Electrostatic Regolith Interaction Experiment (ERIE) Electrometer Initial Flight Results

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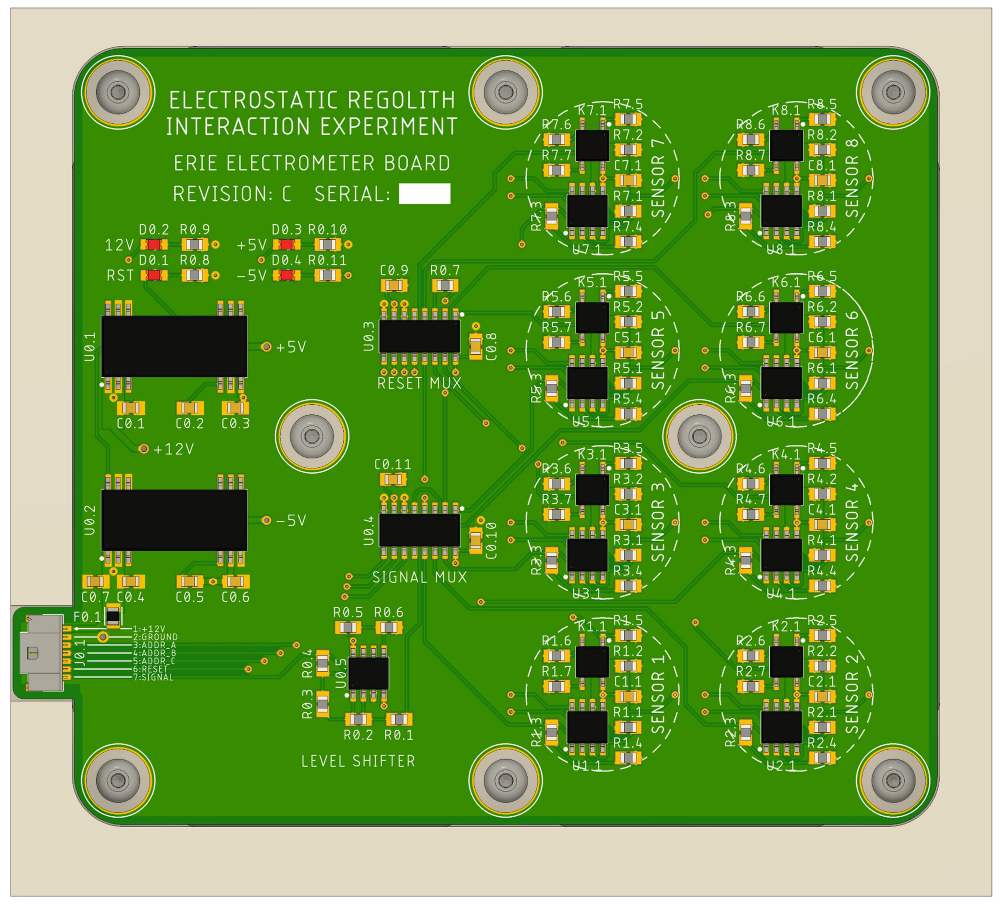
Background

Purpose: to advance understanding of natural and induced charged grain behavior on the Moon, asteroids, and other low gravity bodies comprised of charged dust particles

- Combines subsystems from UCF Hawking Center and NASA KSC ESPL to retain dust under vacuum, **measure charge transfer** between insulators and dust grains, and **observe trajectories of charged grains** under microgravity as they traverse through an external electric field generated by a parallel plate capacitor
- Flown once on Blue Origin New Shepard NS-17/P11 suborbital flight in Aug. 2021. Dust retention door did not fully open, and sensors charged due to nearby corona discharge from high voltage plates. Measurements decayed quickly due to leakage through reset system transistors (presented AGU21 P55E-2002)
- Improvements were made to address all issues above and re-flight was attempted on New Shepard NS-23/P12 mission in Sep. 2022; however, an anomaly prevented the capsule and experiment from reaching the required environment

