HASP Student Payload Application for 2015

Payload Title: Solar Ultraviolet Radiation Measurement Apparatus II (SURMA II)			
Payload Class: (check one) ☐Small ☒Large	Institution: Louisiana State University		Submit Date: December 18, 2015

Project Abstract

The goal of the Solar Ultraviolet Radiation Measurement Apparatus II payload is to measure UVA, UVB, and UVC irradiance as a function of altitude, with emphasis on the transmission of UV radiation above the stratosphere. Pre-SURMA Louisiana State University UV measurement payloads featured fixed pointing angles. However, due to rotation of the HASP gondola, the sensors observed solar UV flux at non-optimum angles. SURMA included UVA, UVB, UVC, and broadband UV measurement photodiodes, data acquisition systems, and a solar tracking system. The solar tracking system was a marked improvement for UV data acquisition, but the payload experienced a number of issues outlined in the SURMA Science Report that could be resolved with a modified and improved design and more extensive calibrations and testing before flight.

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Table of Contents

List of Figures:

List of Tables:

1.0 Payload Background and Objectives

SURMA II is a continuation of SURMA, a payload designed for interfacing on High Altitude Student Platform (HASP) and operating in sunlight. Staging operations on the HASP provided SURMA three significant benefits. First, HASP flies to an altitude of roughly 36 km (above the majority of the ozone layer). This allows the payload to be exposed to the UVC-band radiation. Second, the gondola remains at float altitude for several hours, allowing the project to obtain accurate upper-altitude UV measurements by averaging many data points over the duration of the float. Finally, the HASP gondola remains fairly stable throughout the flight profile, with no significant change in elevation angle and only small degrees of azimuthal rotation. For these reasons, the motion of the Sun across the sky with respect to the payload is slow and simplified the requirements for solar-tracking and UV data collection.

The payload and flight data were analyzed for errors, leading possible improvements for more consistent data and better calibrations concerning the system. As outlined in the SURMA science report, more pre-flight calibrations combined with an improved design to reduce errors would result in more accurate and consistent data.

1.1 Scientific Background

Ultraviolet radiation is light with a wavelength from 100 to 400 nm. It lies between the visible light spectrum and X-Rays. Its spectrum is broken down into three 'bands': The UVA band ranges from 320-400 nm, the UVB band ranges from 280-320 nm, and the UVC band ranges from 100-280 nm. As shown below, each band is transmitted differently through the atmosphere.

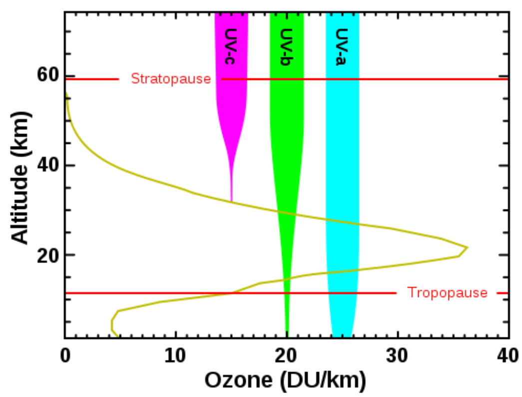

Figure 1: Depiction of UV transmission through the atmosphere, which indicates different behavior of the UV band transmissions.

UVA is the lowest energy band and is slightly absorbed by the atmosphere, as seen in Figure 1. Due to its low energy, it has negligible effects on organic material. UVB has a higher energy than UVA but experiences significant attenuation as it passes through the ozone layer. Extended exposure to UVB causes sunburns and some genetic damage. UVC is the highest energy UV band and is completely absorbed by the ozone layer. No UVC is present below ~30 km altitude.

Exposure to UVC rapidly burns the skin and causes significant genetic damage. Because of this, UVC is used as a sterilizer in labs, restaurants, and wastewater treatment facilities. Due to the destructive properties of UV radiation, many materials are subject to weaken under heavy or extended exposure. This effect is more observable above the ozone layer, but does occur at ground level (over the duration of several months/years). The degradation causes fading/discoloration as well as loss of mechanical integrity [2]. Therefore the study of UV absorption in the atmosphere is useful for further understanding of Earth's atmosphere and could improve efforts for long-duration high-altitude missions.

There are two ways to quantify the amount of UV power incident through a given area: irradiance and spectral irradiance. Spectral irradiance is the amount of radiation power of a given frequency contained in a given area (units of $W \cdot m^{-2} \cdot Hz^{-1}$). Irradiance is the integral of spectral irradiance with respect to frequency (units of W/m^2). Irradiance is an important metric to achieving this goal. As UV radiation passes through the atmosphere, the energy contained within UV-band photons is absorbed by atmospheric matter (specifically ozone), causing a decrease in the total transmitted radiation power. Because irradiance is a direct measure of the total radiation power, changes in UV irradiance directly measure the absorption of UV in the atmosphere.

In 2011, LSU's SMITH payload was launched to sample the upper atmosphere for microbial life. With an interest in understanding the germicidal effects of UV irradiance on upper altitude microbes, SMITH was also equipped to measure UV irradiance in the atmosphere. However, due to inconclusive data, the exact irradiance could not be determined.

1.2 Expected Results

Team Pleiades conducted a literature review and were unable to find published results of directly measured UV irradiance values in the atmosphere. In order to determine expected results, the team will draw on two UV measurement and simulation platforms:

SMARTS: Developed by the National Renewable Energy Laboratory, this program simulates the transmission of UV radiation through the atmosphere. It is capable of calculating expected direct-incidence irradiance values for the UVA + UVB bands on a wide range of atmospheric conditions (i.e. pressure, humidity) at almost given altitude.

Ultraviolet Radiation in the Upper Atmosphere (URUA): This 2011 HASP payload was developed in conjunction with SMITH. The payload measured UVA, UVB, UVC, and broadband UV irradiance through the entire HASP flight profile. However, the results are sub-optimal. The payload sensors were mounted at a fixed angle, thus were subject to the rotational motion of the HASP gondola and the Sun's movement across the sky.

The measurements from URUA were cross-correlated with the simulated values from SMARTS. The two data sources matched fairly well in terms of magnitude of direct-incidence UV irradiance for the UVA and UVB bands. SMARTS is unable to simulate the UVC band. Despite the motion of URUA, it observed UVC irradiance above 30 km altitude. Taking into account off-nominal sensor angles, URUA provides us with a reasonable expected irradiance curve for the UVC band.

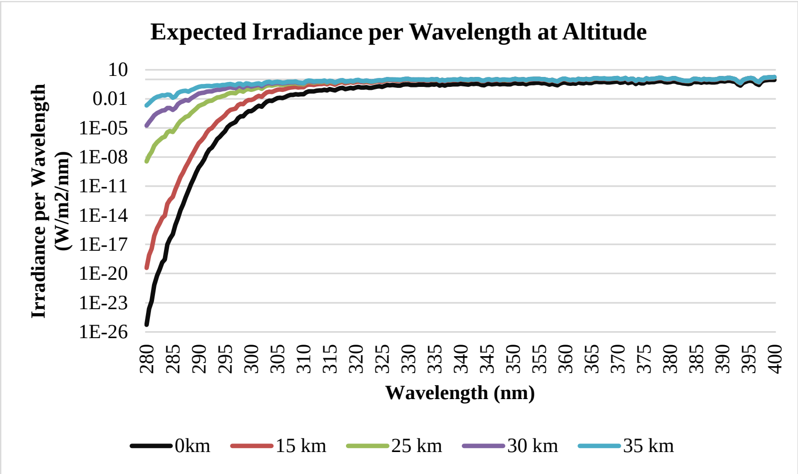

Figure 2:
Irradiance results calculated for 0, 15, 25, 30, and 35 km. Note that the magnitude of UVB-band wavelengths are dramatically affected by the atmosphere at different altitudes. The magnitude of UVA-band wavelengths remain fairly constant through the flight profile. Data computed using SMARTS.

Using this data, the team was able to calculate the expected irradiance per UV band by integrating the individual curves across each UV band. Computing these integrals yields the following values:

Band	**0 km**	**15 km**	**25 km**	**30 km**	**35 km**
UVB	0.046	0.236	0.548	0.807	1.123
UVA	3.361	7.521	8.251	8.407	8.488

Table 1: Computed per-band irradiance (W/m^2) at Specified Altitudes

Per-band irradiance values are important because UV photodiodes are sensitive to wide ranges of input wavelengths, so these values represent actual expected sensor outputs at each altitude. Taking the difference between each consecutive altitude measurement and dividing it by two yields the minimum required UV sensor accuracies for each band and altitude, which can be found in the fourth level payload requirements.

Expected UVC band irradiance values are obtained from the URUA payload, shown below.

Band	**0 km**	**15 km**	**25 km**	**30 km**	**35 km**
UVC	-	-	-	0.001	0.005

Table 2: Measured UVC irradiance (W/m2) at Specified Altitudes

UVC is completely absorbed by the ozone layer. URUA was only able to detect UVC above 30 km. The team expects to see similar UVC readings on this payload.

