LSU Solar Eclipse Video Streaming System (VSS) HASP Flight Test Report

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Introduction

On Monday, August 21, 2017, the Earth, Moon, and Sun will be perfectly lined up to result in a total solar eclipse along a narrow path from Oregon to South Carolina. For a brief two minutes, the Sun will be completely covered during the eclipse, only allowing viewers to see its corona and experience an amazing iridescent light show [1]. Often times, observers will attempt to capture images of their experience from Earth's surface. However, the NASA Space Grant 2017 Solar Eclipse Ballooning Project aims to take it further by using balloon-borne payloads to send live video and images of the event from near space to the NASA website. As a part of the collaborative effort, the scientific ballooning group at Louisiana State University (LSU) has taken up testing the High-Definition (HD) video capture and streaming hardware for the project. During this process, the HD video payload was integrated to the High Altitude Student Platform (HASP) to test its performance over long distance streaming and extended durations. This document details the experimental set up and results from the 2016 HASP flight, launched on September 1st 2016 out of Ft. Sumner, New Mexico.

Team Definition

The VSS project team (Team Pleiades) is composed of a multidisciplinary undergraduate group of students at LSU. Several members of the team have participated and successfully passed the Louisiana Aerospace Catalyst Experiences for Students (LaACES) program held at LSU. Since 2013 several members of the team have returned to further attain and refine their experience in scientific ballooning, physics, mechanical design, software design, electronics, payload integration, and project management. Names and basic demographics for the VSS experiment student team members are included in Table 1.

Student Team Demographics							
Name	**Role**	**Degree**	**Gender**	**Classification**	**G.D.**	**Ethnicity**	**Disability**
Jordan Causey	Mechanical Design	ME	M	Junior	Spring 2019	Black	No
Joshua Collins	Electrical Lead	EE	M	Senior	Spring 2017	Caucasian	No
Robert "Bob" Cottingham	Volunteer Member	PHYS	M	Senior	Spring 2017	Caucasian	No
Allen Davis	Mechanical Lead	ME	M	Senior	Spring 2017	Caucasian	No
Victor Fernandez-Kim	Assistant Project Manager	ME	M	Senior	Spring 2017	Hispanic	No
Kyle Hamer	Software Design	PHYS	M	Sophomore	Spring 2019	Caucasian	No
Brad Landry	Primary Contact, HASP Project Manager	PHYS	M	Senior	Spring 2018	Caucasian	No
Adam Majoria	Solar Eclipse Project Manager	PHYS	M	Senior	Spring 2018	Caucasian	No
Connor Mayeux	Software Lead	CSC	M	Sophomore	Spring 2019	Caucasian	No
Samuel Reid	Electrical Design	EE	M	Senior	Fall 2017	Caucasian	No

Table 1: Student Team Demographics

Science and Technical Background

Total Solar Eclipse

The Sun is about 400 times larger than the diameter of the moon, but the moon is about 400 times closer to the Earth than the Sun. As a result, the apparent size of the Sun and the Moon in the sky is the same. During an eclipse these two bodies overlap and the Moon is able to just barely cover the Sun, but not its corona (Figure 1). Due to the tilt in the Moon's orbit, these events are infrequent and can span decades. The next total eclipse will be on April 8, 2024, while the last American total solar eclipse was in 1991, 26 years ago [1].

Figure 1: Total solar eclipse surrounded photographed from a ship in Polynesia, 2009. [1]

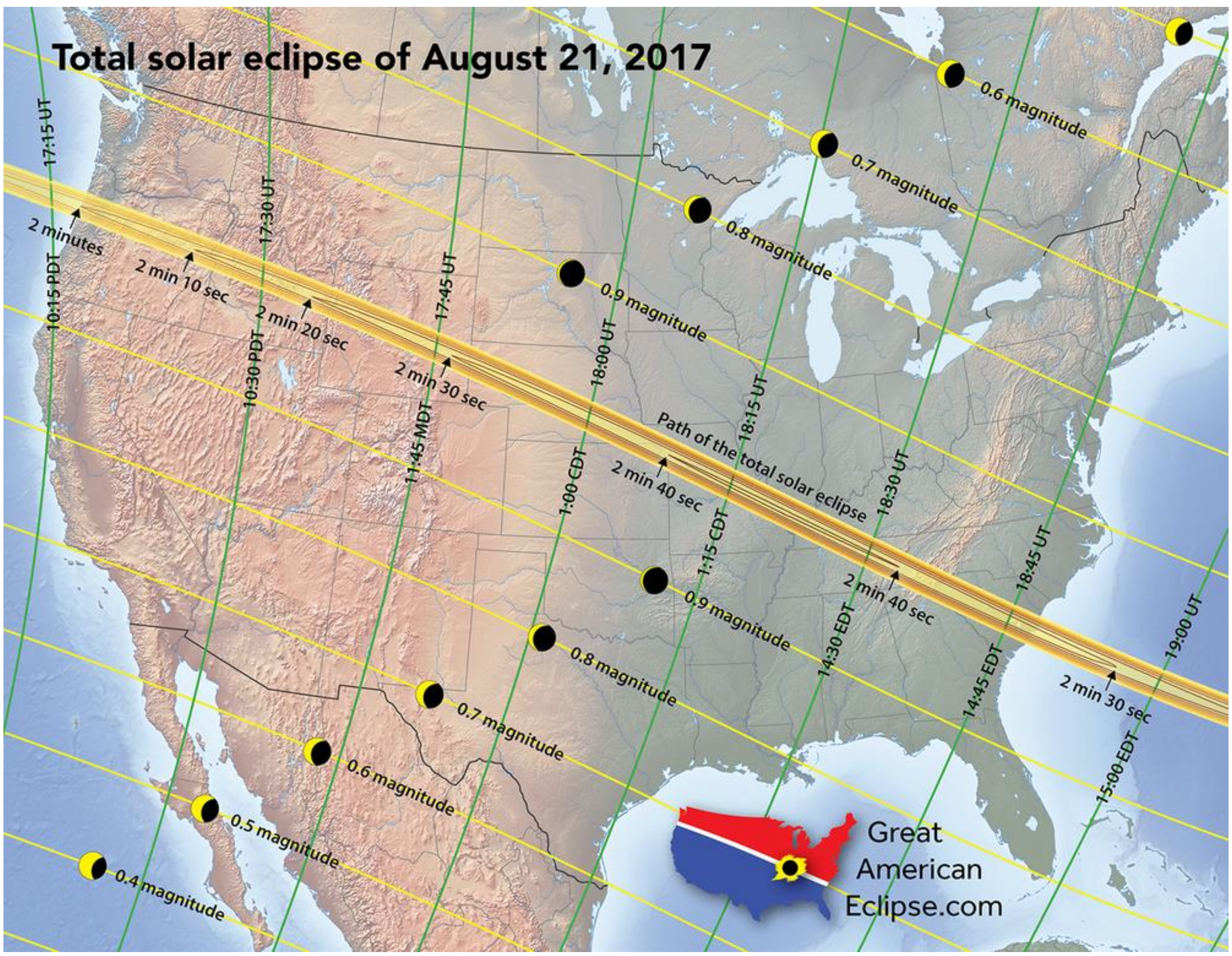


Figure 2: Eclipse Path of Totality. [1]

NASA Space Grant 2017 Solar Eclipse Ballooning (SE17) Project

This project is led by the Montana Space Grant Consortium (MSGC) students and staff and is collaborating with teams at LSU, University of Minnesota (The U of M), Iowa State University (ISU), and the University of Colorado Boulder (CU) to develop the "Common Payload(s)" that will be flown during the total solar eclipse. Starting in January 2016 and through July 2016, workshops were held in Montana State University to get teams involved, refine the Common Payload, and ultimately distribute the system to 65 participating teams from across the country.

The objectives of the SE17 project are:

- Reproducible, low-cost platform that can be distributed across all participants
- Primarily designed and built by students
- Near real-time streaming of video, snapshot images, and position reports from the balloon at altitude
- Uniform operations protocol for flight notification, NOTAM, and position reports used by all participants

The platform developed for the SE17 is made up of five major systems. The video payload and image payload both use a Raspberry Pi (Pi) and camera module to record HD video or images, respectively. The signal from the Pi is then routed to a modem to be transmitted to a paired receiving ground station. To track the position of the payloads, a commercial tracking system is used. Finally, the flight can be terminated through an automated cut-down mechanism. Block diagrams for these systems, created by the MSGC students, are shown in Figures A1 through A5 [2].

