Graduate Projects Fall 2020

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5018/6028-801 Human Spacecraft Design

Advisor Colonel (retired) James Voss

Enrollment: *Space in this section is limited and is managed through a priority waitlist. Contact nicholas.rainville@colorado.edu for more information.*

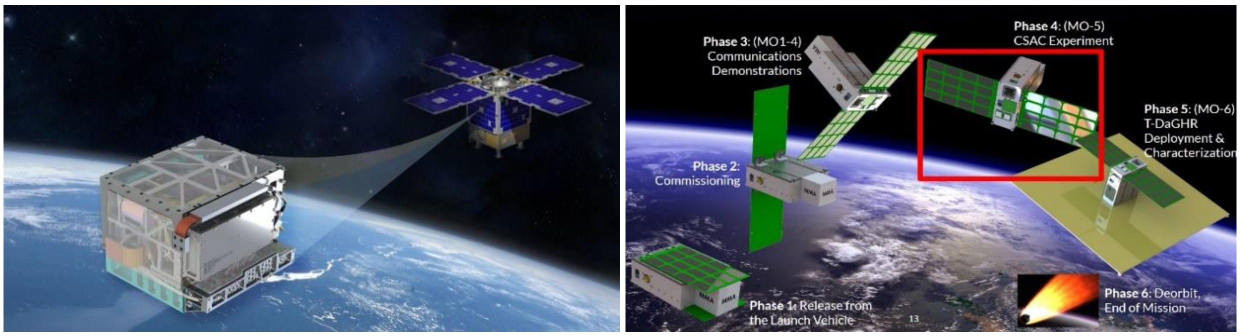
The current project is to construct, test, and validate the design of Lockheed Martin's ascent element design for the upcoming Artemis missions to the moon. Students will interface with our industry partner, Lockheed Martin, to assist with assessment of their lunar lander design. Students will work with the customer to acquire specifications on the ascent element cockpit, build a high-fidelity mock-up of the cockpit, and conduct/analyze human factors testing in the completed mock-up. Other tasks include increasing fidelity of landing simulations and upgrading the functionality of mock xEMU spacesuits to give better human factors testing data.

5018-012/6028-802 Clock Ensemble Testbed for PNT on Small Spacecraft or UAVs

Advisor Dr. Penina Axelrad

Sponsored by The Air Force Research Laboratory

Enrollment: *No additional approval necessary*



JPL Deep Space Atomic Clock (Left) and CONTACT Orbital CSAC Experiment on MAXWELL (Right)

In space, TIMING is everything. Launched in 2019, NASA's Deep Space Atomic Clock is paving the way for the future of space exploration by facilitating autonomous, high-precision maneuvers such as EDL, orbit insertion, and rendezvous. Closer to Earth, GPS provides precise time dissemination and plays an essential role in nearly all critical infrastructure in the developed world. The CONTACT team is working with the Air Force Research Lab to develop novel satellite timing technology on the cutting edge of both space exploration and in alignment with some of the highest priorities of national security. If you are interested in getting your hands dirty with hardware or building software from the ground up, planning and executing an orbital experiment, and having a big influence on a small-team technical challenge, this project might be for you!

The continued development of accurate, robust onboard timekeeping technologies is foundational to the improvement of non-GPS positioning, navigation, and timing (PNT) capabilities for a multiplicity of military and civil applications. Complementary PNT enabled by low-SWaP (Size, Weight, and Power) onboard timing systems can increase the resilience of communication and navigation systems in degraded or denied GPS environments. The limited performance inherent in low-SWaP clocks can be mitigated by ensembling several independent devices and generating a steered output frequency signal based on the weighted averages of the inputs. A low-SWaP atomic clock ensembling testbed can be used to evaluate the performance of various clock configurations and signal steering techniques as well as to measure the effects of environmental factors and clock errors. The objective of this CONTACT satellite timing project is to design implement, and operate this clock ensembling testbed on a Software Defined Radio (SDR) hardware platform with three Chip Scale Atomic Clocks (CSACs). Results from this clock ensembling testbed could be used in the development of low-SWaP onboard timing systems capable of meeting Precise Time and Frequency (PT&F) requirements in the absence of GPS. Additionally, the CONTACT team is preparing to execute an orbital CSAC performance experiment, which will fly on the MAXWELL CubeSat and characterize clock performance on orbit.

The CONTACT satellite timing project is roughly halfway through its 3-year timeline. The team has completed much of the groundwork and initial prototyping, and the next stage of the project is where the system as a whole will start to come together – its an exciting time to join! Students with interest or experience in any of these areas: clocks, GNSS, electronics, software defined radios, software development, testing, timing, small satellites/UAVs are welcome.

