# OreSat1B Final Science Report

High Altitude Student Platform (HASP) 2021

*Revision A*

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# 1. Introduction

The failure rate of university-built CubeSats has historically been high, with around half of missions failing within 60 days of deployment. Often, a lack of proper testing on various subsystems and components results in such failures.

In 2016, Portland State University along with several other universities and industry partners submitted a 2016 NASA CSLI Application, aiming to build and launch Oregon's first CubeSat, "OreSat". OreSat is a 2U CubeSat planned to be launched in Q1 of 2023 from the International Space Station. One of OreSat's primary missions is to collect data on high altitude (> 12 km) cirrus clouds with the "Cirrus Flux Camera" (CFC) science instrument, a short wave infrared (SWIR) camera. Additionally, several technology readiness demonstration projects are being pioneered on OreSat, including a long-distance S-band telemetry link using off-the-shelf components ("DxWiFi'') and an open-source CubeSat "kit" called the OreSat bus.

The OreSat1B test system seeks to test these three subsystems for extended periods in a space-like environment: the thermal performance and data collection abilities of the Cirrus Flux Camera instrument, the long-distance performance of the "DxWiFi'' S-band radio link, and the OreSat CubeSat system. OreSat1B also serves as a STEM Outreach component for OreSat, as students at Westview High School lead in the assembly, integration, and flight of the payload.

# 2. Mission Overview and Design

OreSat is a 2U CubeSat being built by the Portland State Aerospace Society (PSAS), an interdisciplinary team of undergraduate and graduate students at Portland State University. Various partner institutions, including Oregon State University, University of Oregon, and some high schools, are helping with the project. As described by the 2016 CSLI Proposal [1], OreSat holds three mission objectives: provision space-based STEM outreach experiences to students in Oregon, map the global distribution of high altitude cirrus clouds, and demonstrate several innovative open-source CubeSat technologies (Figure 1).

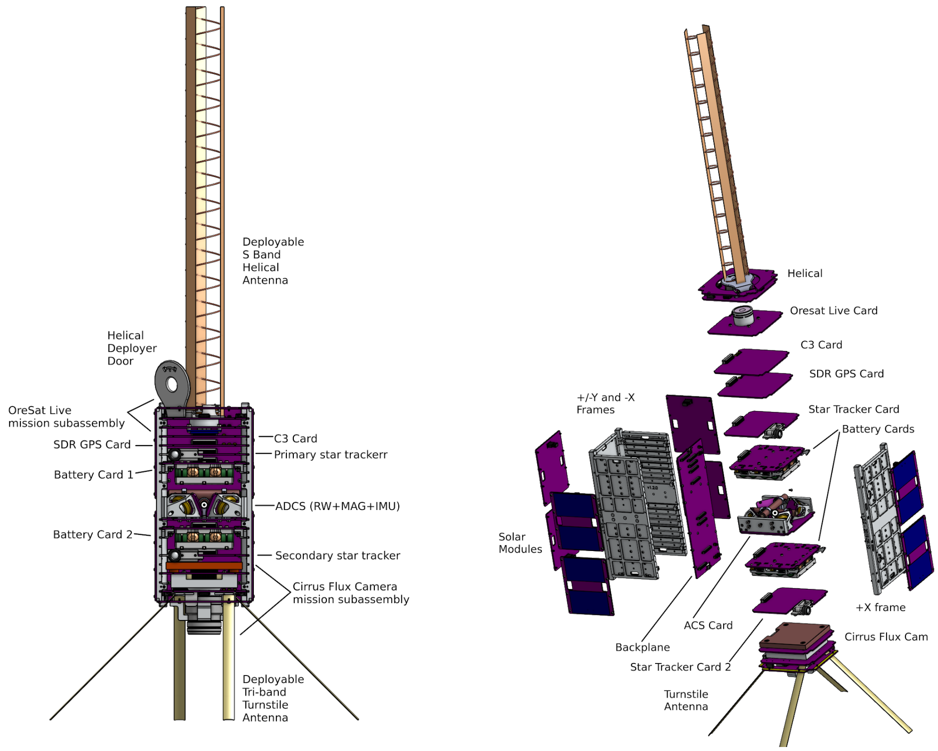


**Figure 1.** OreSat 2U CubeSat. Left shows the card-cage structure, right shows an exploded view of the aluminum frame and cards.

OreSat1B tested these systems in the unique near-space environment that the 2021 High Altitude Student Payload (HASP) can provide (Figure 2). The long duration near-vacuum and thermal environment of a HASP payload are as close to testing in space as possible; testing and demonstrating the operation of OreSat's critical subsystems will ensure future mission success in orbit. We proposed to test three main subsystems of OreSat:

(1) The primary mission of OreSat is to study the global distribution of high-altitude cirrus clouds which have a profound impact on building accurate global climate models. In collaboration with faculty and students at the University of Maryland Baltimore County and University College London, the Cirrus Flux Camera (CFC) instrument has been developed to provide an inexpensive, thermally controlled system to gather multi-band shortwave infrared (SWIR) image data reflected off of high altitude (> 12 km) cirrus clouds. OreSat1B gathered SWIR images and thermal performance data from the CFC instrument on the HASP flight, proving its operation in a near-space environment.

(2) OreSat's secondary mission is to provide a unique space-based STEM outreach to students across the state of Oregon with the "OreSat Live" mission. The OreSat Live payload transmits live images of the student's location down to the students. Students receive the video on an inexpensive receiver called the Oresat Live Handheld Ground Station. Oresat1B tested three critical parts of the OreSat Live mission: The camera, the radio link, and the ground station.

Video and images were gathered from the innovative 3 cm Schmidt Cassegrain telescope lens and camera system. These were transmitted on the innovative open-source "DxWiFi" S-band radio system, which uses commercial-off-the-shelf WiFi hardware to create a long-distance WiFi link under an amateur radio license. This signal was then received on the ground using prototypes of the OreSat Live Handheld Ground Station.

