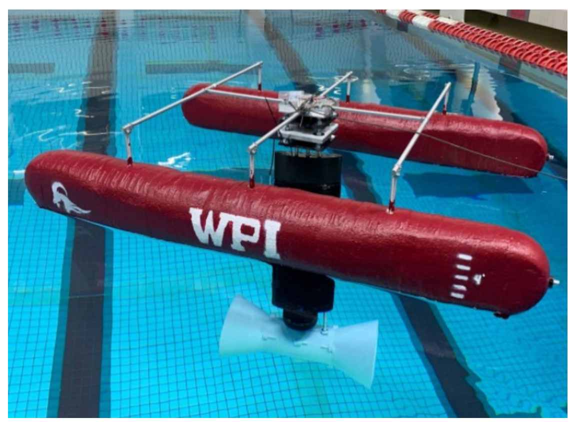
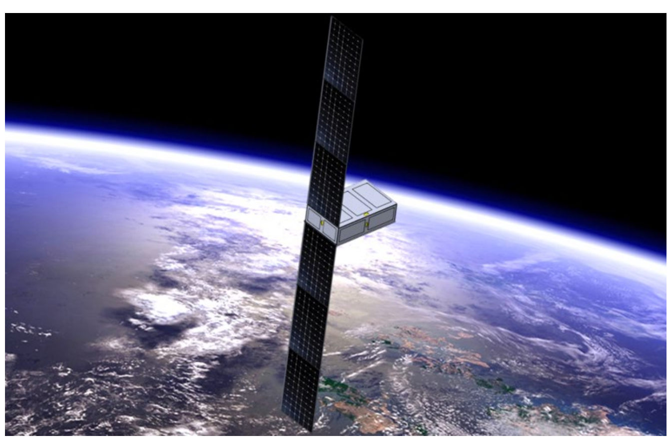
# Aerospace Engineering Department

## Major Qualifying Projects

## 2021-2022



100 Institute Road, Worcester Massachusetts 0160

## Projects

### Low-Cost Quadrotor Micro-Aerial Vehicle

**Students:** Akul Agarwal, Antonio Calcagni, Martin Runquist, Nicolas Hesel

**Advisor:** Professor Raghvendra Cowlagi

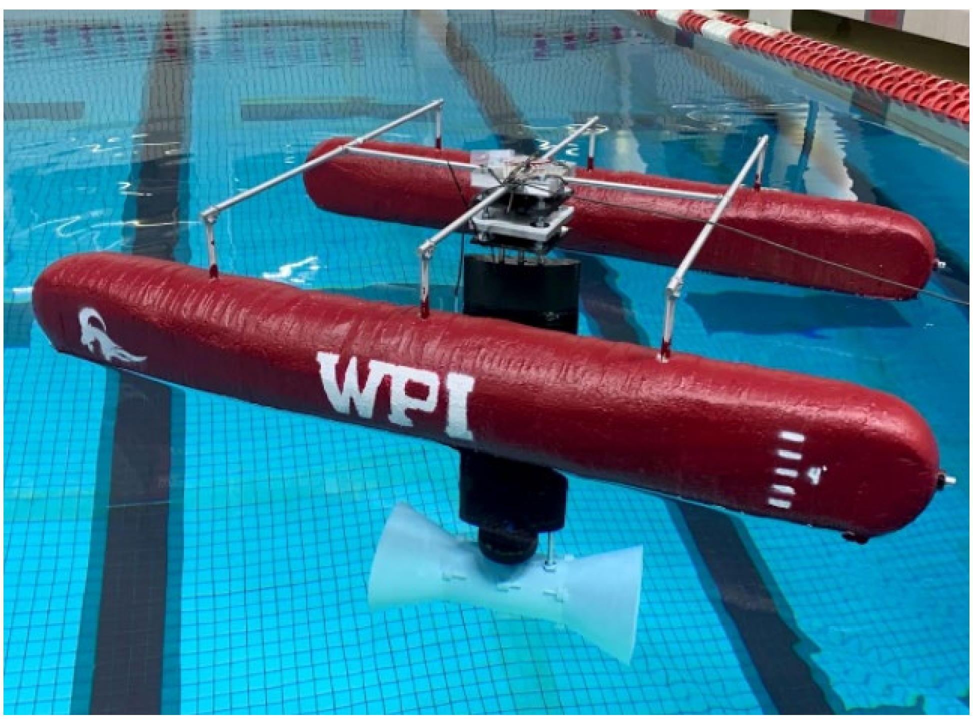
The objective of this project was to design and construct a low-cost quadrotor micro-aerial vehicle (MAV) with a multi-sensor payload capable of indoor flight using localization by a motion-capture system. Design considerations included low overall weight, ease of construction, and ease of replacing the sensor payload. To meet these objectives, the literature was thoroughly reviewed. An existing MAV frame design was adapted and modified. Motors and propellers were chosen to accommodate the desired sensor payload. An autopilot was implemented in conjunction with a high-level microcontroller for future implementation of intelligent control algorithms. A series of unit tests and bench tests were conducted within the motion-capture environment to demonstrate feasibility of the design.