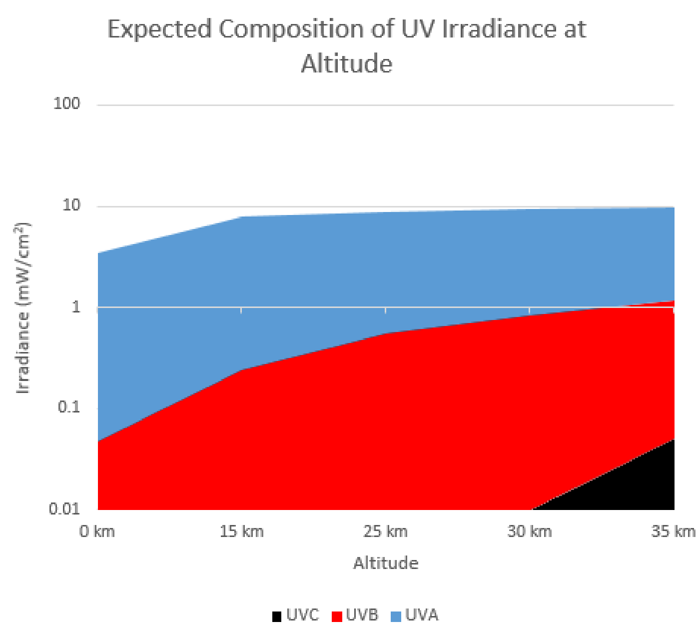

Figure 3:
Expected irradiance per UV band. Note the emergence of UVC (black) at 30 km altitude. UVA (blue) and UVB (red) are present through the entire flight profile, although UVA has significantly higher flux in the same measurement area. (Source data from SMARTS simulations and URUA payload measurements.)

1.3 Mission Traceability

The goal for the SURMA II experiment was to model the absorption of UV radiation by the atmosphere by measuring UV irradiance flux on a HASP balloon flight profile. Therefore, the objectives and requirements shown in **Appendix B** were generated to provide the foundation for the SURMA mission implementation and instrumentation. While the goals and objectives of the flight have not changed, the shortfalls and issues with SURMA shall be addressed and the overall design will be improved based on these failures.

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1.4 Issues Warranting Improvements on SURMA

The thermal insulation kept the internals of the payload warm enough, but as the flight went on the inside would get too hot, causing the power regulator to shut off. The solution used on the flight was to move the hottest regulator onto the central mounting bracket as a heat sink, but this only slowed down the process without completely stopping it.

A possible fix for this would be to have a sink that connects to the externals of the payload that can be actuated if the internal temperature rises too high.

The actuator could not extend high enough during the middle of the day to accurately track the sun, an issue that could be fixed simply using a larger actuator, or calibrating the actuator to climb higher. The actuator also relied on input from commands and did not track vertically, though it has the capability to track vertically if there are sensors added to do so.

This can be fixed by adding photodiodes to track vertically in addition to the horizontal tracking diodes on SURMA II.

Another issue on SURMA was rotation during cold periods, due to a lazy susan rotational assembly that was not designed for the flight profile. There are coatings and bearing that can be ordered specially for this profile that would mitigate this issue. Considering lack of movement after nearly 6 hours of float, the set screw on the coupler that facilitated the drive shaft through the slip ring came loose. Using a motor instead of a motor will increase movement in the cold with more power, while securing all screw connections with Loctite will prevent mechanical connections from coming loose.

Bad wiring connections were another source of error on the flight, and issue that can be fixed using more reliable and better tested connections.

SURMA II would also include pre-flight calibrations to increase accuracy for the UV measurements and the tracking system.

The HackHD was not calibrated, either, meaning the photographs of the sun were not direct.

The table of SURMA improvements from the SURMA Science Report is listed in **Appendix A.**

2.0 Payload Design

2.1 High Level System Design

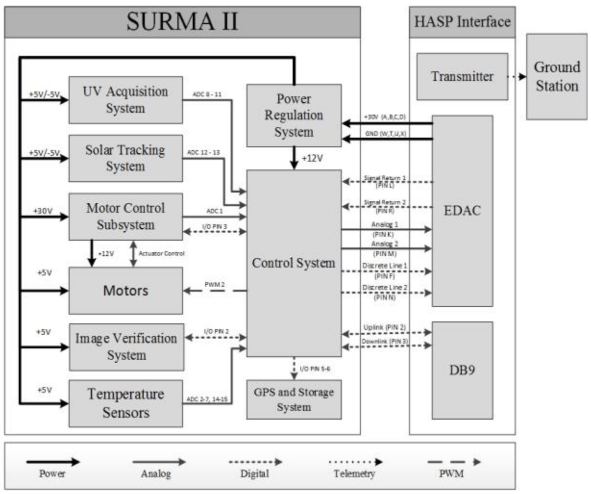

Figure 4: SURMA II High-Level System Design

SURMA II is designed to track the motion of the Sun while collecting UV irradiance as a function of altitude. To achieve this, a control subsystem will read analog values from externally-mounted, light-sensing photodiodes to determine where the Sun is positioned relative to SURMA II. It will then command a motor to make azimuthal rotations. The vertical pointing angle will now be controlled using photodiodes for vertical tracking that send the vertical orientation to one of several pre-set commands saved to onboard. Therefore, SURMA II's front face and UV sensing photodiodes shall be within the Sun's direct irradiance. A power regulation system will distribute the 30V from the HASP gondola's EDAC connector to the individual subsystems. The HASP gondola will downlink data via CSBF radio systems to a ground station, where team members will monitor the payload and ensure proper operation. In the case of errors, an uplink system shall also be available for issuing commands or performing manual adjustments to the viewing angle. Downlinked data will be duplicated into onboard memory as backup.

2.2 Electrical Design

UV Measurement Sensors

In order to measure UV irradiance in the atmosphere, SURMA II will house four individual UV photodiodes (UVA, UVB, UVC, and broadband UV total). The team is currently considering the SG01 series photodiodes from Boston Electronics.

Figure 5: Image of an SG01 series UV photodiode

UV Photodiodes are usually connected in a reverse-biased configuration, as shown below. All PN junctions are sensitive to incident electromagnetic radiation. If a photon strikes a PN junction it creates a free electron within the junction. The built-in field of the depletion region applies a force on the free electron and sweeps it across the junction. This movement of charge is called a 'photocurrent', and is the basis of operation for light detection photodiodes [6]. The photodiodes for this project are composed of Gallium Nitride or Aluminum Gallium Nitride semiconductor PN junctions that are highly sensitive to sub-400 nm wavelengths. They will be connected as shown below.

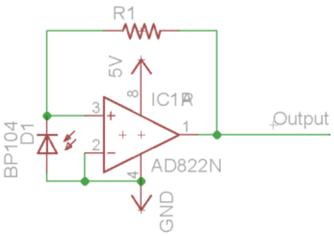

Figure 6: Amplifier schematic for SURMA photodiodes

This circuit creates a measurable voltage across R1 as photocurrent is pulled through photodiode D1. Each UV photodiode will require its own amplifier circuit. The exact amplifier gain values (i.e. value of resistor R1) will be determined through sensor testing and calibration. Additional output filtering may be required to overcome Johnson dark current noise; this will also be determined through system testing and calibration **[7].**

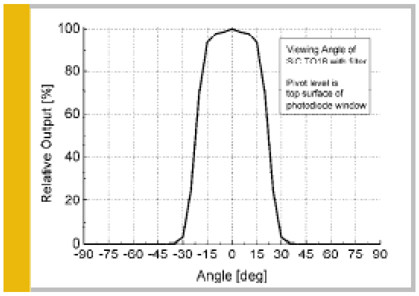

Figure 7: Actual UVC photodiode directional characteristics. Note the narrow peak viewing angle (~ ±15° for this photodiode).

One of the primary technical challenges associated with this project is that UV photodiodes typically have a narrow peak viewing angle. In order to measure UV irradiance through the entire flight, the UV sensors must be pointed at the sun. This necessitates the use of a solar tracking system.

Solar Tracking System

SURMA II must be able to track the azimuthal and elevation position of the Sun with respect to the payload, and must be able to compensate for the rotation of the HASP gondola. SURMA II will have two pairs of broadband EM sensitive photodiodes. They operate in a similar manner to the UV photodiodes, and will use the same amplification circuit. As detailed below, two of the solar tracking photodiodes will be mounted at a 90° angle from each other (and 45° off-centered from the payload). In this configuration, each solar tracking photodiode receives light at a different angle. When the HASP gondola is perfectly pointed at the Sun, each solar tracking photodiode outputs the same value. As the platform rotates, the pair of photodiodes create a differential signal, the magnitude of which increases with increasing angle away from the Sun. The flight computer needs to monitor this differential signal and make corrective turns to keep SURMA II pointed in the right direction.

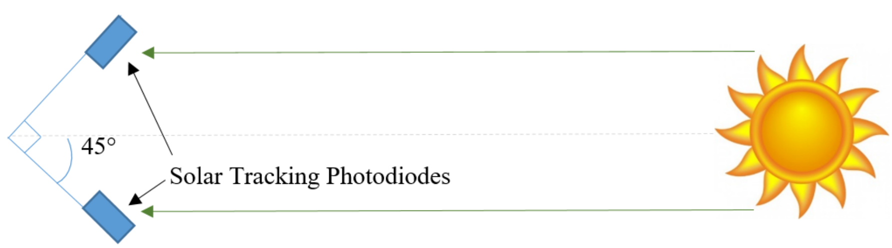

Figure 8: Conceptual diagram of the Solar Tracking System

A similar method will be used to track the elevation position. The photodiodes will be mounted at a 90° angle from each other (and 45° off-centered from the payload) with a vertical orientation. This will allow the tracking of the sun' relative elevation. Heavier baffling will be required due to the reflective properties of both the balloon and the HASP gondola.

Figure 9: Image of the OSRAM SFH 206K.

The team is currently considering OSRAM SFH 206K photodiodes, shown to the left. Its detector is sensitive to 400-1100 nm wavelength light (visible + infrared) with a peak response at 850 nm (close to the peak wavelength of the Sun).