(3) The tertiary mission of OreSat is to demonstrate an open-source CubeSat "bus" (technology infrastructure) called the OreSat bus. This includes an onboard computer, amateur radio telemetry system, a star tracker, inertial measurement unit, and magnetometer system. OreSat1B provided an invaluable near-space long-duration test for these systems.

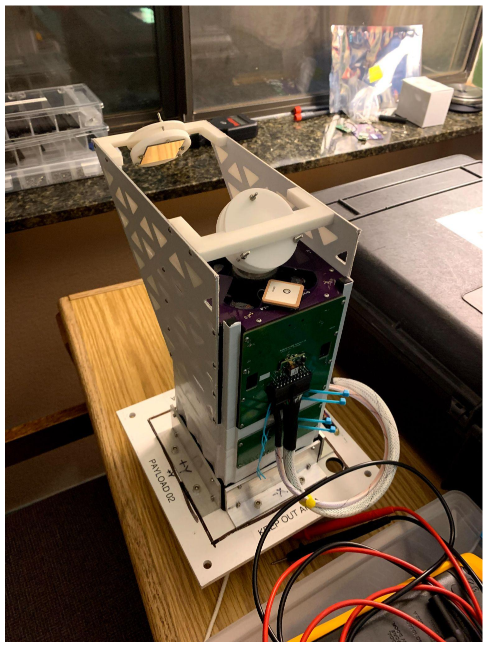


**Figure 2.** OreSat1B payload for 2021 HASP flight consisting of the OreSat frame, the OreSat Live mission, the Cirrus Flux Camera, and a subset of the OreSat CubeSat bus.

OreSat1B was configured similar to the flight configuration of OreSat, in order to provide the most accurate simulation. This said, several subsystems, most notably the Gallium Arsenide solar cells, Lithium-Ion battery cards, and the reaction-wheel and magnetorquer-based attitude control system, were removed from the system because of constraints placed by HASP requirements (e.g., no batteries). Further, high-resolution thermal and mission performance data was stored on-board the satellite for recovery after the flight, rather than beamed down via telemetry.

## 2.1 Mission Objectives

<u>Cirrus Flux Camera Mission System</u>
Demonstrate image acquisition and thermal management of the Cirrus Flux Camera Shortwave Infrared camera system in a space-like environment.

- ❏ ≥ 100 image captures from the shortwave IR camera to local flash memory.
- ❏ Obtain continuous measurements of thermal performance of the camera system under operation without thermal control
- ❏ Demonstrate thermal control of the SWIR sensor to < -8 °C for five separate 10 minute periods at altitudes above 30 km if the temperature rises above 8 °C.
- ❏ After the flight, compare actual thermal performance compared to the Thermal Desktop models.
- ❏ Process captured images to confirm SWIR lens performance, system ground resolution at flight altitude.
- ❏ Possibly identify cirrus clouds in images if local weather conditions are favorable for cirrus cloud formation during flight.

<u>OreSat Live Mission System</u>
Demonstrate video acquisition and compression from the OreSat Live camera system. Demonstrate transmission of the data over the S-band DxWiFi radio system to both a commercial ground station and the OreSat Live Handheld Ground Station. Demonstrate system operation in a space-like environment to a ground station with a line-of-site distance of > 100 km.

- ❏ Successful onboard capture of images and short video segments from the OreSat Live Schmidt-Cassegrain lens and camera.
- ❏ Reception of video and data from the DxWiFi S-band telemetry link using the OreSat Live Handheld Ground Station from > 100 km line-of-sight distance with low bit error rates (BER $< 10^{-5}$).
- ❏ Reception of video images and data from the DxWiFi S-band telemetry link on the ground using COTS high gain antennas and receivers from > 100 km line-of-sight distance with low bit error rates (BER $< 10^{-5}$).
- ❏ Depending on ground station location (altitude), vehicle flight path, and system performance, an attempt to break the world record for WiFi transmission of 430 km.

<u>OreSat CubeSat Bus</u>
Demonstrate continuous, error robust operation for the full duration of the flight.

- ❏ Demonstration of continuous operation of the C3 onboard computer and telemetry radio across extreme thermal conditions.
- ❏ Hourly functionality and performance tests of OreSat's subsystems, including the SDR GPS card, image captures from the star tracker card, and data captures from the IMU and Magnetometer card.

# 3. Payload Overview

## 3.1 OreSat 2U Frame and Backplane

The OreSat frame and card cage is an open-source design by Portland State University students. The system is designed to provide maximum modularity to independent student teams by using a common card architecture and hardware and software APIs. The 6061-T6 Aluminum frame provides the structure for the CubeSat, in addition to a non-electrical thermal connection from the cards to the frame using an innovative wedge and triangle "clamp" system. The card clamping system compresses type 2 anodized aluminum surfaces onto large copper surface runs along the edge of each card, allowing for a thermally conductive but electrically insulating path. Wedges and triangles are located on the +X, -Y, and +Y sides of the frame.

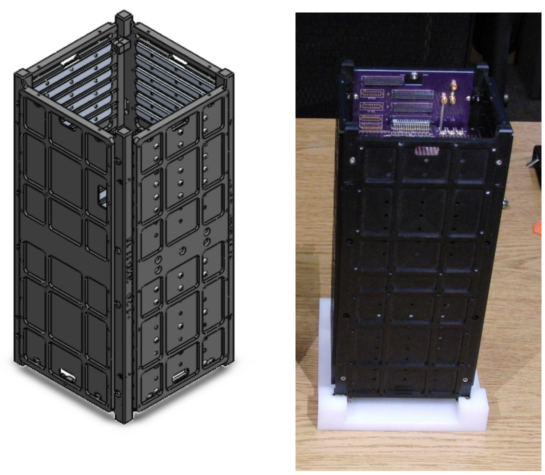

**Figure 3.** V1.2.0 configuration of the OreSat Frame Assembly with machined frame

The backplane of OreSat1B, located on the inner -X side of the frame, allows for the cards of each of the subsystems with power, data, and RF connectors. Each card can connect to the main 40 pin connector, 20-pin auxiliary connector, and 3 RF connectors. These connectors allow the cards to interface with onboard Controller Area Network (CAN) buses, the 7.2$V_{NOM}$ VBUS power rail, OreSat Power Domain signals (which allow each card to be powered up independently), and the U/L/SL band microstrips.