# Redesign and Testing of a Surface UnderSea Kite Model

**Students:** Olivia Chiasson, Adrianne Curtis, Thomas Rau, Zachary Sotland, Andrew Ventura Molina

**Advisor(s)**: Professor David J. Olinger (AE), Professor Nancy A. Burnham (PH)

Surface UnderSea Kites (SUSK) are an emerging renewable tethered ocean energy technology. SUSK systems use a vertical underwater wing suspended beneath a surface hull that moves cross-current in a simple arc on the ocean surface. This concept moves the tether above the water surface to greatly reduce tether drag and increase wing speed and power output. Our project builds on earlier Tethered UnderSea Kite (TUSK) research at WPI. An improved SUSK scale-model with a higher aspect ratio wing, improved hull configuration and new turbine was designed, analyzed, and tested. We determined the optimal hull shape for our design is a catamaran structure that will maximize stability in the water. A 3D printed Wells turbine within a converging nozzle at the lower wingtip allows for increased power output during forward and backward SUSK motions along the ocean surface arc.



# Design of a NanoSat for an Ionospheric Science Mission

**Students:** Phillip Durgin, Veronika Karshina, Samuel Waring

**Advisor:** Professor Zachary Taillefer

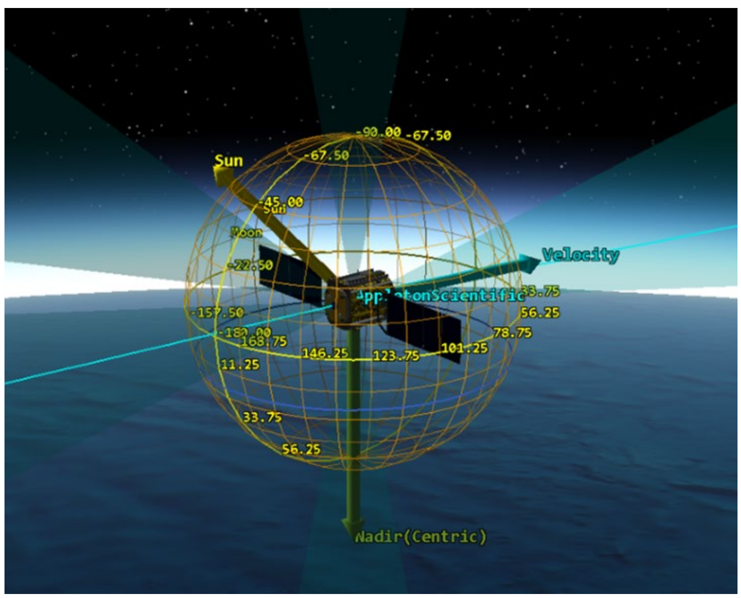
This project presents the conceptual design of a 6U nanosat carrying a miniature Ion Neutral Mass Spectrometer (mini-INMS) and Gridded Retarding Ion Drift Sensor (GRIDS), and the development of a Helmholtz cage. The nanosat is designed to measure the composition of the ionosphere on a 180 km by 800 km orbit and uses the NPT-30 I2 thruster for main propulsion. Orbital analysis is performed using Systems Tool Kit (STK) and optimizes the lifetime of the nanosat. Attitude determination and control schemes using magnetic torquers are developed in MATLAB. Mechanical and power analysis are performed using SolidWorks, ANSYS, and STK. The Helmholtz cage is designed and fabricated to provide testing of the nanosat under simulated the magnetic field experienced during orbit.

