ARIZONA STATE UNIVERSITY 2013

H.A.T.S 2.0

High Altitude Tracking Solar Survey

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12/14/2012

High Altitude Tracking Solar Survey payload for H.A.S.P 2013 proposes to test three solar collection methods to quantify the differences in efficiency between each method at high altitude, compare the data to validate theoretical models for the devices by comparing the results with predictions calculated in advance, and to determine if any of the enhancements are viable for use in small space payloads such as the CubeSat. These methods include a standard flat solar panel, optimally angled solar panel on a solar tracker with Fresnel lens concentrator and another without, totaling three methods to test solar collection methods for the purpose of contributing research to alternative energy resources. It is hypothesized that the method with a Fresnel lens concentrator and tracking system will yield a 49% increase in efficiency relative to standard flat solar collection method.

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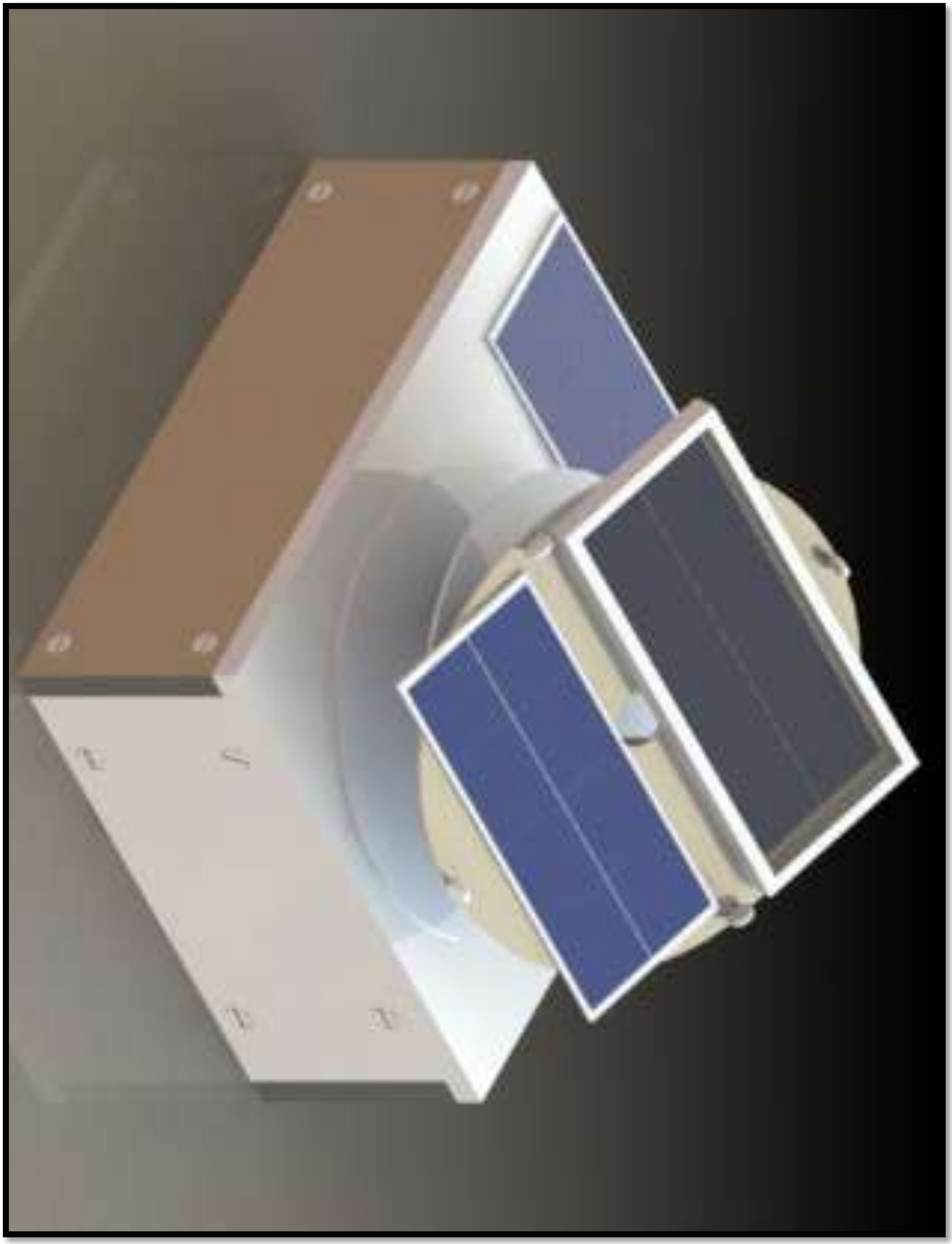

