

Prognostics and Health Management of Batteries and Composites

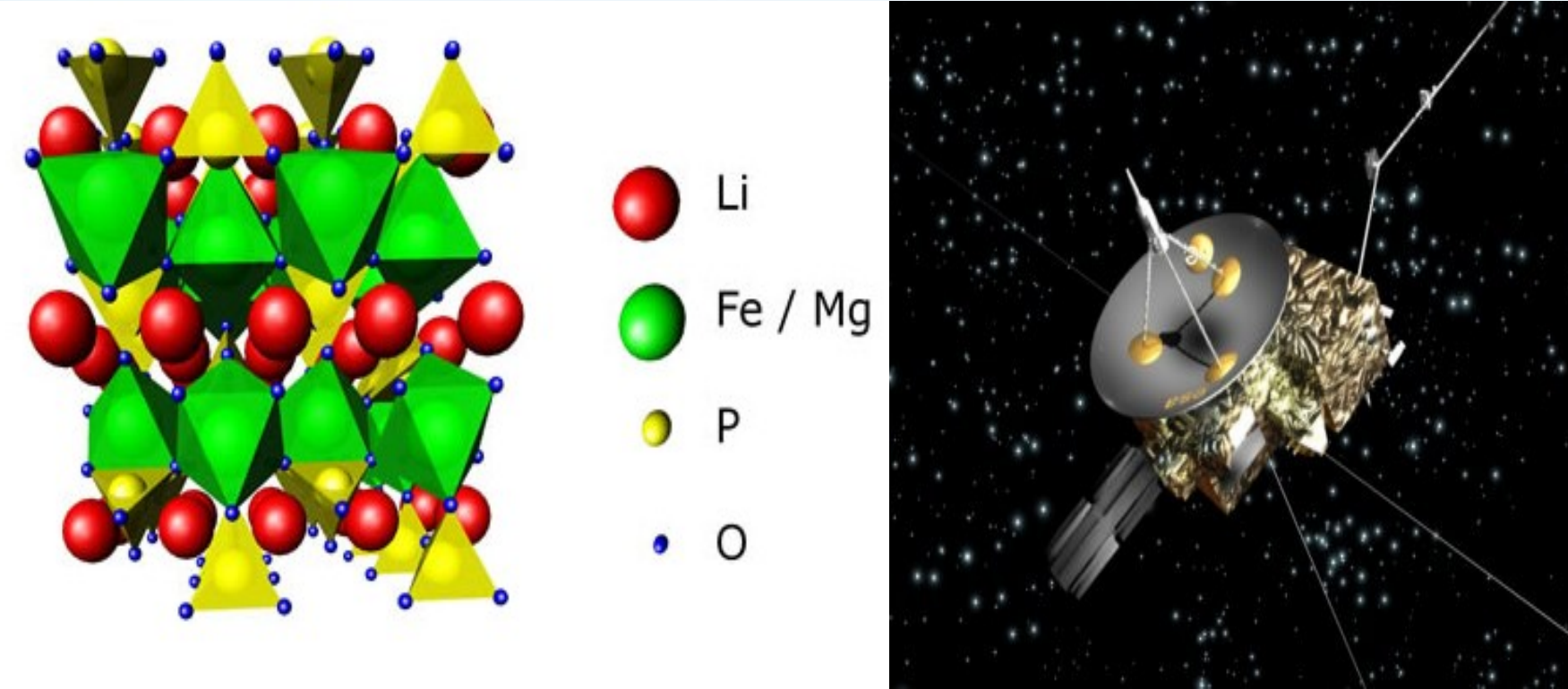


Ishrat Khatoon*, Bhaskar Saha, Abhinav Saxena, Kai Goebel
 i_khatoon@yahoo.com, bhaskar.saha@nasa.gov, abhinav.saxena@nasa.gov, kai.goebel@nasa.gov
 Chemistry/AP Environmental Science/Earth Science Educator, Research Scientists, and PCOE

