Extending Battery Life via Load Sharing in Electric AirCraft

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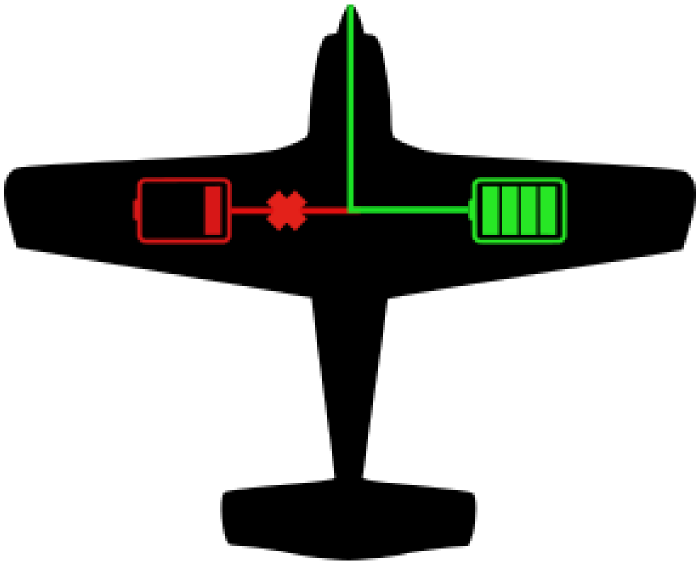
Intro to electric aviation

- Electric Aircraft have the potential to change short distance travel
- Electric motors require less maintenance
- Battery life is the limiting factor for range and capacity

Image Credit: https://www.pipistrel-aircraft.com/wp-content/uploads/2020/05/Velis_Electro_horizontalSlider2.jpg

Goals of model

- Modeling the recovery of maintenance cycle for an electric airplane that loses one battery prematurely
- By aligning the replacement of the two batteries maintenance cost is reduced by streamlining supply chain and the maintenance cycle of the battery



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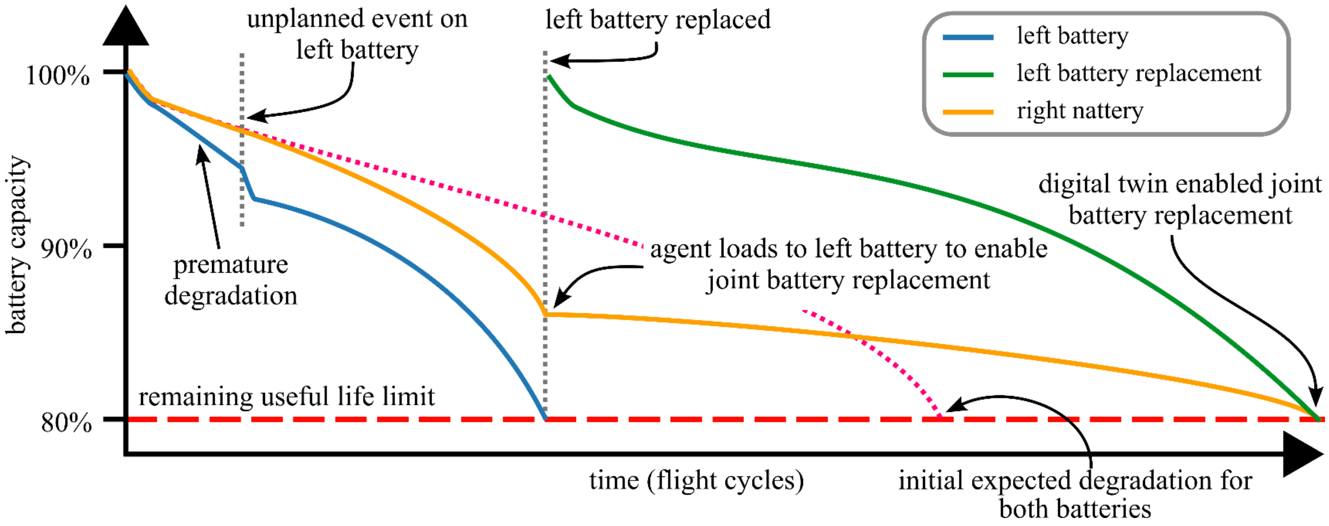
Goals of model

