Exploratory Investigation of Early Detection for High-C Discharge-Induced Failure in 18650 Lithium-ion Batteries

George Anthony[a], **Connor Madden[a],** Emmanuel Ogunniyi[a], Austin R.J. Downey[ab], Ryan Limbaugh[a], Jarrett Peskar[a], Jingjing Bao[a], Xinyu Huang[a]

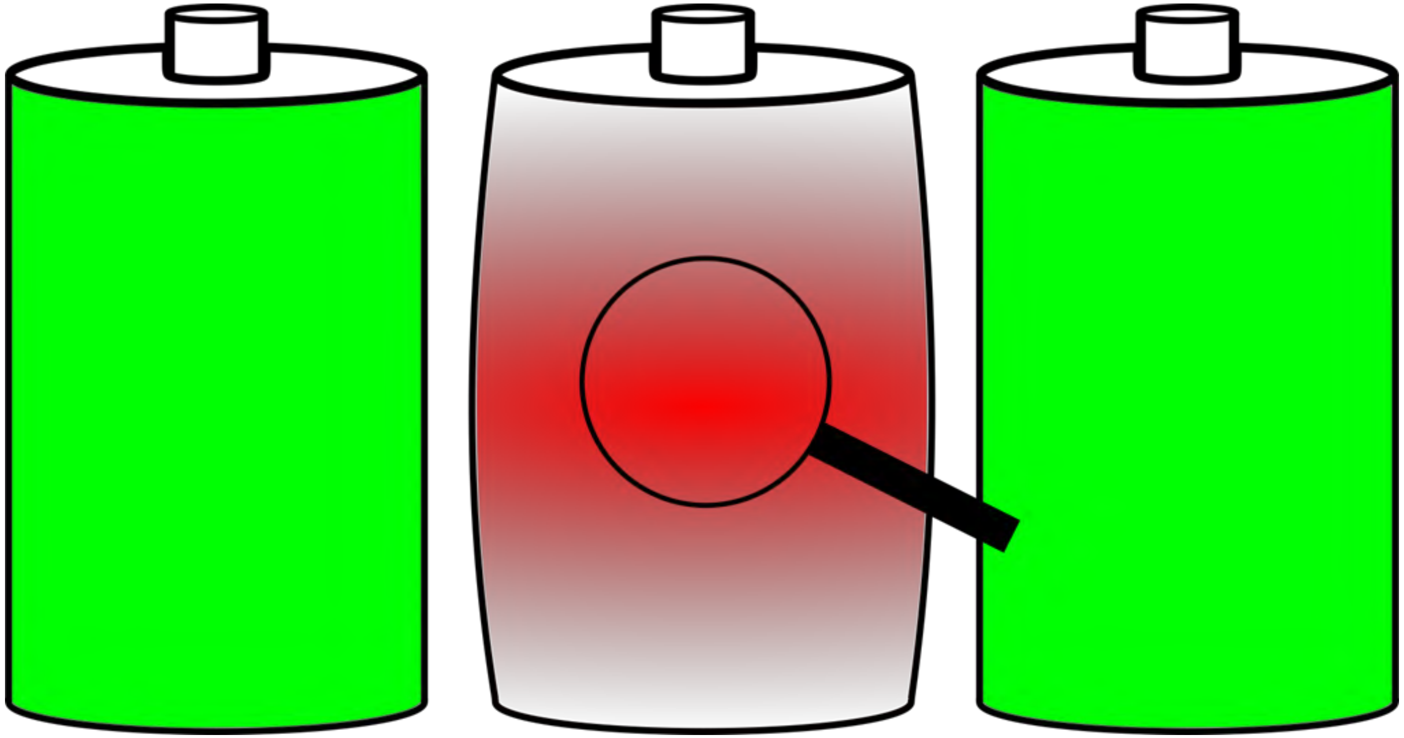
[a]University of South Carolina Department of Mechanical Engineering
[b]University of South Carolina Department of Civil and Environmental Engineering

UNIVERSITY OF SOUTH CAROLINA

Methodology → Challenges → Results and Discussion → Future work

Outline

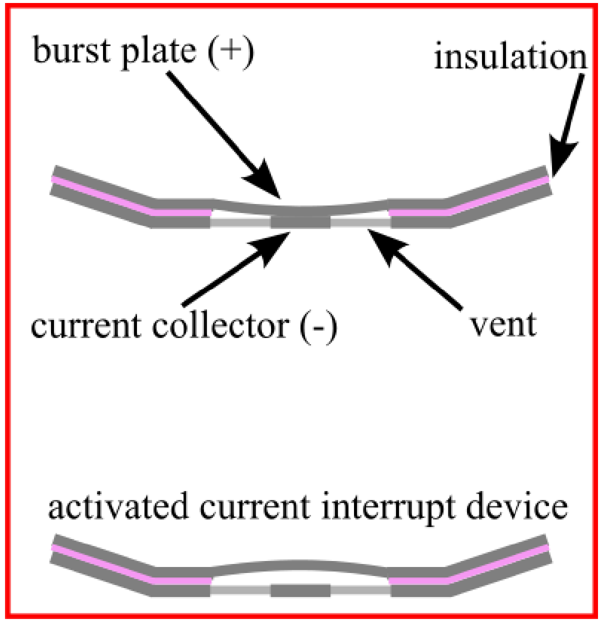
- Methodology:
  - Digital Image correlation setup
- Challenges:
  - Improvements to setup
- Results and Discussion:
  - Experimental outcomes
  - Findings and limitations
- Future work:
  - Strain Gauge employment
  - Thermal Camera usage

