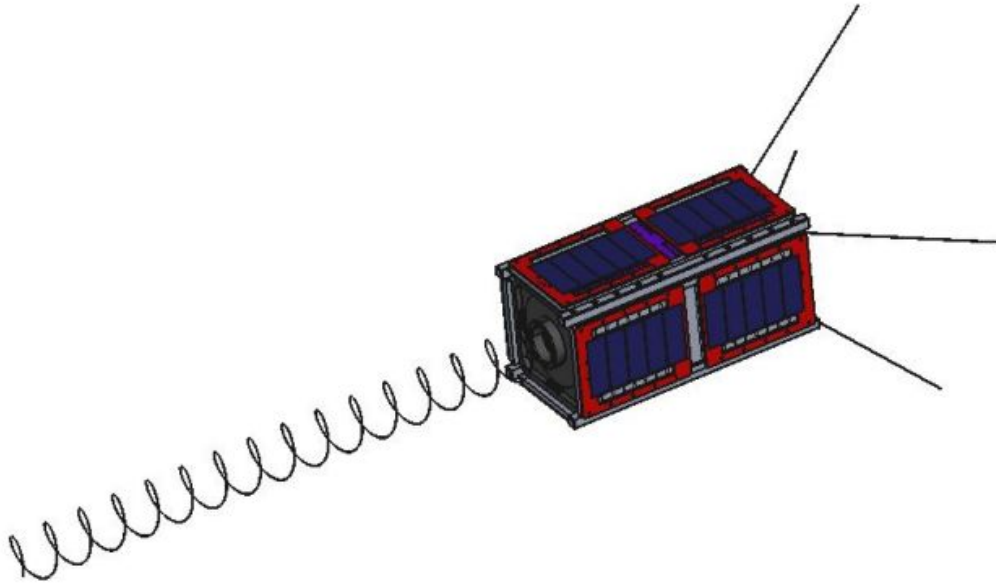# OreSat Deployable Antennas

Calvin Young

Shivani Nadarajah

John George

Justin Burris

Paijanne Jones

ME 492-493

Gerald Recktenwald

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Team Membership and Structure:

1. **Calvin Young** | *youngcal@pdx.edu*
   Past projects include development and testing of sounding rocket recovery system; assistance in design of reaction wheel control system and preliminary structural design of cubesat. Summer internship research focused on R&D of shape-memory alloy spring tires for extraterrestrial rovers. Works with industrial 3D printers and mass-market consumer products. Experience in PTC Creo, SolidWorks, Blender, MATLAB, R, C++, Python. Coursework includes material science and mechatronics focus.

2. **Shivani Nadarajah** | *shivani@pdx.edu*
   Undergraduate researcher studying mechanical fatigue due to turbulence in the Wind Energy and Turbulence lab at Portland State, experience with data analysis software (R and MATLAB) and other C-based programming such as Python and JavaScript, manufacturing processes and stress analysis, fluid mechanics with an emphasis on turbulent flow, currently working in quality engineering.

3. **John George** | *george22@pdx.edu*
   5 years of experience in design and production of high purity semiconductor industry products (3D modeling, drafting, precision machining and quality documentation control). Design and manufacturing team member of Portland State Aerospace Society electronic nose cone separation and recovery system. Experience in AutoCAD, Solidworks, Matlab, PTC Mathcad, Arduino, Python.

4. **Justin Burris** | *burris2@pdx.edu*
   Solidworks CAD CSWA designer, machine shop experience, MATLAB experience. Works with 3D printing additive manufacturing, experience with automotive applications and restoration, former president of Viking Motorsports. Experience with pneumatic tool troubleshooting and repair. Coursework experience with design, geometric dimensioning and tolerancing and material science.

5. **Paijanne Jones** | *paijanne@pdx.edu*
   Certified Computer Aided Drafter and Designer (AutoCAD, Inventor, and Solidworks) with a mechanical and industrial focus. 20 years experience as an architectural and structural designer and drafter. Experience with C++, LISP, and microcontroller programming. Experience in automotive mechanics and engine rebuilds. Currently working as an assistant engineer for a structural and mechanical PE.

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 a capstone-specific GitHub repository integrated with the larger OreSat organization. Non-technical documentation will be shared 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, an open-source messaging platform, suggested by the client.