# Design and Analysis for a CubeSat Mission

**Students:** Drake Tierney, Christopher Ritter, Jeremy Gagnon

**Advisor:** Professor Michael A. Demetriou

This work presents the design of a 6U CubeSat utilizing the NASA-designed miniature Ion Neutral Mass Spectrometer (mini-INMS) and Gridded Retarding Ion Drift Sensor (GRIDS) to measure the composition of the ionosphere's F layer. The CubeSat will operate in a semi-Sun-synchronous elliptical orbit with a perigee of 180 km and apogee of 600 km. This report covers the attitude determination and control, telemetry and communications, and the command and data handling subsystems of this mission, in addition to the mission payload. Attitude dynamics modelling was performed using Systems Tool Kit (STK) along with MATLAB's Simulink software. Attitude control required actuation via magnetorquers and reaction wheels, guided by an on-board computer. Telecommunications analysis was performed using STK.

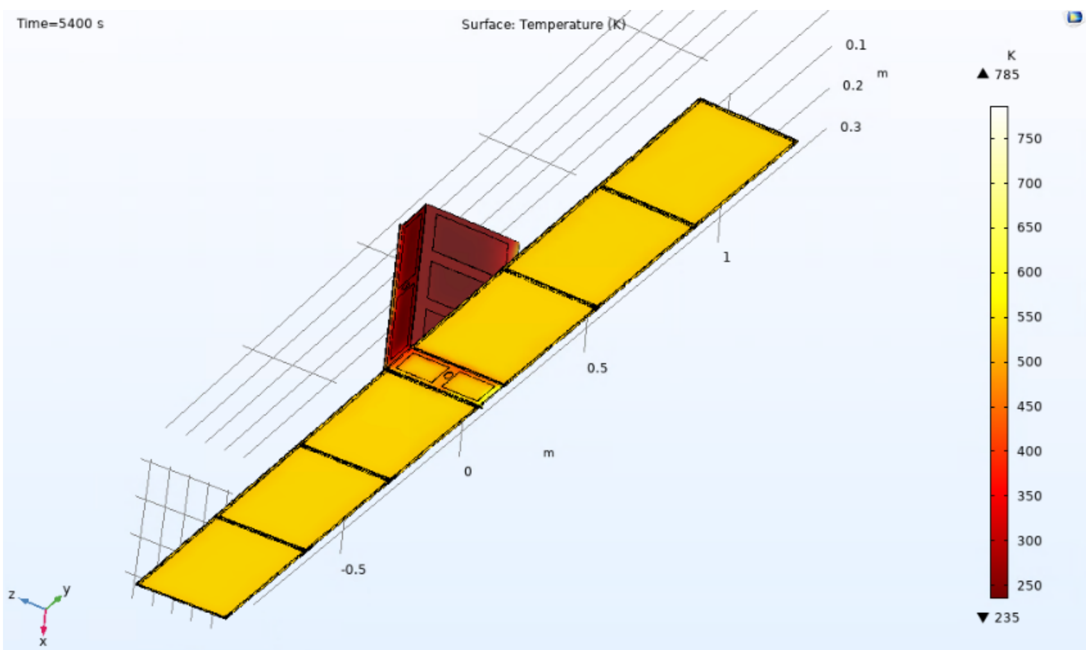


# Design of a 6U CubeSat for an Ionospheric Science Mission

**Students:** Tyler Lizotte and Harrison Smith

**Advisor:** Professor Nikolaos Gatsonis

This project presents the thermal and environmental analysis of a 6U CubeSat designed for ionospheric composition measurements on a 180-600 km elliptical orbit. Thermal analysis with the Systems Tool Kit (STK) and COMSOL software shows that components temperatures are within requirements. Surface charging analysis using the Space Plasma Interaction System (SPIS) software shows low surface potentials under nominal ambient plasma conditions. The total radiation dosage, micrometeorite and space debris impact fluxes evaluated with STK's Space Environment and Effects Tool (SEET) present minimal risks. The magnetic fields induced by the magnetic torquers may require repositioning of the magnetometers. This project also presents the design and fabrication of a Helmholtz cage for future testing.