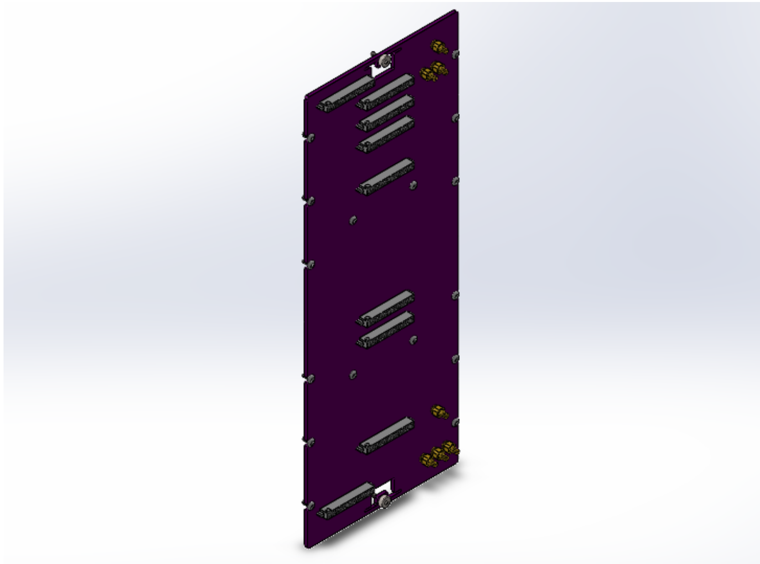

***Figure 4.*** *OreSat Backplane Assembly*

## 3.2 C3 On-board computer card

The OreSat C3 onboard computer controls the OreSat system and provides telemetry via amateur radio. Based on an STM32F439 microcontroller with an external radiation-tolerant watchdog circuit, the C3 is in charge of radio beacons, engineering data link (EDL) communication over OreSat ground stations, powering individual subsystems, and monitoring the general health, state, and status of the various systems over the CAN busses on the backplane which connects to all card subsystems.

The C3's radio system is a UHF (436 MHz) transceiver that provides an Amateur Packet Radio System (APRS)  beacon with telemetry and health data, and an L band (1.2 GHz) receiver. For the HASP mission, only the UHF transceiver was used.

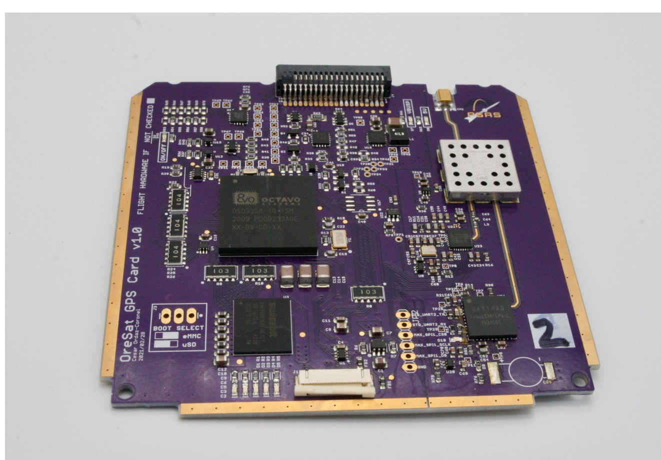


**Figure 5.** Assembled and stuffed C3 flight computer card, flown on the OreSat1B payload

### 3.3 S-Band and UHF antennas

Due to space constraints on the OreSat1B payload due to the downwards facing aperture of the Cirrus Flux Camera, a monopole antenna was used to transmit the UHF telemetry and receive the UHF uplink at 436 MHz.

Similarly, instead of the high gain helical antenna that will be flown on OreSat, a hemispherical patch antenna on the bottom of OreSat1B was used to transmit the OreSat Live S-Band at 2.422 GHz.

Extensive RF testing was conducted at various distances to verify the performance of the system. This includes a test from the Portland State Business Accelerator to the Oregon Museum of Science and Industry (1km) and a test from Council Crest to Rocky Butte (12 km). Both resulted in success, ensuring adequate performance for the HASP 2021 flight.

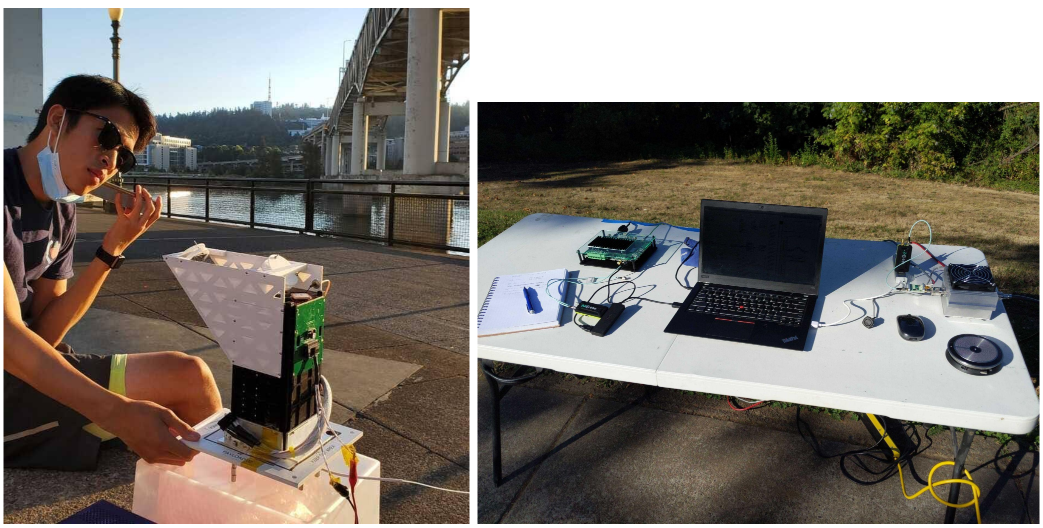

**Figure 6.** RF Testing of the OreSat UHF telemetry system at 12km

### 3.4 OreSat Live System

The OreSat Live system consists of three subsystems:

