Prognostics HIL Testbed

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Motivation

Demonstrate ability to distinguish between components at different health states having similar external observables and then to predict the end of life

To facilitate research in prognostics, it is imperative to have a hardware testbed that mimics the complexities and issues encountered for a real system. Such a system will support:

- Algorithm development
- Testing and validation of prognostic tools
- Benchmarking of different approaches
- Development of metrics for prognostics
- Collection and dissemination of run-to-failure data

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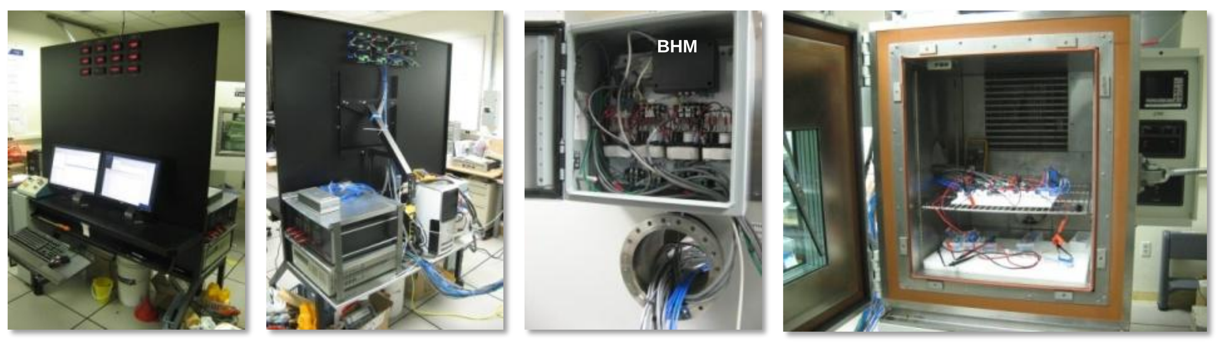
Requirements

The testbed shall:

- Resemble a system that has real-world relevance
- Allow for repeated run-to-failure of components
- Perform run-to-failure in reasonable time
- Support monitoring of ground truth
- Collect data for state assessment
- Support demonstration of prognostic solutions
- Allow control of several operational and/or environmental variables
- Allow quantification of uncertainty sources
- Support repeated run-to-failure within a finite budget
- Support automated data collection during the aging

Experimental Setup

- A set of Li-ion cells
  - Aging dynamics slow enough to be observable and fast enough for reasonable run-to-failure times (~1 month)
  - Low cost
  - May be aged either inside or outside an environmental chamber
- Programmable Charger and Electronic Load
- EIS equipment for battery health monitoring (BHM)
- Sensor suite – Voltage, Current, Temperature
- Custom switching circuitry and data acquisition
- Computer for control and analysis