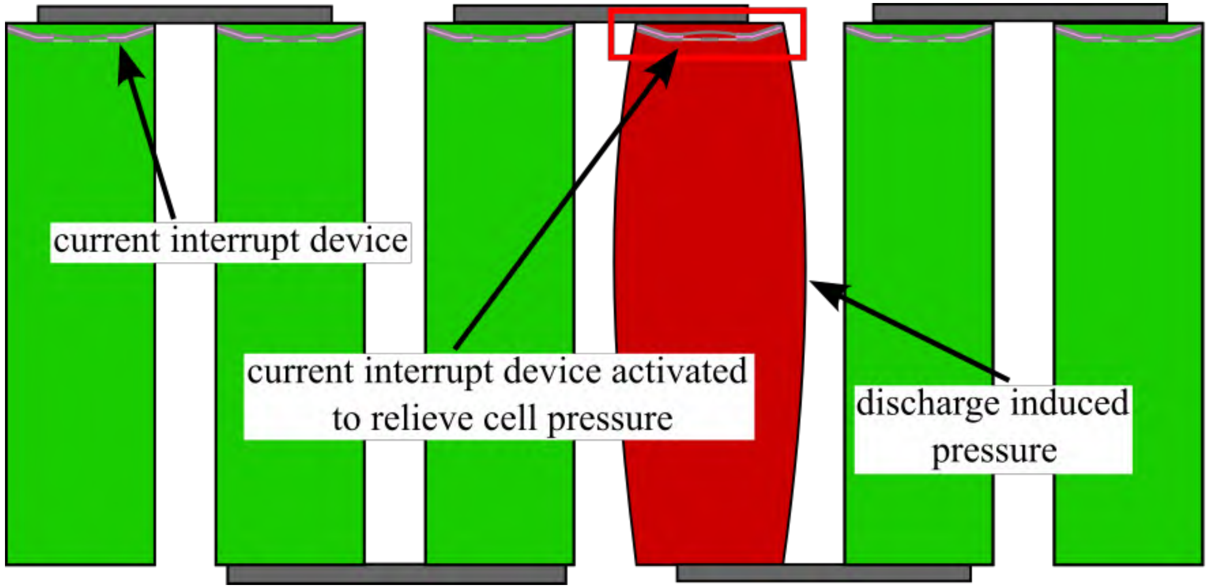


The battery that experiences excessive strain should be identified to reduce the likelihood of failure

Introduction

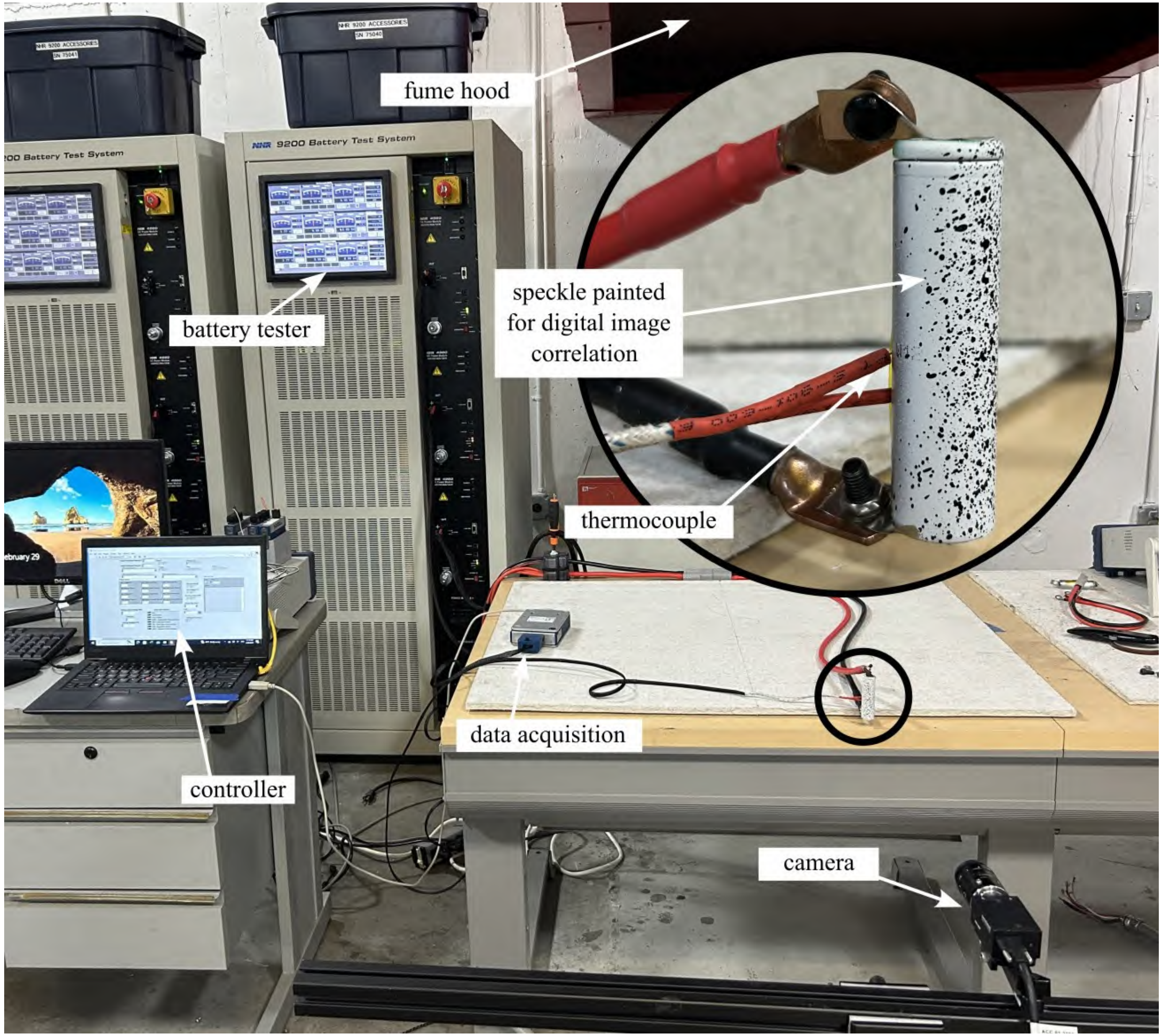
- Due to high energy capacity of batteries:
    - safety measures are put in place to open the internal circuit before it enters thermal runaway
- Problem statement:
    - Gas expansion within the battery causes Current Interrupt Device(CID) activation
    - Relies on irreversible changes to the structure of the cell
    - Prevents future use of the battery
- Proposed approach:
    - Pressure sensing through external strain measurement
    - Digital Image Correlation to monitor the battery during discharge