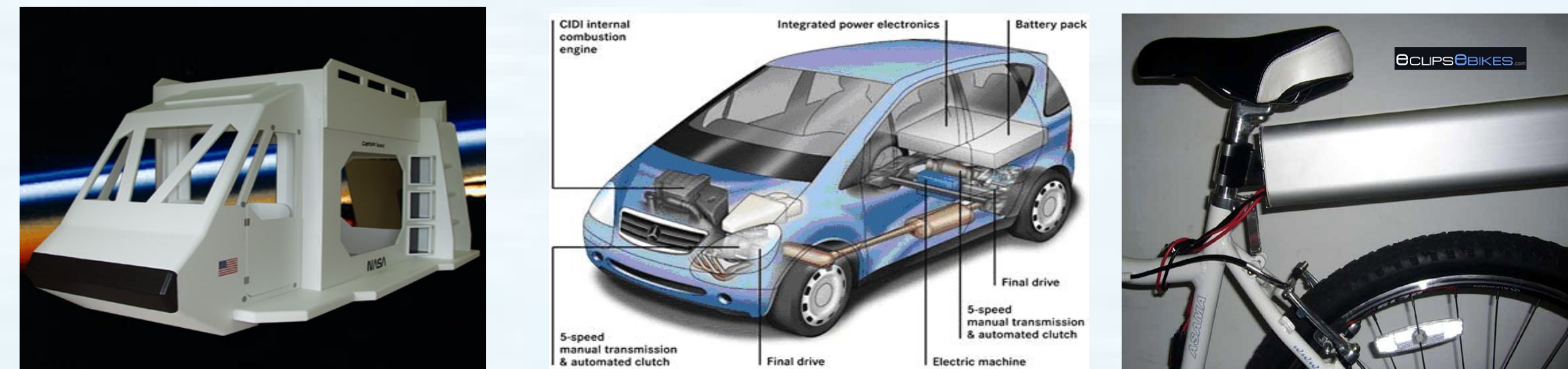


Introduction

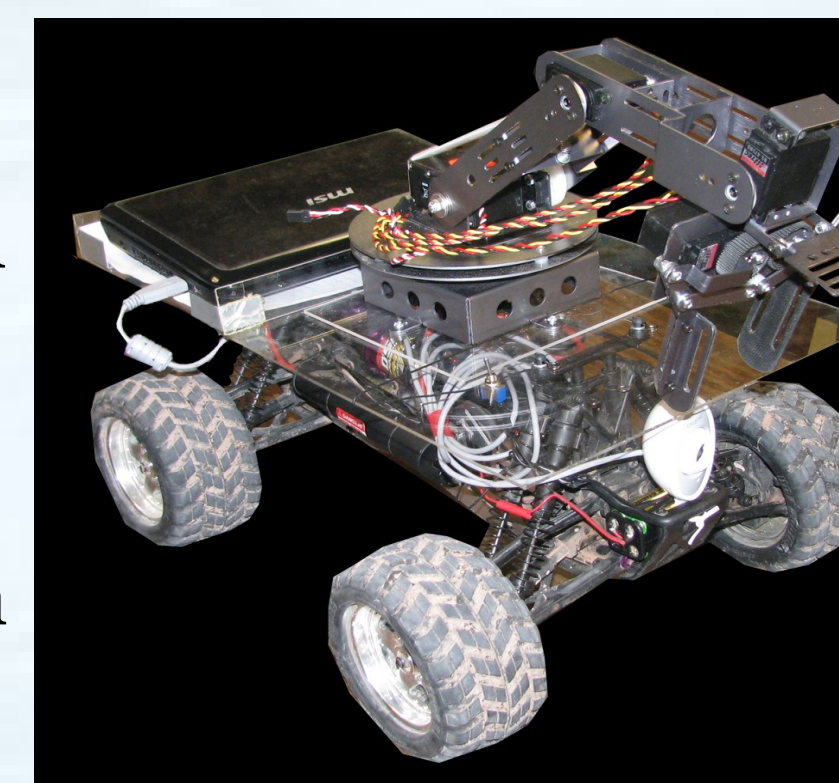
- Prognostics and health management (PHM) algorithms track the health condition of a system and make an assessment of the time until which this system can perform within desired specification.
- I will be working on PHM of Lithium Iron Phosphate (LiFePO₄) batteries and Carbon-Carbon Composites (CCC).



Lithium Iron Phosphate Batteries



- LiFePO₄ is positive electrode used for portable electronics, hybrid electric vehicles (HEV), plug-in HEV (PHEV), laptops, aircraft, space craft, rovers etc.
- LiFePO₄ has high capacity of about 170mAh/g.
 - High stability during lithium extraction /insertion
 - Good chemical and thermal stability
 - Cheap and easy for production
 - Environmentally friendly in production and recycling.