- A single battery fails prematurely causing the 2-battery system to have different maintenance cycles
- The agent helps equalize the batteries for future maintenance



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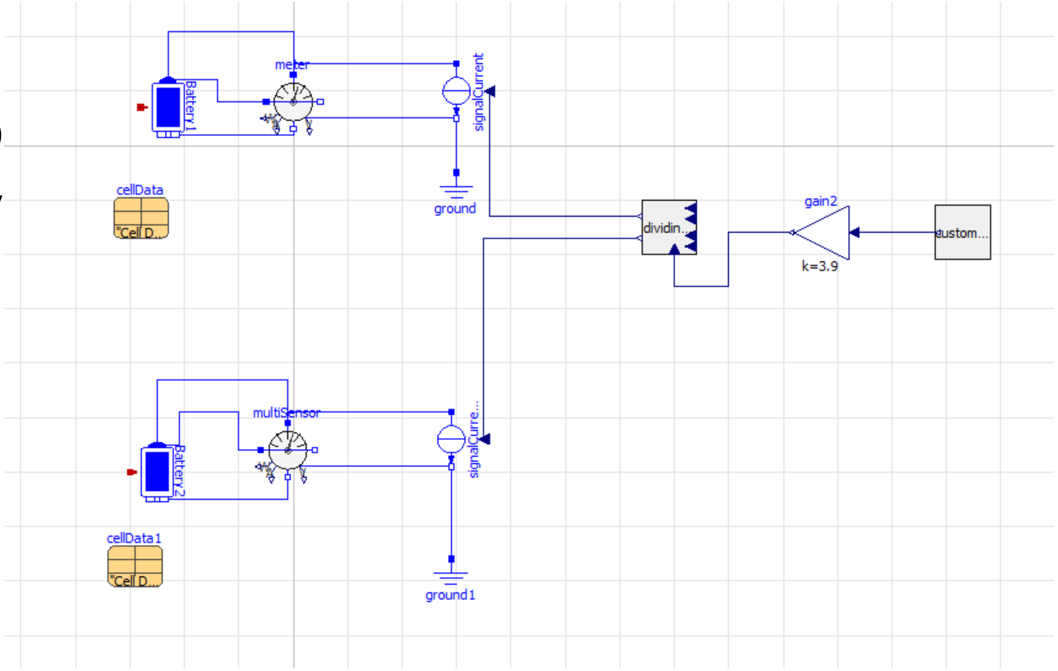
Current battery model

- Two one load is distributed between two battery stack models by dividing model
- Modeled in OpenModelica



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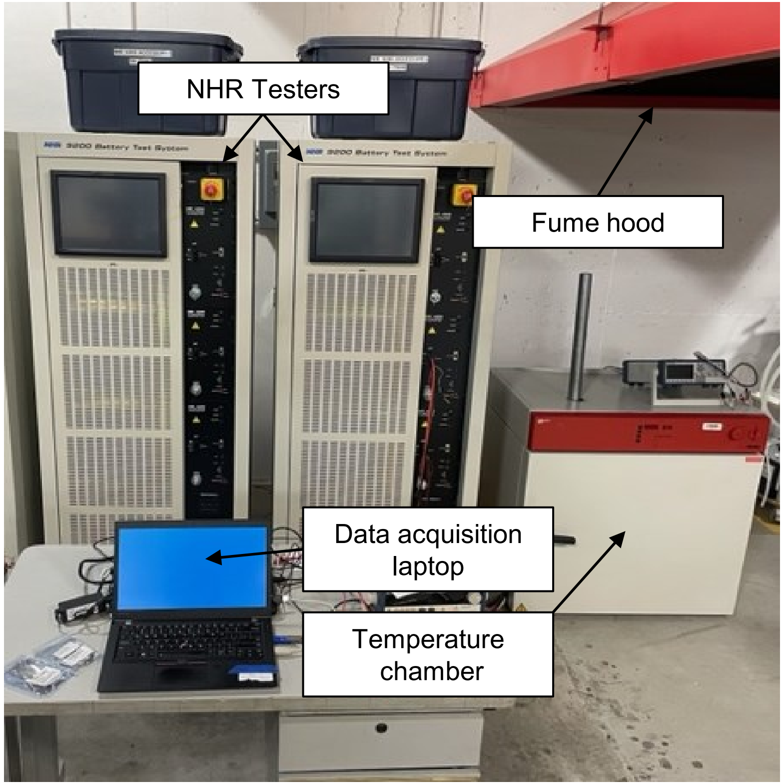
Battery Characterization