In addition to its broadband response characteristics, the SFH 206K has a fairly linear response with respect to angle. Due to the fact that the sensor will be mounted at a 45° angle, it needs to be able to detect solar output from that direction. As shown below, the photodiode meets this need.

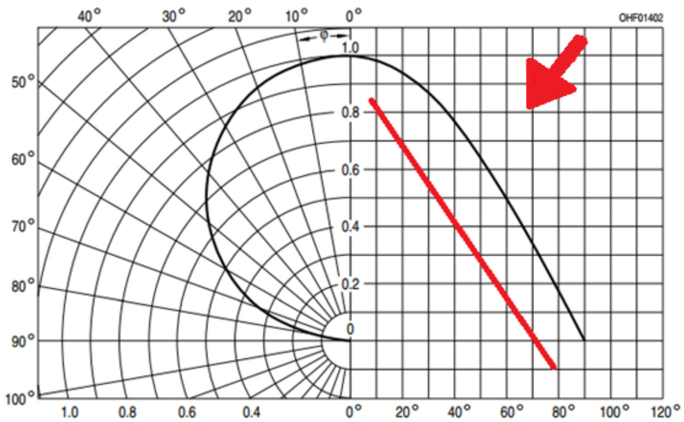

Figure 10: Broadband EM photodiode directional characteristics. Note the fairly broad, linear response as a function of incident angle, which makes this photodiode a good candidate for off-nominal solar detection.

A major flaw in the SURMA design was the lack of baffling. At multiple points during the flight, the reflections of the sun led to incorrect tracking. This can be remedied by heavier baffling and comparing the four photodiodes to each other to determine if a reflection or shadow has interfered with tracking.

Onboard Storage

As described in Section 4.4: *Telemetry*, the team expects to transmit 290 data packets once per seconds using the HASP telemetry downlink. These packets will also be recorded in backup onboard storage. SURMA will store data into an SD card housed within the electronics bay. For 15 hours of data collection (daytime collection only) at a rate of 1 data packet per second, SURMA will need roughly 15.6 MB of storage space. This required capacity is easy to obtain with an SD card.

Rotation Motors

There will be two control motors on SURMA II: the azimuth control motor and the elevation control motor. The azimuth motor will operate off of a digital PWM signal generated by the flight computer. The azimuth control motor must be able to spin 360° in order to observe the entire sky during flight, and must be capable of rotating the payload at least 20° per minute. The elevation motor will be controlled through a flight computer controlled H-bridge circuit. The flight computer will send commands to the H-bridge and move the elevation motor to the appropriate position. The elevation control motor will need to rotate less than 180° throughout the flight, and will also be controlled in response to the solar tracking system

Image Verification System

An onboard camera will be used to verify when the payload is correctly orientated. The camera will take pictures after every UV measurement. These images will be used to calculate the solar tracking error and the off-incidence irradiance angle. Each of the images must have a timestamp that is synchronized with the UV measurements.

Flight Computer

The SURMA II flight computer is a single Arduino Mega. During the flight, it will perform the following actions:

- Monitor the azimuthal rotation of the HASP gondola and make corrective maneuvers
- Measure and record UV irradiance
- Transmit data packets to the HASP gondola via the DB9 serial connector
- Respond to commands issued by ground control

Arduino Mega was chosen because it can perform the required actions in a relatively small footprint at a relatively low cost. Arduino Megas have sixteen 10-bit ADC channels, which is enough to monitor all UV and solar tracking photodiodes, as well as temperature and rotational sensors. Arduino Megas have native digital PWM control, which will be used to control the motors. The Arduino IDE also has built in libraries for interfacing with SD cards, which will be used for onboard data storage.

The Flight Computer will connect to the SURMA daughterboard, which will house all of the required sensor signal conditioning and power regulation circuits.

Power Regulation

SURMA must be able to handle a nominal 30V from the HASP gondola. The voltage will decrease from ~33V to ~29V through the duration of the flight, thus the power system must be tolerant of a range of input voltages. This voltage must be regulated and made available to the individual electronic systems. The team is currently considering the 30W Murata UHE-12/2500-D24-C DC/DC converter, shown below, to step the voltage down to a manageable 12V. The 12V will be passed to subsystem-specific linear regulators to provide the proper operating voltages for the components.

Figure 11: Murata UHE Regulator

The DC-to-DC converter outputs a constant 12V DC from an input voltage range of 18-36V. It is capable of delivering 2.5A DC and has built in over-current protection. It also has a small footprint, measuring 2” x 1.6” x 1.6”.

The Arduino can either run off of a filtered 5V or through its own 9-15V input linear regulator. The amplifier networks can be powered by up to 15V, but shall be properly conditioned to output 0-5V based on the expected range of irradiance inputs.

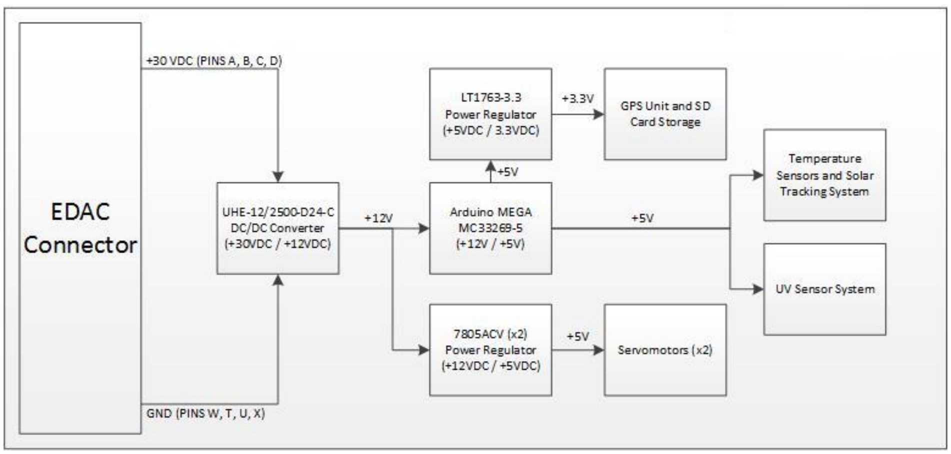

Figure 12: Power System Diagram

Improvements from SURMA

Most SURMA electronics performed as expected. The major flaw in the SURMA I design was the poor management of electrical connections. Many of the connections were loose wires within the electronics bay that were allowed to move freely as the payload rotated.

SURMA II will feature a more compact and integrated electronic system with a focus on reducing the number of required connections to remove this possibility. This will require new PCB designs for the UV acquisition system and the power system, a PCB design for the solar tracking and image verification systems, and lock-in connectors.

2.3 Mechanical Design

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SURMA II is to be composed of two enclosures mounted on a rotating platform. The electronics bay (lower enclosure) is fixed to the rotating platform and contains the processor boards and motors. The sensor enclosure (upper) is attached to the electronics bay by a hinge. A linear actuator is mounted below to tilt up the sensor enclosure and raise the viewing angle. Within the sensor enclosure are the UV sensors, light photodiodes, and camera.

SURMA's maximum total vertical clearance is 10.47 inches, approximately 1.5 inches under the vertical clearance limit. The rotational footprint of the payload is within a 10.04 inch diameter circle.

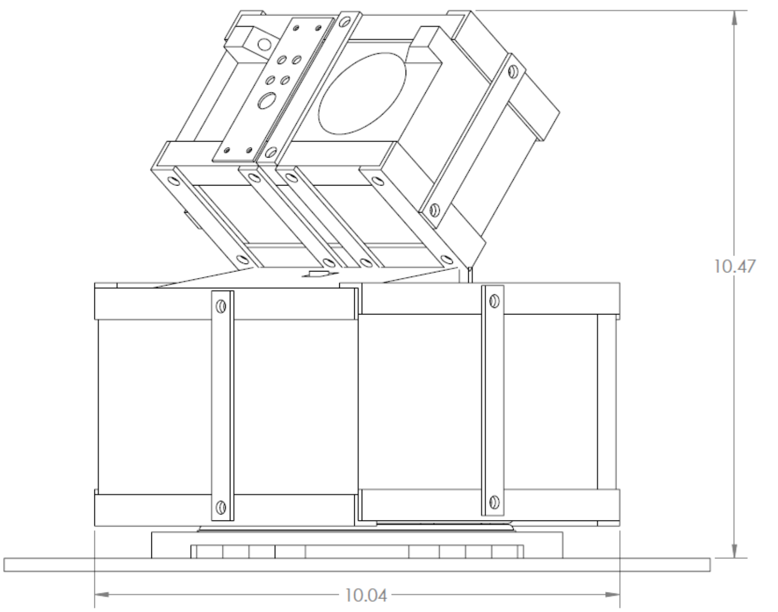


Figure 13: Full Payload Assembly

The two enclosures mounted on the rotating platform provide SURMA with a three-dimensional viewing capability. At its elevated position the maximum height is 10.47" and its rotational footprint remains within a 10.04" diameter circle.

Rotation Platform

To achieve azimuthal rotation, SURMA II's electronics will be mounted on a rotating platform that is driven by an onboard motor. The rotational platform is composed of two 0.25" thick PVC sheets with an aluminum rotational bearing plate ("Lazy Susan") in between them. The lower rotational platform footprint is 8 x 8 inches while the top platform (also the floor of the electronics bay) is 7 x 7 inches.