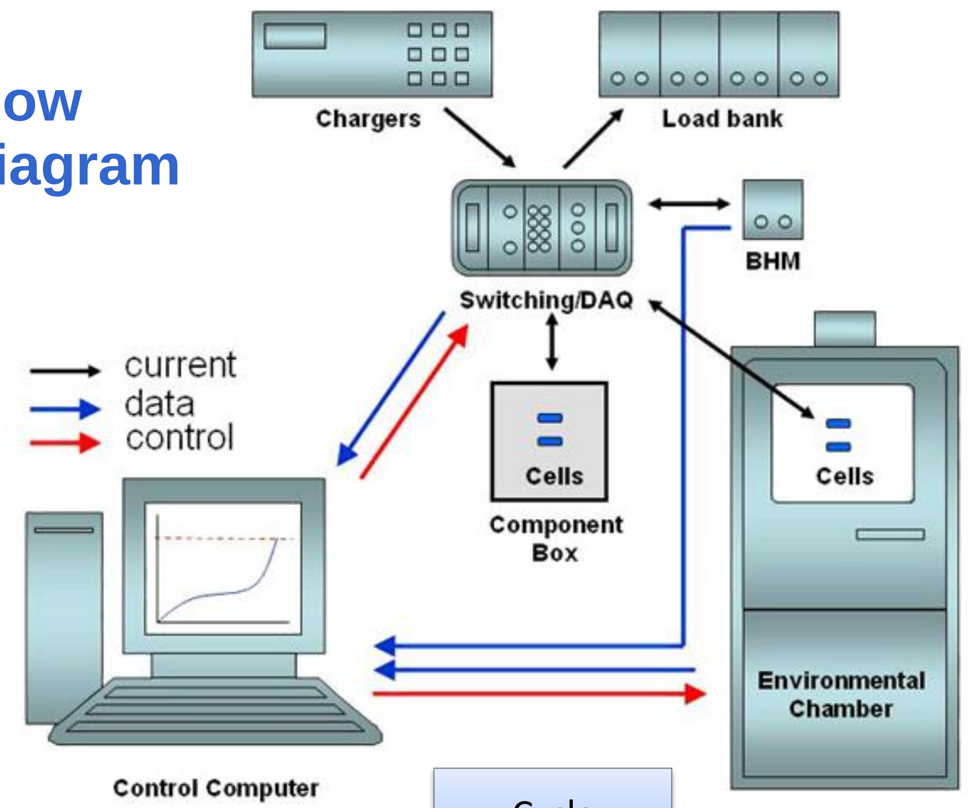
Data Collection

Experimental Plan

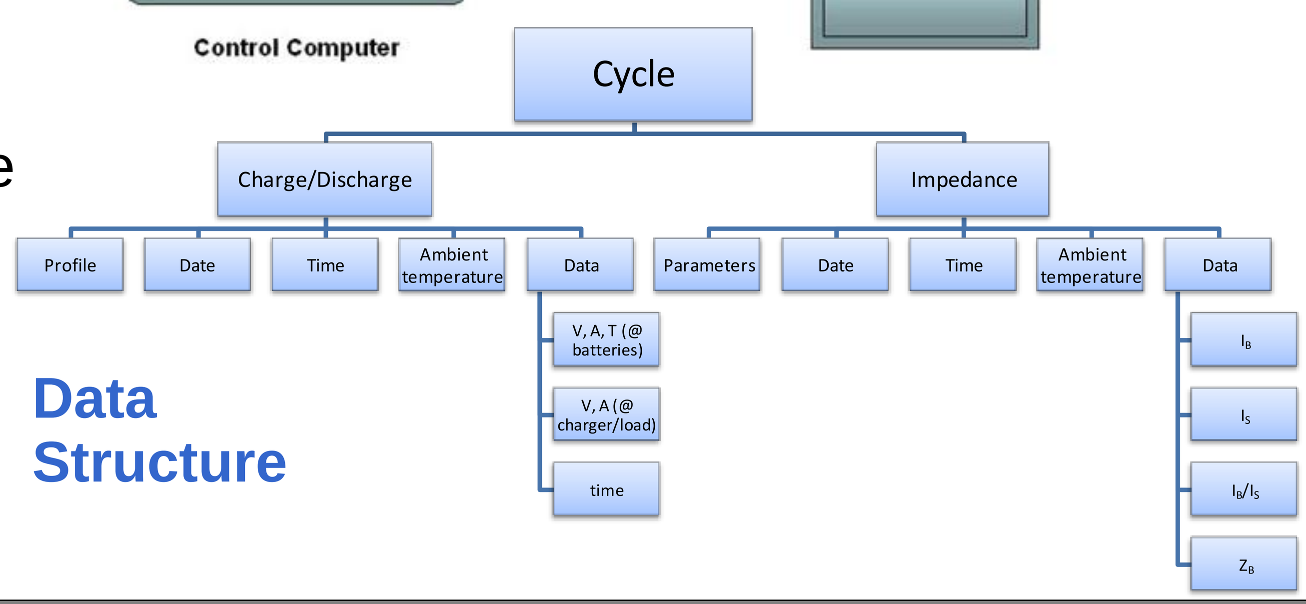
- Cells are cycled through charge and discharge until failure (30% capacity fade) under different operating conditions set by the electronic load and environmental chamber
- Periodically Electrochemical Impedance Spectroscopy (EIS) measurements are taken to monitor the internal condition of the battery
- DAQ system collects sensor data like voltage, current and temperature
- Switching circuitry enables cells to be in the charge, discharge or EIS health monitoring state as dictated by the aging regime
- The datasets are available at http://ti.arc.nasa.gov/project/prognostic-data-repository