- Used NHR 9200 Battery Test system to run tests to characterize batteries
- Controlled using LabVIEW
- Batteries were kept in temperature chamber to provide constant ambient temperature



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Battery Characterization

- Characterized LiFePO4 22650 Battery Cell for the model

- LiFePO4 was chosen for its chemical stability in a test environment

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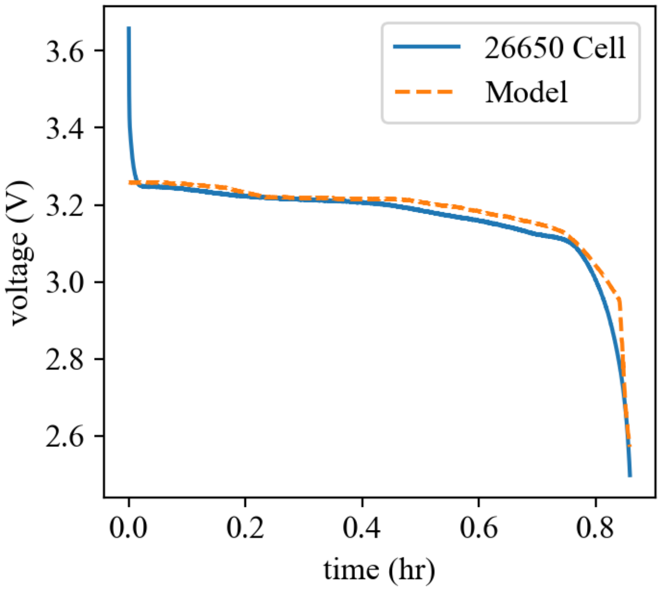
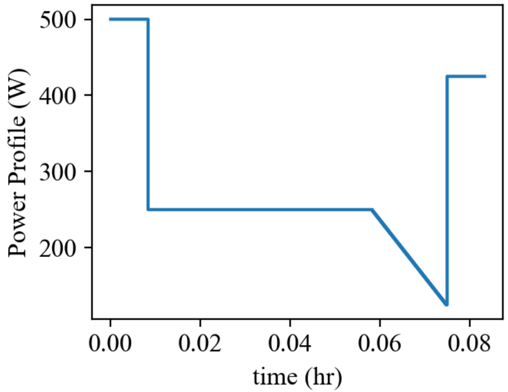
Battery Characterization

- Parameterized LiFeP 22650 cell based on literature and internal data collected
- Graph compares a 1 C discharge of the model vs a single 26650 cell