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Mission Overview

The Arizona State University High Altitude Tracking Solar Survey (HATS 2.0) payload proposes to test the efficiency of solar collection methods at high altitudes. A previous Arizona State University high altitude group, The Arizona State University High Altitude Turbine Survey (HATS) payload, proposed and flew, with HASP, a payload design with four experimental propeller designs as a function of altitude and wind speed using optical encoders to record the turbine speed. A wind sensor consisting of a wind vane and anemometer was also incorporated into the design. Despite successful collection of data by HATS, HATS 2.0 proposes an experimental payload design to test solar collection methods for the purpose of contributing research to alternative energy resources.

Given the finite nature of fossil fuels and the continuously expanding rate of global population growth, renewable energy is a critical research field with great scientific and economic potential. Solar voltaic power is one of the most popular forms of renewable energy due to its high potential for widespread application and adaptation to economies of scale. Solar panels are also very useful for spacecrafts when refueling and maintenance is prohibitively expensive. To expand on the sustainable energy research started by Arizona State University's 2012 High Altitude Turbine Survey, this proposal will focus on solar voltaic power generation instead of wind turbines. The goal of this H.A.S.P. payload is to investigate the feasibility and efficiency of multiple methods of solar collection for use at high altitude. The energy production of three different configurations of photovoltaic cells will be compared as a function of altitude and temperature.

The payload will consist of three separate solar panels, each operating at a different configuration for solar collection. The first of the solar panels will be a fixed, flat solar panel, which is commonly used for commercial and residential purposes. The second configuration will consist of a tilted solar panel, which is attached to a single axis solar tracker. The third solar panel will also be attached to a solar tracker, but will also use a Fresnel lens to concentrate the solar energy onto the cell. It is necessary to keep track of several variables such as temperature, altitude, and I-V curves of the various configurations as the payload cruises in the upper atmosphere. This data will be used to calculate the efficiencies of the three solar collection configurations, with temperature and altitude and solar irradiance as the dependent variables. This data will further expand the research that has already been done on solar collection in space. A secondary goal of this payload is to determine the relative efficiencies of the different solar configurations to further validate the research that has already been done. Data collected from the payload will allow the production of graphs similar to the one shown in Figure 1, with each configuration having their own set of graphs.

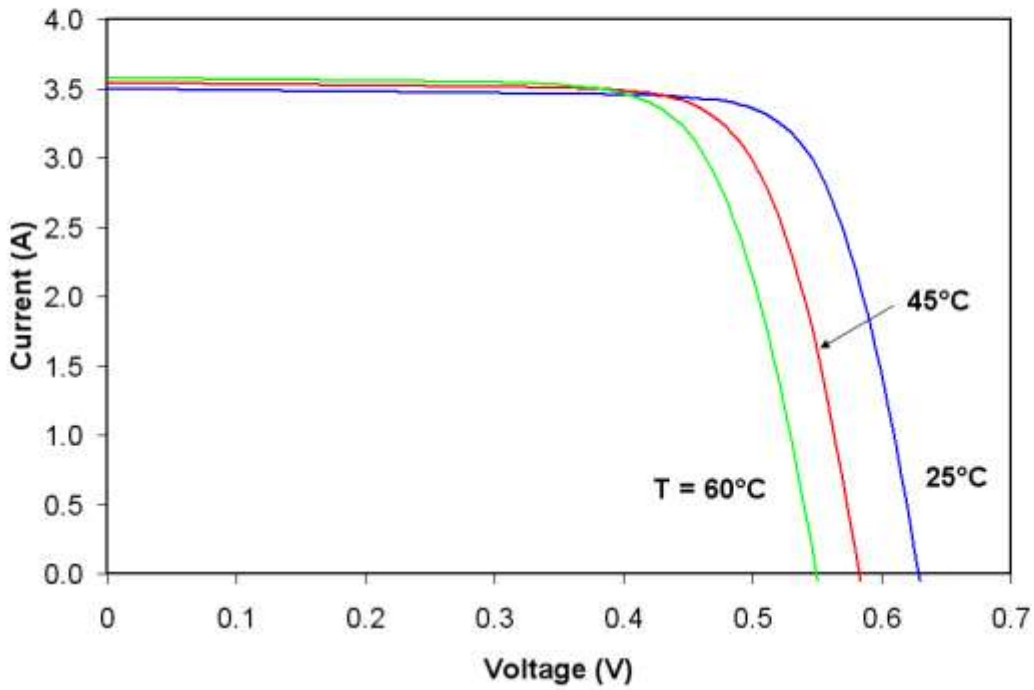


Figure 1 I-V curve of a PV cell at different temperatures.