Goals and Objectives for HASP

In January 2016, the LSU ballooning team was invited to participate in the first workshop, with the intent to acquaint the team with the payload hardware. Since then, the team returned home with a set of the equipment and began working to conduct reliability tests. As part of this testing process, the video streaming payload was interfaced to HASP as an experiment to test the performance of the system over the extended flight profile. The objectives of this experiment were as follows:

- Verify that the position of the payload string can be tracked through telemetry
- Verify that the payload hardware is able to withstand a high-altitude environment
- Verify that a video stream can be established and maintained throughout the flight profile

Payload Design

Electrical Design

The payload included the standard video streaming payload, an Arduino Mega with attached temperature sensors, and a power board to convert the 30V from HASP to the voltages needed for each of the boards and payloads.

Figure 3: Electrical components within the payload.

The power board was a protoboard with 3 attached regulators that converted the +30V from the HASP interface to +12V and two +5V lines. The +12V line served as a step-down regulator to lower the power requirements on the subsequent converters. The +12V line also supplied power to the Arduino Mega and Micro-Trak Beacon. The +5V lines were used to power the video streaming payload.

The standard video streaming payload included the eclipse power board that took +5V and regulated it to +5V and +12 using boost converters. The 5V line was used to power the attached Raspberry Pi and Pi Camera, while the 12V line was used to power the Ubiquity M5 Modem. The M5 power was delivered through an Ethernet cable.

Figure 4: Cable terminations used for supplying power the M5 (left) and the Micro-Trak (right).

The Arduino Mega had 4 temperature sensors attach to the board and an RS232 converter to communicate with the HASP Interface. However, a flaw in the manufacturing of the temperature sensors connection to the Arduino rendered them useless for duration of the flight.

The M5 and Micro-Trak beacon were powered by cable that exited the payload interior. The M5 was powered through an Ethernet cable ending in a RJ45 connector. The Micro-Trak was powered by a twisted pair of wires terminated in Anderson clips.

Mechanical Design

The external structure of the payload is constructed of aluminum sheets. The payload exterior is painted white, while the inside of the aluminum exterior is polished. There is a cross bracket on the inside of the payload that sections the internals to 4 different sections while connecting the walls structurally and thermally. The payload is mounted using 90⁰ brackets and wing nuts for easy removal of the payload from the HASP plate. The lid is constructed of a foam insert and a metal lid that fits on top of the payload.

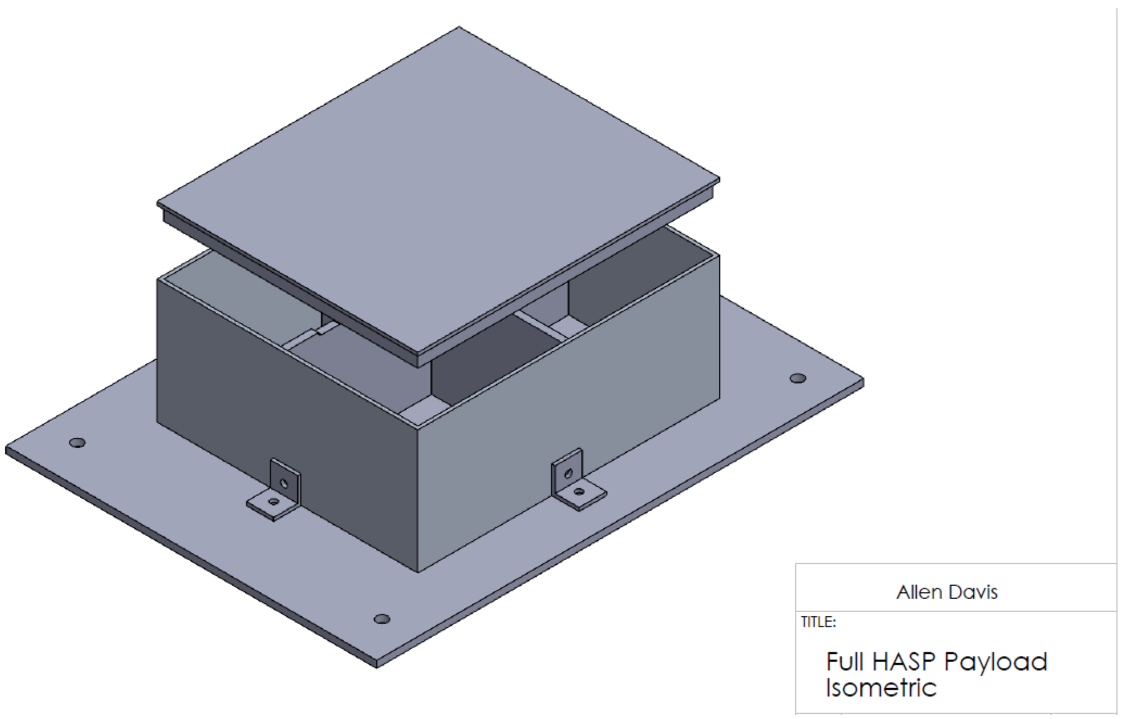
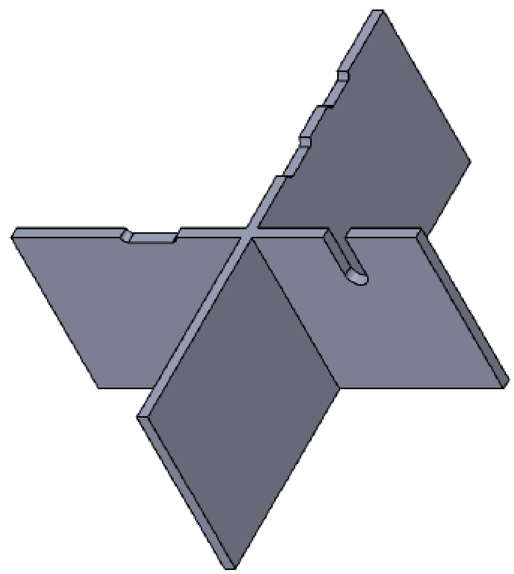


Figure 5: HASP Payload Structure

Thermal

The largest concern for the mechanical structure is heat transfer and regulating the internal temperature of the payload through a cold ascent profile that gradually heats up at float altitude in a near-vacuum altitude. During the ascent, the low temperatures could reduce the functionality of our electronics, particularly the raspberry pi. While at float the near-vacuum environment means that power generated by the electronics and received from solar radiation has nowhere to go, causing overheating of all the electrical components.

After researching previous designs and running preliminary heat transfer calculations, the solution selected was to use white aluminum on the outside of the payload and polished aluminum on the inside. The white aluminum on the outside reflects heat while the polished aluminum on the inside absorbs heat. This facilitates the exterior absorbing heat from the payload internals while reflecting it from the sun, creating a net movement of heat travelling from the payload internals to the payload walls by conduction and radiation. This heat is then emitted by radiation to the surrounding environment through the aluminum, which is still emissive under the white paint. Since the lid will almost always be in the sun, the aluminum lid has a layer of foam underneath it to insulate the payload from the constant solar radiation.



A problem with depending on radiation to cool the payload is that any sides in view of the sun will have a reduced effectiveness for net radiation outward. This means any heat transferred to walls in the view of the sun could simply heat up and not remove the heat as intended. Conjoined with concerns that radiation from the electronics would not remove heat fast enough by itself, the internal cross pictured to the right was installed in the center of the payload.

This internal bracket has cuts to facilitate the wire moving around the payload. This bracket allows for heat to move around the walls of the payload more efficiently, with the net total movement of heat transfer going to the coolest walls, ensuring that all walls are radiating heat outwards. This bracket also allows the internal electronics to connect physically to the thermal structure, increasing the effectiveness of the heat transfer by introducing conduction internally.

The walls and internal bracket were all connected using 90^{o} brackets and thermal paste to ensure that heat transfer was not lost at the connections.

From previous HASP flights, the HASP team is aware that a large risk of overheating occurs at the power regulator for the payload, so this year's design was designed to ensure that would not happen again. The power regulator was connected to the internal bracket using a 90^{o} bracket to introduce conduction between the largest source of heat and the internal bracket. The regulator also has a set of radiation fins as well to further encourage heat transfer.

The quadrant housing the raspberry pi was surrounded on its external sides with foam to ensure the pi did not get too cold during the ascent.

For the actual sizing and wall thickness, heat transfer analysis was run for a steady state situation at the float altitude to ensure that the payload would not heat over time to temperatures above the maximum operating temperature of any of the internal components.

Structural

The structural design for this payload follows from the thermal design, with the walls supporting the structure and the internal bracket supporting the walls. The walls are connected to the haps plate and to each other with 90^{o} brackets. The internal components are also connected to the HASP platform using standoffs. The standoffs connect to the HASP plate by screwing into tapped holes in the HASP plate. The wires are secured in the payload using zip ties connected to the internal bracket.