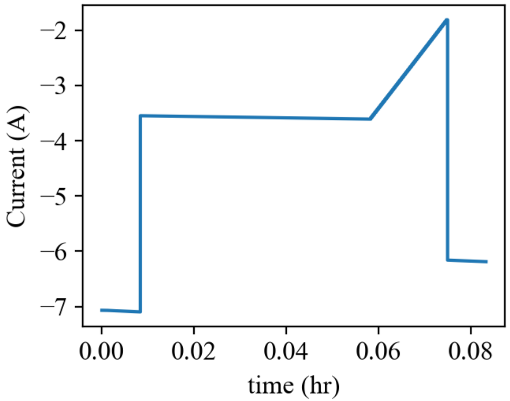


Battery

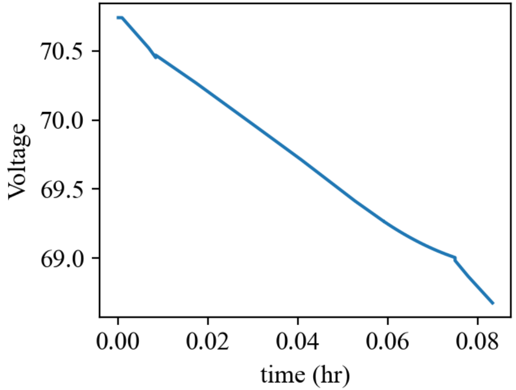
- Response to eVTOL load profile
- Model response scaled as predicted for a larger Battery pack



Power profile

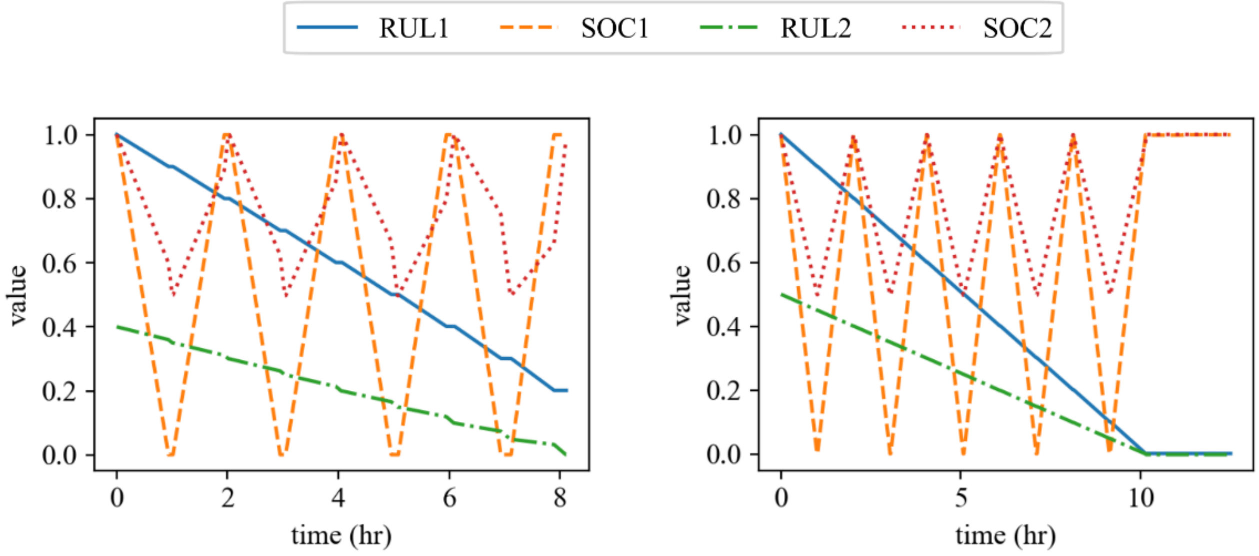


Current response(negative)



Voltage response

Load sharing explanation



Limits to the model were shown when the battery was lower.

If the difference is manageable, it can equalize.