Science Objectives

The main scientific objectives of HATS 2.0 are:

- Quantify the differences in efficiency between each method at high altitude.
- Compare the data to validate theoretical models for the devices by comparing the results with predictions calculated in advance.
- Determine if any of the enhancements are viable for use in cheap space payloads like CubeSat.

Objectives are outlined in Table 1.

Table 1 Science Traceability Matrix

Science Objective	Science measurement requirement	Instrument Functional Requirement	Mission Functional Requirement
Measure the solar efficiency of a flat solar panel	Measure the voltage and current output	Serves as a control to the experiment	Continuous power and current supply
	Calculate power efficiency by multiplying the voltage and current output	Collect high resolution data to incorporate small fluxes in solar panel input	Unobstructed sunlight (minimal shadows from neighboring payload)

Measure the solar efficiency of fresnel lens tracking method.	Measure the voltage and current output Calculate power efficiency by multiplying the voltage and current output	Collect high resolution data to incorporate small fluxes in solar panel input Move to highest solar intensity for direct sunlight Concentrate light onto solar panel	Continuous power and current supply Unobstructed sunlight (minimal shadows from neighboring payload) Height for optimal photoresistor sensitivity
Measure the solar efficiency of solar tracking method	Measure the voltage and current output Calculate power efficiency by multiplying the voltage and current output	Collect high resolution data to incorporate small fluxes in solar panel input Move to highest solar intensity for direct sunlight	Continuous power and current supply Unobstructed sunlight (minimal shadows from neighboring payload) Height for optimal photoresistor sensitivity
Compare data to validate theoretical models	Calculate efficiencies from current and voltage readings to compare with previously published theoretical models	Collect sufficient data at all altitudes to accurately represent the relationship	Ability to obtain usable data
Determine if concentrator technology is viable for use in small low cost satellites	Analyze cost and compare to efficiency data	Collect sufficient data at high earth altitudes to simulate a more space like condition for comparison in efficiency vs. cost.	Reach high earth altitude Ability to obtain usable data.

Theory and Concepts

Research on solar collection for energy production is not a new concept; in fact, there have already been several studies comparing the efficiencies of various solar configurations at ground level. Some research has already shown that tracking photovoltaic arrays are estimated to have a gain in energy production as high as 40% over optimally tilted arrays. Ground level solar concentrators generally use a 2-axis sun tracking system, which is considered the default for such systems. Research done by Gomez-Gil et al. has shown an expected energy production gain of 14.3%, 33.5% and 37.9% for concentrated photovoltaic cells, 1-axis tracking and 2-axis tracking flat panel PV cells respectively, when compared to a fixed flat PV panel (Gomez-Gil, Wang & Barnett, 2011). Technology is being upgraded constantly, yet limitations such as cloud cover and weather processes will continue to negatively affect ground based solar collection. HATS 2.0 payload aims to determine the efficiency of a Fresnel based solar concentrator at high altitude. In addition, solar tracker integration is essential to determining efficiency of collection at high altitudes for multiple collection strategies. Designs have been proposed for the use of solar arrays stationed in orbit, but the distance from the surface is too great to efficiently transfer the energy. A high altitude solar panel station could be a solution that overcomes the cloud limitation while making energy transfer possible. Since extensive experimentation of collection efficiently of photovoltaic cells at high altitudes, or low temperatures has not been done, this will be a great opportunity to expand the science of solar cells, and help to determine the feasibility and practicality of high altitude or space solar energy collection.