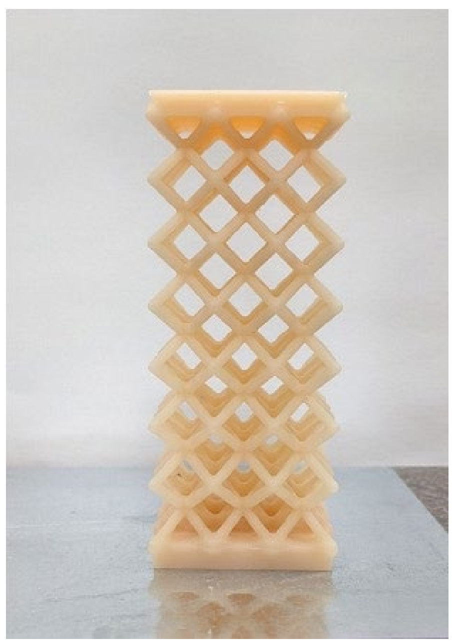


# Design and Testing of Lattice Structures for Noise Reduction

**Students:** Jake Franklin, Alexander Hodge, John Spencer Kerwin, Bethany Ramsbottom

**Advisor:** Professor Nikhil Karanjgaokar

Jet engines generate significant amounts of noise and vibrations during normal operation. This noise can be potentially harmful to the efficiency of the aircraft, the health of passengers and crew, and the environment. To limit noise produced by a jet engine, aerospace engineers must design mechanisms to attenuate the vibration being transmitted from the engine to the body of the aircraft. One way to do this is through the utilization of lattice structures in the housing of the engine. Lattice structures have natural properties that make them capable of absorbing a wide range of vibrational frequencies. They can be designed with computer-aided design (CAD) software, modified to produce relevant bandgaps, and produced using additive manufacturing methods. The nature of lattice structures makes them a particularly promising area of study for aircraft noise reduction. This paper explores the use of lattice structures for vibration reduction. Lattice structure designs for vibrational attenuation in jet engines were tested experimentally and with simulation and are presented in this paper. Substitution of individual cells with ferromagnetic materials was also explored, with the testing also incorporating magnetic fields, changing the response characteristics of the lattice.



# Long Range Aerial Delivery System

**Students:** Benjamin English, Anthony Gosselin, Johnathan Lazo, Trevor Shrady

**Advisor:** Professor Raghvendra Cowlagi and Gregory Noetscher (Army Lab)

The goal of this project is to develop and build a prototype of an autonomous multi-point aerial delivery drone with the goal of delivering packages to forward deployed soldiers. This project was commissioned by the United States Army with the objective of designing a drone that can drop between 100-250kg worth of payload over multiple points with a range of 200-500 km with a high precision payload drop, within 100 m. A fixed wing aircraft with a wingspan of 10m and 8.6m length was designed and scaled down to 1/10th the size. A subscale aircraft was designed and constructed to be as accurate of a model as possible to the full-scale design.

## Aircraft Design for AIAA Design Build Fly Competition

**Students:** Bridget Wirtz, Joshua Martin, Christopher Davenport, Jordan Jonas, Samuel Vinson, Harrison Mazur

**Advisor:** Professor Zhangxian Yuan

The goal of this MQP was to design, build, and fly a radio-controlled aircraft that meets the 2022 AIAA DBF competition design and flight requirements. The objective of this competition was to produce an aircraft to complete humanitarian missions related to the ongoing Covid-19 pandemic. The missions included deployment of the aircraft, storing of vaccination syringes, and delivery of environmentally sensitive vaccine vial packages. There were four missions total: one relating to speed, two focused on payload transportation, and another relating to payload loading. The maximum linear dimension of the aircraft was 8 feet, and the aircraft was limited to a maximum battery capacity of 100 watt-hours.