1. The OreSat live camera system, which has an innovative 3 cm wide hand-ground Schmidt Cassegrain telescope lens and a high-resolution Sony CMOS image sensor.
2. The OreSat Live card, which contains an Octavo SM processor running Linux from an eMMC flash IC. This card controls the camera, processes the video, and runs the wireless system.
3. The DxWiFi radio system, which is a commercial, off the shelf Atheros AR9721 802.11b USB to WiFi adapter IC operated through a bi-directional amplifier which includes a 1W power amplifier in order to get a long-distance WiFi system.

Following submission of the HASP payload application, a volume waiver was submitted to add the OreSat Live "Periscope" to OreSat1B. Since OreSat1B does not have the attitude control of the CubeSat, and we wished to still test the OreSat Live camera system in the +Z (upward-facing) side of the CubeSat, the team has designed a periscope to point the upward-facing camera down, and allow the sensor to view the Earth. In doing so, significantly more valuable data on the performance of the OreSat Live sensor could be collected. The addition of the OreSat Live Periscope allowed for the accuracy of the verification of the image quality and transmission of the OreSat Live subsystem.

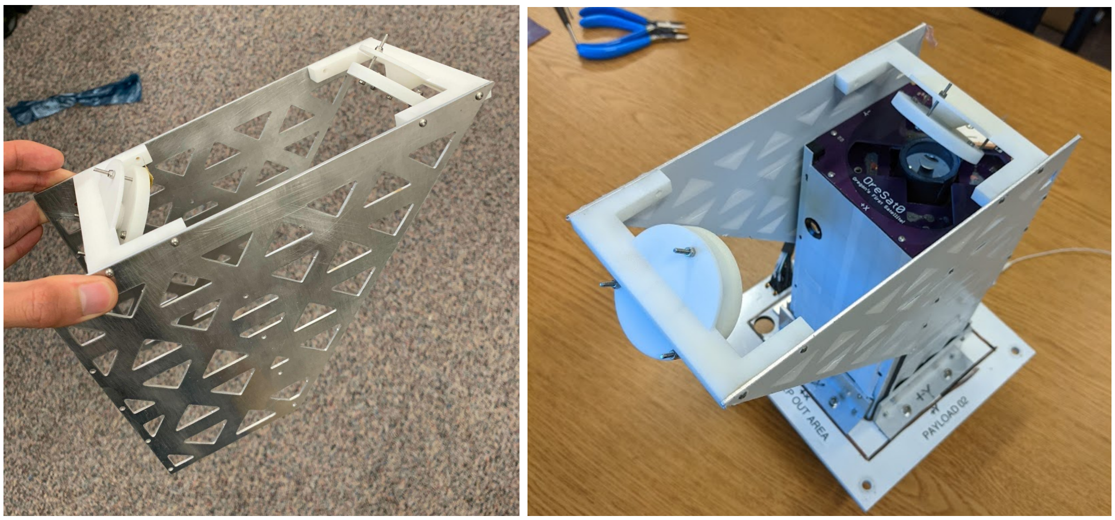

**Figure 7.** Assembled OreSat Live Periscope attachment. Note two front-surface mirrors held at 45° degree angles by 3D printed holders (white) bracketed between periscope frames (Aluminum).

## 3.5 Cirrus Flux Camera System

The Cirrus Flux Camera (CFC) is a Shortwave IR (SWIR) imaging multiband science instrument. It consists of several parts:

1. The CFC processing card, which contains an Octavo SM processor running Linux with an eMMC flash IC. This card controls the camera and stores the raw images taken from the sensor.
2. The sensor card, which holds the Princeton SWIR imaging sensor that has its own built-in thermoelectric cooler (TEC), and a large copper thermal mass.
3. A Navitar 25mm SWIR lens is mounted via the lens mount on the sensor card. Additionally, a thermal lens strap mounted to the -Z end card serves to not only dissipate heat from the Navitar SWIR lens but also to provide structural support (Figure 8).

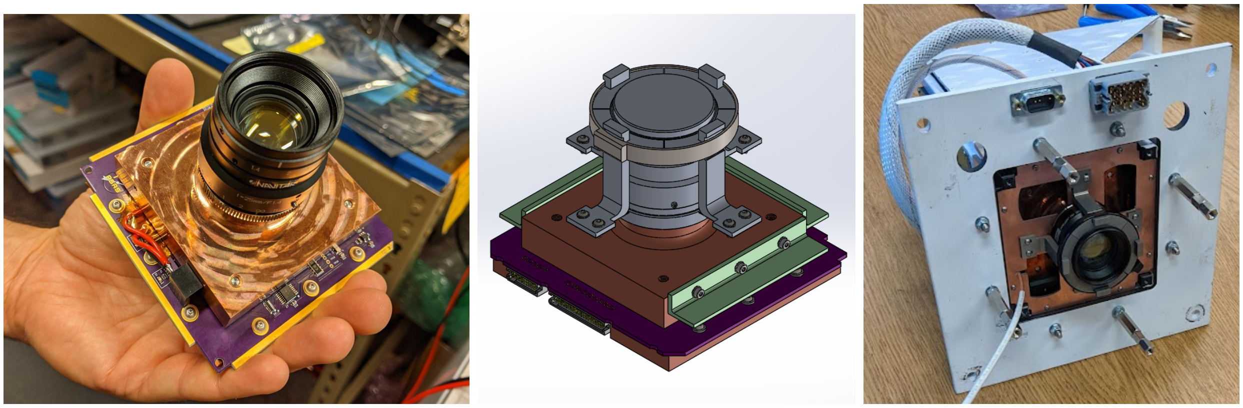

**Figure 8.** Assembled CFC assembly as of 2021/12/14 for OreSat1B payload. The assembly includes the lens mount, thermal lens straps, CFC card, Navitar 25mm SWIR lens, and copper thermal mass.

