Scientists have discovered that exposure to microgravity has an effect on proteins. However, the specific effect is mostly unknown and could be critical to the study of human physiology. Biological research has thus far been limited to the International Space Station where experiments can cost hundreds of thousands of dollars. Over the past two decades, advancements in technology have enabled the development of miniature satellites known as CubeSats which have drastically reduced the cost of accessing low-earth orbit for conducting research. As of mid-2015, three CubeSats have successfully launched and performed biological experiments but none have examined proteins directly.

The goal of this project was to design a cost-effective bioassay that could be integrated into a CubeSat. The end result is a functional prototype that performs automated folding analysis of bovine serum albumin (BSA) and contains on-board electronics that store and transmit data to a computer for analysis. The prototype meets NASA's requirements of Technical Readiness Level 4 to demonstrate proof of concept in a laboratory environment. This process should greatly reduce the cost of performing experiments on proteins in space.

Technical Aspects of Project

Electrical Subsystem

- Provides stimulus to BSA via UV LED and records data to be processed
- Autonomous mixing feature to re-suspend proteins for analysis
- Uses Atmega 32U4 microcontroller as the brains of the system
- Programmed with Arduino software and interfaces with Processing software
- Board is designed to interface with a standard CubeSat chassis and bus layout
- The board consists of a power regulator that supplies two separate power lines. One supplies 24V to the solenoids, and the other supplies 5V to all other components including the microcontroller, op-amp, UV LED driver, and photodetector. Components also include an optical filter for specifying tryptophan excitation wavelengths, and a custom 3D printed solenoid mount for orienting the LED with the photosensor and sample.
- The board draws about 0.5W when not active, and increases to 0.75W when running the UV LED and sending data.
- All the electrical components were ordered through Digikey, and the board was ordered from OSH Park.

Mechanical Subsystem

- CubeSat Chassis' utilized for space flight are very expensive due to special surface coatings
- Created a prototype to serve as a "stand in"
    - Waterjet 2mm aluminum
    - 3D printed model chassis
- CubeSat will undergo extreme temperature swings in space

- Thermal analysis was done modeling radiation from the sun's rays to give us an idea of the effects
- NASA requires that the 1st resonant frequency cannot be above 100 Hz due to the launch pod.
- Modal analysis done to ensure we were meeting this standard. Difficult to change once the system is designed.
- 3D printed support structure keeps the spectroscopy equipment in correct positioning.

Microfluidic Subsystem

- Large well holds reagent separate from dried protein in center well
- When solenoids activate, they push reagent into small center and side wells to combine protein and reagent
- Large well holds 200uL of reagent
- Center well holds 100uL of protein and reagent solution
- Total device made of six layers of 600um thick polydimethylsiloxane (PDMS)
- Layers bonded using plasma wand

Spectroscopy Subsystem

- Column components, in order from top to bottom
    - UV LED
    - Polydimethylsiloxane (PDMS) test well with BSA protein
    - 350 nm filter
    - Photodiode
- Many proteins, including BSA, contain tryptophan molecules
- Tryptophan molecules are fluorescent
- Tryptophan fluorescence works as follows:
    - Excitation wavelength (280 nm) from UV LED excites tryptophan molecules
    - Molecules emit a wavelength (350 nm)
- 350 nm filter theoretically removes all wavelengths of light except for approximately 325 nm to 375 nm
    - This cuts out light from UV LED, leaving only the emission light from the tryptophan molecules to proceed through spectroscopy system
- Photodiode registers tryptophan fluorescence and sends signal to computer
- If protein is mixed with urea, then the protein is denatured, or unfolded
- Unfolded protein results in higher voltage reading than folded protein, indicating that the tryptophan molecules may be more exposed when the protein is denatured
    - This goes against our theory that the voltage reading would be lower due to quenching, which is when fluorescence dies out, after exposure to the reagent