The video camera is situated in a custom 3-D printed mount. This mount features a two-part case for the camera and a front plate. The front plate mounts on the exterior of the payload, with bolts connecting it to the camera on the inside. Holes are drilled in the aluminum wall for the bolt holes and the aperture for the video camera. The video camera pieces are shown below:

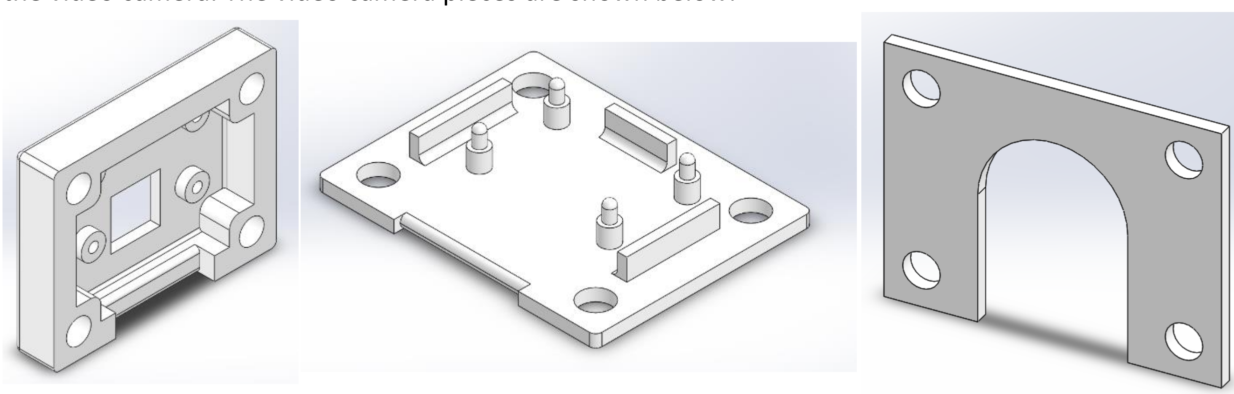


Figure 6: 3D Printed Camera Module Case

Ground Station

The ground station developed by MSU included components necessary for both the image and video payload systems. This was simplified by the LSU team to just have the components necessary to track and receive the video payload signal. Additionally, the LSU ground station is set to track APRS packets as opposed to the original Iridium packets. During HASP flight operations, this portable ground station was set up to test its tracking capabilities. Additionally, a second ground station was mounted to CSBF's tracking system to provide a control. This set-up is described in detail in the HASP Flight Operations Section of this report.

Figure 7: The portable ground station at LSU

HASP Flight Integration

Three members of Team Pleiades, Joshua Collins, Allen Davis, and Brad Landry participated in HASP Flight Integration at NASA's Columbia Scientific Balloon Facility in Palestine, Texas from July 31st to August 5th 2016. During integration, tests were performed in order to verify student payload compatibility with HASP and survivability in a near space environment.

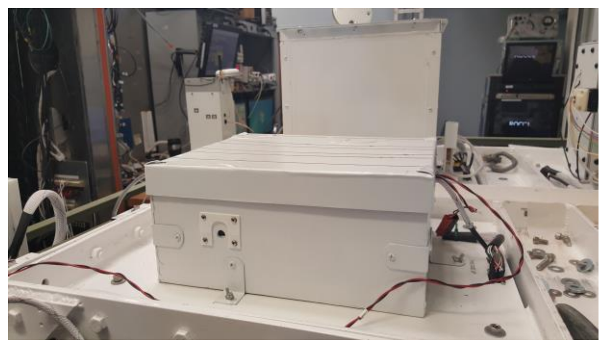


Figure 8: The VSS mounted to HASP at integration

The VSS was successfully integrated to HASP on Monday, July 31st after integration tests were performed. These tests involved verifying payload communication and making sure that the payload did not exceed HASP's maximum current draw or weight limit.

Two thermal vacuum tests were performed in CSBF's BEMCO Thermal Vacuum chamber. The purpose of these tests was to confirm the functionality of the HASP vehicle and the student payloads in a near space environment. The BEMCO chamber exposes the student payloads to extreme temperatures, both cold and hot while at low pressure to mimic the HASP flight profile.

The first thermal vacuum test took place on Wednesday August 2nd 2016. For this test the VSS main payload was in its normal flight configuration in large payload slot 12. The Ubiquiti modem was inside an enclosure on a small payload plate, and the APRS beacon was in its enclosure underneath the HASP vehicle. For this test video was streamed from the payload inside of the chamber and was received at a temporary ground station outside of the chamber. APRS packets were also broadcast from the beacon inside the chamber and were received using a handheld HAM radio outside of the chamber. Before the test began the VSS was powered on and all systems were operating nominally. The video stream and APRS packets were being received at the ground station. About one hour into the test, the VSS payload was powered off in order to test if another student payload was being affected by the RF emissions coming from the VSS. After it was determined that the RF emissions were not interfering with the other payload, the VSS was powered back on. Once the VSS was powered back on though, a video stream was not able to be established, but APRS packets were being received. A video stream was not established again until the heating cycle of the test began. The system then operated nominally until late in the heating cycle when there were more issues maintaining a stream.

The reason why the video stream was initially lost was because the internal temperature of the payload dropped below the minimum operating temperature of the Raspberry Pi. This would not normally be an issue, but since the payload was powered off, heat was no longer being generated inside of the payload and the internal temperature dropped too low. In order to mitigate this issue, thermal insulation in the form of polystyrene foam was added to the interior walls of the Raspberry Pi compartment of the payload.

Upon inspection of the Ubiquiti modem after the thermal vacuum test, it was found that the interior of the Ubiquiti enclosure was hot to the touch. It was possible that the maximum operating temperature of the Ubiquiti was exceeded during the hot cycle of the test. In order to mitigate this issue, the Ubiquiti modem was removed from its enclosure and moved to the lower portion of the HASP vehicle.

The second thermal vacuum test took place on Friday August 4th 2016. For this test the VSS was in the same configuration as the first test, with the exceptions being the extra insulation on the Raspberry Pi compartment and the Ubiquiti was placed inside of the lower bay of the HASP vehicle without an enclosure. Throughout the test, video and APRS packets were received at the ground station. The video stream was lost a few times during the test, but it was reestablished soon after it was lost each time.

At the conclusion of integration, the VSS was shipped directly to Ft. Sumner, New Mexico.

HASP Flight Operations

One member of Team Pleiades, Brad Landry, attended and participated in HASP Flight Operations in Ft. Sumner, New Mexico. Before mounting the VSS to HASP it was tested to ensure that all systems were operational. There were issues with the VSS's onboard temperature sensor system. After all attempts at repairing the system failed, the temperature system was replaced with four temperature sensors from the HASP system. After this was resolved the VSS was mounted to the HASP flight vehicle. For flight, the APRS beacon payload was secured to the lower level of the CSBF flight platform and the Ubiquiti payload was suspended below the flight platform (Figure 11). The APRS beacon's antennae was dangled below the CSBF flight platform.

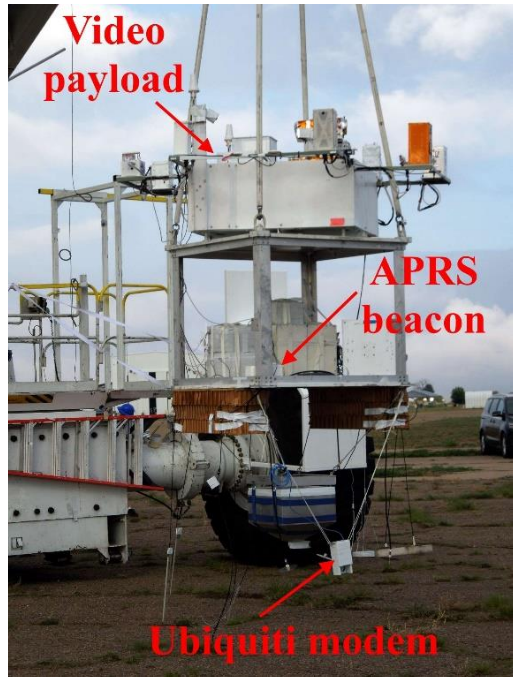
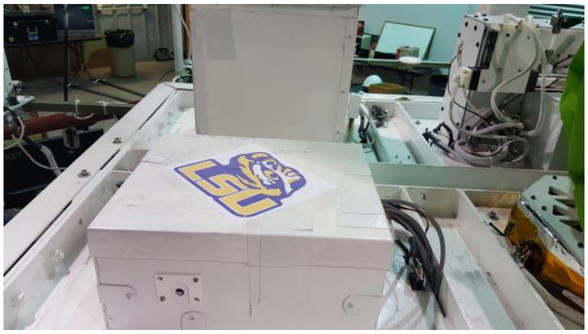


Figure 9: The locations of the VSS, APRS beacon and Ubiquiti on HASP. [3]

During HASP flight operations, a Ubiquiti modem and dish were mounted to the CSBF tracking station that was used to track HASP throughout its flight. This was done in order to ensure that the video stream could be received from the payload for as long as possible.