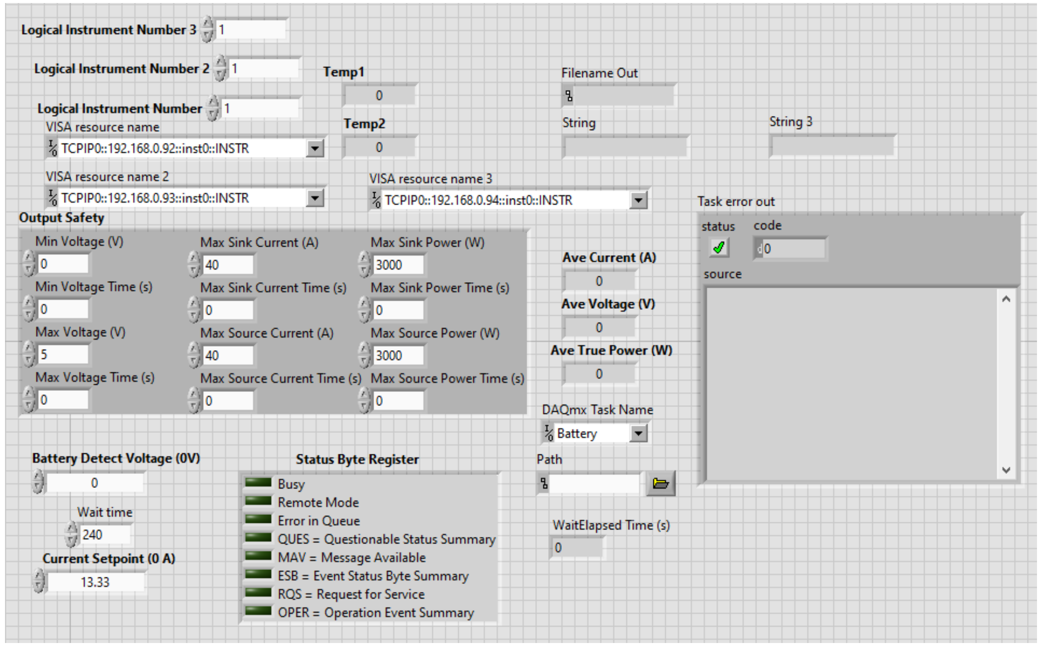
Digital Image Correlation Setup

- 3 module battery tester to allow for high-C discharge
- Battery is speckle painted for digital image correlation nodes
- Controller for:
  - digital image correlation cameras
  - battery tester
  - thermal data acquisition



