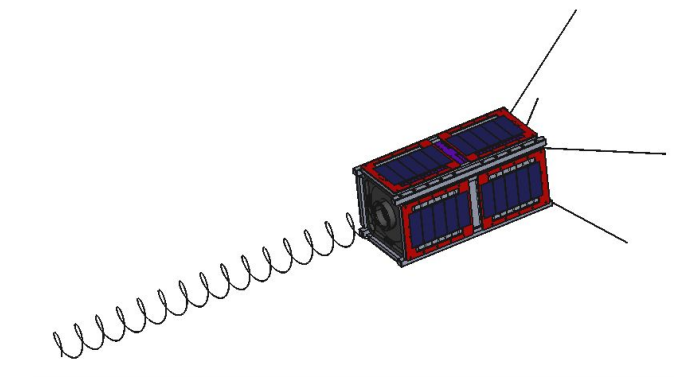
ME 491 Bid Proposal: **OreSat Deployable Antennas**



**Team Members:**

1. **Calvin Young** | *youngcal@pdx.edu*  
   *Parametric and direct modeling; MATLAB analysis; microcontroller programming; works with industrial 3D printers at HP; worked with shape memory alloys at NASA.*
2. **Shivani Nadarajah** | *shivani@pdx.edu*  
   *Statistical analysis in MATLAB; undergraduate research in mechanical fatigue due to turbulent flow; manufacturing processes and stress analysis; C-based programming languages.*
3. **John George** | *george22@pdx.edu*

*3D modeling and design for production; manufacturing and machine shop experience; solidworks and autocad; 5 years experience designing for high purity semiconductor industry; PSAS recovery system design and manufacturing team member.*

1. **Justin Burris** | *burris2@pdx.edu*

*Solidworks CAD CSWA designer, machine shop experience, works with 3D printing additive manufacturing, experience with automotive applications.*

1. **Paijanne Jones** | *paijanne@pdx.edu*

*CAD certified (AutoCAD, SolidWorks, and Inventor); C-based programming; 20 years work experience in architectural and structural design; experience with automotive rebuilds.*

**Team Structure:**

The team will be managed by Calvin, who will also serve as the primary contact for the project and the principal liaison for the rest of PSAS. Work on the project will be controlled through GitHub as a capstone-specific repository within the larger OreSat organization. Non-technical documentation will be stored on a shared Google Drive folder nested within the PSAS organization. Weekly updates will be provided to the client during regular PSAS meetings and interim communication will take place on Zulip.

**Project Objective:**

The primary objective is successful deployment of two antennas-- the most important being the omnidirectional turnstile array, and the second being the highly directional helical antenna. The two antennas each provide a unique set of challenges, including but not limited to: design, function and deployment strategies, material specifications, spatial limitations, stability, timeline for completion, budget, and collaboration with multiple engineering teams.

**Client Needs:**

The satellite has two deployable antennas: a turnstile array and a helical antenna. The turnstile antenna is mission critical; if it does not deploy successfully then the ground station cannot communicate with the satellite and trigger the de-tumble sequence which would allow the directional helical antenna to point towards Earth. As such, successful deployment of the array is the top priority of this capstone and the client’s most important need. Deployment of the helical antenna enables the satellite’s secondary and tertiary missions. Successful deployment of the helical antenna is critical for full mission success.

Each antenna must be deployed in a stable and predictable fashion. Care must be taken to not introduce too much oscillation from an uncontrolled deployment. The turnstile antenna must be deployed with expedience (within an hour) in order to enable baseline communications with the ground station. The helical antenna can be deployed over a longer time scale (within a week), allowing for careful and controlled decompression of the helix.

The mechanical requirements imposed by the client are limited: the material chosen must comply with the electrical requirements of the antenna; the supporting and deployment structure must not interfere with the communications; and the antennas must come to rest in a predetermined orientation. The tolerance of the position of the turnstile array has been determined. The tolerance of the parameters of the helical antenna has yet to be specified.

Far more rigid are the mechanical specifications laid out by the CubeSat Design Specifications (CDS) outlined by Cal Poly. Of primary concern to the capstone team are the dimensional specifications. The antennas, prior to deployment, must pack tightly within a specified volume. In their packed configuration, the antennas should occupy minimal space to leave room for the rest of the satellite’s internal components.