After three scrubbed launch attempts, HASP was launched at 10:08 AM MDT on September, 1st 2016 from the Ft. Sumner Municipal Airport in Ft. Sumner, New Mexico. Brad had to leave immediately after the launch of HASP to catch a flight, so the ground station was monitored by HASP management for the duration of the flight.

Figure 10: HASP on September 1st 2016 the morning of flight.

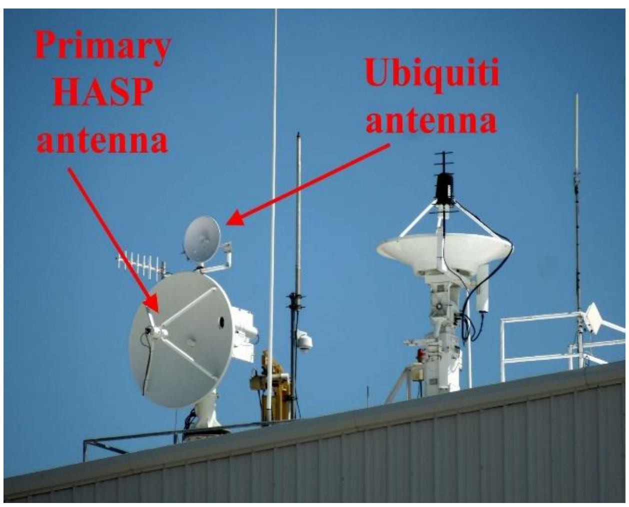


(a)

(b)

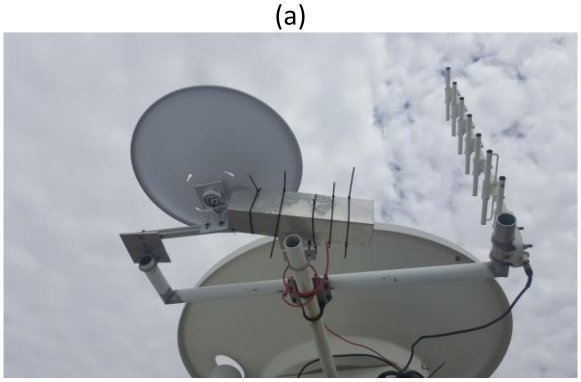
(c)

Figure 11: a) The VSS, b) APRS Beacon, and c) Ubiquiti payload



(a)

(b)



(c)

Figure 12: a) The Ubiquiti dish mounted to the CSBF tracking system. [3] b) Mounting the dish with the assistance of Bobby. c) Close up view of the mounted dish.

Results and Analysis

Throughout the flight, the video stream was lost several times, but was usually recovered soon after it was lost. A screenshot of the video received from the payload can be seen in Figure 13. The video stream was last received at 1:17 PM (3 hours and 9 minutes after launch) when the payload was at an altitude of 122,946 feet and 56.5 miles away from the receiver. Table 2 details every time that the stream was lost and regained from the beginning of the flight at 10:08 AM to 1:17 PM when the stream was last received. For each event, the table includes the time, latitude, longitude, and altitude at which it occurred. The table also includes the distance over ground and the true distance of the payload to the receiver. Towards the end of the flight, the bit rate and resolution settings of the stream were lowered to 700kbps and 1366x705. After this change was made, the stream performed better before moving out of range. Throughout the duration of the flight, the video stream was lost a total of 25 times. The stream was reconnected to successfully each time until the stream was lost for the last time at 1:17 PM.

Figure 13: A screenshot of the video received from the payload.

Time (MDT)	Event	Lattitude	Longitude	Altitude (ft.)	Distance over ground (mi)	True Distance (mi)
10:08 AM	Payload Launch	34.473162 N	104.242232 W	4160	0	0.78787904
10:14 AM	Connection to Stream Lost	34.491699 N	104.218956 W	10157	1.84	2.661977641
10:16 AM	Reconnected to Stream	34.490555 N	104.221916 W	12398	1.67	2.881406879
10:35 AM	Connection to Stream Lost	34.449932 N	104.208496 W	31292	2.5	6.432231675
10:45 AM	Reconnected to Stream	34.418663 N	104.156342 W	41630	6.18	10.01784918
10:48 AM	Connection to Stream Lost	34.41098 N	104.136909 W	44701	7.39	11.23774752
10:55 AM	Reconnected to Stream	34.395813 N	104.104973 W	51299	9.48	13.57444915
11:37 AM	Connection to Stream Lost	34.396278 N	104.253021 W	79921	5.34	16.05088734
11:38 AM	Reconnected to Stream	34.3974 N	104.261292 W	80711	5.33	16.18876686
11:44 AM	Connection to Stream Lost	34.405132 N	104.314255 W	85603	6.24	17.37207718
11:44 AM	Reconnected to Stream	34.405888 N	104.323204 W	86354	6.55	17.61778131
11:45 AM	Connection to Stream Lost	34.406143 N	104.332108 W	87021	6.91	17.87120241
11:46 AM	Reconnected to Stream	34.40736 N	104.340294 W	87608	7.21	18.09123596
11:52 AM	Connection to Stream Lost	34.417469 N	104.394608 W	91105	9.51	19.70193303
11:52 AM	Reconnected to Stream	34.417133 N	104.40033 W	91601	9.82	19.93512204
11:54 AM	Connection to Stream Lost	34.418758 N	104.417366 W	93080	10.68	20.61156862
11:54	Reconnected to Stream	34.420284 N	104.42244 W	93615	10.92	20.82314892
11:57 AM	Connection to Stream Lost	34.426708 N	104.444427 W	95561	11.98	21.70443777
11:57 AM	Reconnected to Stream	34.428139 N	104.449478 W	95980	12.23	21.90921946
11:59 AM	Connection to Stream Lost	34.43328 N	104.46241 W	97319	12.87	22.48025928
11:59 AM	Reconnected to Stream	34.434402 N	104.464684 W	97555	12.98	22.57997414
12:01 PM	Connection to Stream Lost	34.438629 N	104.478241 W	98887	13.68	23.19273649
12:03 PM	Reconnected to Stream	34.442635 N	104.495636 W	99983	14.62	23.92327997
12:04 PM	Connection to Stream Lost	34.444401 N	104.505463 W	100830	15.16	24.38248588
12:04 PM	Reconnected to Stream	34.445023 N	104.50927 W	101145	15.37	24.56011093
12:06 PM	Connection to Stream Lost	34.446827 N	104.525238 W	102552	16.26	25.33041998
12:07 PM	Reconnected to Stream	34.447525 N	104.533913 W	103421	16.75	25.77257229
12:11 PM	Connection to Stream Lost	34.448647 N	104.568619 W	106866	18.71	27.56288741
12:11 PM	Reconnected to Stream	34.449219 N	104.571335 W	107198	18.86	27.71096394
12:14 PM	Connection to Stream Lost	34.451454 N	104.58786 W	109484	19.79	28.66373552
12:22 PM	Reconnected to Stream	34.472301 N	104.654236 W	115967	23.52	32.1804865
12:23 PM	Connection to Stream Lost	34.478615 N	104.660828 W	117112	23.9	32.60638216
12:25 PM	Reconnected to Stream	34.487236 N	104.673744 W	118917	24.65	33.38967617
12:25 PM	Connection to Stream Lost	34.487831 N	104.675651 W	119032	24.76	33.4856257
12:27 PM	Reconnected to Stream	34.489944 N	104.691711 W	119908	25.68	34.28118942
12:29 PM	Connection to Stream Lost	34.487701 N	104.703629 W	121276	26.36	34.96315367
12:32 PM	Reconnected to Stream	34.480389 N	104.737152 W	122982	28.26	36.6216784
12:33 PM	Connection to Stream Lost	34.478676 N	104.74054 W	122772	28.45	36.74331277
12:33 PM	Reconnected to Stream	34.477932 N	104.74218 W	122664	28.54	36.80012665
12:45 PM	Connection to Stream Lost	34.446377 N	104.847351 W	122395	34.59	41.63917908
12:45 PM	Reconnected to Stream/Aspect Ratio change	34.445992 N	104.849907 W	122506	34.75	41.78385725
12:47 PM	Connection to Stream Lost	34.440685 N	104.863548 W	123362	35.55	42.54033443
12:49 PM	Reconnected to Stream	34.432201 N	104.877693 W	122933	36.39	43.20092129
12:56 PM	Connection to Stream Lost	34.418774 N	104.937897 W	123133	39.9	46.21539551
12:56	Reconnected to Stream	34.415539 N	104.947889 W	123156	40.49	46.72789395
1:04 PM	Connection to Stream Lost	34.397053 N	105.00795 W	123021	44.04	49.82354334
1:05 PM	Reconnected to Stream	34.394714 N	105.018051 W	122952	44.64	50.34863135
1:09 PM	Connection to Stream Lost	34.388226 N	105.048706 W	123041	46.43	51.94983442
1:12 PM	Reconnected to Stream	34.380241 N	105.087219 W	123074	48.69	53.98192128
1:14 PM	Connection to Stream Lost	34.376007 N	105.104378 W	122910	49.7	54.88146023
1:16 PM	Reconnected to Stream	34.371178 N	105.124664 W	122874	50.98	56.04041122
1:17 PM	Connection to Stream Lost	34.368767` N	105.134674 W	122946	51.48	56.50126154

Table 2: Log of Events During Flight.