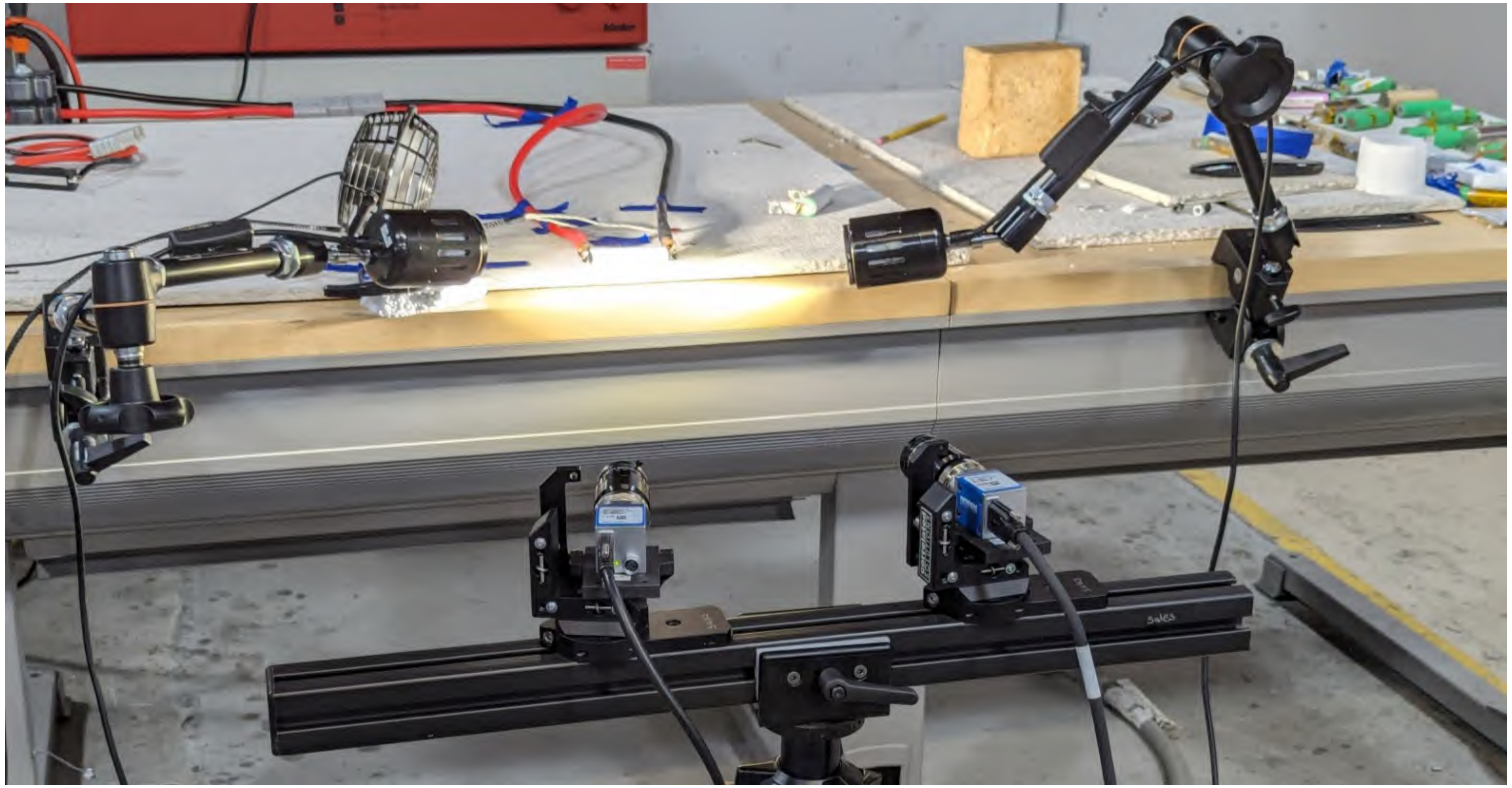
Digital Image Correlation Setup

- Hardware:
  - Samsung 25R nickel cobalt aluminum (NCA) 18650 Cell
  - NHR-9200 battery tester
  - NI-9210 compact data acquisition
  - J type thermocouple
  - ThinkPad T470s
  - 5MP Cameras
- Software:
  - LabVIEW 2020 SP1
  - NI-MAX 2022 Q3
  - VIC-Snap
  - VIC-3D