## 3.6 Altitude Determination System

The attitude determination and control system, or ADCS, of the space-bound OreSat is designed to orient and maneuver the satellite in the environment of space. Since OreSat1B is not in orbit, the control systems (magnetorquers and reaction control wheels) were not flown. However, a star tracker card and GPS card were flown and tested. Data from these systems were stored locally.

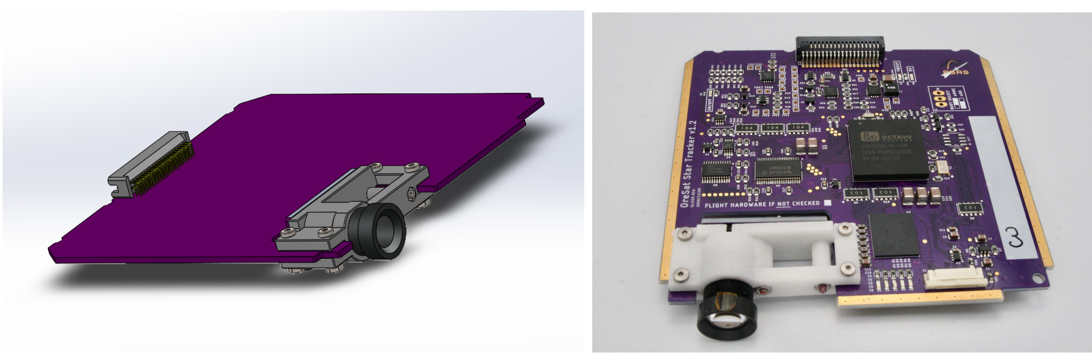

***Figure 9.*** *Assembled Star tracker card*

## 3.7 HASP Mechanical and Electrical Integration

The structure on the OreSat1B payload was the 2U configuration of the open-source OreSat frame. The frame of OreSat is made of 6061-T6 Aluminum with type 2 anodization, manufactured to the specifications as represented in the drawings in the "Preliminary Drawings and Diagrams" section. Each "card" slides into a slot of the card cage and connects to its respective connectors on the 2U backplane. Cards are held down using a triangle-wedge system, thermally connecting each card to the frame.

OreSat1B was attached to the payload plate via 4 L-brackets on each side of the frame. Each L-bracket is mounted to the frame of OreSat1B with 4 fasteners, which is then mounted to the HASP mounting plate with 2 fasteners and nuts. The L-brackets are machined out of aluminum, providing the required strength for the 5g horizontal and 10g vertical shock tests (Figure 10).

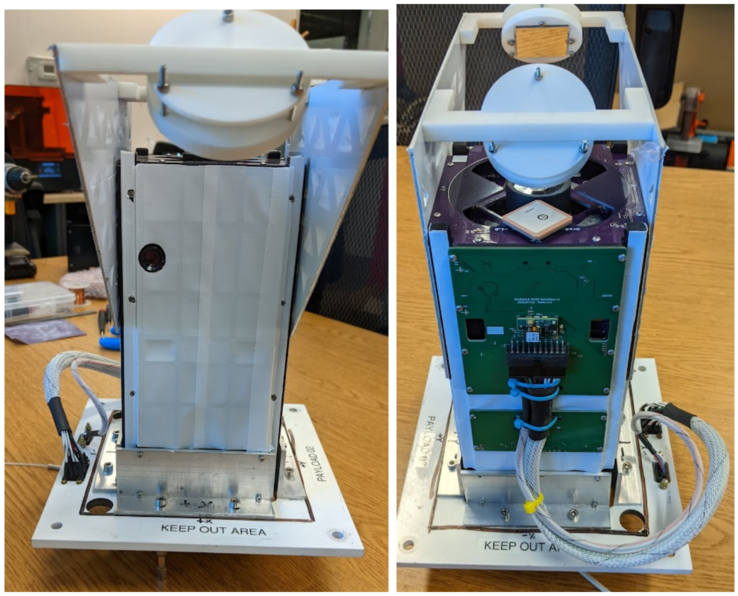


**Figure 10.** Left: OreSat1B with Small Payload HASP interface plate, connector, and L brackets. Right: The back of OreSat1B, showing the “solar panel” HASP power adapter.

For power, OreSat1B used HASP-provided 30V @ 0.5A power. We replaced one of our external solar panels with a 30V to 7.2V DC-DC converter mounted on a solar panel PCB: the input was a 1ft cable to an EDAC 516-020-000-301 connector, and the output was the standard OreSat solar connector which interfaces with OreSat's electrical main bus (Figure 10).

# 4. Flight Operations Overview

## 4.1 Planned Flight Operations Procedure

The following was the preliminary flight operations plan. Following this section, a detailed overview of on-site operations, success/failure of the operation, and impact on the mission.

**Pre-Launch**
The OreSat team will choose a location within a few km of the balloon launch site to set up a ground station camp. A commercial ground station will be set up, along with several OreSat Live Handheld Ground Stations. The ground station teams will coordinate with the launch team using cellphones and amateur radios.

**Launch**
OreSat1B will be powered on during launch as much as possible and can handle any power cycling of the HASP power subsystem during pre-launch. OreSat runs off of a 7.2 V internal power bus; OreSat1B will convert the HASP's 30V at 0.5 A power supply using a DC-DC converter mounted on

the unused solar array area down to 7.2 V at 2A. On power-up, OreSat1B will immediately begin autonomous high-resolution temperature recording and begin beaconing on its 1W UHF (436 Hz) amateur radio system. The beacon has truncated temperature and performance data that the ground teams will receive and process live.

**Operations**

After 30 minutes of simple beaconing operations, OreSat1B will begin autonomously testing mission subsystems.