# Estimation of a Plume with a UTV

**Students:** John McCarthy, Vincent Mitala, David Ibrahimi

**Advisor:** Professor Michael A. Demetriou

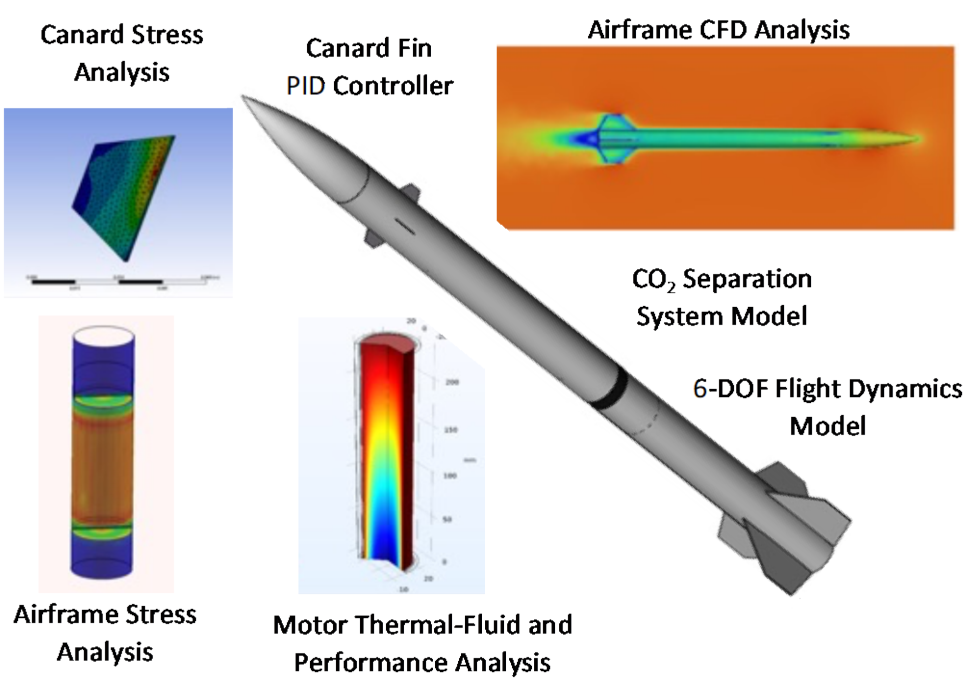
This project supports the design of a gas sensing system onboard the ClearPath® Robotics Husky mobile robot. The gas sensing system determines the spatial gradient of the gas and subsequently guides the mobile robot towards the gas source. The project also consisted of developing upon the work of earlier projects to build a gas dispersion setup which was used to test the sensing system. The Carbon Dioxide sensor system that was optimized by previous teams was placed on a 3D-printed stand. The work done by this project team will help advance the field of autonomous vehicles, especially relating to gas sensing.

# Design and Analysis of a High-Powered Model Rocket

**Students:** Kirsten Bowers, Abigail Collins, Alex Harrigan, Tyler Hunt, Theresa Larson, Daniel Mattison, Troy Otter, Connor Walsh

**Advisor:** Professor John J. Blandino

This paper describes the design and analysis of a high-powered model rocket designed to use actively controlled canard fins for stabilization, a retromotor to slow its descent, and a compressed CO2 pressurization system to separate the upper and lower stages, releasing the main parachute. The airframe, custom nose cone, canards, and main fins were modeled using SOLIDWORKS. Aerodynamic loads on the vehicle airframe, canards, and main stabilizing fins were evaluated using computational fluid dynamics (CFD) tools in Ansys Fluent. Results from the CFD analysis were used as inputs to a 6DOF dynamical simulation of the vehicle trajectory and attitude, written in MATLAB using an object-oriented structure. A proportional–integral–derivative controller was designed to control the canard stabilization fins in flight. The control software was tested using MATLAB and Simulink. Ansys Workbench was used for structural analysis of the airframe and main fins. An analysis of the composite motor was completed using Cantera and COMSOL to model the chemical equilibrium reaction and evaluate the temperature distribution in the motor during flight. These results were used to provide chamber conditions in a MATLAB model for ideal rocket performance. Results are presented from these analyses as well as a description of partial prototype construction completed at the subsystem level.