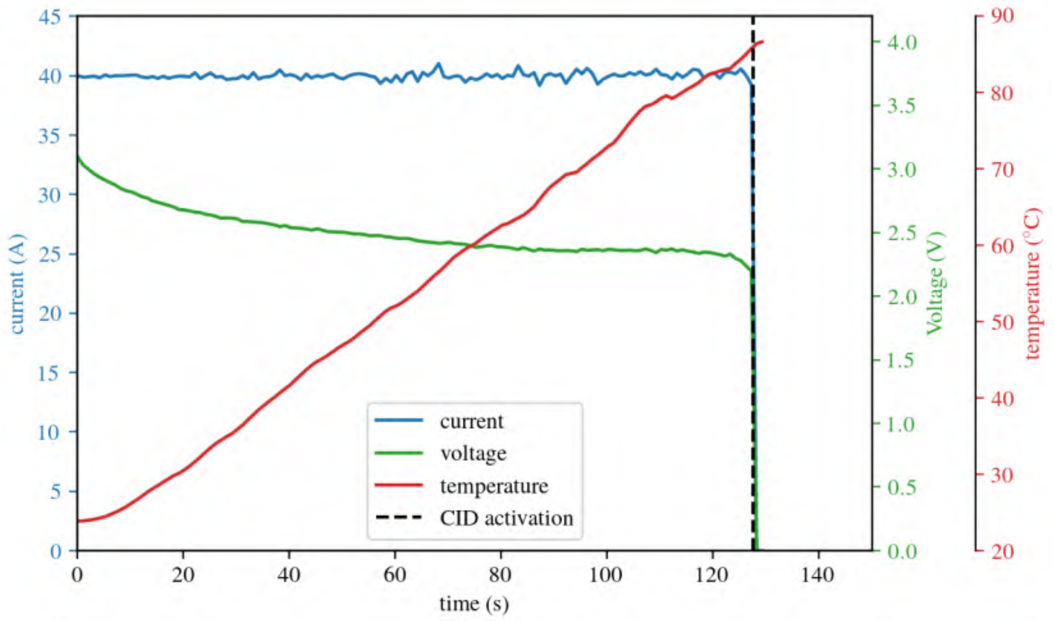
Digital Image Correlation Setup

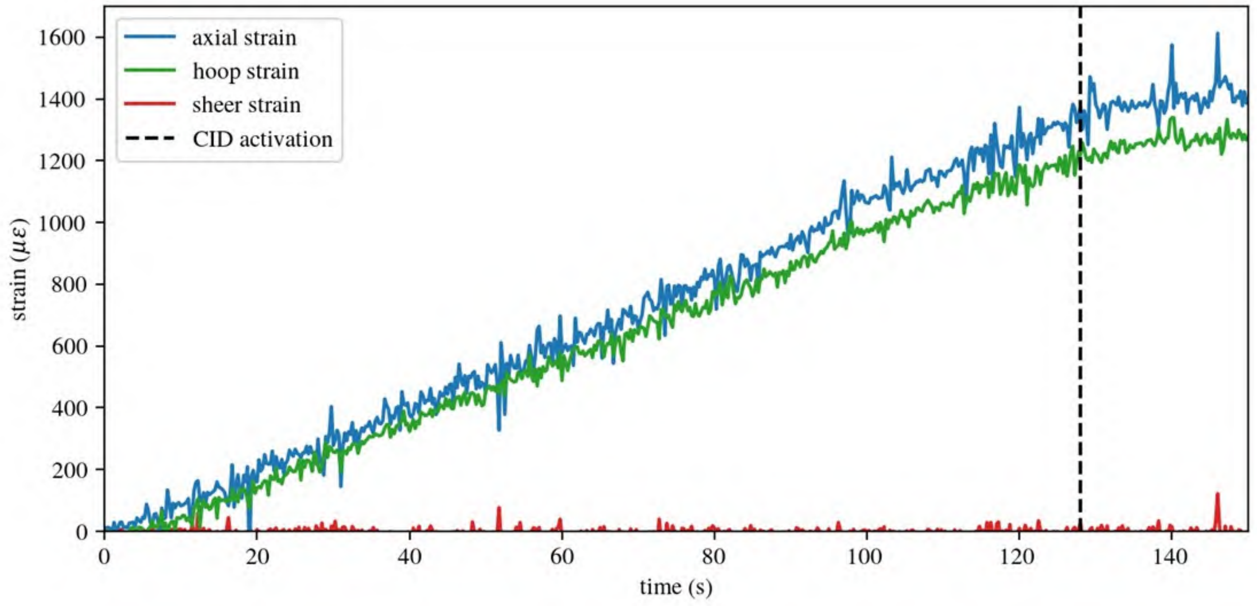
- Improved speckle painting methods
- Added better lighting for speckle detection
- Added fan to mitigate heat waves



Experimental outcomes

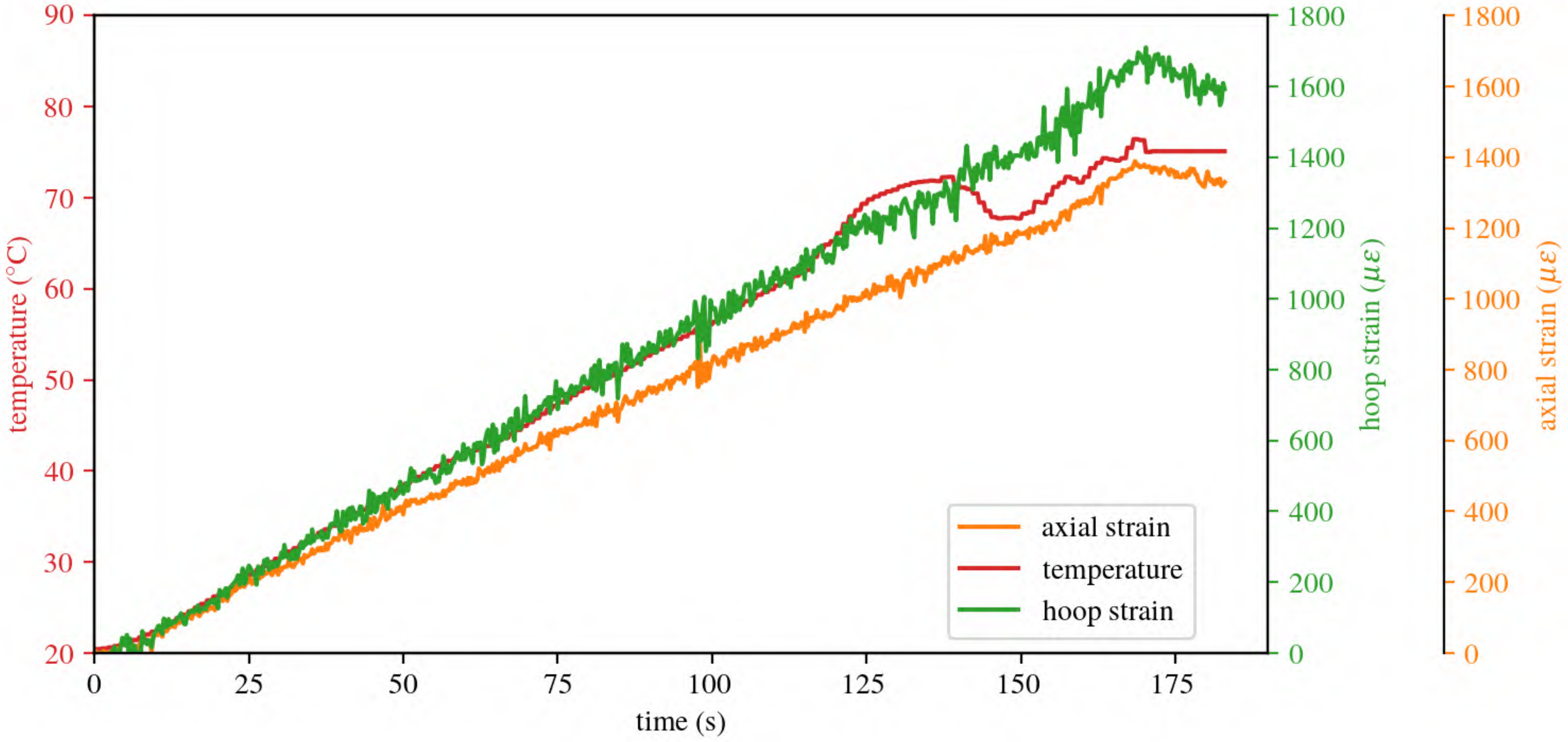
- Strain increase from temperature should be isotropic and we see that for the first minute
- As the test progresses divergence of axial and hoop strain can be observed
- Evidence of a force besides the temperature expansion
  - could be the gas generation leading to CID failure





