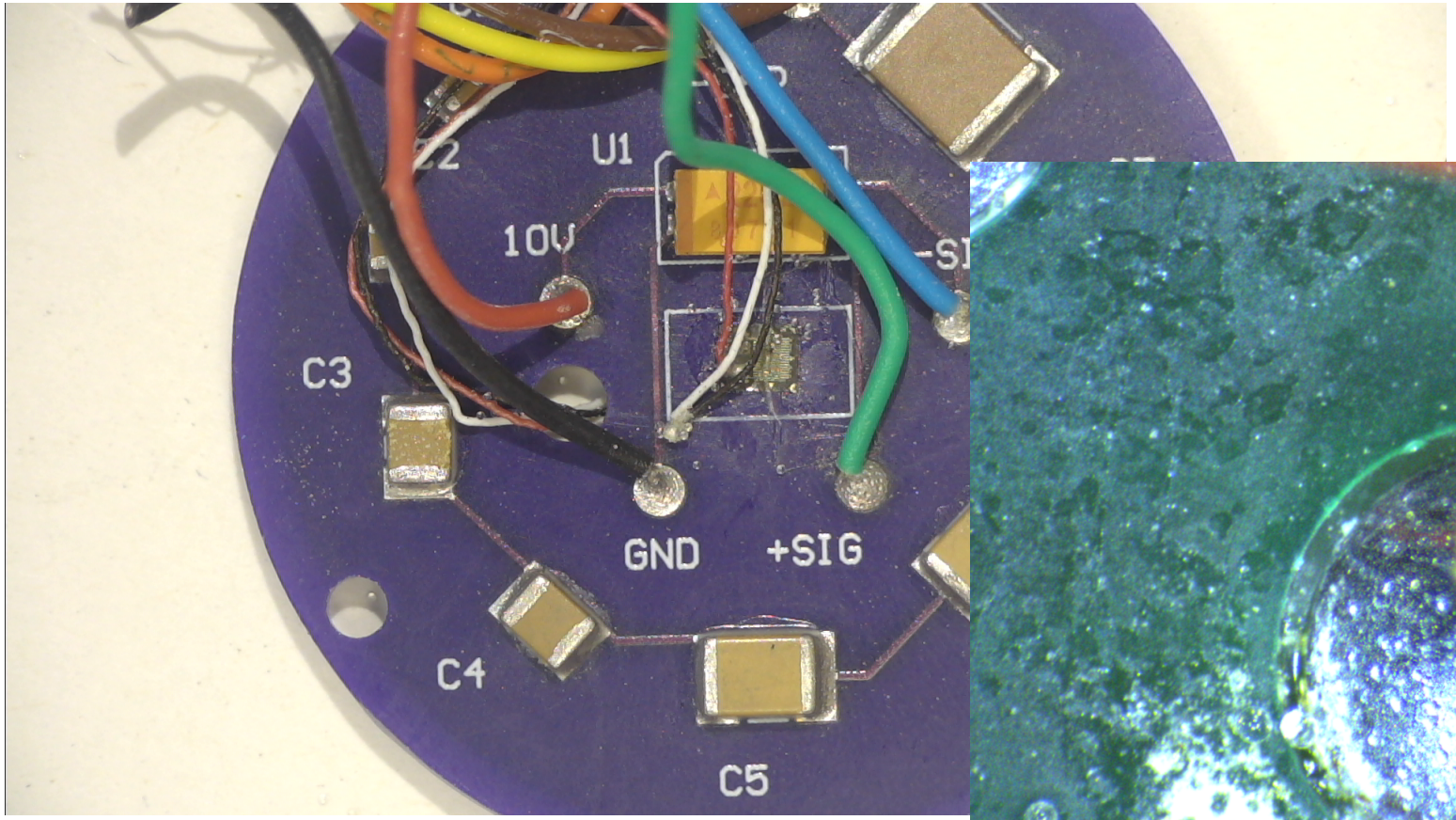
Post Test Photos

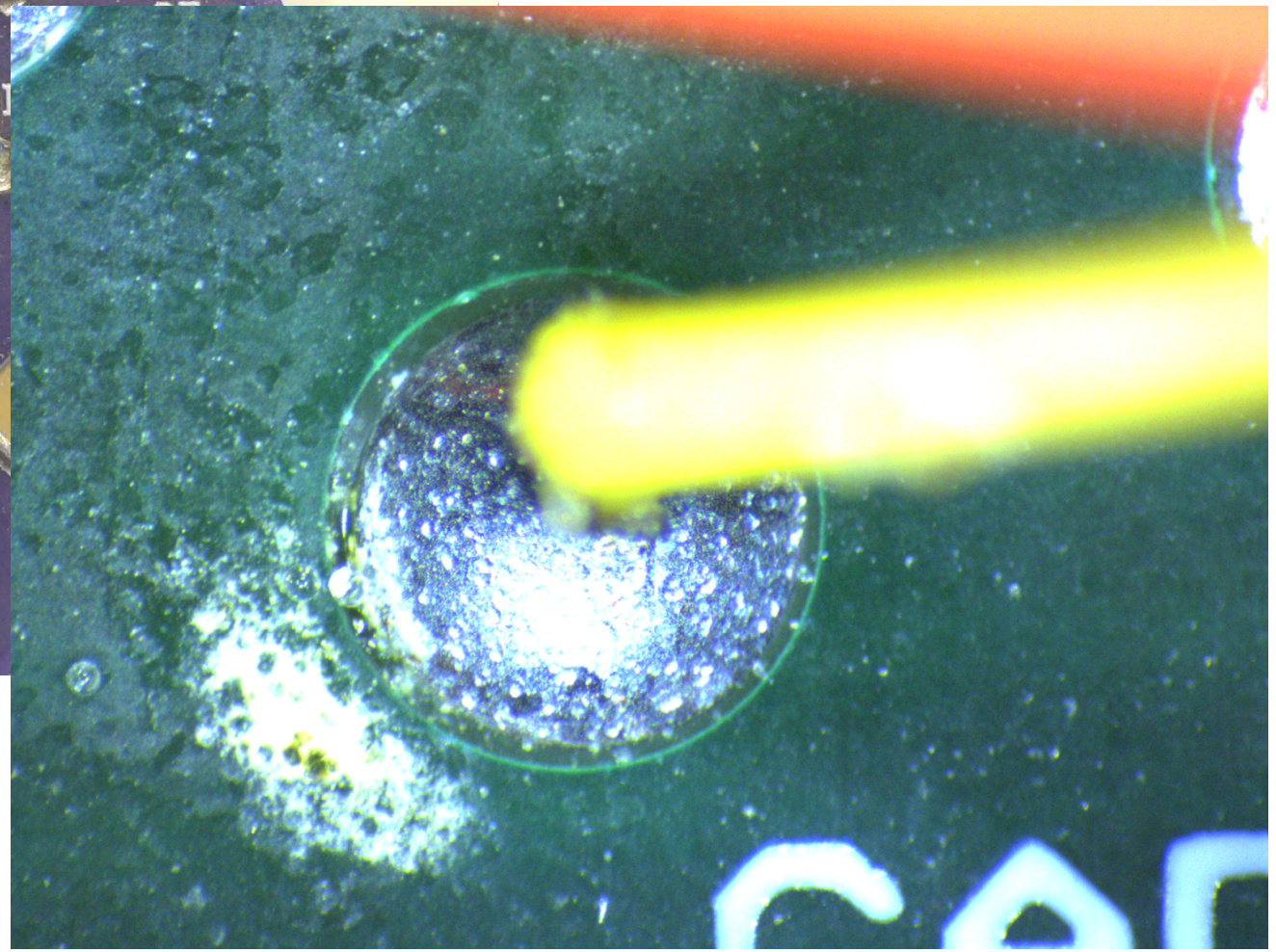


Accel is dented slightly

Wires are stiffer than anticipated

Solder Dimpling

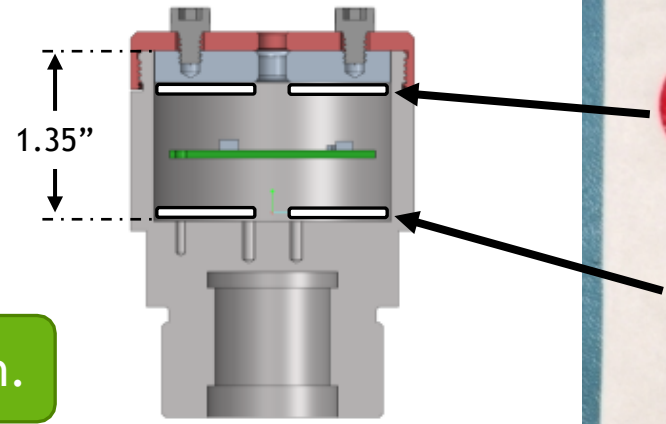


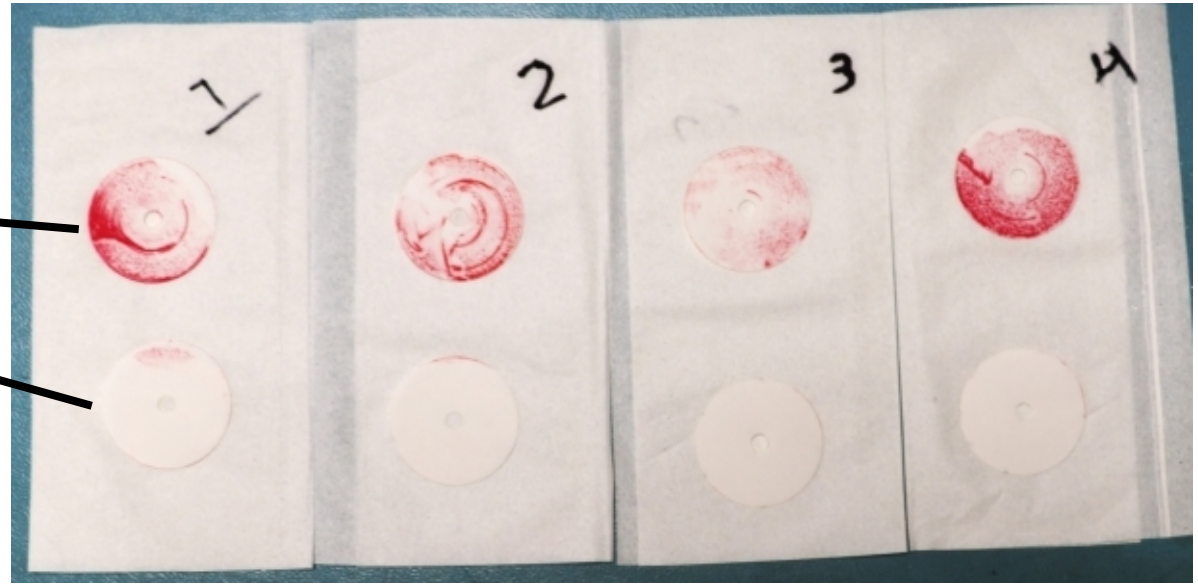


Dimples in solder from beads after shock.

Preload Investigation Post Testing

- All units tightened to 50 in/lbs