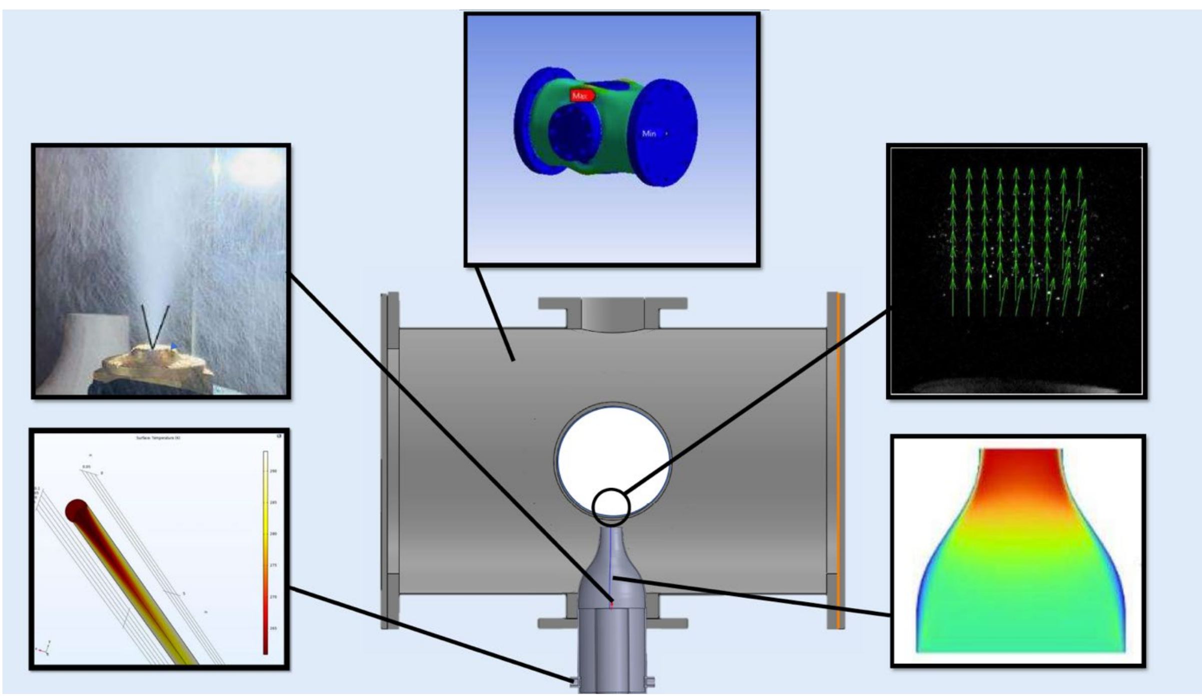


# Design, Implementation, and Testing of Apparatus to Investigate Combustion Phenomena Relevant to High-Altitude Relight

**Students:** Ethan Davis, Meenakshi Kodali, John Sirois, Jonathan Stern

**Advisor:** Professor Jagannath Jayachandran

Relight is the process of reigniting an aircraft engine after the extinction of the flame in the combustion chamber. With flameout typically occurring at low pressure and temperature conditions, present at cruise altitudes, successful relight can be a challenge, especially for modern low-NOx, lean-burn engines. This project aimed to replicate high-altitude combustor conditions in a custom-built experimental apparatus. This design consisted of a counterflow configuration supplied with fuel spray droplets to understand ignition and flame propagation relevant to high-altitude relight. A pressure vessel and cooling system were designed to emulate high-altitude atmospheric conditions. To improve the designs, structural, fluid, and thermal analyses were conducted using ANSYS, FLUENT, and COMSOL. Lastly, testing was conducted to validate the experimental apparatus.