Finally the antennas and their deployment mechanisms must be able to withstand the harsh environment of low Earth orbit and the mechanical stresses experienced during launch. Specifically, all mechanisms and materials must be able to withstand: temperatures between -40 and +125 degrees Celsius; intense vibrational forces (specified by the launch provider); exposure to a hard vacuum (without outgassing) and unmitigated radiation. Additionally, the system must be able to operate after being in storage for up to six months.

OreSat is an open-source, DIY project and as such all work must be publically accessible and should be as well-documented as possible.

**Design Challenges:**

For both the turnstile array and the helical antenna, the most difficult challenges are housed under the umbrella of spatial limitations, followed by their proper deployment and stabilization tactics. The small budget adds another fun spin to the material selections process, as will the requirements for thermal and structural resilience. Coordination with multiple engineering groups may provide even more demands, but it will also allow for acute focus, creative problem solving, and meticulous execution of the individual components for the entire OreSat project.

**Design Techniques to be Used:**

The helical antenna must compress significantly in order to fit within the specified volume and it must be able to deploy in a slow and controlled fashion. One approach entails the use of a shape-memory alloy (SMA). If the transition temperature is well above anything that the satellite might encounter prior to deployment time, the helix could be safely stowed in a tightly packed coil in its martensite phase. A resistive heater (or exposure to direct sunlight, if hot enough) could trigger a transition to the metal’s austenite phase at the appropriate time, causing the helix to decompress to its full pitch. Alternatively, with the right ternary alloy, the transition temperature can be moved below any low temperature that the satellite might encounter, ensuring that the metal stays in the superelastic region. This would allow the helix to be fully compressed without undergoing plastic deformation. A mechanism would have to be developed to slowly guide the antenna to its full length in order to avoid introducing uncontrolled oscillations.

Shape-memory alloys are difficult to manufacture and process. Calvin, during a summer internship at NASA’s Glenn Research Center, developed relationships with key figures in the SMA field that would prove to be valuable resources in these endeavors. Stock wire is relatively cheap and readily available. The wire can be fixed to a helical mandrel and shape set in a furnace.

The canted turnstile is comprised of four straight wires that extend out of the -Z face of the cubesat. In order for them to stow within the specified volume, they must either bend tightly at the base or be mounted on some sort of hinged mechanism. Designs for both styles exist on other cubesats and either approach would be acceptable. The hinged design will have more failure points and will be more expensive and difficult to design. However, it would allow for the antennas to be placed further towards the perimeter of the -Z face. The bending radius of the other design is dependent on the antenna’s proximity to the perimeter. Depending on the (as-yet undefined) electrical and mechanical restrictions of the -Z face, the antennas might be required to be positioned near the perimeter.

The use of beryllium copper was suggested by the client. This will be investigated further although the material choice will ultimately depend on the deployment design which in turn is dependent on the as-yet unknown electrical and mechanical restrictions. Design meetings will be scheduled with the client (and other OreSat engineers) in order to nail down those restrictions.

The turnstile antenna is based on a design published by NASA in 1967. Since then, numerous organizations (both private and public) have implemented derivative designs on their cubesats. Literature review and analysis of these similar turnstile antennas will assist the team in its decision making during the design process.

**Physical and Other Resources Needed:**

While materials will be a key component, the more pivotal resource will come from testing and analysis in a facility that can simulate the environmental requirements for deployment in space, followed by a low orbit around the Earth. Successful testing will not only require well-functioning prototypes, but will most likely require several trips out of state to a location that can provide a thermal vacuum chamber, as well as a vibrations/stability testing environment. The drop tower (for fun) may also prove to be a valuable testing resource. Programs responsible for the computer simulations testing and data analyzation will come from SolidWorks and MATLAB. Both programs can be found in the MCECS computer lab. ??

**Key Milestones and Deliverables:**

*Milestones***:**

1. Because the configuration and dimensions of the canted turnstile array will be provided by another engineering group, the first priority shall be its working deployment mechanism, followed by its proper implementation into the cube satellite’s end cap. (End of January?)
2. Design for the “s-band” helical antenna will be second priority, followed by its proper implementation into the satellite’s opposing endcap. (End of March?)
3. Finally, once design and incorporation have been completed, the antennas will be thoroughly tested, analyzed and refined to meet all system specifications. (Testing begins in April ?)

*Deliverables***:**

* Working, proven prototypes.
* Complete documentation, including:
  + CAD models (SolidWorks)
  + Theory and research
  + SOPs for antenna construction
  + SOPs for antenna flight preparations
  + Full reliability reports

**Appendix**

We are currently putting together further details for this section.