  - Fujifilm Prescale Pressure Indicating Sensor Film located at top and bottom of unit
  - Super Low 70-350 PSI
- Samples 1,2,3 used 50 in/lbs
  - Inconsistent patterns
- Sample 4 used 100 in/lbs
  - No pressure at bottom of unit

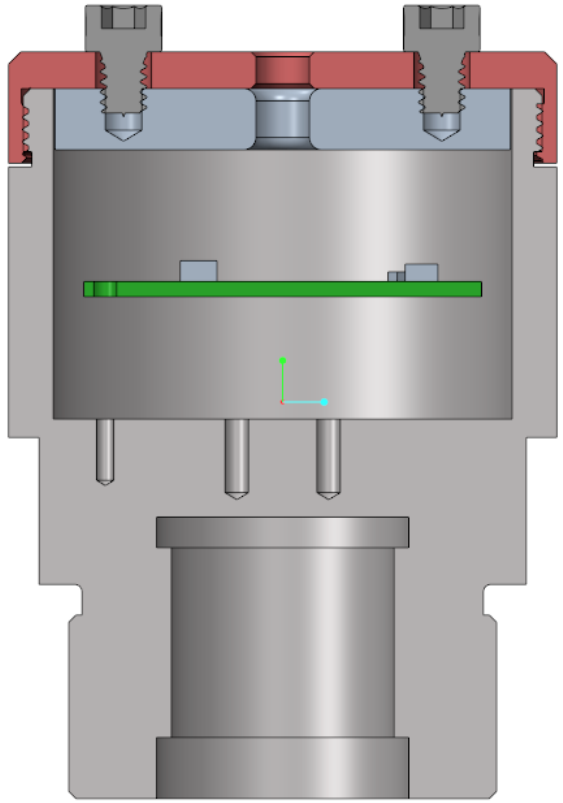




Pressure varies with depth.

Future Work

- Need a better mechanical design
- Requirements
  - Need to achieve a uniform preload on beads
    - Optimally, we would like to know how much preload we have on the beads
  - Lid cannot be an inertial mass, needs to also be supported
  - Currently, wires need to come out of the center, perhaps a new design with wires out of the side could work as well
- Packing process needs to be controlled, we hypothesize that the variability in the data comes from inconsistencies
- Acceleration data from potting materials