Datasets have been downloaded over a 1000 times already.

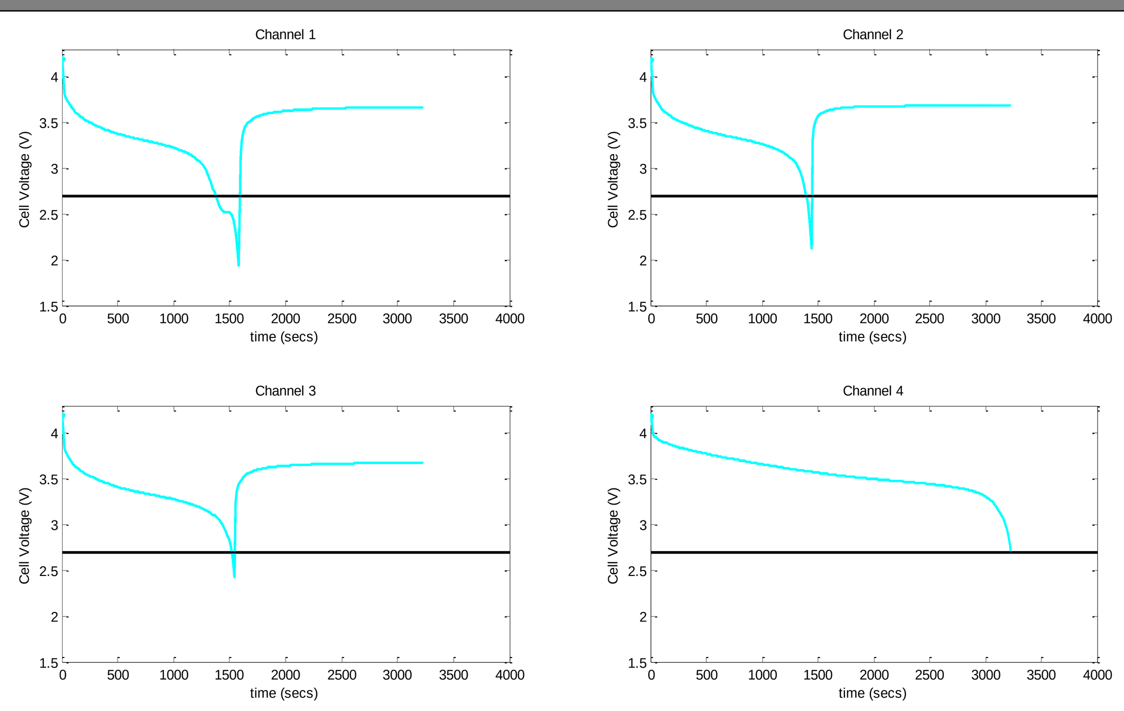
Flow Diagram



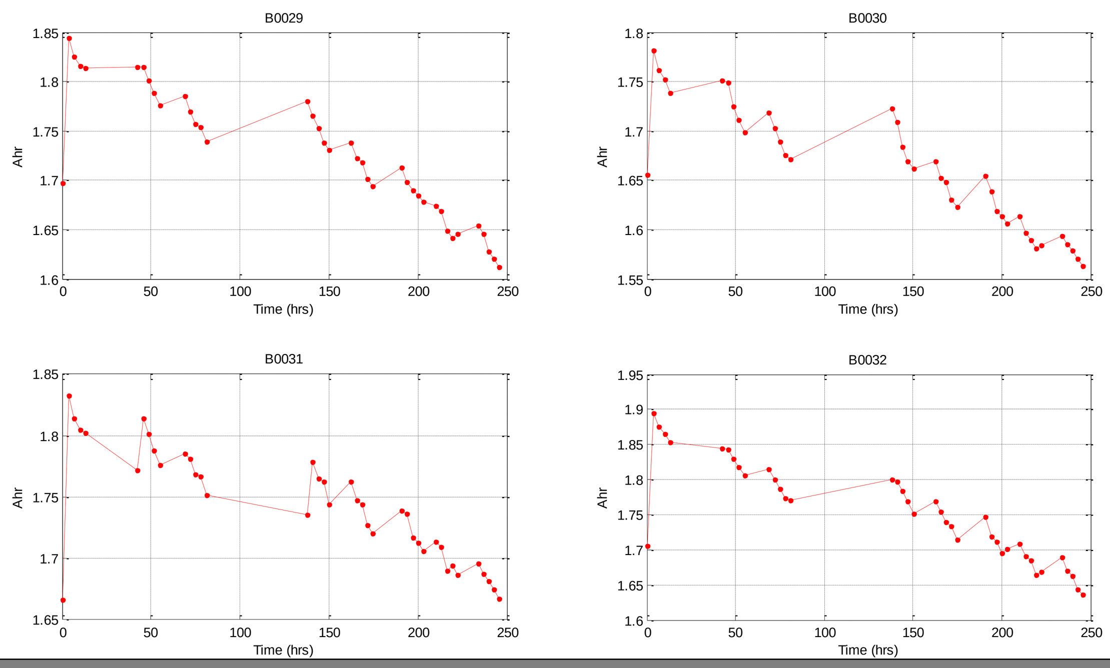
Data Structure



Discharge Cycle



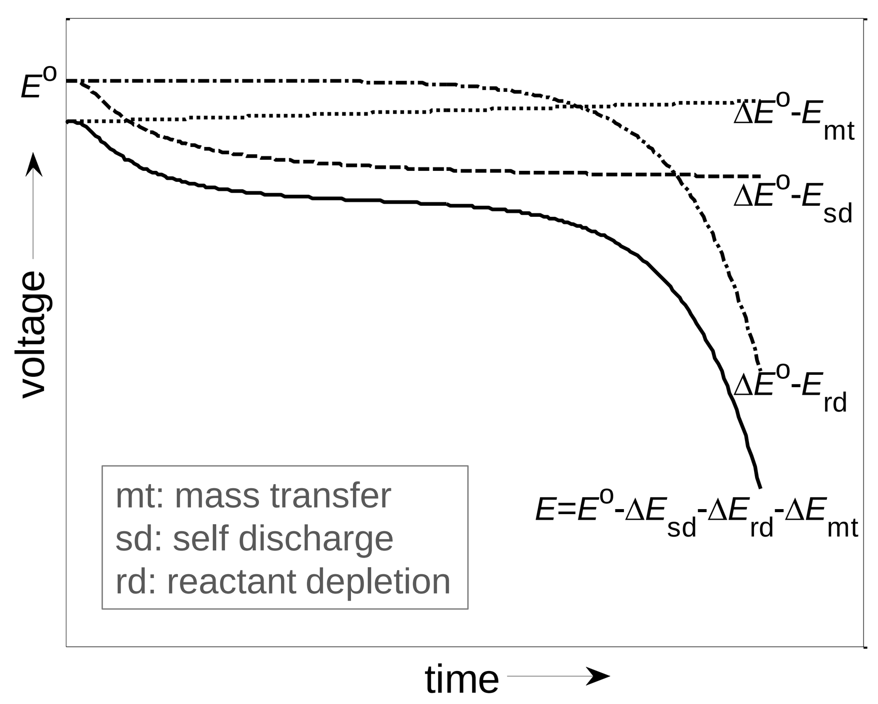