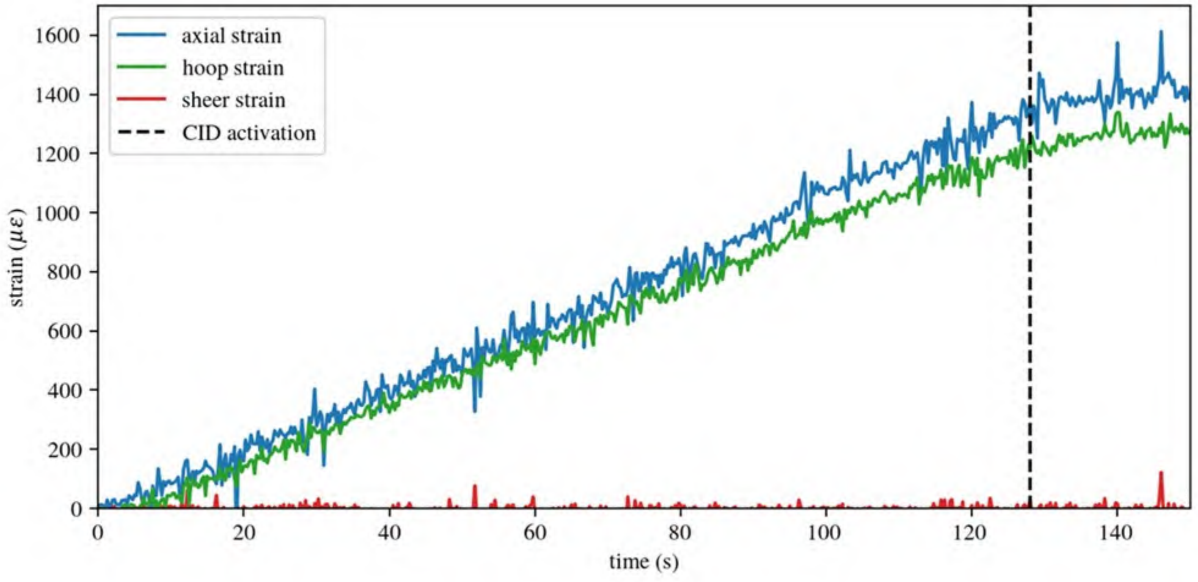
Experimental outcomes

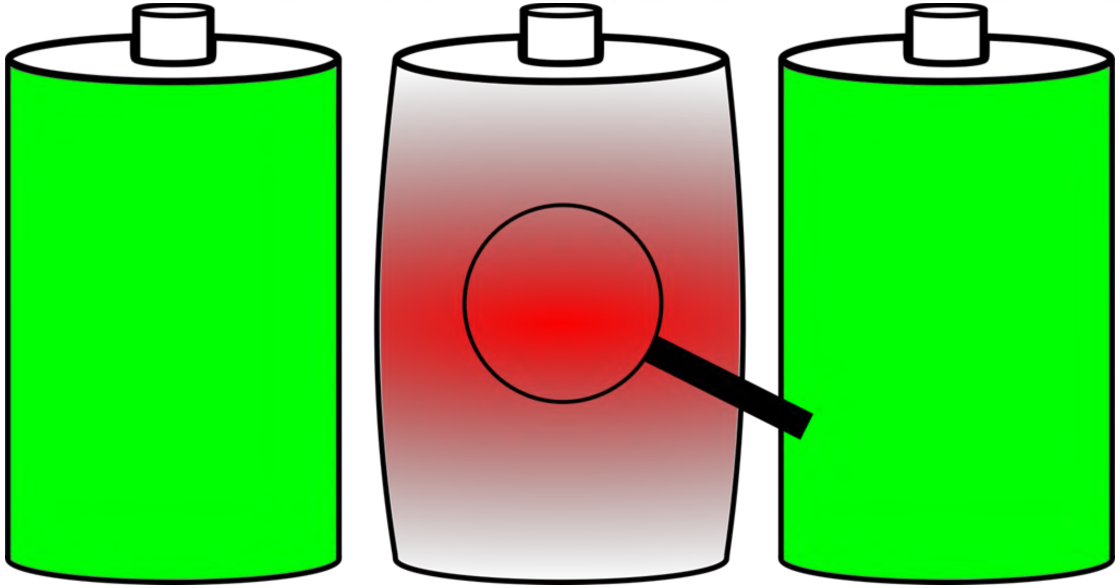
- Improved Digital Image Correlation setup
- Less noise likely due to new speckle method
- Current Interrupt Device activation is more pronounced