- The C3 onboard computer will power up the OreSat Live mission subsystem, which includes its own processor and memory system. Images will be continuously captured from the camera system and transmitted over the DxWiFi system via the omnidirectional 4 element turnstile antenna system. The ground station will pick up these transmissions on both the commercial and hand-held ground stations, measuring link budget through bit error rates and overall performance by successful frames per second.
- The C3 onboard computer will power up the Cirrus Flux Camera, which includes its own processor and memory system. The CFC will run a continuous series of automated tests to capture SWIR images and test the thermal performance of the passive and active thermal control system.
- The C3 onboard computer will continue to beacon on the UHF radio once a minute. Every hour, the ground team will connect to the C3 using the Engineering Data Link (L band uplink, UHF band downlink) and perform a series of data captures and operational status checks.
- Once an hour, the C3 onboard computer will sequentially power up and test other CubeSat subsystems, including the SDR GPS receiver, star tracker, IMU, and magnetometers. Each subsystem will capture and store its own data, while the C3 will record the thermal state of each system.

**Recovery**

The system will be powered down before descent. Upon recovery, the system will be carefully housed for a careful teardown analysis looking for any damage or thermal effects. Then as each subsystem is removed, its high-resolution data will be read off the various flash memory systems and uploaded to the OreSat shared drive for safekeeping and future analysis.

## 4.2 Actual Flight Operations Results

The following is a breakdown and analysis of flight operations at Fort Sumner, NM.

| Time | Task | Description | Result |
|---|---|---|---|
| T=-6 days | Integrate Payload | The payload is integrated onto HASP. | Integration of the payload went smoothly and without any hitches. Upon integration, |

| | | | |
|---|---|---|---|
| | | | the payload powered on and began sending telemetry packets, which could be picked up by the OreSat1B ground system equipment.  |
| T = -3 hours | Ground Station Set-Up | Ground systems for the OreSat1B payload were set up at the designated location provided by HASP and CSBF. | Success! The ground control systems were set up successfully by the OreSat1B team.  |
| T = 0 | HASP Launch | The HASP platform takes flight on a zero-pressure balloon | Systems continued to be monitored throughout the launch process. All systems were nominal throughout the flight.  |
| T = 0 - +2.5 hours | OreSat1B data monitoring, system control, and ground station testing | HASP is approaching float and the OreSat1B team continues science operations for the mission | Payload continues to perform as expected. RF links are consistent and commanding to the payload continues. |
| T = +2.5 hours | Loss of stable transmission | HASP has been in flight for multiple hours and has reached a distance of ~ 125 km at which transmission using the Engineering Data Link (EDL) can no longer be stably received. | Despite losing reliable transmission and commanding the OreSat1B payload, data packets are still being received by the portable ground station. Operations continue and payload performance is monitored. |
| T = 4 hours | Unable to receive | HASP has been at float for multiple hours and | Full loss of communication with the OreSat1B payload. The portable ground |

| | | | |
|---|---|---|---|
| | packets; autonomous operation mode | the OreSat1B portable ground station is no longer able to receive packets from the payload. HASP is around 250km from the ground station | station is unable to maintain transmission or reception of data packets due to the high noise nature of the system. The OreSat1B payload continues to operate in autonomous mode. |

# 5. Science Overview

Overall, the OreSat1B mission was successful. The primary objective, testing the Cirrus Flux Camera under varying environmental conditions, was wildly successful and provided insightful data essential towards the OreSat1 NASA CLSI mission. While other aspects of the mission were unsuccessful, the overall results provided beneficial data to continue the development of the OreSat platform. Below is a breakdown of performance and data collected from various subsystems.

## 5.1 Cirrus Flux Camera

Upon recovery and return of the OreSat1B payload back to Portland, the SD card contained over 11 GB of compressed raw images from the SWIR sensor. These images were processed into an accessible format and histogram equalized version. An example of one of the numerous captures is seen below:

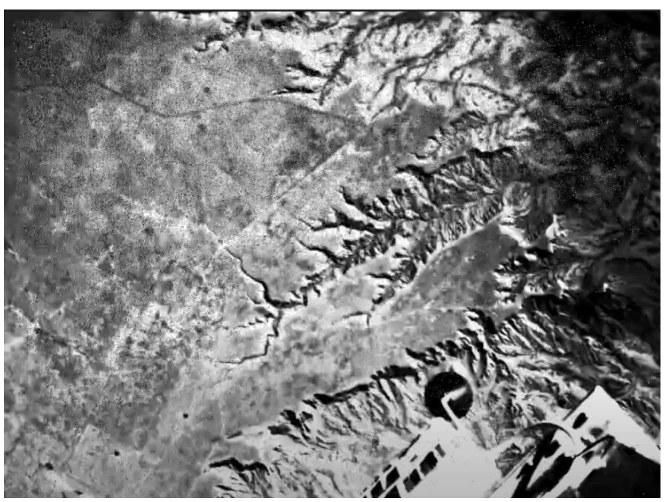

***Figure 11.*** *One of several histogram balanced images from the Cirrus Flux Camera*

Upon completion of processing over 11 GB of raw images into readable and equalized files, the files were compiled into a video format for ease of analysis. This video can be found on YouTube: https://www.youtube.com/watch?v=jDAOgZoTRyo.

Each image was geotagged with the precise location, as collected by the onboard GPS. The OreSat1B GPS data was compared against HASP GPS data, in addition to data from a partner payload from Montana State University. The 11 GB worth of geotagged data was sent to partners at the University of Maryland at Baltimore County and University College of London. The data is still under analysis, and we look forward to reports from our science partners later this winter.