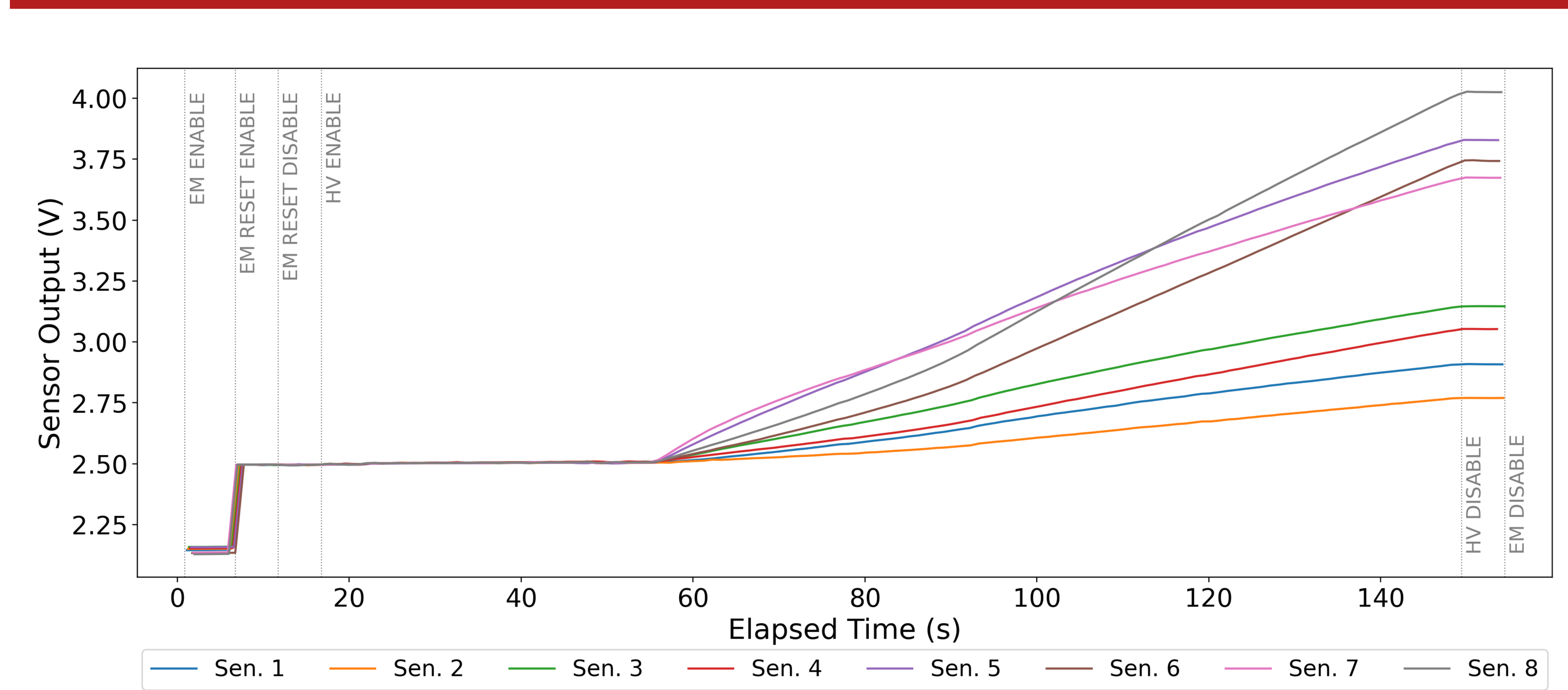
Electrometer Board Assembly

Below is a CAD model of improved electrometer board assembled inside the dust retention door as flown most recently. Two pairs of four different insulator materials were installed between PCB and door housing such that they protrude to contact granular material underneath (insulator boundaries denoted by dashed circles).