5018/6028-803 CubeSats for Space Science

Advisor Dr. Robert Marshall

Enrollment: *Approval by Robert.Marshall@colorado.edu is required prior to enrollment.*

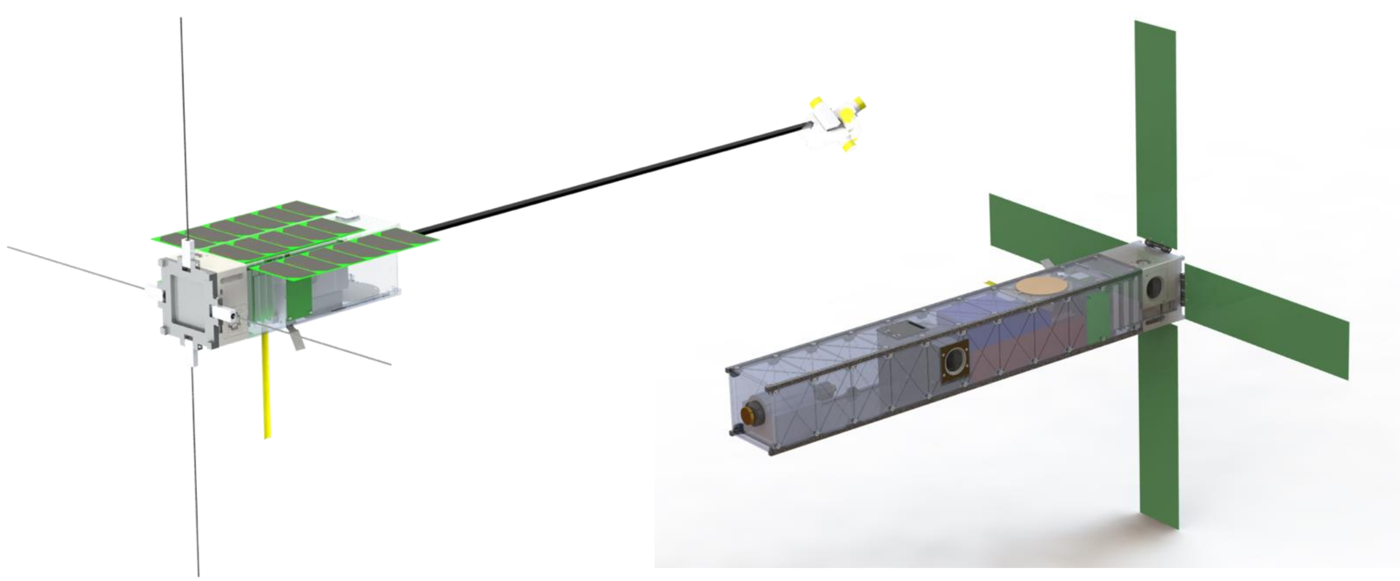
The "CubeSats for Space Science" Graduate Projects section is currently developing two sister CubeSats, COSMO and CANVAS, which are being developed with several subsystems shared between them. Using MAXWELL and MinXSS heritage with minor changes to the shared key components, the development schedule for COSMO and CANVAS has been reduced. Both missions are in the critical design phase, and will be moving into fabrication, assembly, and testing in the 2020/2021 academic year.

The Compact Space-borne Magnetometer Observatory (COSMO) is a 6U CubeSat designed to take high-resolution, precise measurements of the Earth's magnetic field from space. These measurements will then be used as input data for the World Magnetic Model (WMM), which needs to be updated regularly as the magnetic field drifts over time. The SWARM spacecraft currently measures the magnetic fields but is scheduled to end in 2024; COSMO aims to replace SWARM, while implementing a much more affordable, compact, and replaceable system. The challenges the COSMO team currently face are to i) design a CubeSat with low magnetic noise, ii) accurately characterize the magnetic bias, and iii) integrate a compact, high-resolution magnetometer.

The Climatology of Anthropogenic and Natural VLF-wave Activity in Space (CANVAS) mission aims to measure the electromagnetic energy input into the space environment from lightning and ground-based VLF transmitters, specifically for the frequency range between 300 Hz and 40 kHz, in order to understand the VLF energy budget as it changes over the course of one year. These waves interact with radiation belt electrons, which pose a major threat to spacecraft. Two orthogonal Electric field measurements are taken along with three orthogonal B-field components; the signals are processed into spectral matrices on board, and time-averaged to one second resolution before the data is stored. Major challenges of the CANVAS mission design include developing the payloads to meet the specified sensitivity and spurious-free dynamic ranges needed to measure the desired VLF energy, as well as integrating a system of deployable structures needed to make these sensitive measurements.