Project Objective:

To design, test, and manufacture an omnidirectional turnstile array and a directional helical antenna for Oregon's first satellite by June 29th, 2018 with help from the Oregon Space Grant Consortium to cover associated costs. *State actual budget available for prototyping*

Client Needs:

define

The satellite has two deployable antennas: a turnstile array and a helical antenna. The former 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 enables 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 by allowing higher-bandwidth communication with the ground station. Successful deployment of the helical antenna is critical for full mission success and is of high priority. *after, or relative to what? Launch? Ejection from launch rocket?*

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 haste (approximately an hour or less) in order to quickly enable baseline communications with the ground station. The helical antenna can be deployed over a longer time scale (within a week or so), allowing for careful and controlled decompression of the helix. The client does not have strict limitations on the duration of the deployment which makes this a lower-priority issue; more pressing is the assurance that the deployment will not significantly perturb the attitude of the satellite.

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. Once deployed, the position of the antennas have relatively loose tolerances. The turnstile antennas can depart the ground plane from anywhere between 15 and 60 degrees - i.e. the placement precision is of low priority. The helical antenna is defined with a similarly loose tolerance on the pitch (that has yet to be defined by the client).

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 volume specified by the launch provider. In their packed configuration, the antennas should occupy as little space as possible 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.

Being an open-source, DIY project, all work related to OreSat must be made publicly accessible and should be as well-documented as possible.

The following chart quantifies the priorities of the client's needs. A value of 10 indicates go / no-go criteria while lower numbers indicate the relative importance of each item.

[handwritten: what do these mean? Add secondary requirements and be more specific]

[handwritten: Performance measures? Requirements matrix?]

[handwritten: Be specific relative to... what is "position"? Are you really referring to volume?]

Turnstile Antenna Reliability	10
Helical Antenna Reliability	7
Antenna Position (Packed)	10
Antenna Position (Deployed)	5
Deployment Speed	6
Deployment Stability	8
Space Ready	9

Table 1: Relative priority of client needs.

Design Challenges:

For both the turnstile array and the helical antenna, the most difficult challenges are housed under the umbrella of spatial limitations. Specifically, the OreSat design team did not set aside much space to store the packed antennas. The helical antenna will need to compress dramatically along its axis, requiring either a very thin wire or a non-traditional metal (such as a shape-memory alloy). The turnstile array can circumvent this by bending at a relatively large radius or by implementing some sort of hinged mechanism.

This leads into the next set of challenges: how to properly deploy each antenna in a manner that minimizes uncontrolled oscillations. The team must dedicate the majority of its resources to researching the best method for overcoming these challenges early on in the design phase.

The budget adds to the consideration during the material selections process - along with the requirements for thermal and structural resilience. The client is still narrowing down the electrical requirements of the antenna. 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 suggested 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. These contacts would be an excellent source of primary research into the effectiveness of these metals in the given application.

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. The client himself will be a great asset in understanding the design of the antenna and similarly executed designs that he has come across in his research.

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

a schematic would be helpful

Design info doesn't really belong

Conceptual design ← (handwritten annotation, red)

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.

Stock nickel-titanium wire is relatively cheap and readily available. The wire can be fixed to a helical mandrel and shape set in a furnace. The team can easily prototype wire helixes and test the compression into the packed state.

Physical / Component / Manufacturing / Resource Needs:

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. Portland State University's Dryden Drop Tower will also prove to be a valuable local resource for testing prototype hardware in microgravity conditions. Computer simulations, testing, and data analysis will utilize software such as SolidWorks, MATLAB, Ansys, and R Studio. Necessary materials will include wire stock of nickel-titanium, beryllium copper, and whatever other metals are deemed viable candidates for the flight hardware. Many of these are readily available from common vendors such as McMaster-Carr while others will be ordered from specialty suppliers (such as the nickel-titanium from Fort Wayne). Perhaps the most useful resources will be least tangible; expert advice will be sought from NASA scientists and engineers along with solicitation of help from faculty and industry advisors at PSAS (the Portland State Aerospace Society).

Key Milestones and Deliverables:

Milestones:
12/31 - Preliminary research into existing designs *task* ← (handwritten, red)
01/31 - Preliminary CAD models for basic antenna deployment designs *task* ← (handwritten, red)

milestone (handwritten)

02/28 - First physical prototypes; testing of initial designs *task* (handwritten)
03/31 - Narrowing down / selection of design; further testing of prototypes
04/30 - Refinement of CAD design; preliminary work on manufacturing flight hardware
05/31 - Final CAD design; manufacturing of final hardware *task* (handwritten)
06/29 - Final testing, delivery of flight hardware; finalize documentation

*Deliverables***:**
- Physical prototypes of preliminary antennas and deployment systems for review by and demonstration for the client
- Flight-ready helical antenna and turnstile antenna with deployment systems fully integrated into OreSat structure; thoroughly tested with assured reliability
- Complete open-source documentation on GitHub and Google Drive, including:
    - CAD models (SolidWorks)
    - Theory, research, and design decisions
    - SOPs for antenna construction
    - SOPs for antenna flight preparations
    - Full reliability reports