As the solar radiation passes from space to the earth, it is weakened in magnitude by the atmosphere in two main ways. The first weakening process is scattering, which includes Rayleigh scattering (atmospheric particles) and Mie scattering (large atmospheric particles). The second is absorption, where the energy from the photons is transferred into heat (thermal energy). The combination of these two processes is called "extinction" (Liou, K. N., 2002, *An Introduction to Atmospheric Radiation*, 2nd ed., Elsevier Science, New York). With the present composition of the earth's atmosphere being what it is, most of the extinction comes from scattering. The total radiation that falls on the earth's surface can be broken up into two main categories: direct and diffuse. The radiation that comes from diffusion increases as it becomes closer to the surface of the earth; which means it is greatest on the ground. The process of extinction also increases as you get closer to the ground and is strongest in areas where cloud coverage is high like northern European latitudes (redi et al , 2010).

Prior to the launch of our payload, theoretical and analytical methods will be used to try and determine the performance of these various configurations, under the conditions they will experience while present on the payload. Data collected during the flight of the payload will also help to either validate, or invalidate these models. Little work has been done comparing the efficiencies of photovoltaic cells at high altitudes, or low temperatures, so this will be a great opportunity to expand the science of solar cells, and will help to determine the feasibility and practicality of high altitude or space solar energy collection.

Concept of Operations

A Fresnel lens is essentially a chain of prisms, which focus light at a point. Most Fresnel lenses that are used for solar energy production were not originally designed for the collection of solar rays, but rather were imaging devices. An imaging Fresnel lens refracts light from an object, and projects the image onto its focal plane (Xie, Dai, Wang & Sumathy, 2011). One of the challenges with imaging Fresnel lenses that are used for photovoltaic generation of electricity is that they often need to employ accurate tracking techniques to keep the focus of the lens in place on the cell. However, plastic Fresnel lenses are very practical for space solar concentrating, since they are light weight, and are capable of elevating the density of solar energy, which make them a great concentrator for photovoltaic power generation. According to Xie et al., a curved prismatic Fresnel-type lens, which is primarily used for concentrating sunlight in a solar collector, is the best known commercially introduced concentrator technology for photovoltaic energy production. Work done by MJ O'Neil, had produced a novel, high-efficiency, extremely light-weight, and stretched Fresnel lens solar concentrator, known as an SLA. This stretched lens array was developed for space power applications. The SLA consists of a flexible Fresnel lens attached to end supports, which is a similar design to what we intend to use for the solar tracking Fresnel lens configuration. The SLA provides significant advantages over the prior space photovoltaic concentrator arrays, due to it being much lighter, more economical, and is easier to stow into a compact volume for launch. In addition, the SLA also eliminates the need for a glass superstrate to support the lens, which greatly improves its robustness. The SLA has also been shown to provide 180W/kg specific power at a greatly reduced cost compared to conventional planar photovoltaic arrays in space.

Expected Results

Based on previous research performed by Gill & Barnett (2011) it is predicted that the single axis tracker will add a 35% increase in energy gain and the concentrator will add at least an additional 14%. It is also predicted from previous research that there will be an increase in energy from the high altitude as well. Less atmospheric gas will is expected to reduce the scattering of solar radiation and, more importantly, provide fewer opportunities for it to be absorbed by other objects and transferred to heat. Avoiding cloud cover will provide the opportunity to increase energy output by as much as 600% over equivalent ground based solar arrays. (Aglietti et. al. 2008). HATS 2.0 expects to have results showing these variable conditions to validate or question claims made in previous researches.

Data collected from the experiment will be analyzed using MatLab program to compile a graph of the solar energy input per solar panel relative to altitude. Similar graphs can also be made of temperature and pressure.

Payload Design Details

Requirements

Detailed Mass Budget

Table 2 Detailed Mass Budget for Complying with Requirement

Components	Mass (kg)
Servo	0.044
Fresnel Lens	0.030
Solar Panel	0.500
Mount System	0.100
Photoresistors (x4)	0.0004
Temperature Sensor	0.001
Pressure Sensor/Altimeter	0.002
Arduino	0.096
Ammeter/Resistor	0.0001
Data Collection	0.006
Base Aluminum Frame	2.900
Communication	0.006
DC Converter	0.170
Electronics Box (Empty)	3.900
Gyro	0.0017
Total Mass:	7.7512
Mass Under Requirement	12.2488

Detailed Power Budget

Table 3 Detailed Power Budget for Complying with Requirements

System Component	Voltage	Current	Power requirements
Arduino Mega	5 V	610 mA	3.05 W
1 axis 360 degree servo	6.0 V	2A	10.8 W
3 axis Gyroscope	3.6 V	6.5 mA	0.0208 W
Pressure Sensors (X 2)	3.6 V	N/A	"ultra low" – N/A
Temp. Sensors (X2)	3.6 V	10µA	0.000036 W
Max power allowed	**82.5 W**	**Power Total**	**13.87 W**

Mechanical System

The mechanical system of the payload is comprised mainly of the solar tracking system. The electronics housing structure of the payload will be re-flown from HATS 1.0 flight. Details of the components in the electronics structure can be found in the section on Electrical System.