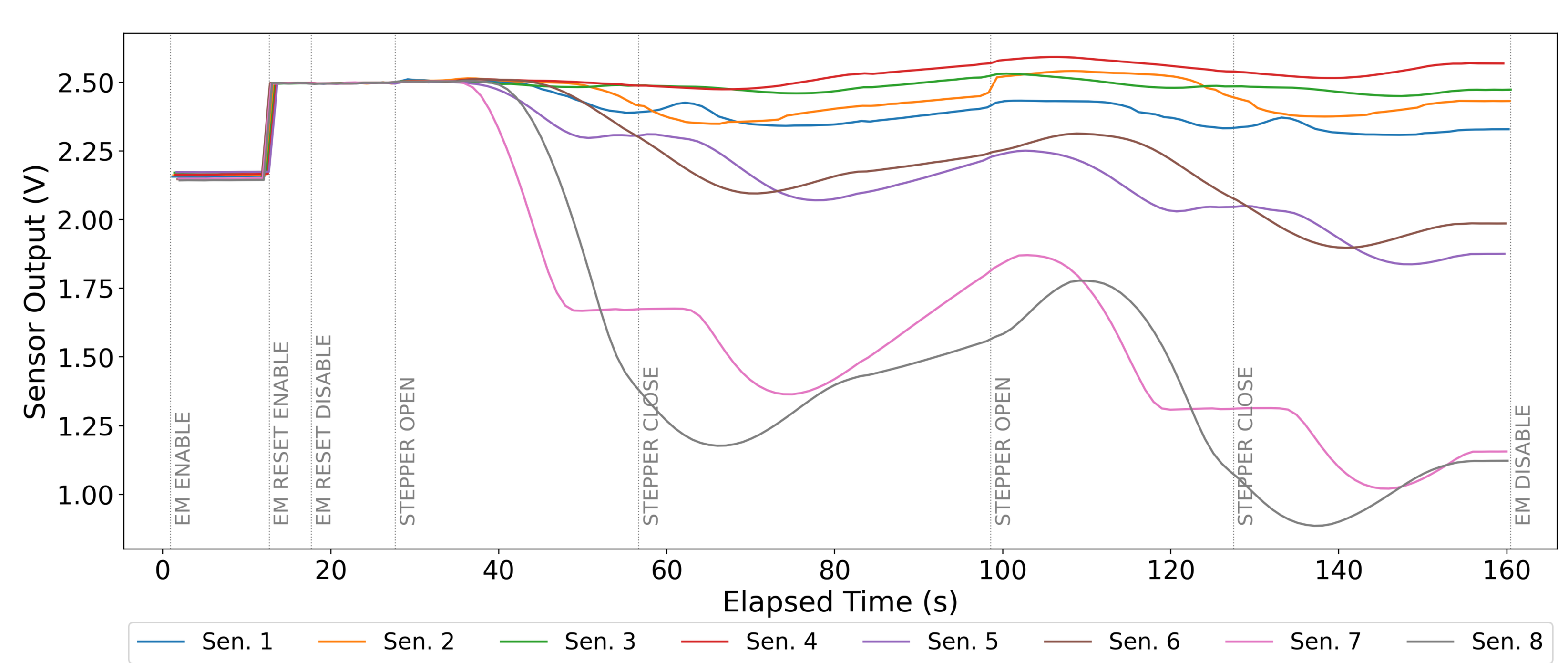
- Insulator disks span the triboelectric series so each will accumulate a charge consistent with its relative position to the grains within the series as the retention door slides open
  - Sensors 1/2 (−−) Teflon™ Polytetrafluoroethylene (PTFE)
  - Sensors 3/4 (+) Garolite™ Fiberglass/Epoxy Composite
  - Sensors 5/6 (++) Lucite™ Polymethylmethacrylate (PMMA)
  - Sensors 7/8 (−) Lexan™ Polycarbonate
- Charge on each insulator is distributed between two series capacitances with the electrometer amplifier returning an analog voltage proportional to charge accumulated
- Zero-point voltage for electrometer was chosen as 2.5 V since analog-to-digital converter (ADC) only measures from 0 to 5 V
  - Neutral charge registers as 2.5 V, so negative charges return *under* 2.5 V and positive charges return *above* 2.5 V

