USU GAS Team Amateur Radio S-band Ground Station

ARDC Grant Application

Utah State University Get Away Special Student Satellite Team

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Photo on title page from SatNOGS [https://community.libre.space/t/s-band-ground-station/4635/7]

Who is your organization, and what is its mission?

Established in 1976, the Utah State University (USU) Get Away Special Student Satellite Team (GAS Team) is a student-run CubeSat team primarily composed of undergraduate students. The team aims to offer students tangible experiences in amateur satellite operation and radio communication technology.

Adhering to its mission statement, "to give students the opportunity to build and fly space hardware," the GAS Team boasts accomplishments such as the recent GASPACS CubeSat mission [https://www.usu.edu/physics/gas/projects/gaspacs]. The GASPACS mission showcased an inflatable structure for passive satellite stabilization developed in-house by the GAS Team. Recognizing these efforts, Utah State University awarded the team its Achievement of the Year Award for the 2022-2023 academic year.

Figure 1. The GAS Team in spring 2023.

The GAS Team is now in development of its next CubeSat, the Get Away Special Radio and Antenna Transparency Satellite (GASRATS). The focus of GASRATS is the development and demonstration of a novel transparent patch antenna (TPA). This focus emphasizes radio communications and expands the team's knowledge and experience into antenna theory and design. GASRATS was accepted to NASA's CubeSat Launch Initiative (CSLI) in March 2024 and is currently targeting an early 2026 launch.

The TPA is a new antenna technology being developed in conjunction with Dr. Reyhan Baktur, a USU professor. The transparent antenna is placed on top of a solar panel, enabling dual-purpose use of a satellite's external face. This is a notable improvement over traditional patch antennas which sacrifice a solar panel and its power generation.

Why do you want to do this project?

What are you trying to achieve with this grant, or – said another way – what is the problem you are trying to solve, and how would the grant help you solve it? Why are these funds needed? Who will your project impact?

This project's primary objective is to upgrade our ground station for effective communication with the transparent patch antenna on the GASRATS CubeSat. The secondary aim of the grant is to develop and build a portable ground station for hands-on demonstrations at outreach events and school presentations.

Current Limitations and Problem Statement: The GAS Team's existing ground station, constructed for the GASPACS mission, is only equipped for UHF communication. However, the transparent patch antenna we're developing for the GASRATS mission is designed for S-band communication. A dedicated S-band ground station is necessary to measure and utilize the transparent patch antenna's capabilities.

Like its UHF counterpart, the S-band ground station will be integrated with the SatNOGS network, a world-wide network of amateur satellite ground stations. Amateur satellite operators can schedule observation time on any SatNOGS ground station. There are currently few operational S-band ground stations available on SatNOGS, so this additional ground station will be a significant enhancement of the network capabilities, enabling amateur satellite operators increased opportunities for S-band radio communications.

Outreach and Community Engagement: A core aspect of the GAS Team's mission is community outreach, particularly targeting younger students throughout Utah. Our engagement strategies include classroom visits, community events, and a future program that will offer all K-12 students in Utah the unique opportunity to have their names on the GASRATS satellite.

A key part of the project and our outreach plans is a portable ground station we are developing. This ground station will include a handheld Yagi antenna and the basic electronics necessary to perform some radio communication demonstrations.

Figure 2. The GAS Team presenting to elementary school students about the GASPACS mission.

The most impressive demonstration will be receiving transmissions from amateur CubeSats in orbit during classroom visits when the circumstances allow. Otherwise, it will facilitate interactive demonstrations by controlling features on a model CubeSat, such as activating lights or retrieving information about its orientation. Such tangible demonstrations are invaluable for sparking interest and providing hands-on experience with space and radio communication technologies.

More information about the GAS Team's other outreach initiatives is available in the "Describe your outreach plan" section.

Why These Funds Are Needed: The funds contributed by the grant will be used to purchase components for the S-band ground station and the portable ground station. These projects will bring our satellite communication capabilities in line with GASRATS mission requirements and enhance the value of our outreach initiatives, especially for radio communication-related activities.

The GAS Team has secured funding for the construction of the satellite for the GASRATS mission. The team is seeking funding for the ground station necessary for the completion of the mission. The GAS Team's calculations put the total cost of the project at $11,529, as detailed in the budget.

Beneficiaries: Direct beneficiaries include the GAS Team and the GASRATS project. On a broader scale, the beneficiaries encompass students and communities we interact with, plus amateur satellite operators via the SatNOGS network, who can schedule the

use of the ground station for their transmissions. By introducing students to space and radio communication technology hands-on, we aim to help inspire the next generation of satellite enthusiasts, engineers, and scientists.

What is your project plan?