Conclusions and Overview

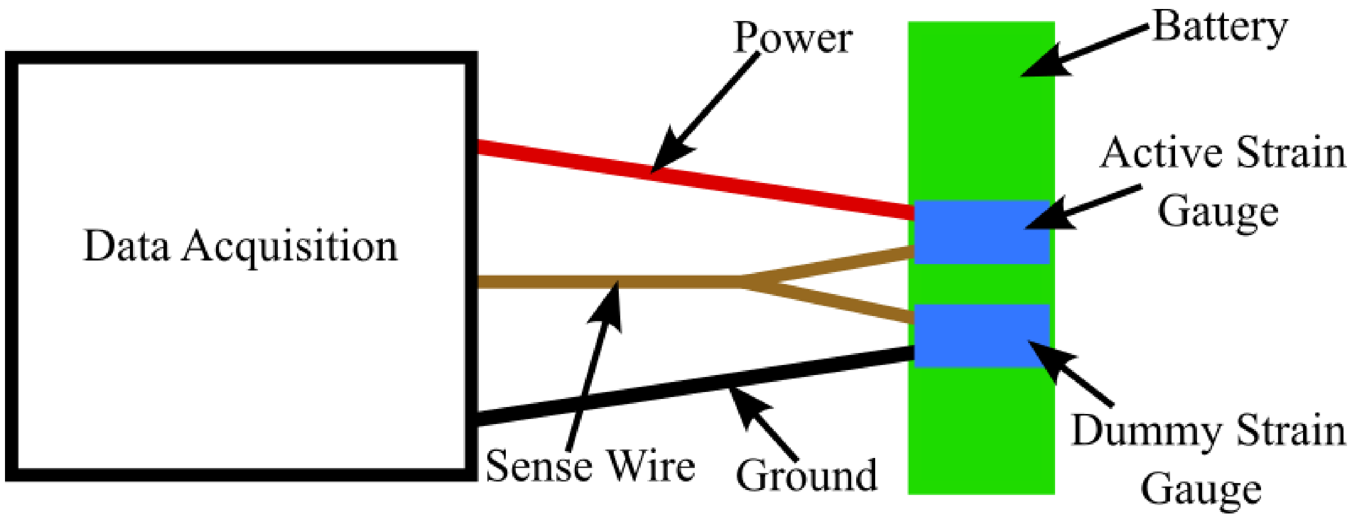
- Potential for using battery deformation as a method of detecting CID failure is evident
- Potential for the integration of non-destructive strain evaluation methods into battery monitoring systems needs further exploration
- Future work will refine current methods and explore alternatives to digital image correlation