High Voltage Testing Prior to Flight



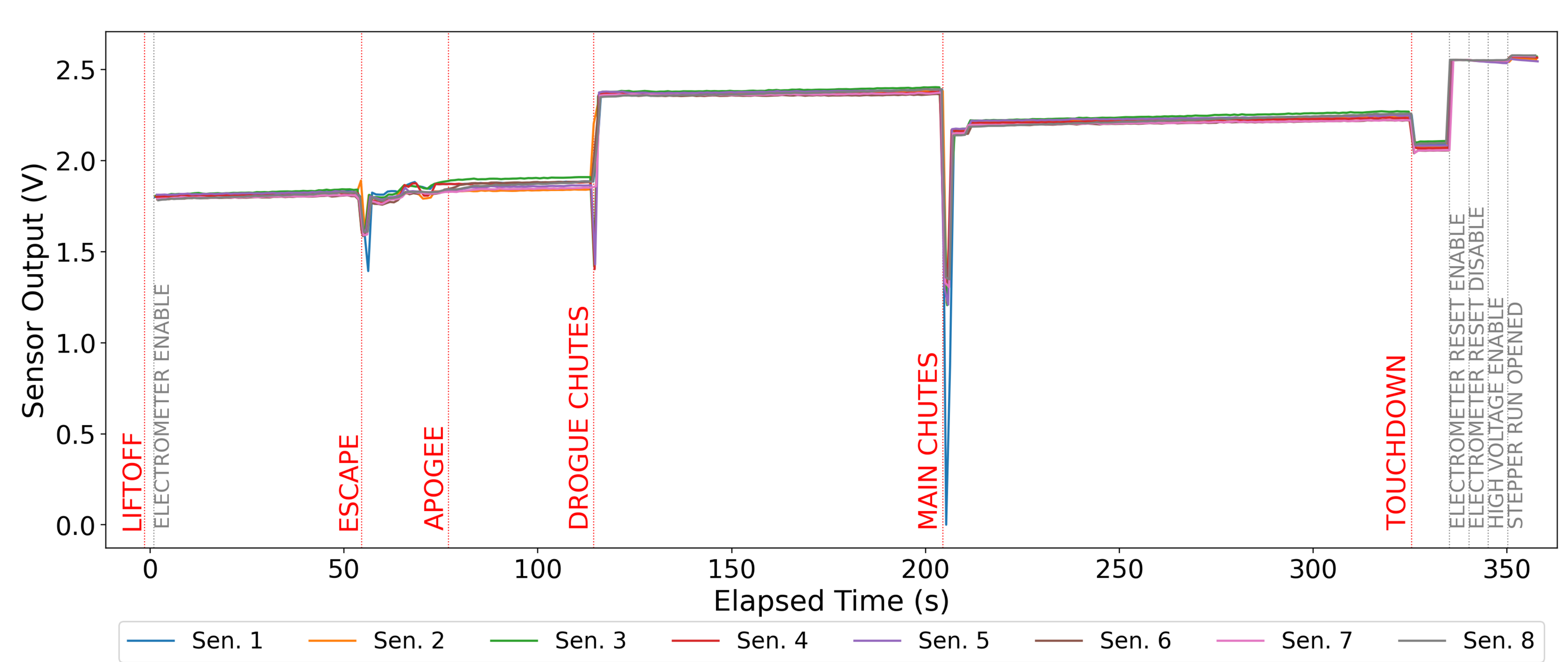
- Lowest pressures attainable during flight were not low enough to suppress corona discharges from high voltage plates
- Vacuum chamber was pumped on until electrometer sensors began to collect charge which indicated corona charging had begun to occur
- Sensor capacitors retained stable zero-point voltages at high pressures until corona charging began at pressures of ~2.5 Torr (time of 55 s on plot)
- To avoid this interference, the vacuum chamber was pumped down to pressure of ~3 Torr prior to installation in capsule

Tribocharging Testing Prior to Flight



- Electrometer reset begins at 13 s so all sensors return 2.5 V as zero-point charge
- Charging events occur as door moves:
  - 28 to 55 s door opens
  - 57 to 84 s door closes
- No motion occurs for 15 s (84 to 99 s)
- Charging events occur as door moves:
  - 99 to 125 s door opens again
  - 127 to 154 s door closes again
- Pairs of sensors (blue/orange, green/red, purple/brown, pink/grey) charge similarly but are slightly different to one another due to positioning within the door