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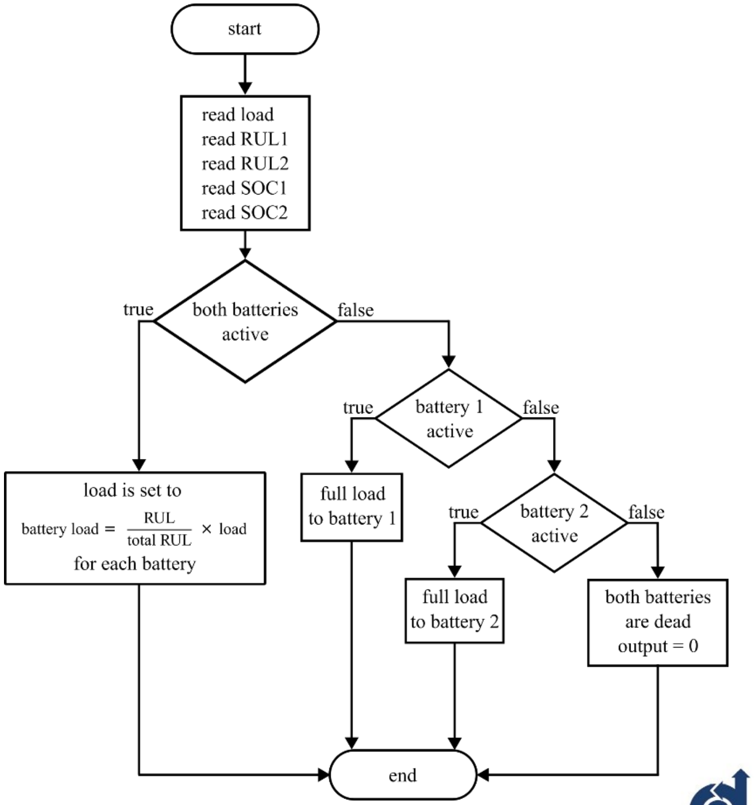
Load sharing explanation

- After reading the status of both batteries the model distributes the load based on the health of the batteries
- The load is scaled based on the ratio of the current RUL to the total RUL of the system



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Results

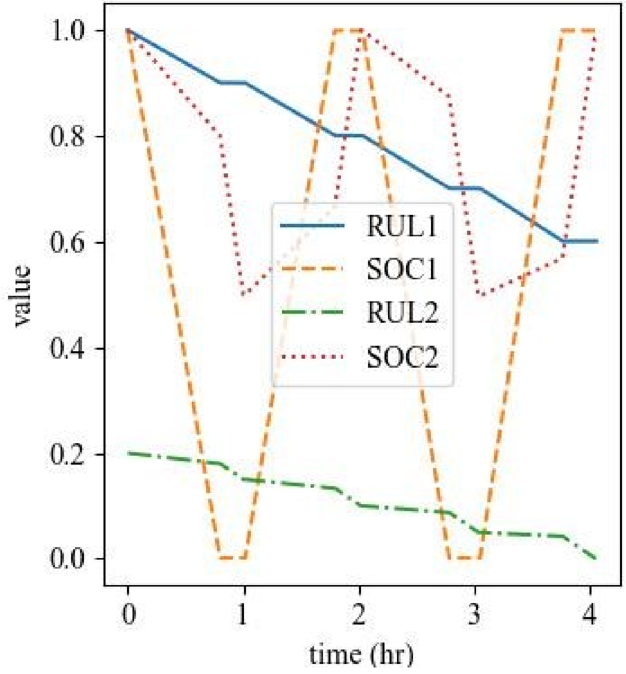
- 3 of the 5 scenarios ended in success
- The load sharing method was able to get the batteries to equalize at 0 when RUL2 was > 0.5

RUL equalization results.

RUL1 Start Value	RUL2 Start Value	Equalization Result	Final RUL1	Final RUL2
1	0.8	Success	0	0
1	0.6	Success	0	0
1	0.5	Success	0	0
1	0.4	Fail	0.2	0
1	0.2	Fail	0.6	0

Results

- For lower RUL2, the system was not able to equalize the remaining useful life until the older battery needed to be replaced
- When Battery 2 is depleted Battery 1 has an RUL of 0.6 which can be equalized in the next maintenance cycle



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Limits of current strategy

- We were able to extend the life of the older batteries by 50% but cannot equalize the batteries in all cases
- Battery RUL can be equalized with further replacements
- Batteries that have a difference in RUL greater the 0.5 cannot equalize in one maintenance cycle
- Small risk of new battery ending at the degraded battery RUL causing endless separation of RULs

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Conclusions

While we made progress in extending the life of the batteries and equalizing the maintenance schedule, more work needs to be done to prevent the loss of redundancy of the current system

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Future Work

- Currently working on several different control strategies in Openmodelica to test using the same scenarios.
- Test algorithms on full scale hardware.

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Open-source project

- Github of open Modelica scan QR code