More info: https://culair.weebly.com/cosmo.html

https://culair.weebly.com/canvas.html



5018/6028-804 CU-E3 and Maxwell CubeSats

Advisor Dr. Marcin Pilinski

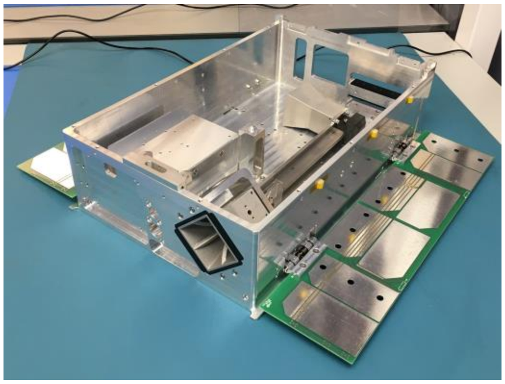
Enrollment: *Approval by Marcin.Pilinski@colorado.edu is required prior to enrollment.*

CU-E3 (Earth Escape Explorer)

The University of Colorado – Earth Escape Explorer (CU-E3) team is one of the first deep-space CubeSats, and will be launching on-board the SLS/Artemis 1 mission. CU-E3 will be competing in the Deep Space Derby portion of the CubeQuest Challenge, which is focused on advancing deep space CubeSat communication techniques. Using the wealth of communication knowledge and technology developed at the University of Colorado – Boulder, such as our reflectarray and X-Band transmitter, CU-E3 believes it has all of the critical components to be successful in this competition.

CU-E3 will use a lunar gravity assist to propel itself into heliocentric orbit in order to distance itself from the Earth. As CU-E3 travels further from Earth, it will demonstrate novel communication technology by establishing contact with our ground station network beyond 4 million kilometers until the end of the one-year mission lifetime. At that point, CU-E3 is expected to achieve an Earth-Satellite distance of more than 27 million kilometers!

Over the next year, the CU-E3 team will be finalizing subsystem testing, flight integration, and environmental testing before gearing up for mission operations of CU-E3 as it flies past the moon.



Maxwell

Maxwell is a 6U CubeSat that is part of the Air Force Research Laboratory's University Nanosat Program Competition. The team has won phase A of the competition which will provide the satellite with a flight to orbit. The flight design builds on the heritage of the CSSWE, MinXSS and QB50-Challenger CubeSats which have been developed at the University of Colorado Boulder and all demonstrated mission success on orbit. This project matures hardware designed by the PI, Dr. Scott Palo, as part of the NASA Small Satellite Technology Program to develop a high rate CubeSat communication system that is compatible with the NASA Near-Earth Network.

5018/6028-805 Spacecraft Multi-Layer Insulation Heat Leak Characterization Testing (EAR Restricted to U.S. PERSONS ONLY)

Advisor Dr. James Nabity

Sponsored by L3Harris

Enrollment: *Restricted to U. S. Persons only*

This project funded by L3Harris will experimentally assess spacecraft multilayer insulation (MLI) thermal performance. The purpose of this effort is to develop a more thorough understanding of the contribution that different parameters have on blanket performance and generate design curves to allow for more accurate system level modeling of blankets for application to large deployable space structures. The Fall 2020 semester will continue testing on a novel deployable MLI configuration developed by the Fall 2019 team. This effort will involve the design, application, and characterization of new origami configurations. Students on this team will utilize Thermal Vacuum (TVAC) test facilities in the Bioastronautics Laboratory. Significant upgrades to the TVAC chamber were completed in Spring 2020. The Fall 2020 team will verify these upgrades then continue experiments to characterize the thermal performance of 10-layer MLI blankets with and without the origami folds.

The Spring 2020 MLI Team next to the TVAC chamber (RALPHEE)

5018/6028-806 Space-based Debris Tracking (ITAR Restricted)

Advisor Dr. Daniel Kubitschek

Sponsored by The Aerospace Corporation

Enrollment: *Restricted to U. S. Persons only*

The Autonomous Cluster Navigation Graduate Project is a two-semester effort that focuses on the development of key autonomous capabilities for the safe operation of multiple spacecraft operating in the same dynamic environment as a group. The project is sponsored by an industry partner with an interest in solving the technical challenges of on-board, autonomous measurement processing, orbit determination and maneuver computation and will require the students to lead, organize, schedule, develop, test, verify, validate and deliver conceptual approaches, algorithms and hardware solutions to the industry partner at the end of each semester. Weekly status teleconference meetings will be held by the student team to keep the industry partner informed of the progress, with a milestone presentations and product deliverables.

Two focus areas have been defined for this project: 1) Concept of Operations (Design Reference Mission, Mission & System-level Requirements Derivation, Communication & Navigation Architecture, Measurement Model Simulation Development and Navigation Sensor Selection), to be completed during the first semester (Fall 2018); and 2) Navigation System Design (Derivation of Software Requirements for Design, Derivation of Software Requirements for Cross-link Design, Development of Navigation and Communication Algorithms, COTS Hardware Selection and Procurement, Hardware Prototype Build, Hardware Prototype Demonstration and Test), to be completed during the second semester (Spring 2020).