Electronics Bay

The majority of the electronics bay is composed from rigid polystyrene foam. However, as mentioned in the previous section, the bottom plate is made of 0.25" thick PVC. The enclosure utilizes aluminum braces along its edges for structural and mounting purposes. The overall dimensions of the electronics bay are 7 x 6.5 x 4.5 inches. There will be a 2" diameter hole located on the bottom of the electronics bay for the azimuthal drive shaft and wires from the HASP platform to pass through. The top aluminum frame for the electronics bay can be removed to expose a top lid for access to the internals. The electronics bay will house the motors and the control boards. The motor will be mounted in the center of the electronics bay, on a 3 inch aluminum mounting channel. The actuator will be mounted on one end of the motor mounting bracket. The top of the actuator will go through the top of the electronics bay box, where it will make contact with the bottom of the sensor box. Throughout the flight, the actuator will extend and retract, which will alter the tilt of the sensor box as needed.

Sensor Enclosure

The sensor enclosure is attached to the top of the electronics bay by a hinge and tilts up and down by the motion of the actuator located in the electronics bay. Aluminum brackets are placed along the edges for structural and attachment function. The sensor enclosure is fabricated from rigid polystyrene foam. Its overall dimensions are 5.5 x 3 x 3.5 inches. The front of the sensor box has seven small holes (for each photodiode and a temperature sensor) and a large bore hole (for the HackHD camera lens). The bore with be filled with Plexiglass coated in solar film to prevent over saturation of the camera, as shown below.

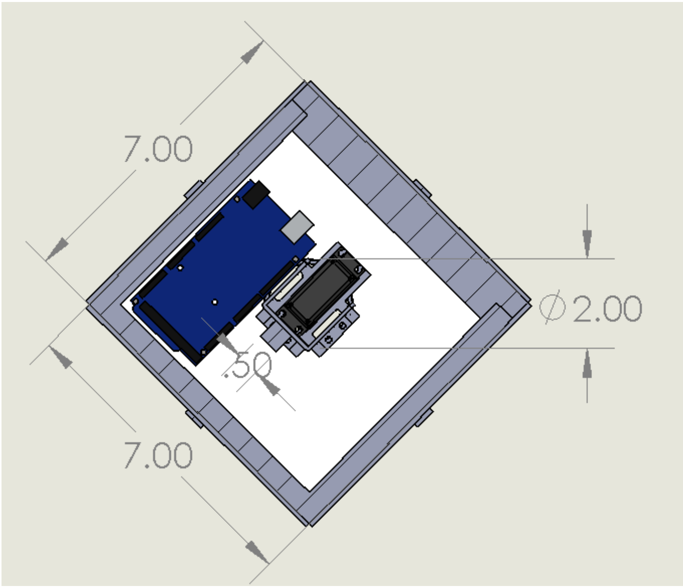


Figure 14: Electronics Bay Internal Top View

The control boards will be located to the side, and a 1.5" aluminum channel will house the rotational servo in the middle of the Electronics Bay. The actuator is directly attached to the aluminum channel. Units in inches.

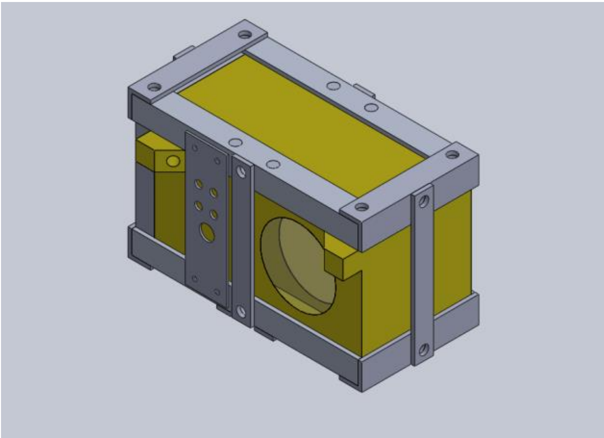


Figure 15: Sensor Enclosure External View

The five small bore holes in the front face are used for the UV photodiodes, while the angled holes on the edges house the light-sensing photodiodes. The largest bore is filled with a solar filter layer and Plexiglass to protect the camera lens.

Mechanical Improvements

On the past SURMA flight there were issues with freezing and overheating. Rotation components struggled with the extreme cold conditions while traveling through the atmosphere to floating altitude. To prevent this for the next flight antifreeze lubricant will need to be used on the rotational bearings and there will need to be better containment of heat or active heating in the electronics bay to prevent the motor from getting too cold. After the payload was at float, the exposure to the sun caused the electrical components to overheat. To prevent this on the next flight, aluminum mylar could be used on the exterior of the payload to reflect infrared radiation from the sun instead of the previously used white finish on the foam.

Another issue that the team encountered was with the slip ring. Due to imprecise construction of the rotational platform, the slip ring could not operate properly which led to tangled and broken wires. While this problem was mitigated for the flight, more precise construction would lead to a more reliable structure.

2.4 Software Design

The payload software will be broken down into distinct subroutines. First, SURMA II will initialize all variables and connections needed by the rest of the subroutines and check the onboard storage for available space. If the onboard memory is full, the program will end, otherwise SURMA II will continue with the rest of the control software. Then, and throughout the duration of the flight, the payload will measure the values provided by onboard sensors and use ADCs to digitize those readings. After taking measurements, SURMA II will record those readings to onboard memory. In the event of a power failure or unexpected error, SURMA II will use the onboard memory to resume previous operations. Then the payload will downlink those readings to the HASP platform at a rate of 4800 Baud in the format specified in **Table 3**. Once readings have been downlinked, if tracking is enabled, SURMA II will then begin the tracking subroutine.

For tracking, SURMA II will use photodiodes for vertical and horizontal solar tracking through onboard ADCs. For the horizontal rotation sensors, when the horizontal photodiodes provide values with a difference above a certain threshold, the payload will use an onboard motor to turn the sensor apparatus toward the sun. When the photodiodes used for vertical tracking have a difference above the threshold specified during calibrations, the payload will command an actuator to extend or retract as needed to direct the sensor apparatus more directly at the sun. Both the horizontal and vertical tracking systems can be overridden by manual uplink commands through the HASP interface. SURMA II will use a filtered onboard camera to take pictures to be used in post-flight analysis to calculate the accuracy of SURMA II tracking accuracy.

Serial Data Record			
ASCII Characters	**Name**	**Description**	**Format**
4 Byte String	Header- Data	Record type indicator for DATA transmission	DATA
2 Byte String	MRC	Most Recent Command Received	XX
8 Byte String	Timestamp	Current RTC Time	HH/MM/SS

6 Byte String	UVA	UVA flight data from ADC	UVA XXX
6 Byte String	UVB	UVB flight data from ADC	UVB XXX
6 Byte String	UVC	UVC flight data from ADC	UVC XXX
6 Byte String	UV-Total	Broadband UV flight data from ADC	UVT XXX
7 Byte String	UV-Temp	Records temperature of UV photodiodes	TEMP XXX
6 Byte String	Left Photodiode	Photodiode positioned to the left of the sensors	PD1 XXX
6 Byte String	Right Photodiode	Photodiode positioned to the right of the sensors	PD2 XXX
6 Byte String	Top Photodiode	Photodiode positioned above the sensors	PD3 XXX
6 Byte String	Bottom Photodiode	Photodiode positioned below the sensors	PD4 XXX
6 Byte String	Rear Photodiode	Photodiode positioned on the opposite side of payload with respect to the sensors	PD5 XXX
6 Byte String	Motor Temperature Sensor	Records temperature of motor controlling azimuthal orientation	SRV XXX
6 Byte String	Actuator Temperature Sensor	Records temperature of motor controlling elevation orientation	ACT XXX
6 Byte String	Reverse Side Temperature	Temperature of the reverse-side of the payload	RST XXX
6 byte String	Internal Temperature	Internal temperature of the payload	INT XXX
6 Byte String	Power Regulator Board Temperature	Temperature of the Power Regulator (PRS) board	PRS XXX
6 Byte String	UHE Temperature	Temperature of the UHE regulator	UHE XXX
120 Byte String	GPS	Position Data	See Format
6 Byte String	Status	Error status	ER XXXX
1 Byte String	Checksum	Truncated check	X
4 Byte String	Footer	Record Type End indicator	ENDD
59 Bytes	ASCII Formatting	Commas, colons, and spaces between each piece of data to clearly delineate different data fields	,
Total: 301 Bytes			

Table 3: Serial Data Record: DATA Transmission

3.0 Team Definition

3.1 Team Positions and Roles

Student Team Demographics						
	Name	**Role**	**Major**	**Classification**	**G.D.**	**Ethnicity**
1	David Bordelon	Software	CSC	Senior	Spring 2016	Caucasian
2	Jordan Causey	Mechanical Design	ME	Sophomore	Spring 2018	Black
3	Joshua Collins	Electrical Lead	EE	Senior	Spring 2017	Caucasian
4	Robert Cottingham	Electronics	PHYS	Senior	Spring 2017	Caucasian
5	Allen Davis	Systems Engineering Lead	ME	Junior	Spring 2017	Caucasian
6	Victor Fernandez-Kim	Mechanical Design	ME	Senior	Spring 2017	Hispanic
7	Stephen Harb	Software Lead	CSC	Senior	Spring 2017	Caucasian
8	Brad Landry	Primary Contact, Mission Operations	ME	Junior	Spring 2018	Caucasian
9	Adam Majoria	Science Investigation Lead	PHYS	Senior	Spring 2018	Caucasian
10	Deanna Petty	Electronics Design	ECE	Senior	Spring 2017	Black
11	Chris Schayer	Software, Timing, Positioning	SE	Senior	Fall 2017	Caucasian
12	David Williams	Science Investigation	PHYS	Sophomore	Spring 2018	Caucasian