Share your plan for carrying out the grant. What steps will you take? When and how will you do the work? Share your plans in as detailed terms as you can. More expensive and complex projects should be supported by more detailed plans.

Primary Objective: Develop a fully functioning S-band ground station that is:

1. Capable of communication with the transparent patch antenna during the GASRATS mission.
2. Integrated with SatNOGS.

Secondary Objective: Construct a reliable portable ground station and a demonstrative satellite to facilitate hands-on experiences and real-time demonstrations.

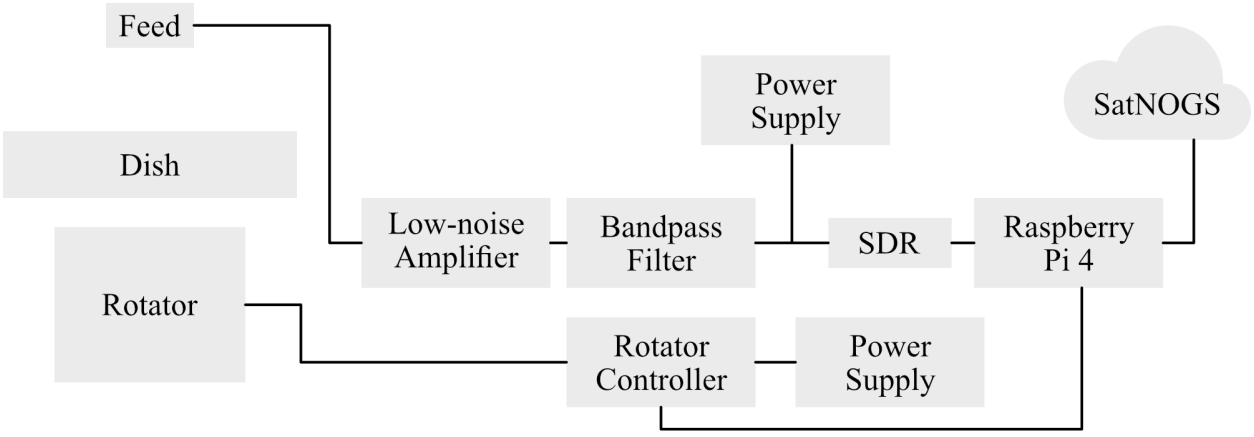

Figure 3. Components of the S-band ground station concept.

Milestones and Timeline

Design Review: Scheduled for May 2024, the design review will validate the ground station's design, ensuring it meets all technical and functional specifications.

Hardware Acquisition and Assembly: After receiving funding for the ground station, the team will focus on hardware acquisition and assembly. The team anticipates this to

take place from June to August 2024. The hardware acquisition and assembly phase will involve procuring and assembling the necessary components.

Software Development and Integration: Set from May to September 2024, software development and integration phase will focus on crafting the software components that drive the ground station's operation and integration into broader systems.

Full Functional Status: By October 2024, the S-band and portable ground stations are expected to be operational and ready to serve their intended purposes.

Risk Assessment and Mitigation

Difficulty in Obtaining Parts: The GAS Team has already communicated with suppliers to receive quotes, and this communication will be maintained to ensure the timely delivery of components. Additionally, the team has researched alternative parts should the preferred components become unavailable.

Challenges in Assembly or Software Development: The team has connections with various individuals with experience in ground station setup, operation, and software development that we can turn to in case of complications. Connections include Kevin Croissant (Libre Space Foundation/SatNOGS), previous and current GAS Team members that set up the UHF ground station, and a group of software engineers at NASA’s Jet Propulsion Laboratory that built the ground data system we will be using.

Integration Challenges with Existing Infrastructure: The GAS Team has members that have worked on all parts of the current ground infrastructure. As mentioned before, the team also has connections to the original developers of the current infrastructure if more information is needed.

Quality Assurance and Testing

The ground stations will be subject to stringent tests, checking for reliability, robustness, and communication accuracy. The testing phase will validate software hardware systems and ensure proper communication with the antenna and SatNOGS. The results of these tests will be used to verify the functionality of the system is in line with the mission requirements. Failures will indicate where further design/development work is necessary.

Feedback and Iteration

The team emphasizes agility with regular evaluations and iterations based on real-time performance and emerging needs. Transparent documentation will be available to the public, elaborating on design decisions, iterations, and enhancements to increase performance or capabilities to grow the knowledge available for amateur radio station operators.

Documentation and Reporting

Platform: All comprehensive documentation will be hosted on Notion. Public-facing pages will ensure open access to interested parties and will be linked to from the GAS Team website.

Content: Documentation will thoroughly cover the planning, setup, development, operation, and maintenance aspects of the ground station. The documentation will also feature links to all the software components, promoting replication or enhancements by the community.