The solar tracking system proposed is intended to satisfy technical requirements that are specific to the studied application of maximizing solar efficiency for comparative analysis. The design of this system aims to maximize solar energy input through optimal condition such as unobstructed path of sunlight. The system is designed to perform under wind, rain, and temperature variation and remain cost efficient and viable relative to other method of solar collection. The HASP dimensional constraints are addressed and complied as the base and interface of the payload to the large seat remains in the exact dimensions as HATS 1.0 flight. See Figure 2 for diagram of payload integration to H.A.S.P platform. The solar tracking system is the main addition built upon the dimension of the top of the electronics structure. A request for height waiver is included in the section titled Waiver Request at the end of the document. The layout and dimensions of the proposed payload are outlined in Figures 3-6.

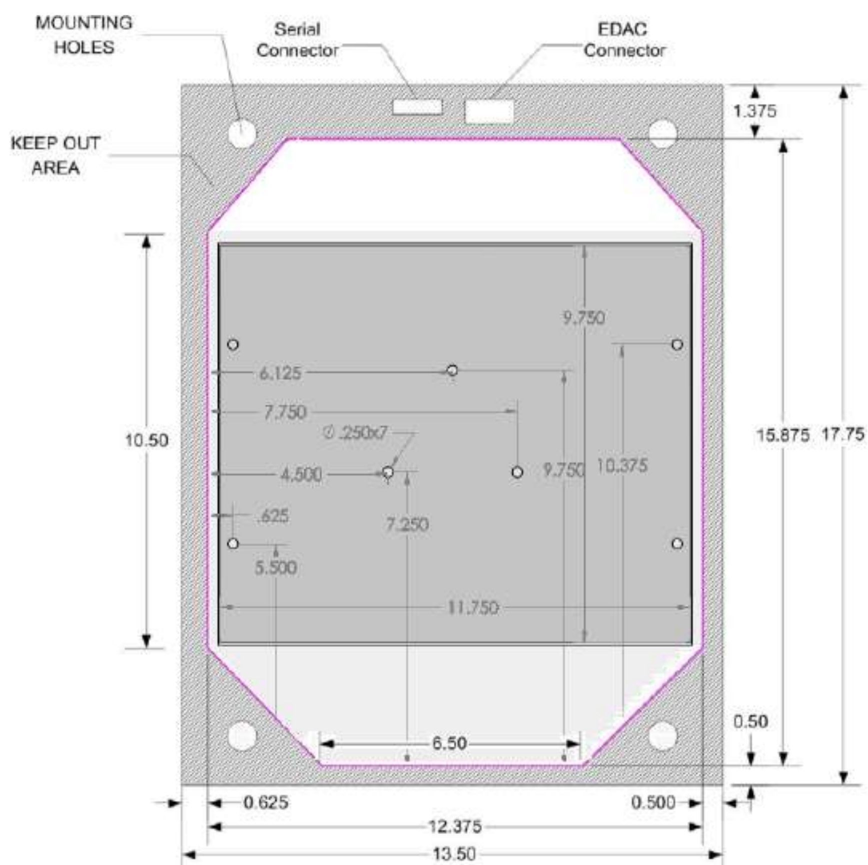


Figure 2 Payload Integration to H.A.S.P

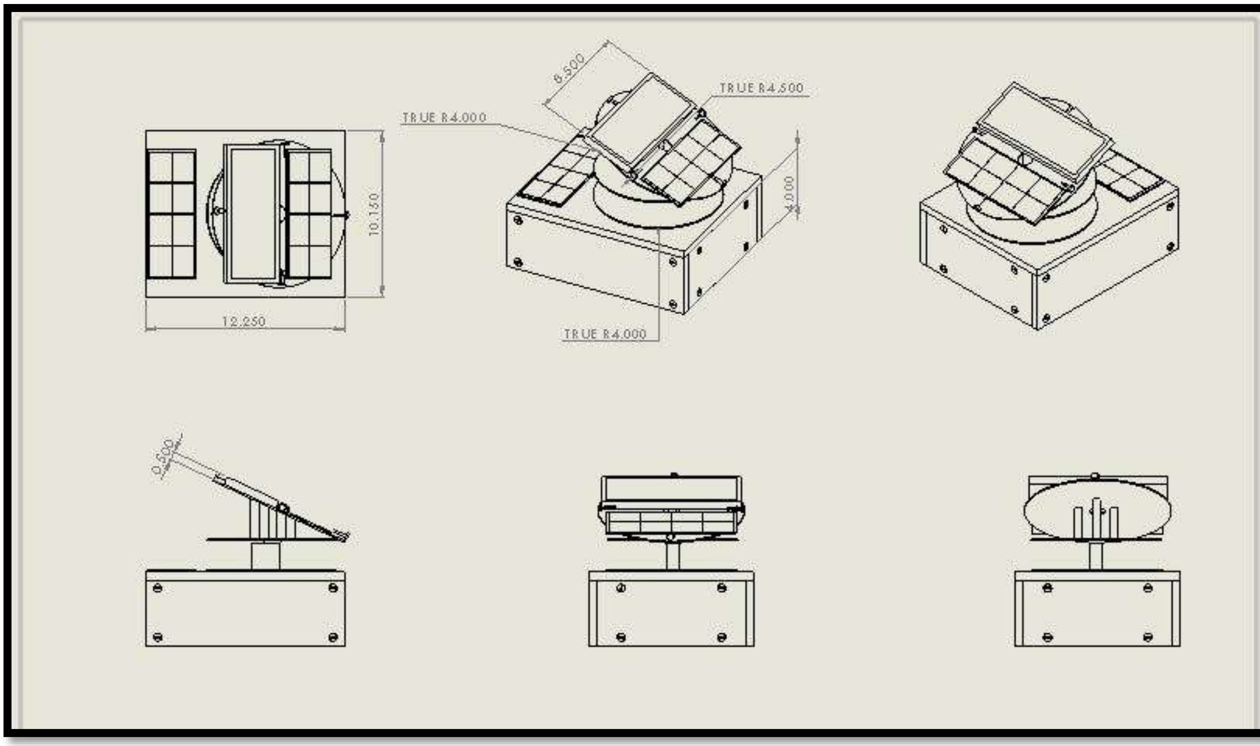


Figure 3 Six sided view of the proposed payload

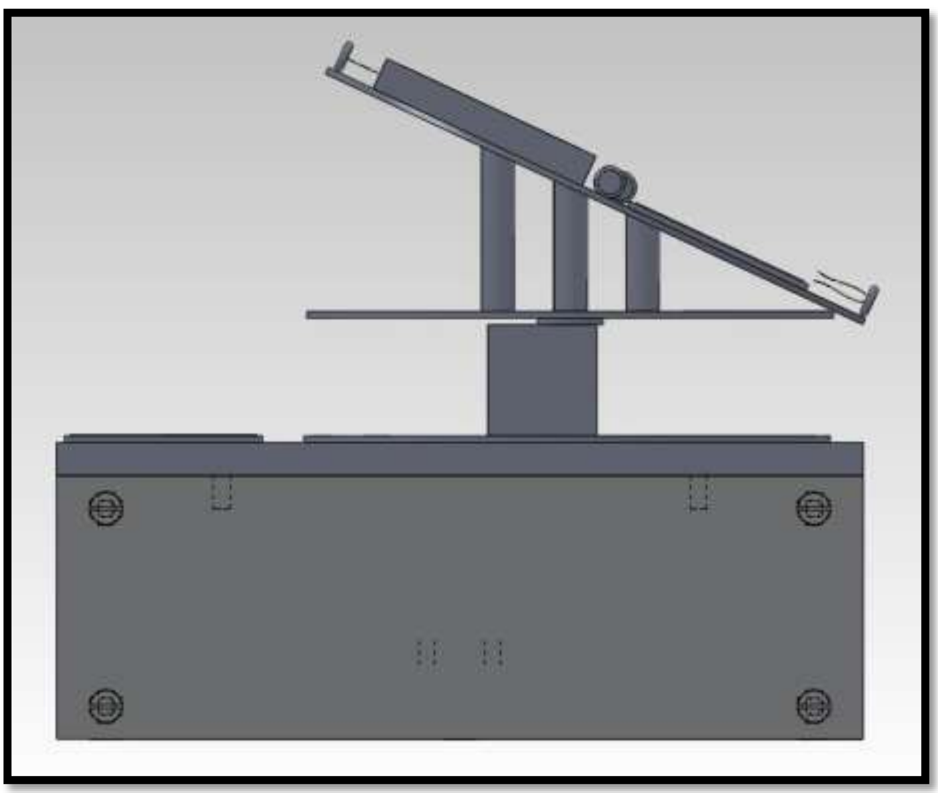


Figure 4 Side rendering of the proposed payload

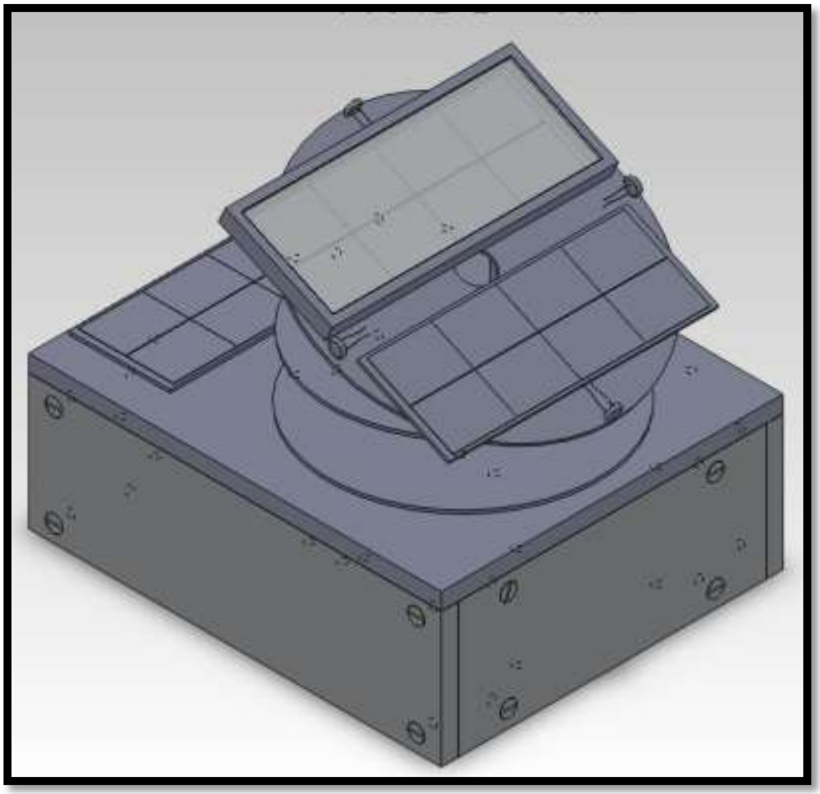


Figure 5 Front Angled View of the Proposed Payload.