Table 4: Student Team Demographics

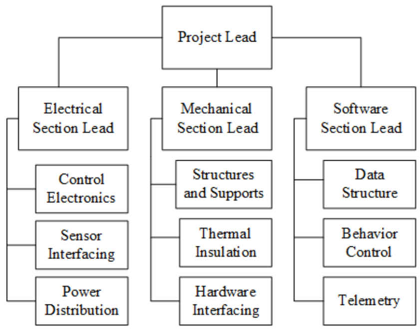


Figure 16: Team Structure Chart shows project team sections and major areas of focus for each section

3.2 Team Contact Information

Student Team Contact Information		
Name	**Email address**	**Phone Number**
Victor Fernandez-Kim	vfernandezkim@gmail.com	(225) 400-8644
Joshua Collins	josbluehill@gmail.com	(985) 287-1093
Stephen Harb	stephenaliharb@gmail.com	(337) 207-2149
Allen Davis	adav156@lsu.edu	(251) 459-4578
Jordan Causey	jcaus17@lsu.edu	(225) 290-3613
Brad Landry	bland77@tigers.lsu.edu	(985) 805-0384
David Bordelon	dbord17@lsu.edu	(504) 579-6252
Chris Schayer	cschay1@gmail.com	(985) 237-0327
David Williams	davidwilliams4036@yahoo.com	(254) 458-5497
Adam Majoria	majoriaadam@gmail.com	(225) 614-0196
Diane Petty	pettydc@chart.net	(334) 467-1193
Robert Cottingham	rcotti1@lsu.edu	(225) 588-6329

Table 5: Student Team Contact Information

Faculty Advisors				
Name	**Role**	**Contact Information**		**Address**
T. Gregory Guzik	Faculty Advisor	guzik@phunds.phys.lsu.edu	225-578-8597	359C Nicholson Hall, LSU
Michael Stewart	Faculty Advisor	stewart@phunds.phys.lsu.edu	225-578-2250	327 Nicholson Hall, LSU
Douglas Granger	Faculty Advisor	granger@phunds.phys.lsu.edu	225-578-4427	326B Nicholson Hall, LSU
Brad Ellison	Faculty Advisor	stewart@phunds.phys.lsu.edu	225-578-8877	133 Nicholson Hall, LSU
Colleen Fava	Faculty Advisor	fava@phunds.phys.lsu.edu	225-578-8680	364 Nicholson Hall, LSU

Table 6: Faculty Advisors

3.3 Timelines and Milestones

Task Name	Start	Finish
Preliminary Design Review	Mon 1/11/16	Mon 2/1/16
PDR Due	Tue 2/2/16	Tue 2/2/16
Critical Design Review	Wed 2/3/16	Mon 3/21/16
CDR Due	Tue 3/22/16	Tue 3/22/16
Pre-PSIP	Wed 3/23/1€	Thu 4/21/16
Pre-PSIP Due	Fri 4/22/16	Fri 4/22/16
PSIP	Sat 4/23/16	Thu 6/23/16
PSIP Due	Fri 6/24/16	Fri 6/24/16
FLOP	Sat 6/25/16	Wed 7/27/16
FLOP Due	Thu 7/28/16	Thu 7/28/16
Payload Integration Ready	Mon 8/1/16	Mon 8/1/16
Fix Integration Issues (if needed)	Tue 8/9/16	Tue 8/30/16
Flight Ready	Tue 8/30/16	Tue 8/30/16
Data Analysis	Mon 9/12/1€	Thu 12/8/16
Science Report Due	Fri 12/9/16	Fri 12/9/16

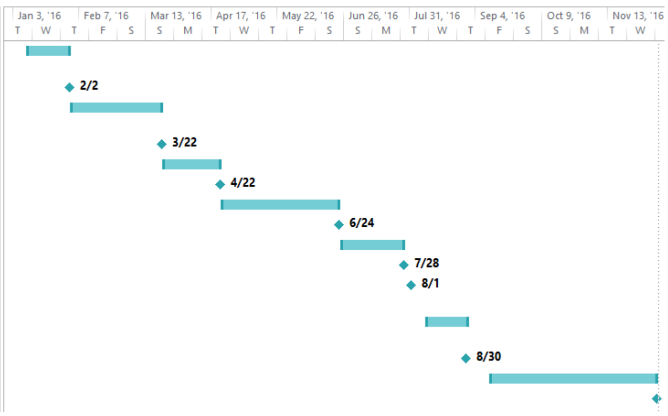


Figure 17: Timelines and Milestones

Team Pleiades will structure milestones based along the requirements for the HASP flight, along with internal deadlines for a preliminary design review followed by a critical design review. The Pre-PSIP will be finished before LSU finals and concentrated study period.

The Preliminary Design Review will focus on improving the design to fix the previous issues found in SURMA.

3.4 Flight Operations

SURMA II has no required orientation on the HASP platform, but a mounting location easily visible by the HASP video camera would be useful to confirm accurate tracking.

None of SURMA II's electronics will utilize the provided analog channels or discrete commands.

Pleiades will have the Project Manager and the three section leads present for the 2016 HASP Integration for COATL.

We will have at least one member present for Flight Operations to ensure the payload is integrated properly, though we hope to have more members available for Flight Operations. Other members involved in Flight Operations will be monitoring COATL's status from Nicholson Hall at LSU.

The uplink commands from the previous SURMA flight have been slightly modified. With improved tracking, more photodiodes, and added vertical tracking, they will not need to be utilized nearly as frequently as they were on SURMA.

SURMA II Commands			
Name	**Bytes**	**Description**	**Check for Successful Command Execution**
Error Request	00H, XXH	Requests an ERRR transmission from payload	ERRR Transmission sent
Info Request	01H, XXH	Requests an INFO transmission from payload	INFO Transmission Sent
Data Request	02H, XXH	Requests a DATA transmission from payload	DATA Transmission Sent
Sensor Request	03H, XXH	Requests an Sensor transmission containing all sensor information from payload	Sensor Transmission Sent
HackHD On	04H, XXH	Switches bool variable to toggle HackHD pictures function	Downlinks the received uplink value
HackHD Off	05H, XXH		The payload waits until it receives an ignore error transmission
Tracking on	06H, XXH	Toggles the Solar Tracking System on/off	Downlinks the received uplink value
Tracking off	07H, XXH		Downlinks the received uplink value
Actuator Extend	08H, XXH	Controls the actuator for a number of seconds equal to the second byte sent XX	Downlinks the received uplink value
Actuator Retract	09H, XXH		Downlinks the received uplink value

Actuator Position 1	0AH, XXH	Moves the Actuator to be fully retracted	Downlinks the
Actuator Position 2	0BH, XXH	Moves the Actuator to the one quarter extended position	Downlinks the received uplink value
Actuator Position 3	0CH, XXH	Moves the Actuator to the one half extended position	Downlinks the received uplink value
Actuator Position 4	0DH, XXH	Moves the Actuator to the three fourths extended position	Downlinks the received uplink value
Actuator Position 5	0EH, XXH	Moves the Actuator to be fully extended	Downlinks the received uplink value
Break Actuator	0FH, XXH	Pauses the actuator movement	Downlinks the received uplink value
Rotate Indef	10H, XXH	Rotates the motor at the speed specified by XX until commanded otherwise	Downlinks the received uplink value
Rotate for Set Time	11H, XYH	Rotates the motor at the speed specified by X until Y seconds have passed	Downlinks the received uplink value
Stop Rotation	12H, XXH	Commands the motor to stop rotating	Downlinks the uplinked command

Table 7: SURMA II Commands

4.0 Payload Specifications

4.1 Preliminary Drawings

Commented [a4]: Jordan, Brad

Mounting

The payload will be mounted by four screws, each going through a corner of the rotational assembly's bottom PVC plate up from the HASP platform. The screws will be sent upwards, with the nuts attached on the top to ensure proper clearance below the HASP platform (0.25"). The payload will be mounted in the center of the platform, which will keep the clearance for the payload under the required size restraints by limiting motion to the 10.04" diameter circle (Figure 18).

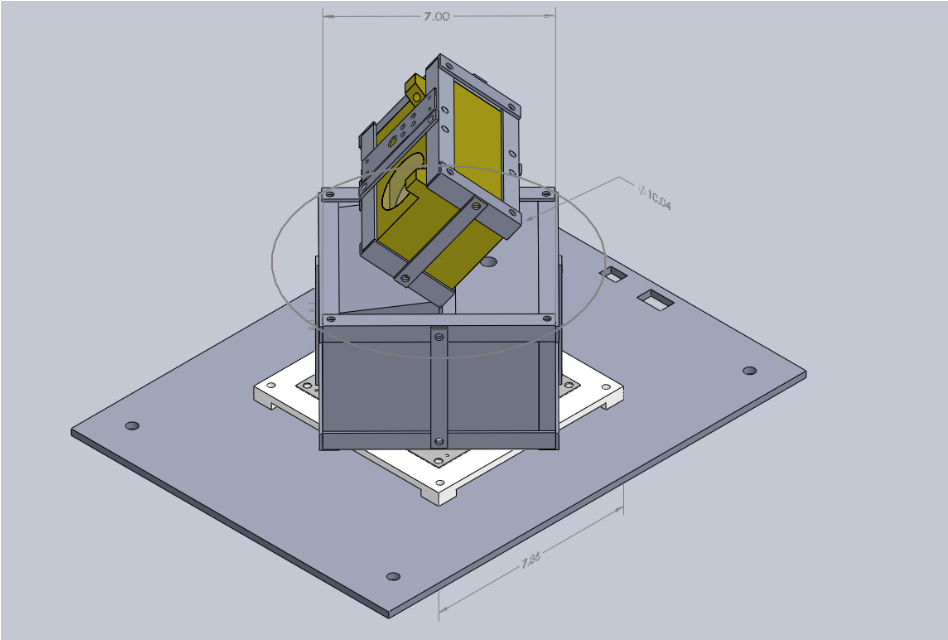


Figure 18: SURMA with HASP Mounting Plate.