As expected, the temperature of the SWIR sensor dramatically affected image quality. The HASP flight provided the perfect opportunity to test the CFC thermal management system across operational extremes. The following image compares the images captured from the Cirrus flux camera throughout flight:

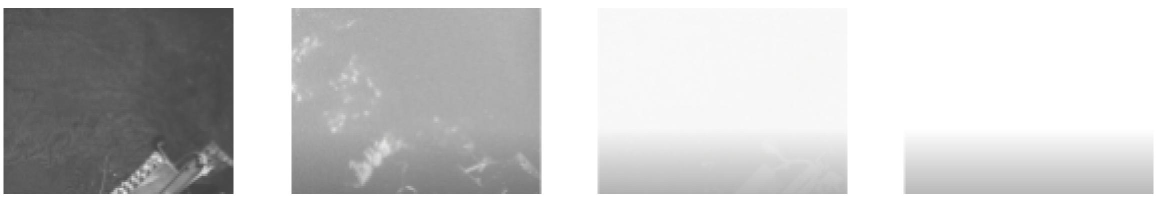

***Figure 12.*** *As the OreSat1B payload progresses through flight, images can be seen to degrade in quality over time as the thermal mass saturates and the sensor's temperature rises*

While fluctuations occurred throughout the flight, in addition to a few irregular captures, the overarching trend presented by the video indicates a clear trend: as expected, high-temperature readings on the Cirrus Flux Camera SWIR sensor severely degraded image quality.

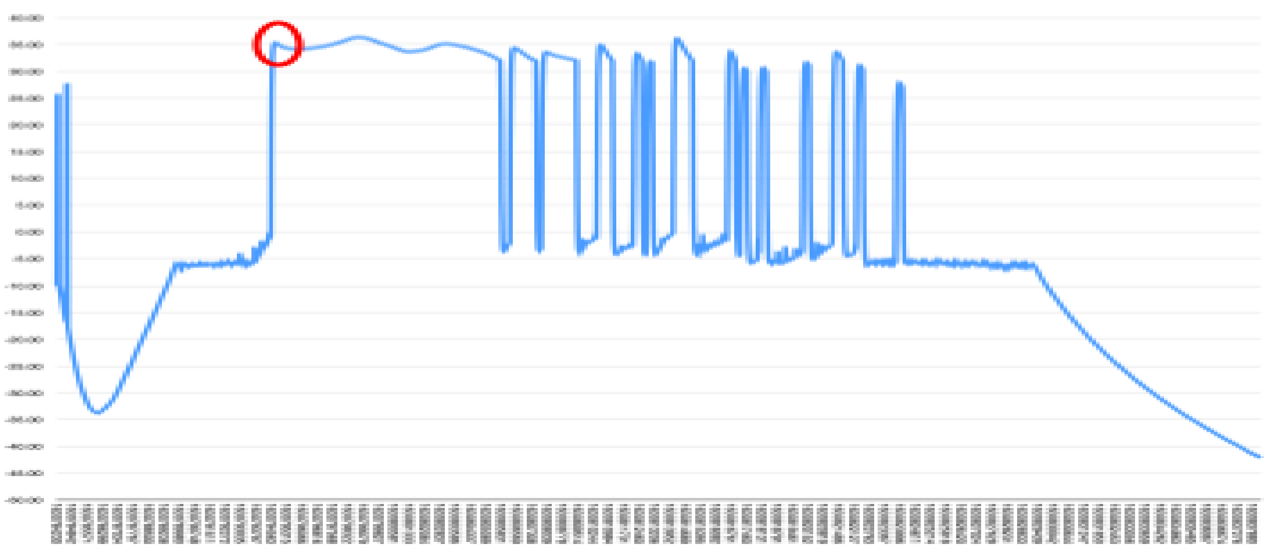

***Figure 13.*** *Graph of temperature of the Cirrus Flux Camera SWIR sensor. The red circle indicates the change of image quality in the video*

Even with the integration of a large copper thermal mass on a thermoelectric cooler (TEC) onto the payload (weighing in at around 1kg), the mass was saturated within hours. This performance is as expected, as the payload is expected to be unable to maintain temperatures while baking in the sun in the HASP environment. This said, we were pleased to see the thermoelectric cooler with the thermal mass was able to initially maintain, then later periodically re-attain, a temperature of -8.2℃. This temperature is most optimal for the operation of the SWIR sensor, and data optimistically indicates that the current design is able to maintain this temperature.

Further analyzing the graph, the changes in temperature throughout flight further indicate the successful operation of the Cirrus Flux Camera thermal management system. While operating in the designed environment of Low Earth Orbit (LEO), the Cirrus Flux Camera is expected to perform image captures for a limited amount of time, then pausing to allow the thermal mass to cool off. The data following the plateau of temperature indicated with the red circle on the previous graph demonstrates the capability of the thermal mass to reduce in temperature and allow the TEC to operate.

The Cirrus Flux Camera's performance on the HASP flight was extremely successful. The system design has been validated, including the thermal management system, image capture system, and mechanical design.

## 5.2 C3 Flight Computer and RF Performance

Throughout the flight, the C3 flight computer operated nominally. We received consistent telemetry beacons for the initial 4-5 hours of flight. We sent several commands to the C3 card during the first 2.5 hours of the flight, proving our UHF uplink. However, at around 125 km of range, we lost the ability to command the C3 (uplink failed) and at 250 km we lost the ability to hear the UHF beacon. Although this did not impact flight performance since the system operated autonomously, we did not expect the loss of communication.

Telemetry data from the HASP flight is available as a YAMCS database format here and available as raw packets here.

Upon further analysis in the lab, we believe we experienced three independent failures:

1. The C3's UHF radio output was 10 dBm less than the expected 30 dBm (1 W) design. We're still investigating this, but it appears that the losses in the power amplifier stages of the UHF transmitter, coupled with suboptimal performance of the power amplifier IC itself, causes this loss of power.
2. The OreSat1B's UHF monopole performed sub-optimally. While it worked as expected, we forgot to take into account the difference in propagation between the linearly polarized monopole antenna and the RHCP turnstile antenna, which lost us another 3 dBm.
3. Finally, our portable ground system had a much higher receiver noise than realized, due to the coupling of the transmit and receiver software-defined radios (SDRs) we use on the ground station. This noise was not apparent in our ground testing at 12 km; it was only

apparent when we were at the extremely long distances of the HASP flight. Discovering that our ground station had a higher noise floor than expected was an extremely important finding that HASP provided for us.