Reporting: Progress, milestones, and significant developments will be communicated through the team's social media channels, the team's website, and presentations at relevant RF conferences.

Describe your outreach plan.

For example, how will you recruit people to participate, volunteer with you, or collaborate with you? How will you share the results of your work?

The GAS Team's outreach plan includes three key objectives: recruitment, community/school engagement through events and the BUSS (Bring Utah Students to Space) program, and communication of results to NASA and the amateur satellite/RF communication communities at relevant conferences.

Recruitment: The team currently has 25 members. We aim to onboard at least 5-10 new students into the team each semester. Recruiting activities include advertising around campus and hosting workshops teaching useful skills for practical engineering.

Community/School Events and the BUSS Program: We will visit 6-8 classrooms per semester to share experiences from GASRATS development and provide hands-on radio communication demos. Students can interact with a model CubeSat using our portable ground station. We also aim to showcase the portable ground station at STEM events the community and university put on.

The BUSS program is an outreach initiative run by the GAS Team where students can submit their names to be flown on the GASRATS satellite. The program will be advertised during school visits and community events. The intent of the BUSS program is to give students a personalized way to participate in the mission and inspire them to follow its progress and stay involved.

Communication of Results: The GAS Team will share open-source documentation for the team's ground station on Notion and GitHub and present project results at amateur radio conferences. The team hosts a live YouTube stream providing constant visibility of ground station operations [http://youtube.com/@usugetawayspecial/live]. The GAS Team also utilizes school social media channels to communicate achievements.

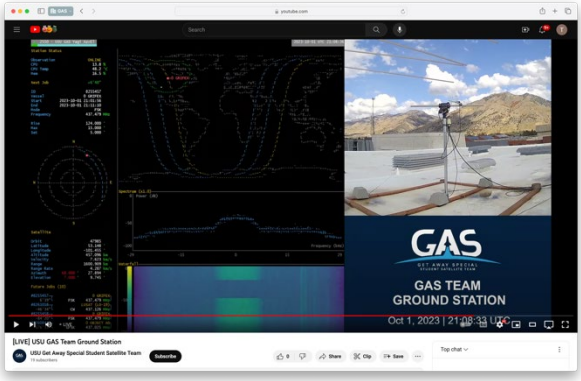

Figure 4. A screenshot of the livestream of the GAS Team UHF ground station on YouTube.

How does your project align with ARDC's mission and granting goals?

The GAS Team's ground station project directly supports the mission of ARDC by advancing digital communication and emphasizing the significance of amateur radio.

We see our project aligning with ARDC's goals in the following ways:

Broad Reach: By integrating our ground station with the SatNOGS network, we enable increased global access for amateur satellite operators. Our commitment to open-source documentation ensures that our developments can be widely replicated, thus benefiting a larger segment of the community.

Social Over Commercial Benefit: A primary motivation for this project is educational outreach and community engagement. Rather than aiming for commercial profits, we choose to spend our time developing open-source radio communication solutions and promoting STEM education in the broader community.

Figure 5. A member of the GAS Team explaining the function of the GASPACS CubeSat at a community event.

Inclusion of Underrepresented Groups: The team includes members from a variety of backgrounds and intends to engage a diverse range of K-12 students through the BUSS outreach program and participation in community events.

Empowerment and Distribution: Our project emphasizes collaboration and the sharing of resources. By making our ground station available on the SatNOGS network, we're advocating for a decentralized approach. Our open-source commitment ensures knowledge dissemination, fostering innovation across different entities in the field. We focus on developing those who work on our team into effective innovators who focus on open-source and contributing to their community.

Preservation of the Right to Innovate: By open-sourcing all aspects of the ground station project, the GAS Team contributes to a community of creators seeking to expand the capabilities of amateur satellite operators by lowering the barriers to high bandwidth transmission over S-band frequencies.

Who will carry out your project?

Please share who will carry out the project, and briefly tell us about the skills they have to do the work.

CJ Wayland and Cooper Gowan will lead the project. They are supervised by the GAS Team Coordinator, Carter Page, and the GAS Team faculty advisor, Dr. Jan Sojka. In addition, other GAS Team members will assist in project design and development.

CJ Wayland: CJ Wayland is a junior in mechanical engineering at USU and has been on the team for over two years. As the Mission Operations Lead, CJ is responsible for all ground systems, including the UHF and S-band ground stations. Through regular maintenance of the UHF ground station, he has become greatly experienced with satellite communication systems.

Cooper Gowan: Cooper Gowan is a senior in mechanical engineering at USU and has been a part of the team for over three years. He assisted in the development of the GASPACS payload and was part of the team that built and integrated the flight payload. Through GASPACS operations, Cooper gained experience with the UHF ground station and radio communications.