Mounted in the center of the plate, SURMA remains within the constraints with extra space available. Units in inches.

Wiring

The power and communications lines will be routed below the rotational assembly, up through a pipe and a slip ring, and into the electronics bay. The rotational assembly is elevated with pillars for the connectors from the mounting plate to fit underneath. The slip ring has a 0.27” diameter bore to house the servo drive shaft that running through it. The sensor connections run from the photodiodes in the sensor enclosure to the processing boards in the electronics bay through sealed holes in both enclosures. The portion of wire that rest between the sensor enclosure and the electronics bay shall also be insulated.

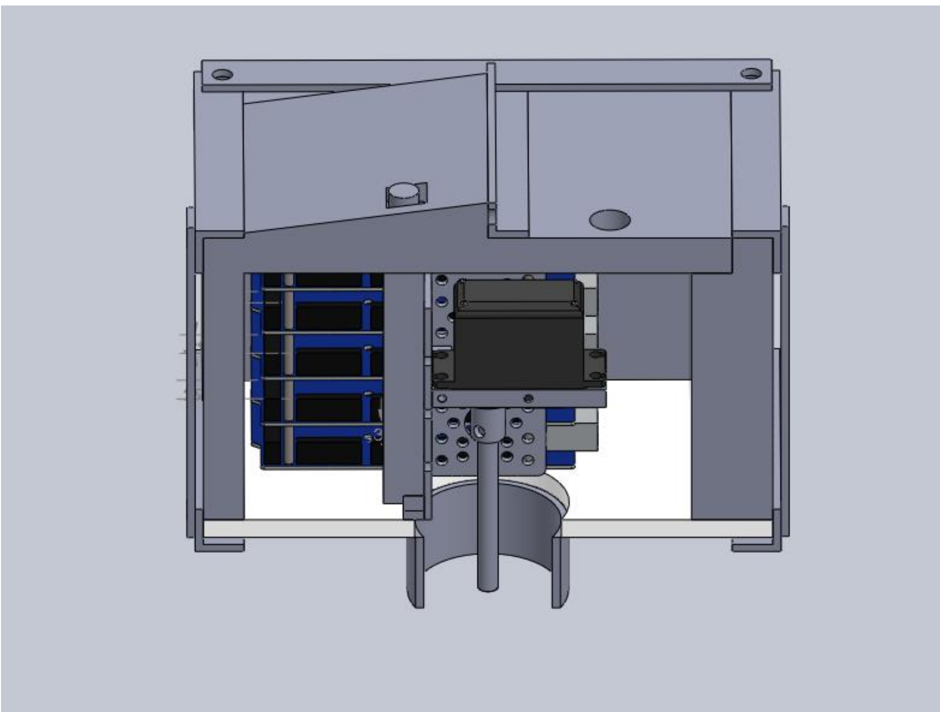


Figure 19: Electronics Bay Internal Cross-Sectional View.

Power and serial lines run from underneath the electronics bay, through a slip ring (not displayed), and into the processing boards. From above, the sensor connections enter the electronics bay through the bore hole cut at the top.

4.2 Weight Budget

Commented [a5]: Jordan

Table 3.2: Weight Budget					
Component	**Material**	**Quantity**	**Mass (g)**	**Uncertainty (g)**	**Classification**
Lazy Susan	Aluminum	1	240	±2.5	Measured
Rotating Platform plates	PVC	2	420	±5	Measured
Motor and mounting	Assorted	1	20	±5	Measured
Foamular insulation	Polystyrene	1800 cm^3	80	±15	Calculated
Sensor boards	Assorted, PCB	5	174.5	±0.5	Measured
Interior Insulation	Mylar	1200 cm^2	90	±10	Calculated
External structural support	Aluminum	4	335	±10	Calculated
Box adhesives	Gorilla glue, tape, etc.	--	5	±3	Estimated
Hack HD	Assorted	1	35	±5	Measured
Clear window	Cast Acrylic	1	10	±5	Measured
Vertical Actuator	Aluminum	1	60	±5	Measured
Securing Hardware	Steel	1	70	±10	Estimated
Slip Ring	Assorted	1	40	±5	Measured
Totals:			**1579.5**	**± 81**	

Figure 20: Weight Budget

4.4 Power Budget

Commented [a6]: Josh, Deanna

The total power draw of the SURMA II is shown below. The first table shows the total draw from HASP, while the second shows the breakdown of the power budget. SURMA II requires 19 W of power with an average current draw of 645 mA. The camera and motors are not expected to operate for the entire duration of the flight. Due to this, the power draw will fluctuate between this average value and zero.

Power Draw from HASP					
Component	Voltage	Current Draw from Regulator (mA)	Efficiency	Current Draw from HASP (mA)	Power(mW)
30V/12V Regulator	30	1075.50	88.00%	645.3	19359
Totals				645.3	19359

Figure 21: Power Draw from HASP

Power Draw from Main Regulator			
Component	Voltage	Current Draw (mA)	Power(mW)
12V/6V Regulators	12	10.00	120.00
Arduino Mega	12	25.00	300.00
UV Acquisition Board	5	10.00	50.00
Solar Tracking Board	5	10.00	50.00
Motor Control Board	12	50.00	600.00
Temperature Sensors	5	0.50	2.50
GPS and Storage Board	5	70.00	350.00
Camera	5	650.00	3250.00
Rotation Motor	5	120.00	600.00
Elevation Motor	12	130.00	1560.00
		1075.50	6882.50

Figure 22: Power Draw from Main Regulator

5.0 Appendices

Appendix A: SURMA Payload Improvement Assessment

Payload Improvement Assessment				
Issue	**Description**	**When issue first arose**	**How issue was mitigated**	**How issue can be eliminated**
Thermal Insulation	Components would overheat in hot-cycles	HASP Integration	Routed the overheating components (regulator) to heat sinks passively dissipate heat	Active heating/cooling system; dissipative conductive piping
Rotational Assembly	Misalignment in slip ring, driveshaft, and platforms; Sluggish in cold-cycles	HASP Integration	Loosened the restrictions on the drive shaft and incorporated a flexible coupler	Proper alignment with appropriate tolerance to accurately seat rotation assembly; Incorporate active heating and anti-freeze lubricant to bearings
Electronic noise	Some components were populated on prototype boards resulting in unwanted noise	Development phase	--	Cleaner wiring and cables, integrated boards accounting for signal noise,
Wiring and Connectors	Interfaces between boards were not well planned resulting in messy wiring set up; Connectors were not rigid and risked coming loose	HASP Integration	Tightly packing and binding wires to help with the wire sprawl; Taped and glued connectors pre-flight to prevent disconnects	Integrated boards, connectors considered in design phase, lock connectors
Payload Structure and Assembly	Cumbersome assembly; hard to reach control electronics; exposed wires between mounting plate and platform; did not take full advantage of available size and weight restrictions	HASP Integration	Slight modifications to payload openings to allow for more accessible control electronics; covered wires with white duct tape	Redesign payload structure and assembly to be more accessible, protective, and appropriately sized
Data handling	Not well formatted; no timestamp; saved data often corrupt or overwritten;	HASP Integration	--	Faster development and testing turnaround time; organized data structure; overwrite protection features
Software Logic Flow	Incomplete; cannot autonomously distinguish sun from other bright objects; cannot account for shadows; does not handle power cycles optimally	Development phase	--	Faster development and testing turnaround time; logical markers that indicate off-sun tracking
Automated Elevation Control	Complex when also implementing automated azimuthal control	Design phase	Rigid/set elevation points during flight to estimate zenith position of sun	Faster development and testing
Image Capture	Camera viewing orientation was not calibrated; images not universally timestamped with data points	Post-flight analysis phase	Saved image file timestamps were used for timeline of images but this does not account for power cycles	Integrated camera with control electronics to provide corresponding data points

Appendix B: Goals and Traceability

Zeroth Level Requirements

Level	Requirement	Derived
0	The goal of the Solar Ultraviolet Radiation Measurement Apparatus (SURMA) payload is to model the absorption of UV radiation by the atmosphere for the duration of the 2015 HASP flight profile.	Mission Goal

First Level Requirements

Level	Requirement	Derived
0.1	Measure UV irradiance through the duration of the 2015 HASP flight profile.	Objective
0.2	Model the absorption of UV radiation by the atmosphere.	Objective

Second Level Requirements

Level	Requirement	Derived
0.1.1	Utilize a positioning and orientation device to locate the Sun and point SURMA in the direction of the Sun.	0.1
0.1.2	Meet all payload standards set by HASP management.	0.1
0.1.3	SURMA shall measure and record UVA, UVB, UVC, and broadband UV with respect to HASP vehicle position in the atmosphere.	0.1
0.1.4	SURMA components shall operate throughout the flight profile.	0.1

Level	Requirement	Derived
0.2.1	Data shall be recorded for post flight analysis.	0.2
0.2.2	Plot UV irradiance (W/m^2) values as a function of altitude.	0.2
0.2.3	Compute the composition of broadband UV irradiance as a function of the individual bands (UVA/UVB/UVC) at different altitudes.	0.2
0.2.4	Compare results to those of SMARTS / URUA models to verify the recorded payload data.	0.2