Life Cycling



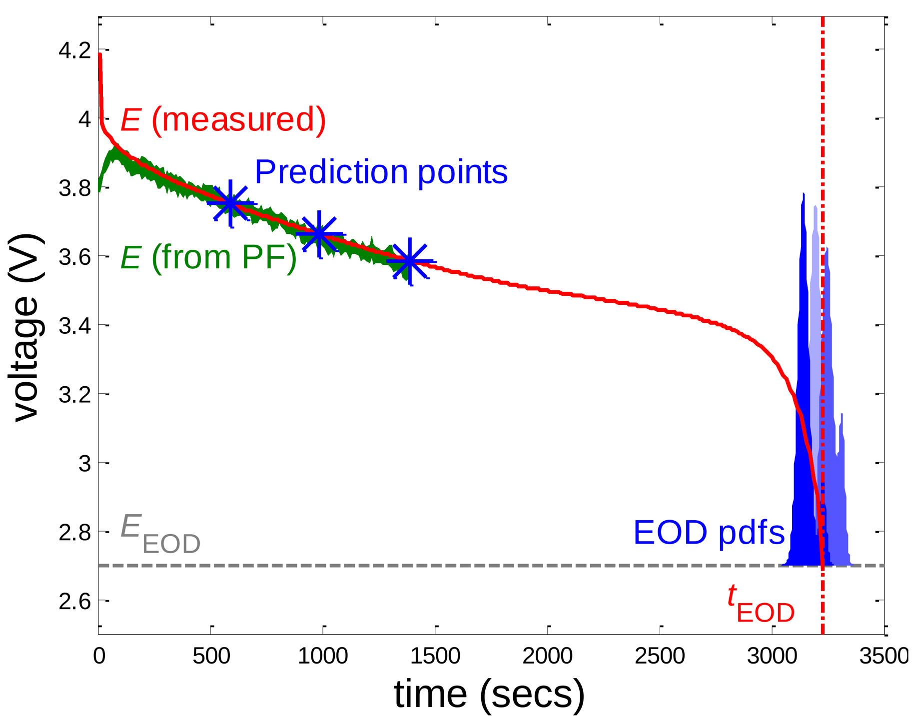
Prognostic Algorithm Development

Short Term Prognosis

- Objective: Predict when Li-ion battery voltage will dip below 2.7V indicating end-of-discharge (EOD)
- Approach
  - Model non-linear electro-chemical phenomena that explain the discharge process
  - Learn model parameters from training data
  - Let the PF framework fine tune the model during the tracking phase
  - Use the tuned model to predict EOD