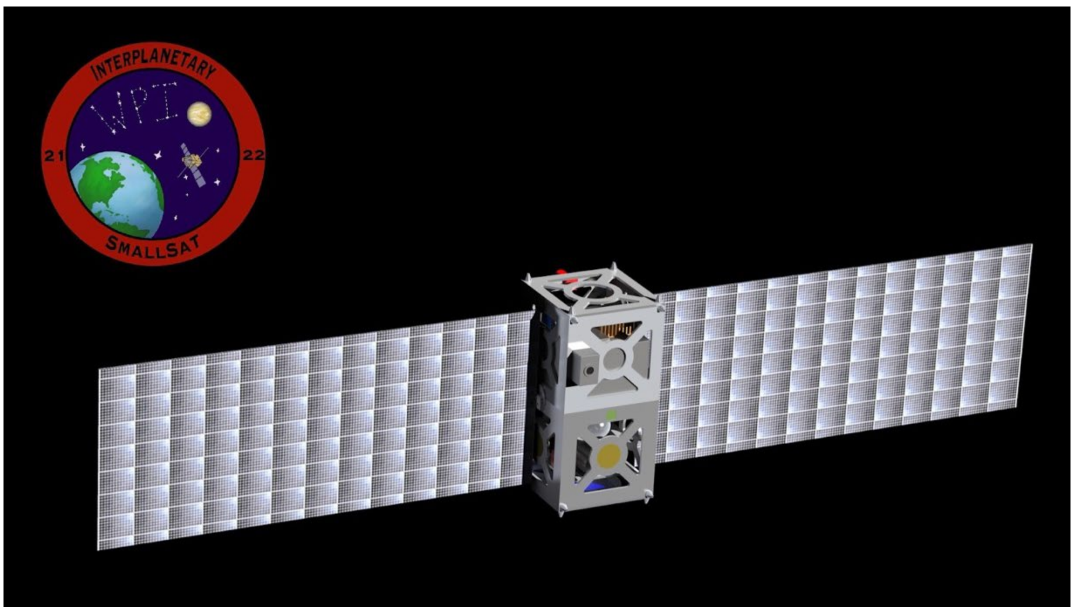


# Design and Analysis of SmallSat Mission to Venus

**Students:** Leila Card, Dakota Cross, Paul Golias, Yuvraj Pathania, Daniel Santamaria-Hopkins, Sidney Williams

**Advisor:** Professor Zachary Taillefer

This project presents the conceptual design of an interplanetary SmallSat to investigate the atmosphere of Venus and the development of a thermal vacuum (TVac) test facility. At Venus, this spacecraft will gather spectral data of the atmosphere. The spacecraft uses a BHT-1500 thruster for main propulsion. Orbital analysis is performed using Systems Tool Kit (STK) and optimizes the trajectory. Attitude determination and control schemes using reaction wheels and microthrusters are developed in MATLAB. Mechanical, thermal, power, environmental, and telecommunications analysis are performed using SolidWorks, ANSYS, and STK. The TVac test facility is designed and fabricated to provide testing of components under relevant space environment conditions.



# Mirco-Aircraft Design for 2022 AeroDesign Competition

**Students:** Samuel Pitkowsky, David Van Sickle, David Tomer, Connor Miholovich, Christian Chadwick, Justin Schoepke

**Advisor:** Professor David Olinger
**Co-Advisor:** Professor Zhangxian Yuan

The goal of this project was to design, build and fly a micro remote-controlled aircraft to participate in the 2022 SAE Aero Design West Competition. The competition imposes challenging design constraints on the aircraft which must carry large or small cargo boxes and payload weight while being limited to a 48 inch wingspan, 450 watts of engine power, and an 8 foot takeoff distance from a raised platform. The final design configuration used large wing control surfaces that extended beyond the wing trailing edge to serve as both flaps and ailerons and a movable wing to increase stability. Although the aircraft experienced stability issues on take-off at the SAE micro class competition, the team placed third overall due to high design report and oral presentation scores.