Third Level Requirements

Level	Requirement	Derived
0.1.1.1	SURMA shall monitor the Sun's azimuthal orientation with respect to the payload.	0.1.1
0.1.1.2	SURMA shall keep the Sun within the peak response region (>90% irradiance detection) of the UV sensors	0.1.1
0.1.1.3	SURMA shall be able to change its elevation angle through the HASP telemetry system.	0.1.1

0.1.1.4	SURMA shall have a method to enable manual override of its azimuthal rotation system.	0.1.1

Level	Requirement	Derived
0.1.2.1	SURMA shall weigh less than 20 kg.	0.1.2
0.1.2.2	SURMA shall be less than 30 cm tall.	0.1.2
0.1.2.3	SURMA shall fit within a 38 cm x 30 cm footprint.	0.1.2
0.1.2.4	SURMA shall accept an input voltage of 29-33 VDC.	0.1.2
0.1.2.5	SURMA shall draw less than 2.5 amps at all times.	0.1.2
0.1.2.6	SURMA shall not interfere with other payloads.	0.1.2
0.1.2.7	SURMA shall be capable of resisting the effects of 10G vertical force and 5G horizontal force.	0.1.2
0.1.2.8	SURMA shall not exceed a serial downlink speed of 4800 bps.	0.1.2
0.1.2.9	For serial communications, the payload shall communicate using the RS232 protocol over a DB9 connector.	0.1.2
0.1.2.10	The payload shall use an EDAC 516 interface with HASP for power transmission.	0.1.2

Level	Requirement	Derived
0.1.3.1	The payload shall have sensors to measure UVA (320 nm-400 nm), UVB (280 nm-320 nm), UVC (100 nm-280 nm), and broadband UV (100 nm-400 nm).	0.1.3
0.1.3.2	The payload shall have a method of determining its altitude.	0.1.3
0.1.3.3	The payload shall have a method of determining its latitude and longitude.	0.1.3

Level	Requirement	Derived
0.1.4.1	SURMA shall maintain a proper operational environment.	0.1.4
0.1.4.2	SURMA shall provide voltage regulation to generate the required component input voltages.	0.1.4

Level	Requirement	Derived
0.2.1.1	SURMA shall interface with HASP to transmit sensor values via its wireless telemetry systems to the HASP ground station for recording and post-flight analysis.	0.2.1
0.2.1.2	SURMA shall save sensor values into an onboard memory unit as a backup for post-flight analysis.	0.2.1

Level	Requirement	Derived
0.2.2.1	UV sensors shall be properly calibrated (i.e. have a method to convert raw values into irradiance).	0.2.2
0.2.2.2	The payload shall have a method to determine the altitude of each data point for post-flight analysis.	0.2.2

Level	Requirement	Derived

0.2.4.1	Record a data point at 0 km, 15 km, 25 km, 30 km, and 35 km altitude to compare with SMARTS predicted UVA and UVB models.	0.2.4
0.2.4.2	Record a data point at 30 km, 31 km, 32 km, 33 km, and 34 km altitude to compare with URUA measured UVC data.	0.2.4
0.2.4.3	The UV Sensors shall have a high enough accuracy to be able to distinguish the data points at the required altitudes.	0.2.4

Fourth Level Requirements

Level	Requirement	Derived
0.1.1.2.1	The UV Sensors shall have a peak response region of at least +/- 15° off-nominal incidence.	0.1.1.2
0.1.1.2.2	SURMA shall be able to counteract the HASP gondola azimuthal rotation	0.1.1.2

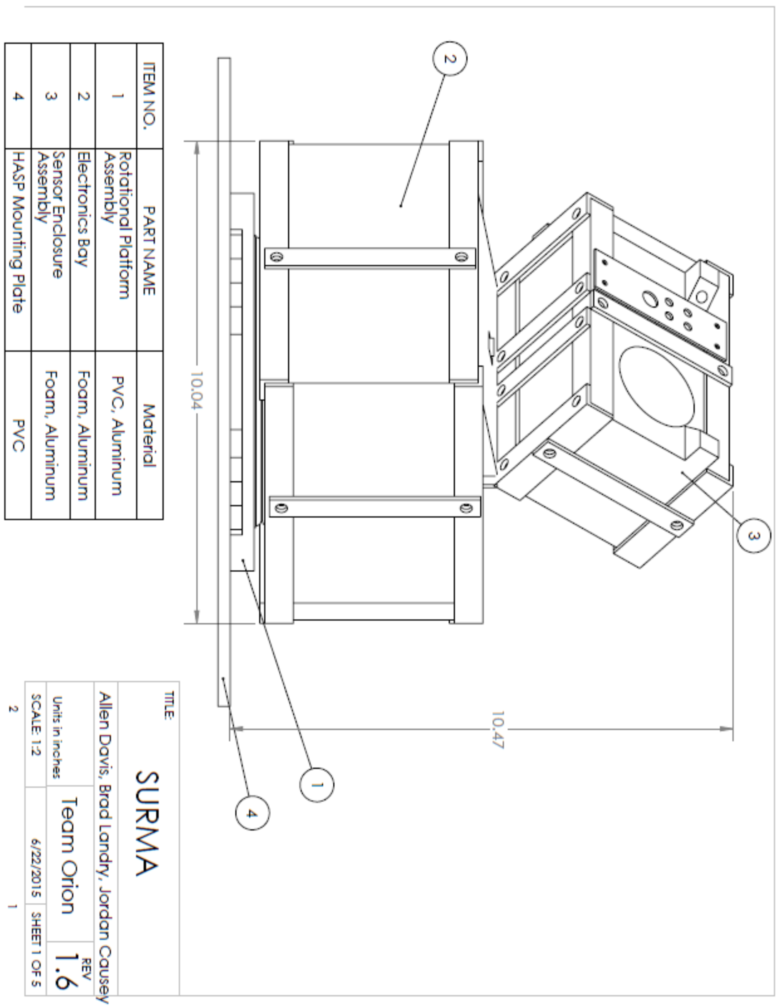
Level	Requirement	Derived
0.1.1.3.1	SURMA shall have a system that monitors the HASP serial connection for commands	0.1.1.3 0.1.1.4
0.1.1.3.2	SURMA shall have a system that executes valid commands.	0.1.1.3 0.1.1.4

Level	Requirement	Derived
0.1.4.1.1	All components shall remain within operational temperature ranges for the duration of the flight.	0.1.4.1
0.1.4.1.2	The payload shall resist the effects of condensation during ascent.	0.1.4.1

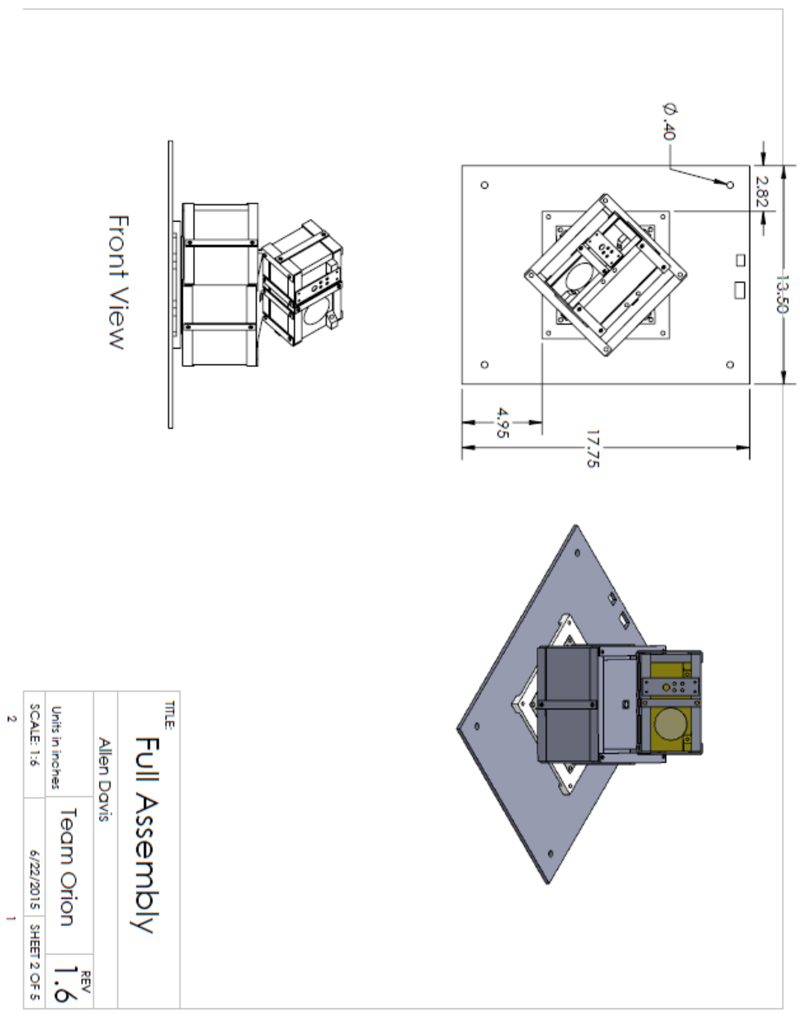
Level	Requirement	Derived
0.2.4.3.1	The UVA+B sensors shall measure irradiance to an accuracy of +/- 20.8 W/m^2 at 0 km altitude.	0.2.4.1 0.2.4.3
0.2.4.3.2	The UVA+B sensors shall measure irradiance to an accuracy of -20.8 to +3.65 W/m^2 at 15 km altitude.	0.2.4.1 0.2.4.3
0.2.4.3.3	The UVA+B sensors shall measure irradiance to an accuracy of -3.65 to +0.78 W/m^2 at 25 km altitude.	0.2.4.1 0.2.4.3
0.2.4.3.4	The UVA+B sensors shall measure irradiance to an accuracy of -0.78 to +0.41 W/m^2 at 30 km altitude.	0.2.4.1 0.2.4.3
0.2.4.3.5	The UVA+B sensors shall measure irradiance to an accuracy of +/- 0.41 W/m^2 at 35 km altitude.	0.2.4.1 0.2.4.3