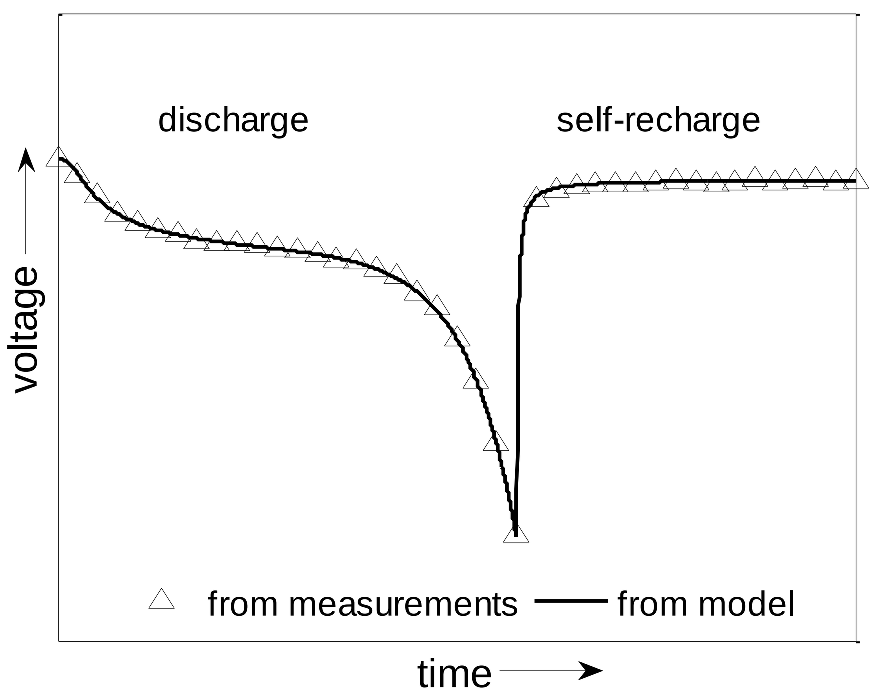
Modeling



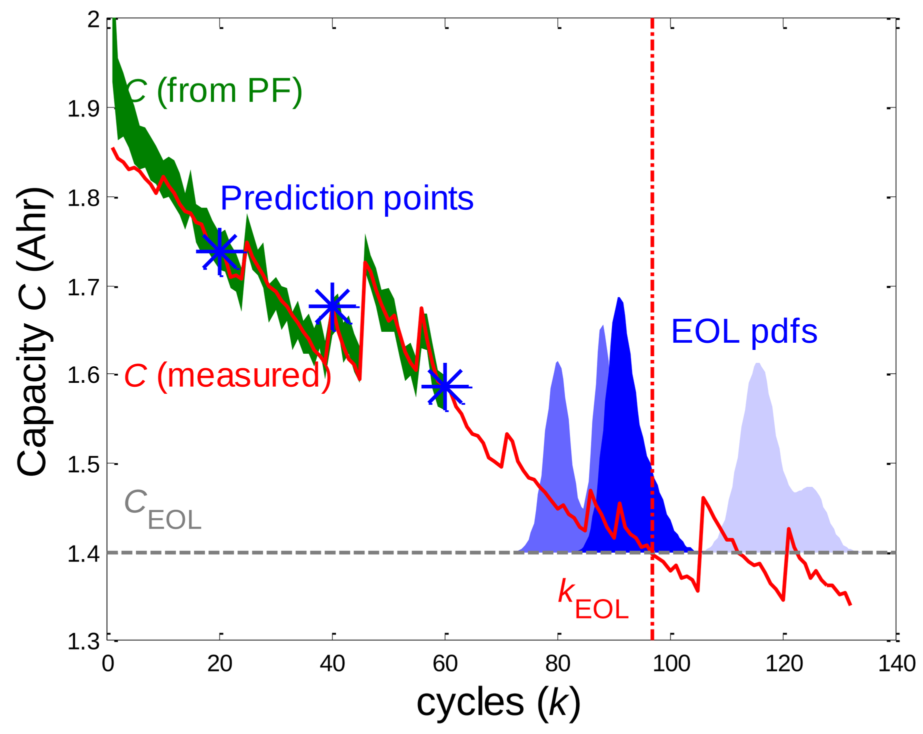
Prognosis

Long Term Prognosis

- Objective: Predict when Li-ion battery capacity will fade by 30% indicating life (EOL)
- Approach
  - Model self-recharge and Coulombic efficiency that explain the aging process
  - Learn model parameters from training data
  - Let the PF framework fine tune the model during a few initial cycles
  - Use the tuned model to predict EOL



Modeling



Prognosis

The paper based on the data collected from the testbed titled “Modeling Li-ion Battery Capacity Depletion in a Particle Filtering Framework” received Best Research Paper award at the Annual Conf. of the PHM Society, 2009.