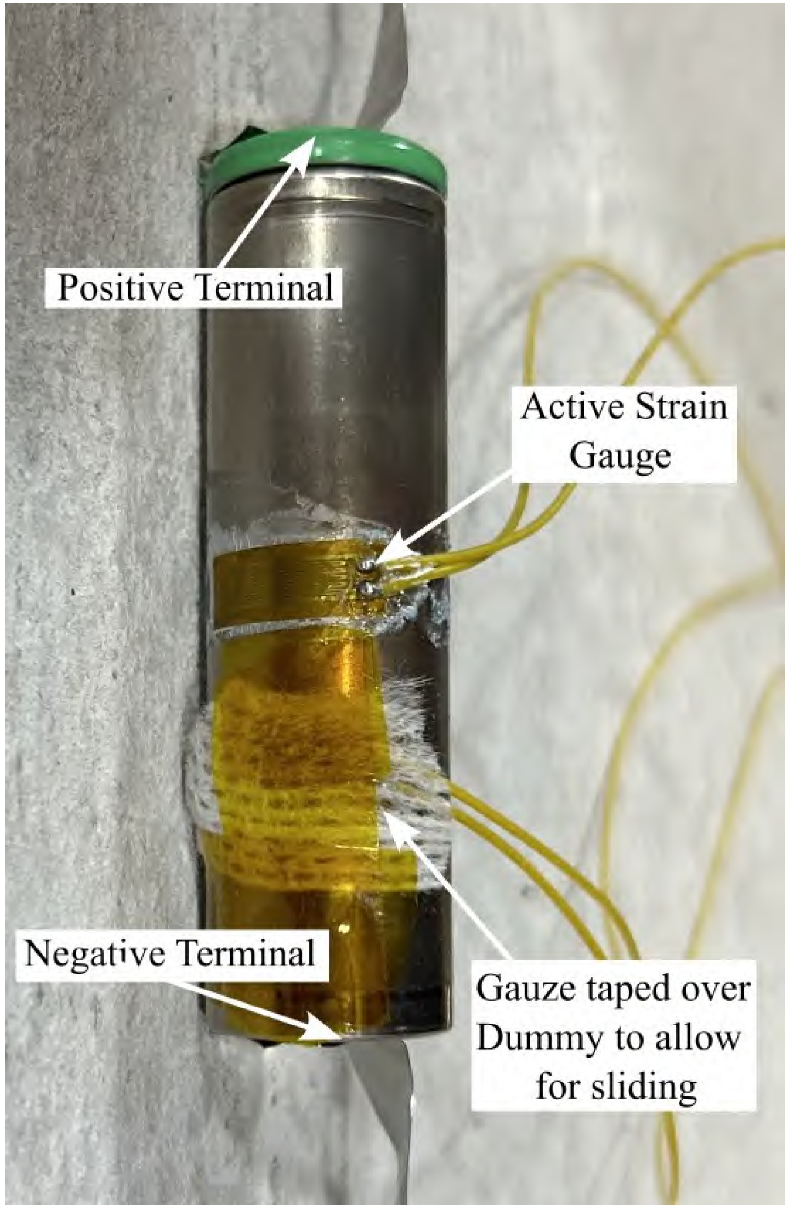




Future work

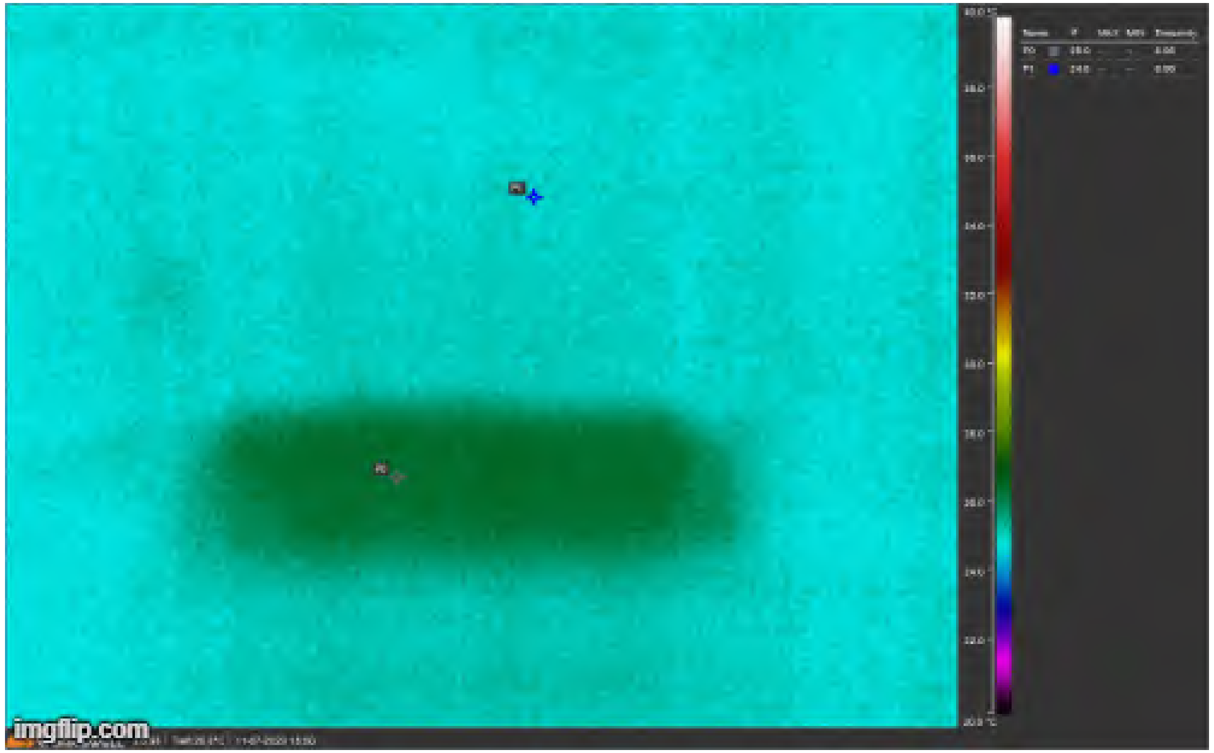
- Implementation of strain gauge will be explored as an alternate deformation detection method
- More applicable to battery management systems
- Will need temperature compensation
- Will run strain gauge and Digital Image Correlation simultaneously





Future work

- Add high resolution thermal camera to understand temperature gradient during battery discharge
- Understanding the temperature gradient of the battery will assist in compensating for the strain generated by temperature



This work is partially supported by the National Science Foundation (NSF) Grant number 2237696. This work is also partially supported by the Air Force Office of Scientific Research (AFOSR) through award number FA9550-21-1-0083. The support of these agencies is gratefully acknowledged. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation or the United States Air Force.

Thank you

Questions?

Presenter Information
Name: Connor Madden
Email: cmmadden@email.sc.edu

Author Information
Name: George Anthony
Email: GA11@email.sc.edu

References:

[1] Grey, C. P. and Hall, D. S., “Prospects for lithium-ion batteries and beyond—a 2030 vision,” Nature Communications 11 (Dec. 2020).

[2] Kim, T., Song, W., Son, D.-Y., Ono, L. K., and Qi, Y., “Lithium-ion batteries: outlook on present, future, and hybridized technologies,” Journal of Materials Chemistry A 7(7), 2942–2964 (2019).

[3] Huang, X., Li, Y., Meng, J., Sui, X., Teodorescu, R., and Stroe, D.-I., “The effect of pulsed current on the performance of lithium-ion batteries,” in [2020 IEEE Energy Conversion Congress and Exposition (ECCE)], IEEE (Oct. 2020).

[4] Xu, B., Kong, L., Wen, G., and Pecht, M. G., “Protection devices in commercial 18650 lithium-ion batteries,” IEEE Access 9, 66687–66695 (2021).

[5] Rowden, B. and Garcia-Araez, N., “A review of gas evolution in lithium ion batteries,” Energy Reports 6, 10–18 (May 2020).

[6] Li, W., Crompton, K., Hacker, C., and Ostanek, J. K., “Comparison of current interrupt device and vent design for 18650 format lithium-ion battery caps,” Journal of Energy Storage 32, 101890 (Dec. 2020)