**Background**

- CubeSats in a low-Earth orbit often experience irregular heat fluxes coming from the sun
- This requires a thermal management system to regulate temperature and heating distribution
- Variable electrochromic devices (VEDs) pose a solution to this problem
- VEDs can change emissivity which allows for temperature regulation when conduction and convection heat transfer mediums are absent
- The project is interested in the performance and manufacturing process of VEDs

**Objectives and Goals**

- **Objective**
  - Investigate VEDs to achieve improvement in manufacturing cost and performance
- **Goals**
  - Develop a manufacturing process that yields a consistent deposition of transition metal oxides
  - Create a transparent electrolytic medium for electrochromic function
  - Implement a vacuum chamber to simulate conditions found in low-Earth orbit during thermal testing
  - Determine whether E-ink technology can be used as an alternative to conventional VED materials

**Requirements**

- The Vacuum Team is building a chamber that can withstand pressure in the high vacuum regime
- The Gel-Electrolyte Team wishes to produce a gel with:
  - Thickness in cell below 2 mill
  - Coloration time below 1 minute at 2 V
  - Transmittance greater than 70%
  - Minimum gas formation through electrolysis with ongoing current
- STMS wants the VED to have an emissivity range of 0.2 < ε < 0.8
- As for the chemical teams, they want consistent slide deposition that only gives a +/- 5% difference of transmission and an opacity with 20% transmission for the nickel.

**Current Status**

- **Tungsten Team [1]**
  - Characterized the tungsten oxide material through SEM and grancing incidence XRD analysis. WO3 has a preferential orientation of (001) and a tetragonal phase.
  - Voltage of -1.5V produces the best coloration without completely destroying the slide
- **Nickel Team [2]**
  - To validate electrochromic properties, synthesized films were tested in 1M KOH solution, utilizing -1.5V and +1.5V to produce the bleached and colored states, respectively.
  - Developing Cobalt doping as its only 1% of Nickel's atomic weight and offers a potential boost in life cycle performance.
- **Gel-Electrolyte [3]**
  - Successfully synthesized and stored a CMC gel in clear liquid form without precipitation, at 0.5 w% CMC
  - Test cells were developed using 1 square-inch FTO glass slides and a 22 mil thick polyethylene tape, 1 mil thick teflon tape, and 2 mil thick Kapton tape that act as spacers to control the thickness of gel in the assembly.
- **Spectro-Volt [4]**
  - Designed, tested, and manufactured an FTO slide holder with a detachable reference electrode holder that can operate in Lithium Perchlorate (LiClO4) solution.
- **Vacuum Team [5]**
  - Earned the approval of all 3 advisors for a design that satisfies: minimum Pressure of 1.45×10^-4 psi, at least 4 Access Ports & 1 feedthrough and Volume Greater than 1000 in3
- **Space Team [6]**
  - Simulated low earth CubeSat orbit which generated data/reports about temperature changes, magnetic flux, eclipse times, and solar intensity.
- **E-ink Team [7]**
  - Designed a low cost test setup to measure emissivity within a vacuum chamber.
  - Designed and fabricated a low cost experiment that utilizes a hot water thermal reservoir to measure thermal conductivity of e-paper

**Next Steps**

- **Tungsten Team**
  - Define film characteristics such as thickness, life cycles, coloration efficiency, and observe material characteristic changes due to coloration.
  - Integrate nickel oxide and gel electrolyte with tungsten oxide.
- **Nickel Team**
  - Explore relationships between aspects of thickness and uniformity.
  - Quantify this process with metrics such as coloration efficiency, switching speed, life cycle testing.
- **Gel-Electrolyte**
  - Gather life-cycle performance data of the PMMA gel electrolyte by incorporating nickel and tungsten film slides and performing potentiostat testing.
  - CMC gel synthesis will continue to aim for a > 70% transmission and structural integrity without precipitation.
- **E-ink Team**
  - Quantify the change in emissivity of the e-paper display (Epd) with constant temperature, one-dimensional heat transfer experiment.
  - Utilize the new spectrometer reflection equipment to measure the change in reflectance of the e-paper.
- **Space Team**
  - Modify the simulation as needed and correlate the software-generated data to the response of a modified satellite in a vacuum chamber.
- **Vacuum Team**
  - Initiate substrate holder and vacuum chamber manufacturing
- **Spectro-Volt Team**
  - Analyze the relationship between life-cycle and the various electrical parameters though voltage, current, and cumulative charge data.

**The Bigger Picture**

- **Engineering Significance**
  - Implementation of an electrochromic cell will help downsize and simplify CubeSat operation as the need for a radiator, a common component for spacecraft temperature control, is no longer necessary.
  - Through the reliability and practicality of the electrochromic cell, operation costs can be reduced, enticing institutions like UCI to participate in quality research through budget-oriented low Earth orbiting satellites.
- **Commercialization**
  - Our simple electrochromic cell design, with its 3 component build up and its low material costs makes it viable for commercialization. The electrochromic cell design is composed of two chemically treated slides, a solid electrolyte for transport of electrons, and a casing joining the cell together.
  - The development of several in-house slide deposition methods and scalability of the deposition process makes the slide manufacturing process inexpensive, versatile, and commercializability comfortably achievable.

**Team Structure & Budget**

**2020 Timeline**

**Winter 2020**
- 02/28/2020: Build a Reflectance Test Setup
- 03/06/2020: Initiate Manufacturing Process of Vacuum Chamber
- 03/10/2020: Create a test cell with epoxy sealant

**Spring 2020**
- 04/10/2020: A complete report of simulation reports will be generated
- 05/01/2020: Change the color of films using the potentiostat.