Conclusions

The HASP test flight of the VSS payload successfully demonstrated the capability of the VSS to transmit video streams over long distances. A video stream was received from the VSS up to 56.5 miles away, with several interruptions to the stream throughout the flight. This range of 56.5 miles was by far the longest range achieved in all testing of the solar eclipse HD video system. Currently LSU is planning to perform more test flights and is working on a modified ground station in order to prepare for the 2017 Solar Eclipse.

References

[1] Great American Eclipse. [Online]. Available: https://www.greatamericaneclipse.com/

[2] Larimer, R.M. (2016). "MSGC BOREALIS and the NASA Space Grant 2017 Eclipse Ballooning Project" [PowerPoint Slides].

[3] T. Gregory Guzik (2016). "The Louisiana Solar Eclipse Project or What Did I Get Myself Into?" [PowerPoint Slides].

Appendix

MSU Block Diagrams

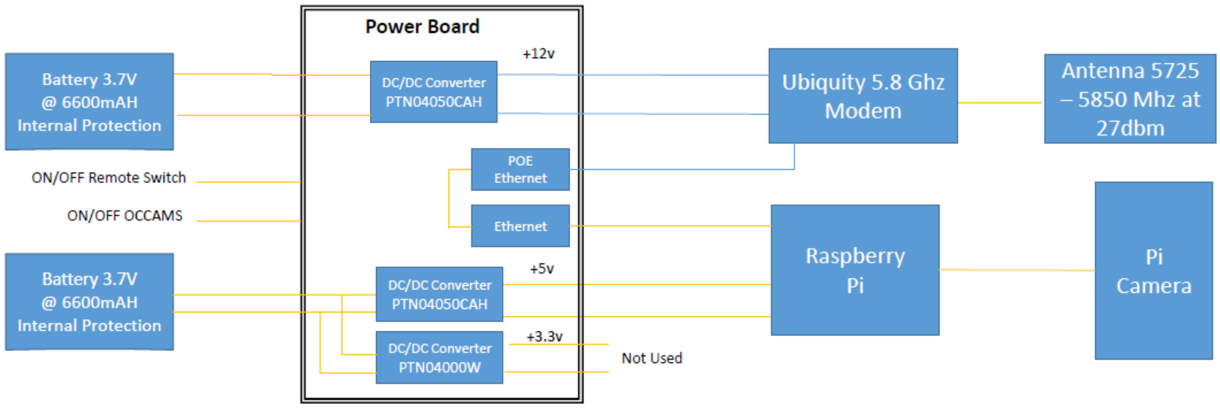


Figure A1: Basic Video Streaming Payload Block Diagram

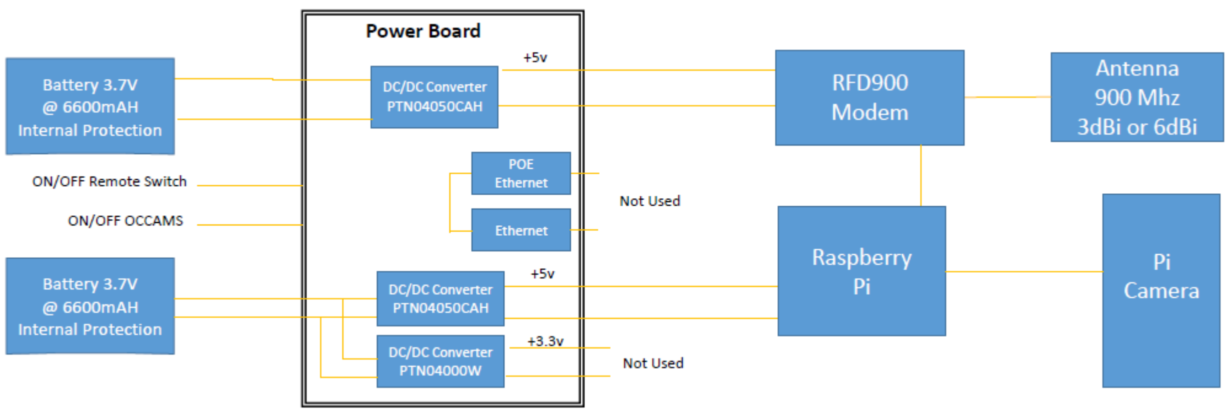


Figure A2: Basic Image Capture Payload Block Diagram

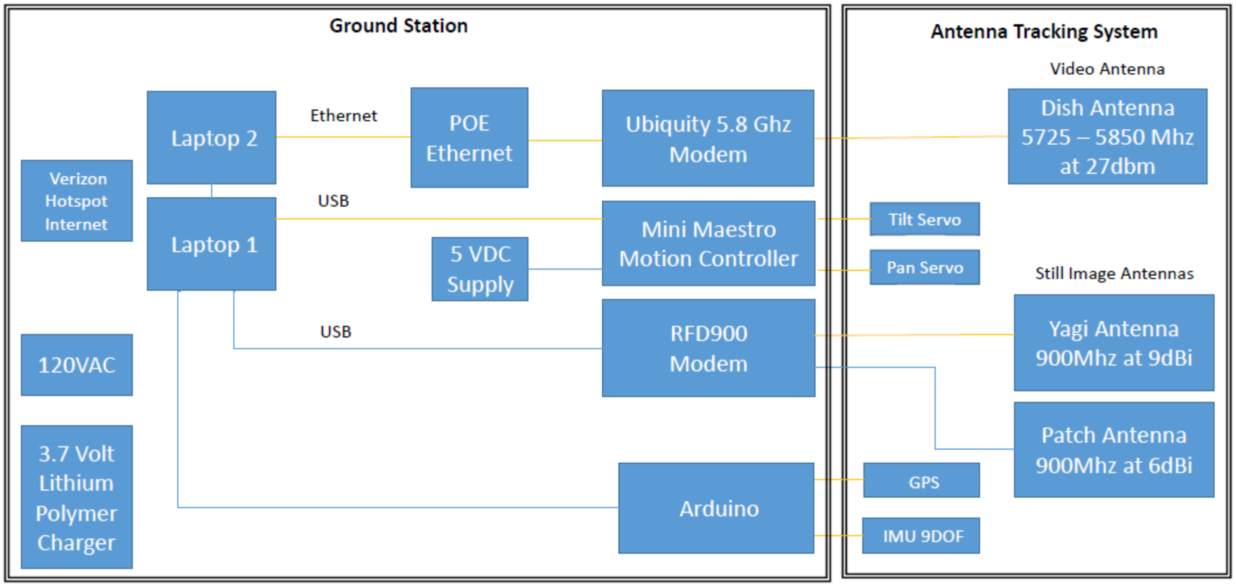


Figure A3: Ground Station Block Diagram

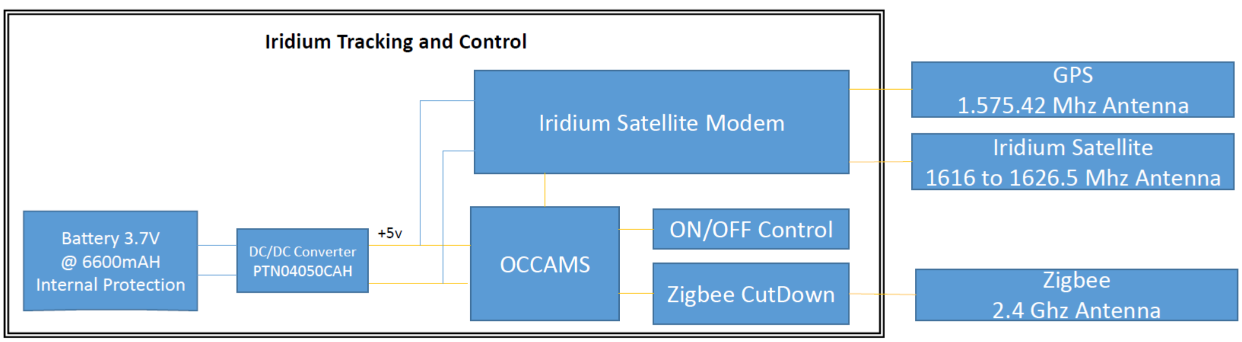


Figure A4: Iridium Tracking and Control Block Diagram

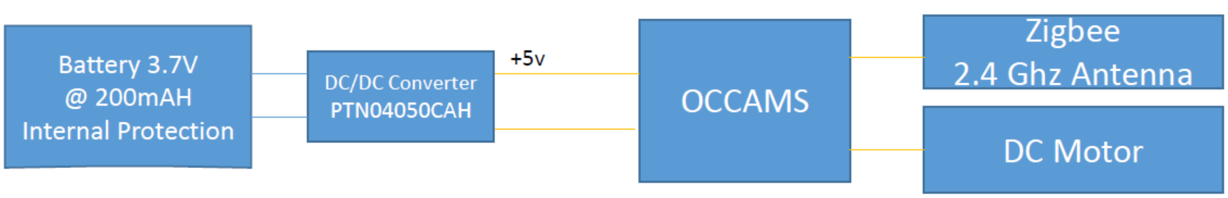
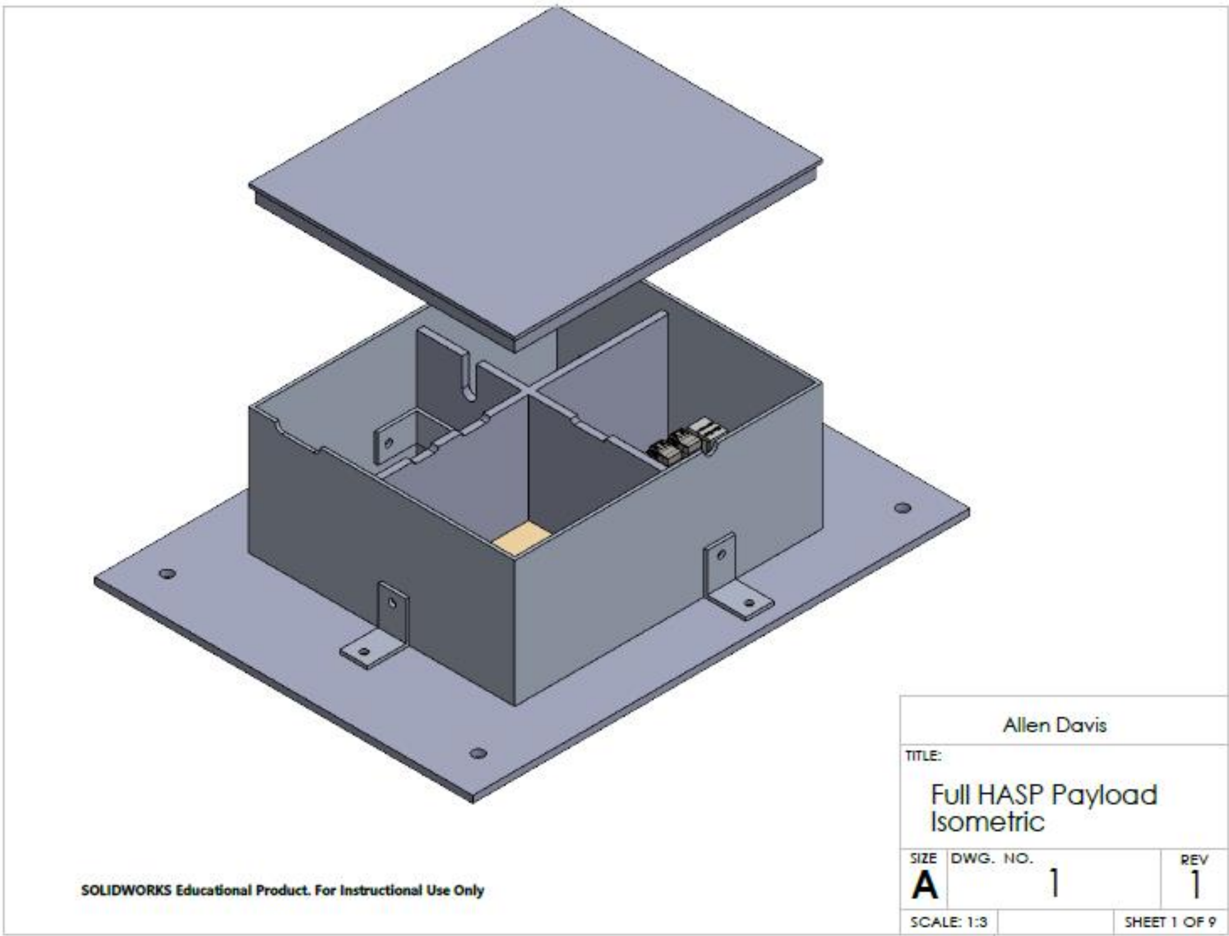
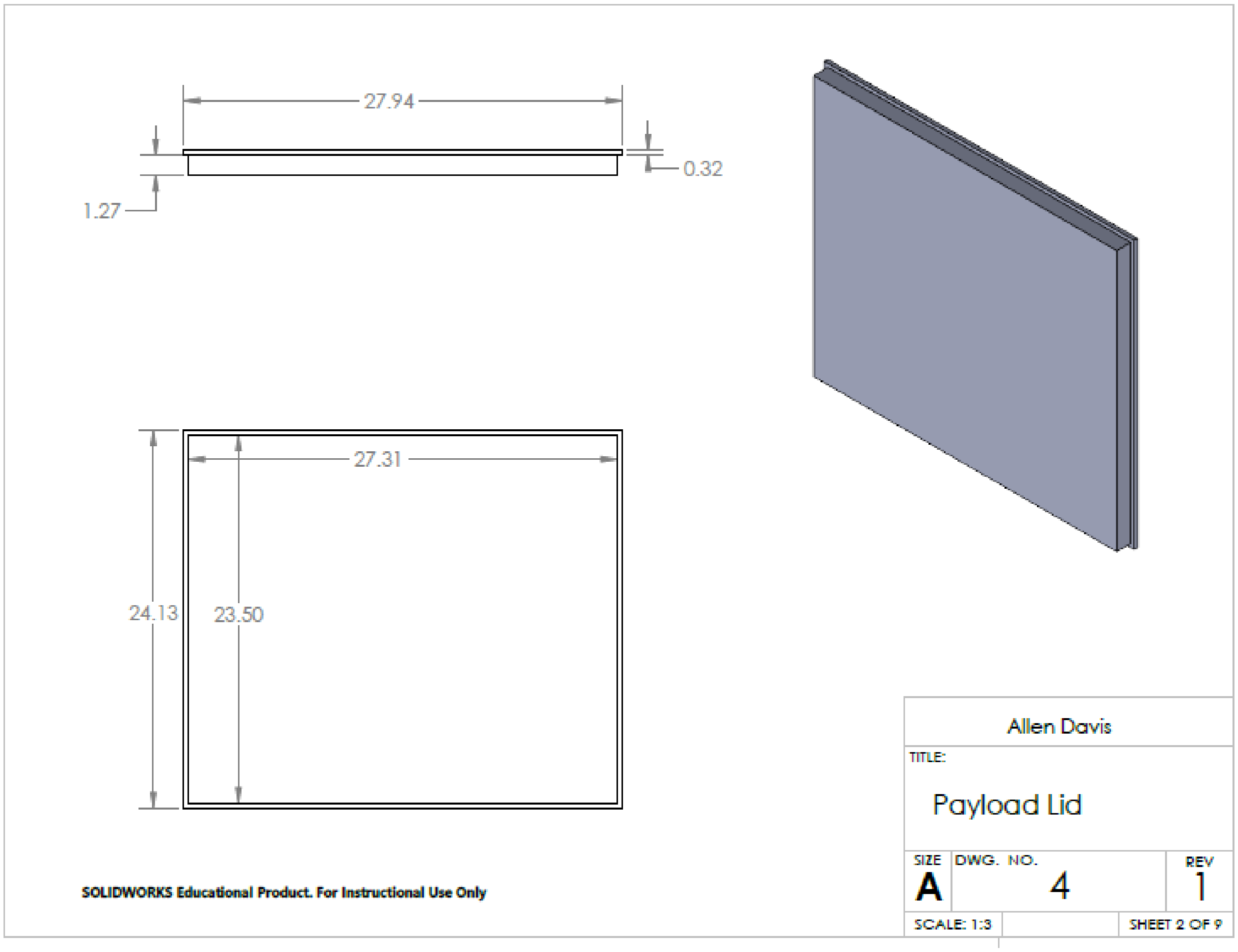