## 5.3 GPS

The GPS operated as expected, validating our GPS design. GPS data can be found here, in the format of: day-of-month,month,year,hh:mm:ss,unix_time(s),lat(deg),lon(deg),height-above-ellipsoid(m)

## 5.4 Startracker Failure Analysis

Disappointingly, the star tracker card captured no images from the onboard CMOS sensor during flight. Although the system was tested during pre-flight, we believe a software configuration mistake during pre-flight turned off the Linux daemon that was supposed to have triggered the sensor captures.

## 5.5 OreSat Live Failure Analysis

The OreSat Live system experienced multiple failures.

Even before the integration of the OreSat1B payload onboard HASP, the commercial-off-the-shelf AR9271 WiFi adapters failed during testing. When activated, adapters would overheat and destroy themselves. Failure analysis is ongoing because the initial analysis has failed to come up with an issue. Voltages, currents, and power-up sequencing are all correct; somehow activation of the DxWiFi software (which puts the ICs in a 1Mbps 802.11b mode) is causing the ICs to fail. These failures made testing the DxWiFi part of the OreSat Live system impossible.

The OreSat Live system camera subsystem failed to capture images of the ground using the OreSat Live periscope. Despite lens focus calibration before the flight (as seen in the image below), the images captured from the camera provided no useful data. Lab testing was unable to conclusively determine a cause for this issue, as the system was able to output data after recovery. The inability to capture images likely is due to issues within the Linux software, perhaps again a configuration issue, rather than hardware failure.

***Figure 14.*** *Focus calibration of the OreSat Live Schmidt-Cassegrain telescope before integration in Fort Sumner, NM.*

# 6. Lessons Learned

Throughout the HASP 2021 experience, several lessons were learned in the design and project management process. Over the course of the year-long design and construction process, the value of designing a reasonable timeline became obvious to the team and especially the student lead. The initial payload application outlined the testing of several subsystems, significantly increasing the complexity and time required to design an operational system. Further, the interdependency of the subsystems on each other, and on other student teams that were already behind schedule, meant that many of the delays were out of the hands of the HASP team. The overly ambitious goals and the subsystem dependencies would eventually catch up with the OreSat1B team, as a partially operational payload was delivered to integration in July at Palestine, Texas. Fortunately, the backlog in the design of the system was primarily the lack of software; these issues were resolved before the flight and allowed for a partially successful mission.

After conducting the flight, we realized the mistake of failing to fully utilize the HASP downlink system. While RF testing was an integral aspect of the technology demonstration mission, a backup data and commanding system would have been invaluable to control and verify the status of the payload.

Software configuration was a major failure point for two of our subsystems; this has led us to both automate the configuration, as well as write verified standard operating procedures for configuration.

Despite these “lessons learned”, we are proud that our more important systems performed close to nominally, and that we learned more about system performance than we ever could have in the lab environment.

Students on the team are taking these lessons learned from the HASP 2021 mission to our upcoming CubeSat work in 2022.

## 7. Impact on the OreSat Project

Conducting the OreSat1B mission onboard the 2021 High Altitude Student Platform has been integral to the success of recent (and future) CubeSat missions. Early verification and test of critical hardware, in addition to core software and RF components, will provide the data in a simulated space environment to identify possible failures before deployment in space.

Following the HASP flight in September of 2021, the OreSat0 1U CubeSat was handed off to Spaceflight Inc. for deployment in LEO. Nearly identical hardware that was tested on HASP 2021 is currently onboard the Sherpa Orbital Transfer Vehicle (OTV), including the attitude determination and control system, C3 Flight computer, and Startracker. Software used and tested on the HASP 2021 mission is also currently onboard OreSat0.

Indirectly related to the HASP mission, the OreSat team presented work at the 2021 Open Source CubeSat Developer Workshop (OSCW). The HASP mission has been integral towards progressing the development of the OreSat Bus

## 8. Diversity Overview and Student Impact

Below is a full list of students and faculty involved throughout the entire 2021 HASP program. Most members contributed and were involved in the project throughout the entire year. Several undergraduate students and high school students are expected to graduate in the coming year.

**Students**

| Name | Role | Student Status | Race | Gender | Disabled |
|---|---|---|---|---|---|
| Marvin Lin | Student Lead and Cirrus Flux Camera Lead | High School Student | Asian | Male | No |
| Emma Levy | Mechanical Engineer | Undergraduate Student | White | Female | No |
| David Lay | Electrical Engineer | Undergraduate Student | White | Male | No |
| Nick Lekas | OreSat Live | Undergraduate Student | White | Non-binary | No |
| Oliver Rew | Cirrus Flux Camera software | Graduate Student | White | Male | No |
| Ryan Medick | Software | Undergraduate Student | White | Male | No |
| Cesar Ordaz-Coronel | Electrical Engineer | Undergraduate Student | Hispanic | Male | No |
| Risto Rushford | Project Management | Undergraduate Student | White | Male | No |

**Faculty / Staff / Industry Advisors**

| Name | Role | Role | Race | Gender | Disabled |
|---|---|---|---|---|---|
| Andrew Greenberg | Faculty Advisor | Faculty Advisor | White | Male | No |
| Russell Senior | Ground System and Equipment | Industry Advisor | White | Male | No |
| Glenn LeBrasseur | RF Lead | Industry Advisor | White | Male | No |
| Scott Dixon | Cirrus Flux Camera Electrical | Industry Advisor | White | Male | No |
| Vanderlei Martins, Phd | Cirrus Flux Camera Science | Science Lead / Advisor UMBC | White | Male | No |
| Peter Muller | Cirrus Flux Camera Science | Science Lead / Advisor UCL | White | Male | No |

# References

1. “OreSat 2016 CSLI Application.” Oresat-2016-Csli-Application-r6-PUBLIC.pdf, OreSat, 22 Nov. 2016, https://drive.google.com/file/d/1QoUjCrilEf-NQFVbSDw6-gpnKTVHqN-n/view?usp=sharing.