Preliminary Flight Data



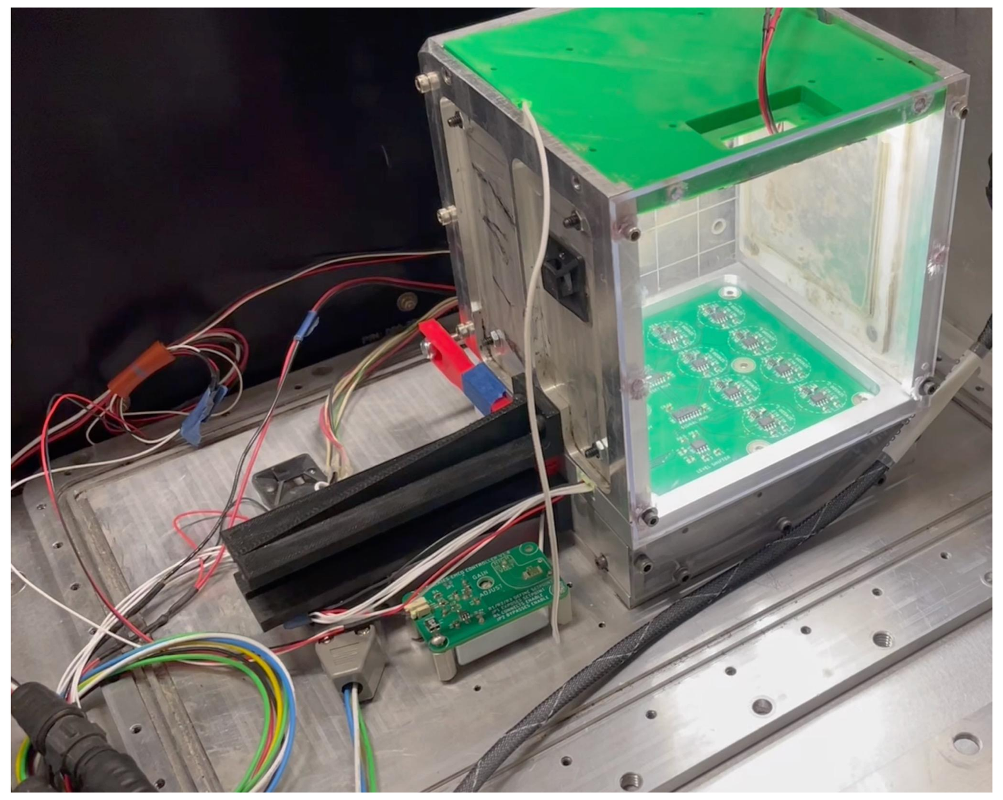
Time (s)	Event	Net Accel.
-1	Liftoff	Positive
+1	EM Enable	--
+54	Escape	Positive
+76	Apogee	Zero
+114	Drogue Chutes	Negative
+204	Main Chutes	Negative
+325	Touchdown	Negative
+335	EM Reset Enable	--
+340	EM Reset Disable	--
+345	HV Enable	--
+350	Stepper Open	--
+358	Power Disable	--

Preliminary Flight Results

- Reset procedures were scheduled to begin after microgravity conditions stabilized and 2.5 V zero-point would be established
- Microgravity was never officially signaled, so sensor readings shown in preliminary flight data are all relative due to no reset
- Reset procedure (335 s) was signaled after touchdown (325 s) and the data reflects that the 2.5 V zero-point was established
- After reset completed (340 s), high voltage deflection plates were energized (345 s), door began sliding open (350 s), and a small amount of dispersion was detected in sensor readings before power to the experiment was cut during safing (358 s)

Experiment

Image below shows experiment setup within vacuum chamber during testing without chamber lid for clarity. Electrometer board and retention door are on bottom face of experiment box above granular material, high voltage plates are on left and right faces, LEDs are on top face, and transparent front face allows camera to capture dust motions relative to scale grid on rear face. Door assembly slides left to release dust grains under microgravity.



Electrometer Improvements

- Decreased leakage from reservoir capacitor and zero-point overshoot by replacing transistor reset circuits with relays
- Decoupled high voltage enable trigger from vehicle events by incorporating delay to ensure vehicle environment was not source of electrometer charge measurement changes
- Minimized time during which high voltage was enabled due to issues from proximity of sensors to corona discharge

Conclusions

At each vehicle event (shown in red) causing significant shock and/or vibration, a change in charge on insulators is seen. Shocks result in plot discontinuities as charge is transferred during collisions. *Positive acceleration* of vehicle tends to compress granular material and increases separation between sensors and charged grains. *Negative acceleration* decreases separation and tribocharging interactions occur.

Future work includes re-flight of improved experiment on a nominal suborbital flight to observe repulsion of dust grains under microgravity. Results from flight presented here show that issues with charge leakage and corona discharge have been rectified, but scientific data the experiment was designed to collect will need to come from a future flight where a few minute period of microgravity is sustained.

Acknowledgements

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