Level	Requirement	Derived
0.2.4.4.1	The UVC sensor shall measure irradiance to an accuracy of +/- .001 W/m^2 during the 30-35 km altitude regime.	0.2.4.2 0.2.4.3

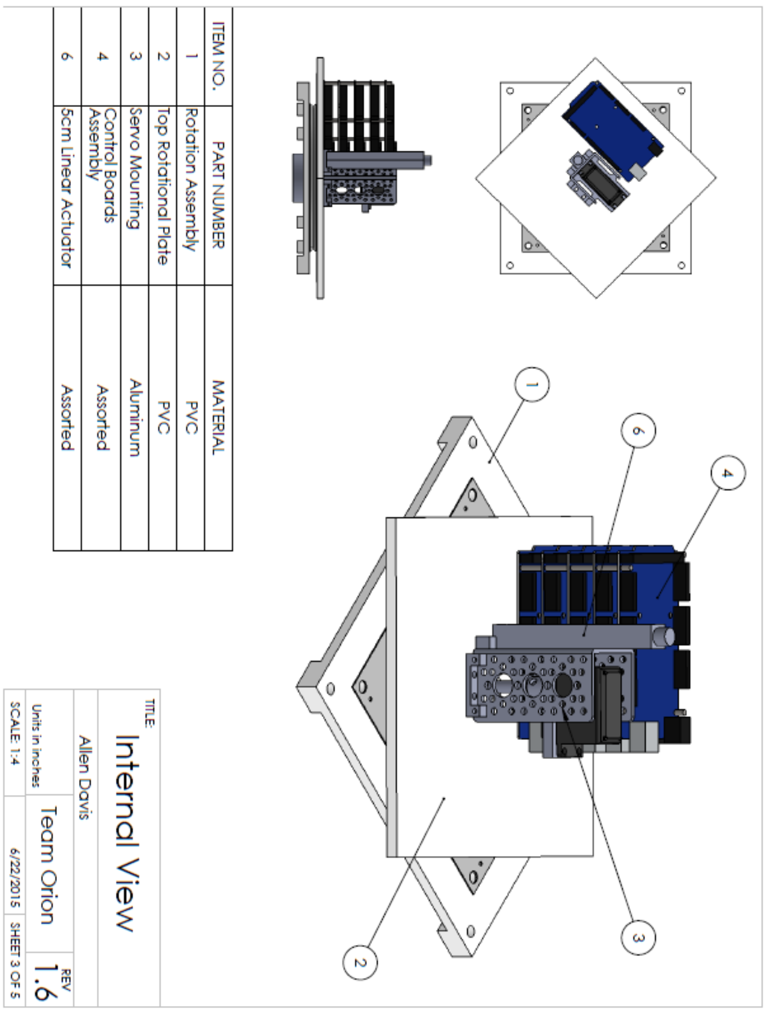
Appendix C: Mechanical Drawings



SURMA Front-View Assembly. SURMA's full assembly shall remain within HASP's flight requirements.

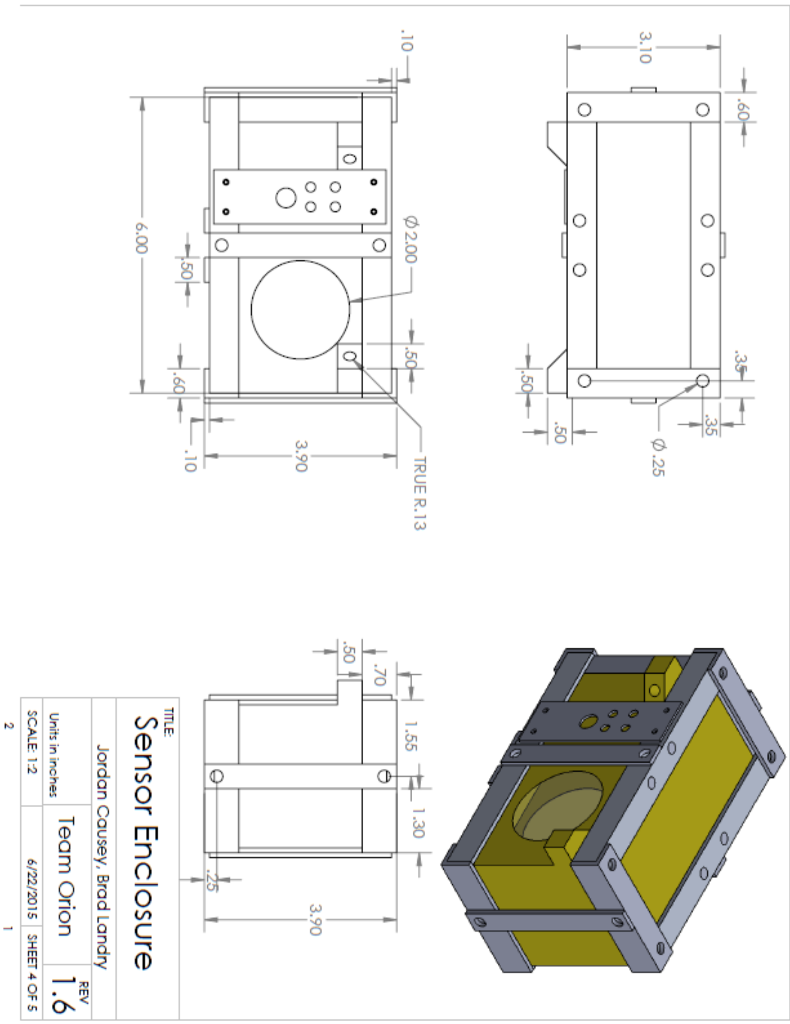


SURMA and HASP Mounting Plate Assembly. The payload will be mounted to the center of the payload and will not exceed HASP flight restrictions.

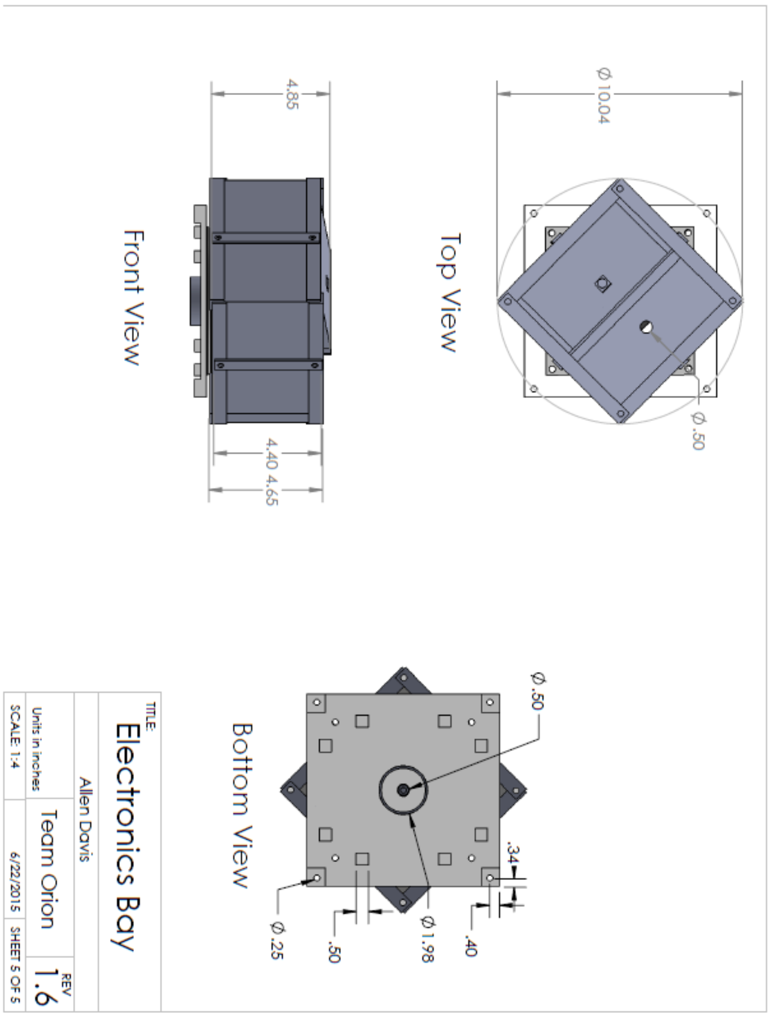


SURMA Electronics Bay Interior. The azimuthal control servo and an adjacent linear actuator is mounted to the top rotational plate with an aluminum bracket. The Control Board Assembly represents the Arduino Mega and its attached shields/conditioning boards. The internal layout is subject to change based on testing results.

Commented [VF7]: Include exploded view of this. There is a CAD drawing of the actuator.



Sensor Enclosure. The HackHD camera, UV photodiodes, and light-sensing photodiodes shall be housed within this enclosure.



External Views of Electronics Bay. SURMA's electronics bay shall be mounted through the holes depicted in the bottom view.

6.0 References

[1] http://en.wikipedia.org/wiki/File:Ozone_altitude_UV_graph.svg

[2] http://hps.org/hpspublications/articles/uv.html

[3] http://solarphysics.livingreviews.org/open?pubNo=lrsp-2007-2&page=articlesu8.html

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[8] http://www.mcmaster.com/#cadinlnord/null/=v2zu97