Figure A5: Termination System Block Diagram

Mechanical Manufacturing Drawings

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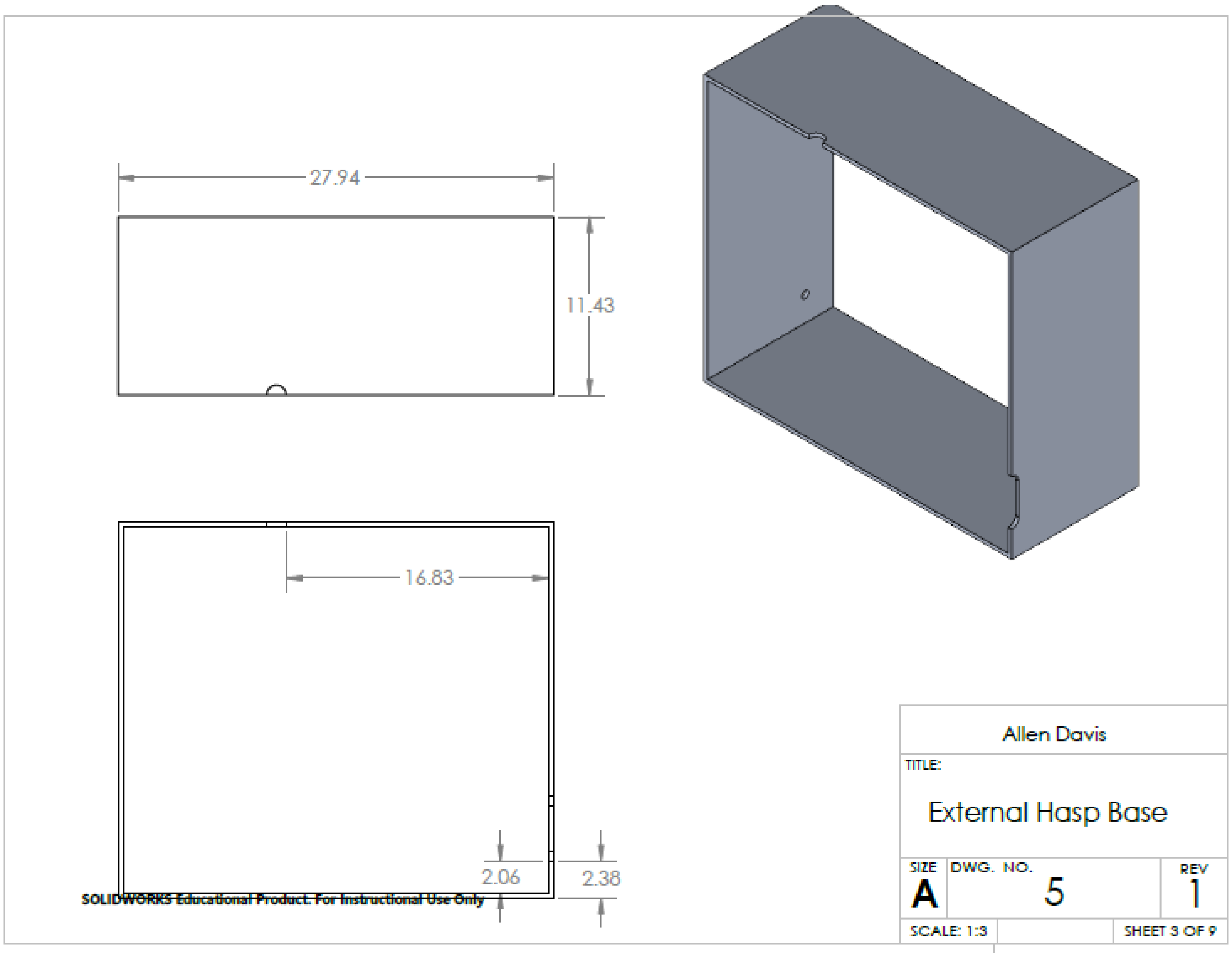
0.32
1.27
27.31
24.13
23.50
SOLIDWORKS Educational Product. For Instructional Use Only
Allen Davis
TITLE:
Payload Lid
SIZE
A
DWG. NO.
4
REV
1
SCALE: 1:3
SHEET 2 OF 9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11.43
16.83
2.06
2.38
SOLIDWORKS Educational Product. For Instructional Use Only
Allen Davis
TITLE:
External Hasp Base
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5
REV
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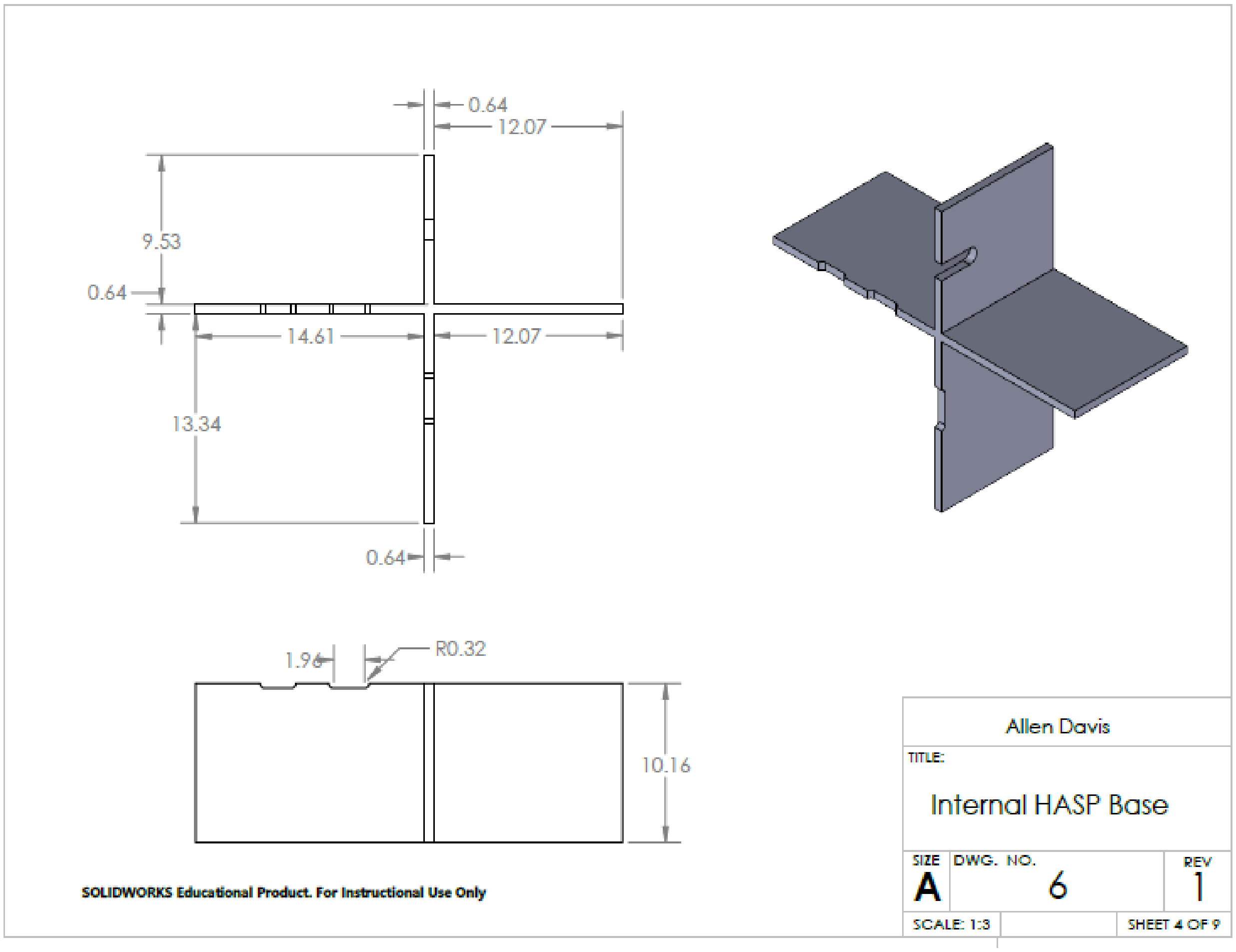
SHEET 3 OF 9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12.07
9.53
0.64
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12.07
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0.64
1.96
R0.32
10.16
SOLIDWORKS Educational Product. For Instructional Use Only
Allen Davis