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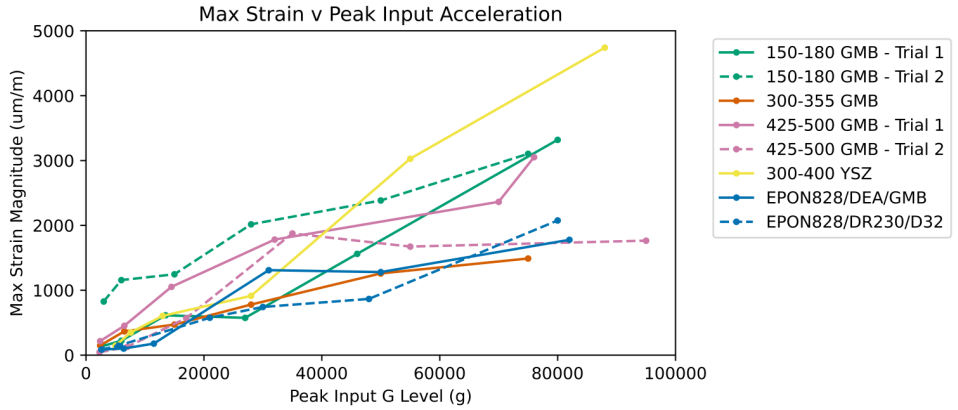
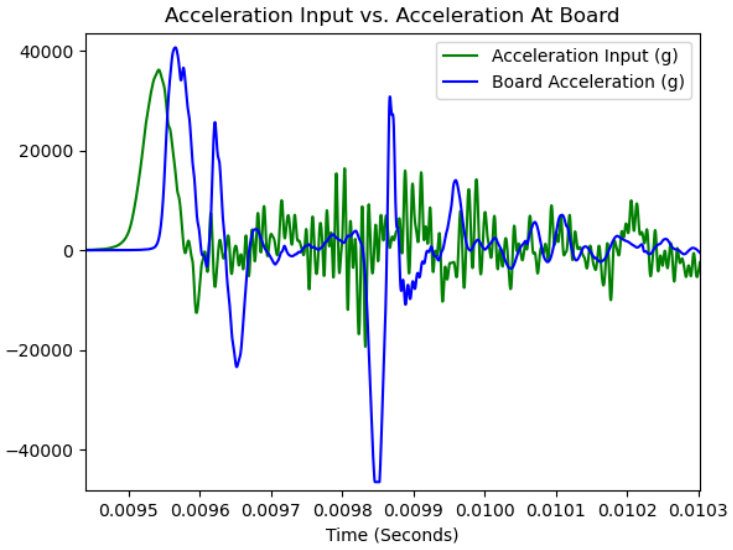
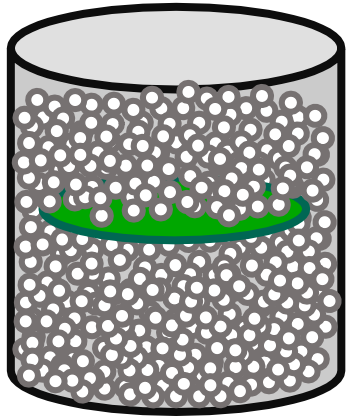
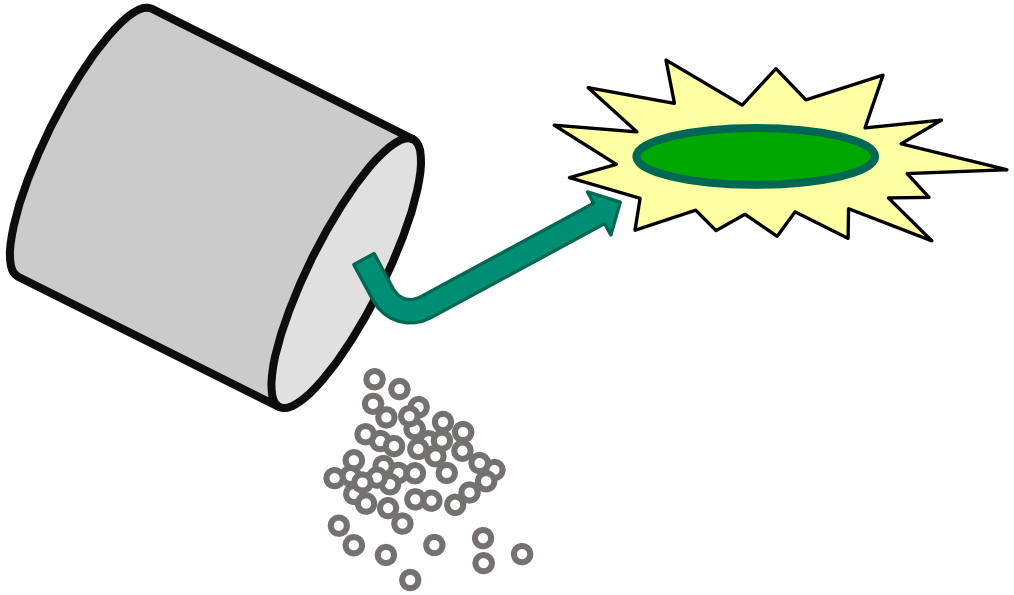
Conclusions

- Strain is similar
- Beaded Encapsulation acts as a filter
- Components are removeable and repackable









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