Carter Page: Carter Page is a junior in mechanical engineering at USU and is Team Coordinator of the GAS Team, overseeing both technical and programmatic aspects. He has been on the team for over three years and led the payload development for GASPACS. Carter also has experience in systems engineering and communications, which he gained while optimizing the performance of the UHF ground station during GASPACS operations.

Jan Sojka: Dr. Jan Sojka is Head of the USU Department of Physics and has been the GAS Team faculty advisor for over 30 years. He is typically hands-off in team activities, wanting the students to have as many learning opportunities as possible. However, his mentorship has been crucial to the team's 40+ years of success and will be for this project as well.

GAS Team Members: The GAS Team has multiple current and future members who will help complete this project. These members have various experience and majors, including mechanical, electrical, computer, and software engineering. The GAS Team members have varying levels of radio communication experience, but all are enthusiastic about space and communication technologies.

Since the GAS Team primarily comprises undergraduate students, turnover is continuous. In recent years, substantial efforts have been made to ensure knowledge continuity, such as improving documentation methods. The GAS Team is always preparing its next leaders and can ensure they will be capable of completing the project in case it extends beyond the expected timeline.

How does your project fulfill ARDC's open-access goal?

In alignment with the principles upheld by ARDC, the GAS Team is committed to fostering a culture of openness and inclusivity. We pledge to make all materials, documentation, and innovations relating to the ground station available to the public.

Details of our Open Access Approach:

1. **Documentation & Construction Guidelines:** Comprehensive documentation detailing the ground station's step-by-step assembly, setup, and troubleshooting will be accessible. This openness ensures that amateur radio enthusiasts, educational institutions, or anyone interested in replicating or learning from our ground station can do so seamlessly.
2. **Software Availability:** All code, including programs interfacing with the SatNOGS network, will be released under an Open-Source Initiative (OSI)-approved license.

This approach ensures a broader collaborative software improvement and encourages the amateur radio community to customize or enhance it to suit individual requirements.

3. **Shared Ground Station Access:** Beyond our satellite communication needs, we will extend the ground station's capabilities to the global community. By integrating with the SatNOGS network, we ensure that any amateur satellite operator seeking S-band communication can schedule and utilize our ground station for their data downlink needs.
4. **Licensing:** To guarantee unrestricted access and foster collaborative development, we will release all non-software materials under the Free Culture subset of the Creative Commons licenses, specifically opting for licenses like CC-BY or CC-BY-SA. This licensing ensures the broader community can freely share, adapt, and build upon our work.

Supporting Materials

Demonstration of the transparent patch antenna is the primary mission of the GAS Team's upcoming satellite mission. The transparent patch antenna integrates an S-band patch antenna with a satellite solar panel. The antenna achieves optical transparency through its meshed design that allows light penetration, ensuring the underlying solar panel remains functional. The design of the flight antenna is ongoing as the team aims to achieve 90% transparency while retaining necessary gain properties.

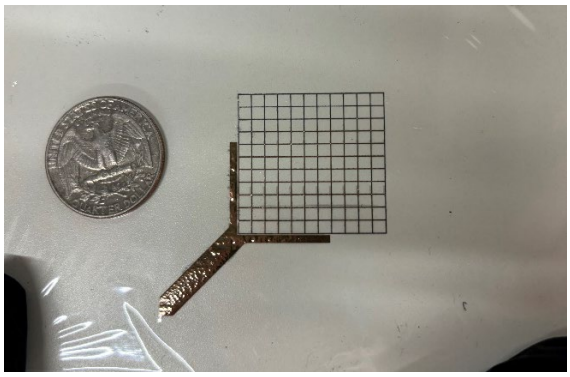

Figure 6. A prototype of the transparent patch antenna with a quarter for scale.

The GAS Team is collaborating with Dr. Reyhan Baktur from USU's Department of Electrical and Computer Engineering to design and refine the manufacturing method for the transparent patch antenna. Dr. Baktur's research focuses includes CubeSat antenna design. She is currently a distinguished lecturer for the Institute of Electrical and Electronics Engineers (IEEE) and involved globally in radio studies.

Manufacturing the transparent patch antenna involves using a specialized inkjet printer to imprint a conductive silver-nitrate ink on a transparent substrate. Once printed, the assembly is oven-cured and conformally coated. It is then mounted on the solar panel and undergoes rigorous testing for frequency and gain pattern validation.

The transparent patch antenna brings tangible advantages to both CubeSats and deep-space missions. For CubeSats, this antenna delivers high-gain without compromising power, which is especially critical during the energy-intensive detumble phase. In deep-space missions, the angle between the Earth and Sun vectors becomes small. This makes it beneficial to employ expansive flat surfaces oriented in that direction, allowing for both high-gain transmission and power generation.