Carbon-Carbon Composites

Carbon-carbon composites (CCC) were originally developed for aerospace industry and later for racing cars. These are used in nose cone and wing leading edges in aircraft and space shuttle because of its cost effective solutions for furnace fixtures applications. These structures are prone to failure. To avert a catastrophic failure or to extend remaining useful life (RUL) structural health management (SHM)/PHM is done for CCC.

- The method of finding the structural damage and prognosis will be done by employing build-in sensor/actuator network and numerical simulation method of damage estimation and propagation.
- The goal for this work is to integrate the above method for SHM/PHM in CCC.



Model of LiFePO₄ Batteries

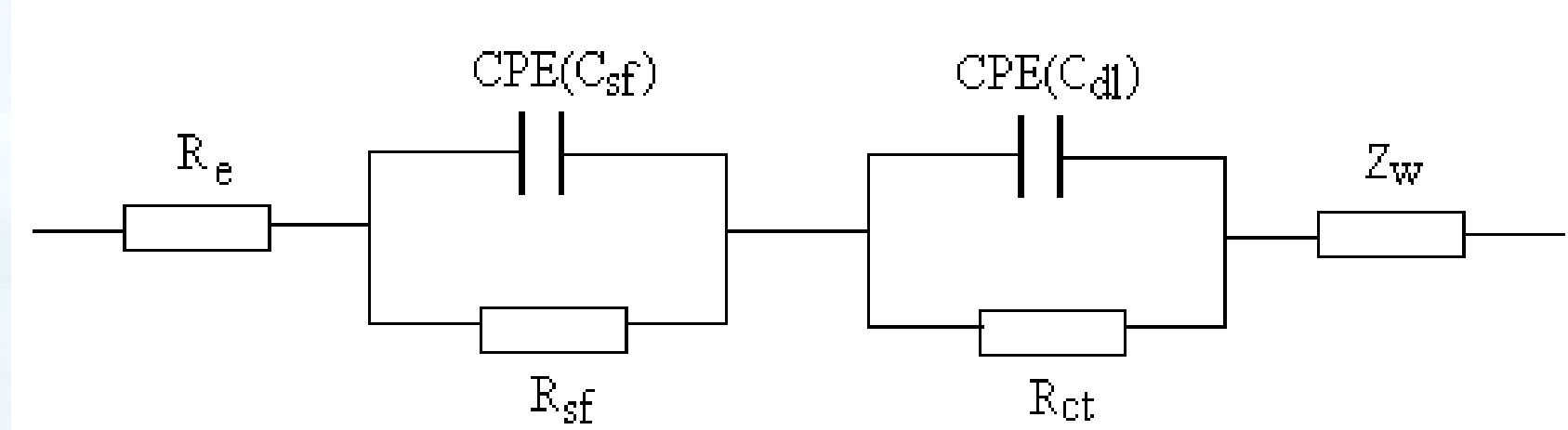


Figure 1. Equivalent Circuit for EIS of LiFePO₄ Cathode

To investigate the LiFePO₄ batteries electrochemical impedance spectroscopy (EIS) will be used. This model will use four parts in serial.

- R_e – electrolyte resistance
- R_{sf} & CPE(C_{sf}) connected in parallel is surface film resistance and capacitance
- R_{ct} & CPE(C_{dl}) connected in parallel is charge transfer resistance and double layer capacitance
- Z_w – Warburg impedance



Electrochemical Theory

The electrochemical reaction of LiFePO₄ undergoes phase transition between FePO₄ to LiFePO₄. I will be using the equation below. Lithium ion diffusion coefficient and exchange current density will be calculated by the equation given

$$J_0 = \frac{i_0}{A} = \frac{RT}{nFR_{ct}A} \quad (1)$$

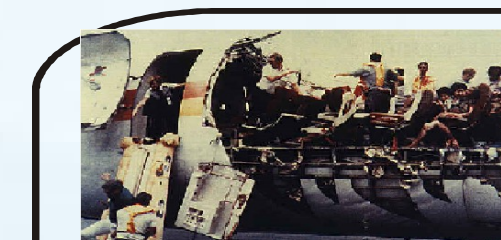
$$D_{Li^+} = R^2 T^2 / 2 A^2 n^4 F^4 C^2 \sigma^2 \quad (2)$$

$$Z_{re} = R_o + R_{ct} + \sigma \omega^{-1/2} \quad (3)$$

Where J₀ is the exchange current, A is area of electrolyte interphase, R is gas constant, T absolute temperature, n number of electrons per molecule during oxidation, F Faraday's constant, D_{Li⁺}, diffusion coefficient, C is concentration of Li ion, σ Warburg factor, Z_{re} is real part of impedance, and ω is angular frequency.