TITLE:
Internal HASP Base
SIZE
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DWG. NO.
6
REV
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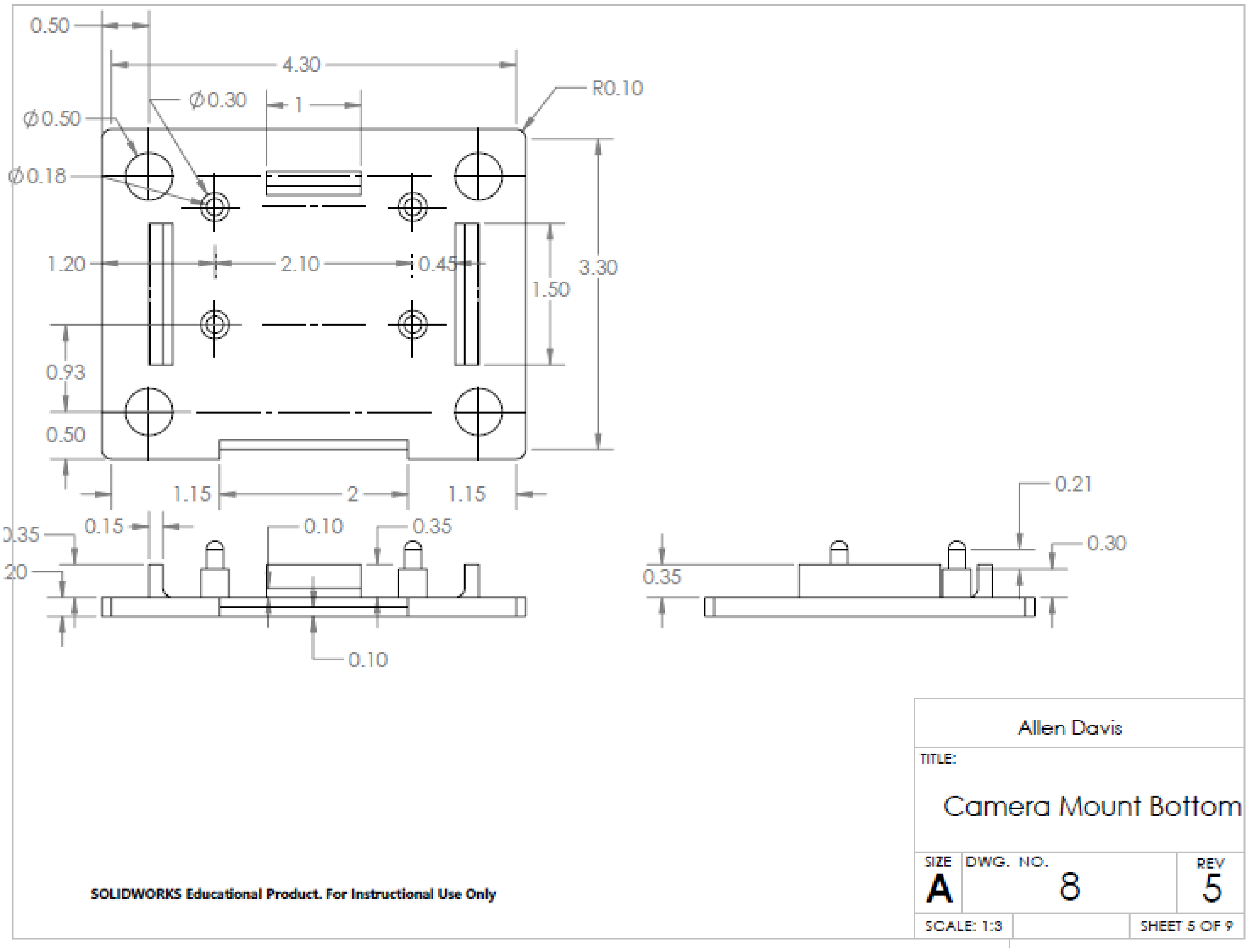
SCALE: 1:3
SHEET 4 OF 9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1.50
0.93
0.50
1.15
2
1.15
0.35
0.15
0.10
0.35
20
0.10
0.21
0.30
0.35
Allen Davis
TITLE:
Camera Mount Bottom
SIZE
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8
REV
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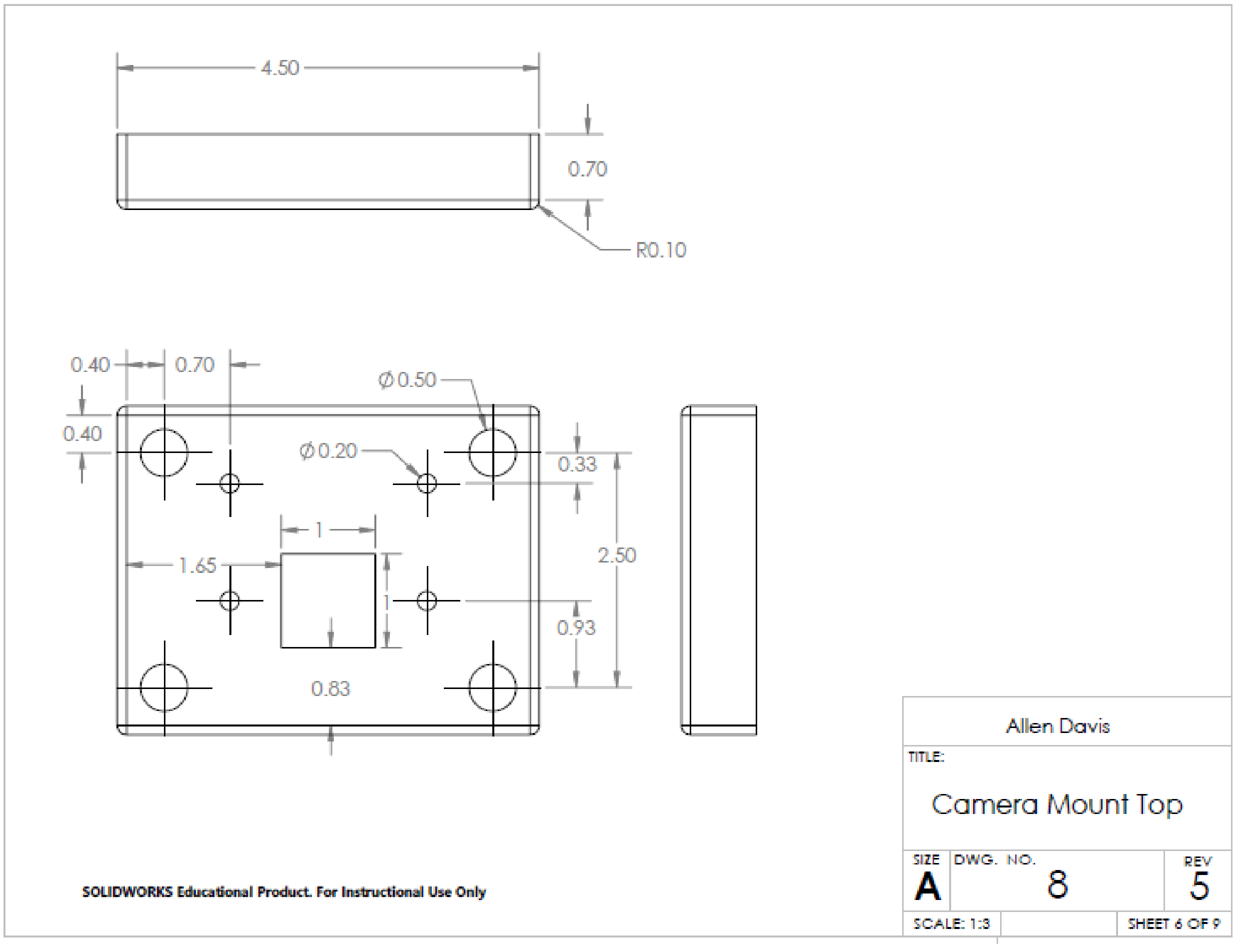
SCALE: 1:3
SHEET 5 OF 9
SOLIDWORKS Educational Product. For Instructional Use Only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0.70
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Ø0.20
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1
2.50
1.65
1
0.93
0.83
Allen Davis
TITLE:
Camera Mount Top
SIZE
A
DWG. NO.
8
REV
5
SCALE: 1:3
SHEET 6 OF 9
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