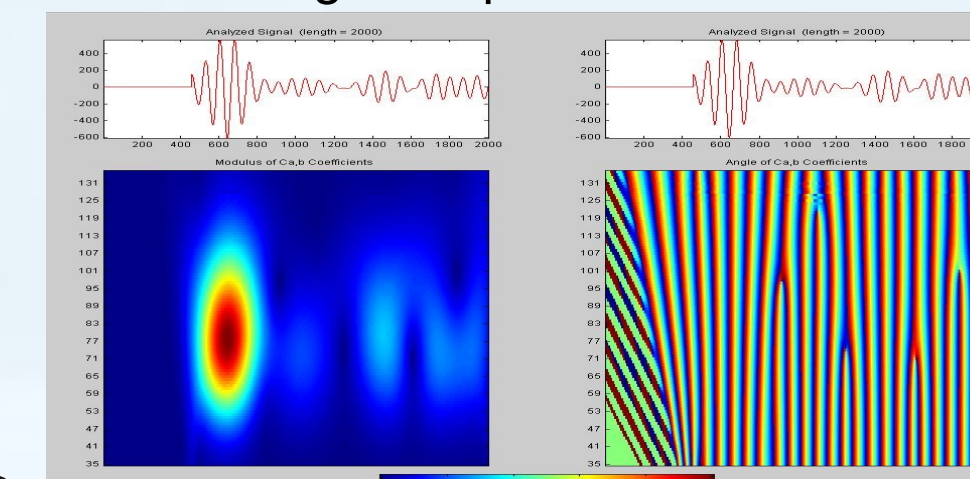


CCC Data Analysis

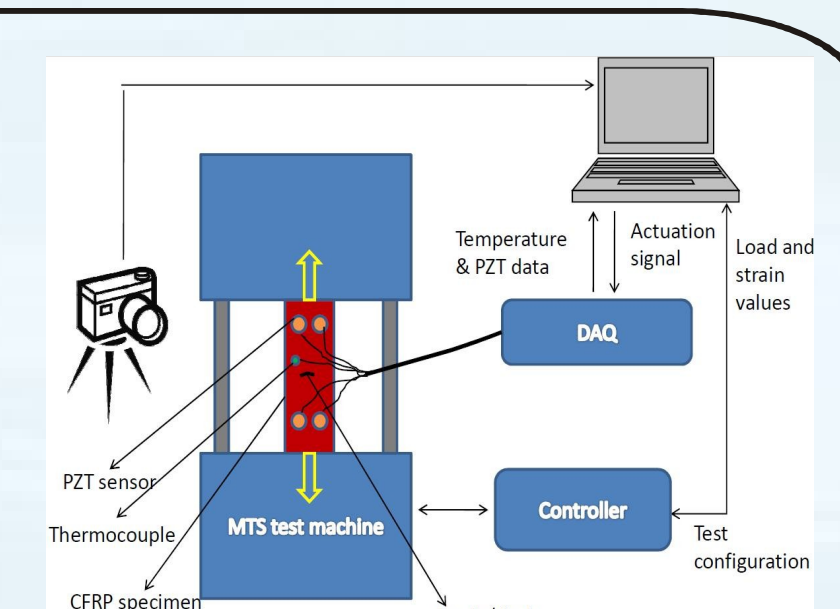


The fuselage ripped apart during flight, just after takeoff.

Image of Specimen Data



CCC are being tested on fatigue testing Machine (MTS) and data collected are being analyzed. The image of specimen shows the signal and the intensity.



My goal is to analyze sensor data to assess fatigue damage level in these coupons. This analysis will help in understanding failure mechanisms in composites which is key to prognostics.

Bibliography & Acknowledgment

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 X. He, J. Zhao, L. Wang, C. Wan, C. Jiang, *Int. J. Electrochem. Sci.*, 5, (2010) 478-488.
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