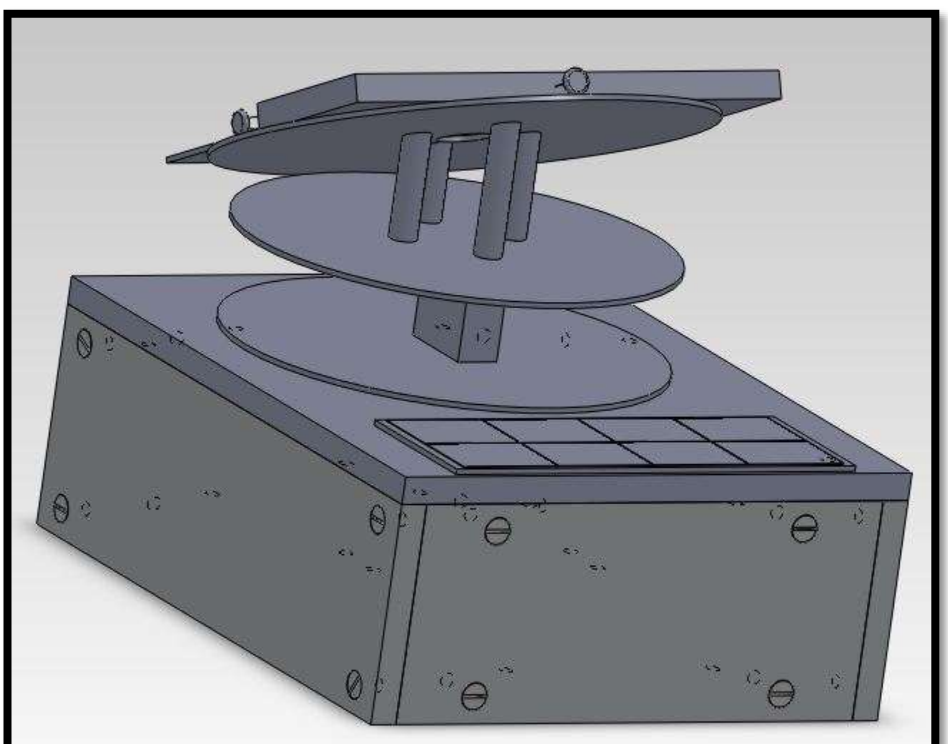


Figure 6 Back Angled View of Proposed Payload

The electronics structure of HATS 1.0 being re-flown serves as a base for the solar tracking system mounted on top. The set of squares in the payload models represent the solar panel. Four photovoltaic cells will be used in total (not imaged), to indicate the highest solar intensity for the servo to rotate the solar panel platform to the position of the photoresistors. One of the solar panels acts as a control, and will lie completely flat on the surface of the frame; the other two are mounted at an angle that can be determined by consulting the following chart that shows the optimum tilt for solar panels at given latitude.

Table 4 Optimum Tilt of Solar Panel

Latitude	Summer angle	Winter angle	% of optimum
25°	2.3	41.1	76%
30°	6.9	45.5	76%
35°	11.6	49.8	76%
40°	16.2	54.2	75%
45°	20.9	58.6	75%
50°	25.5	63.0	74%

The latitude of Fort Sumner, New Mexico is 34.5° N with a launch in September, the ideal tilt for the solar panel is approximately 49°. This angle will be fixed, and will not fluctuate throughout the entire flight. The solar tracking system, increasing solar efficiency, will be mounted on top a plate connected with a single axis servo with a 360° freedom to rotate to the position of the photoresistor in which the sunlight it is receiving is highest, thus most direct. Fresnel lens will be mounted over one tilted panels using aluminum rods secured with hex nuts and screws which will be fixed at a focal distance, allowing the sunlight to be concentrated onto the solar cells.

The microcontroller, Arduino Mega, will power the servo through the 5V DC pin. The Arduino will be acquiring power from HASP power supply. Check the section Electrical Systems for drawings of the power distribution. The photoresistors will be mounted centered between the tilted solar cells. These resistors will be stationary relative to the platform, and will be oriented in four orthogonal directions. As sunlight hits these resistors, it will experience a greater amount of energy relative to the others. This information will be relayed to the Arduino, which is programmed to rotate the servo to the photoresistor with highest light intensity output.

With the exception of the photoresistors and the servo, electrical components will be housed in the electronics structure to mitigate failure from thermally variant conditions.

Electrical System

The electrical system will consist primarily of a set of sensors, a 360 degree one axis servo, and an Arduino Mega. The sensors include two pressure sensors, two temperature sensors, and a gyroscope. These set of sensors are connected in parallel with the Arduino and the HASP power source converted to 5V using a 5V out DC to DC converter. The servo is powered through the 5V power source from the Arduino. The primary components and their power requirements are outlined in Table 7. Power distribution drawing is included in Figure 7.

The electrical system will be in the base structure of payload with the exception of the servo and photo resistors, to ensure functionally in variant thermal conditions incurred while ascending to high earth altitude.

Electrical components not included in the drawing are: three data loggers, three solar panels, three current sensors and four photo resistors.

Table 5 Electrical System Components and Power Requirements

System Component	Voltage	Current	Power requirements
Arduino Mega	5 V	610 mA	3.05 W
1 axis 360 degree servo	6.0 V	2 A	10.8 W
3 axis Gyroscope	3.6 V	6.5 mA	0.0208 W
Pressure Sensors (X 2)	3.6 V	N/A	“ultra low” – N/A
Temp. Sensors (X2)	3.6 V	10 μA	0.000036 W
Total Power Required			**13.87 W**

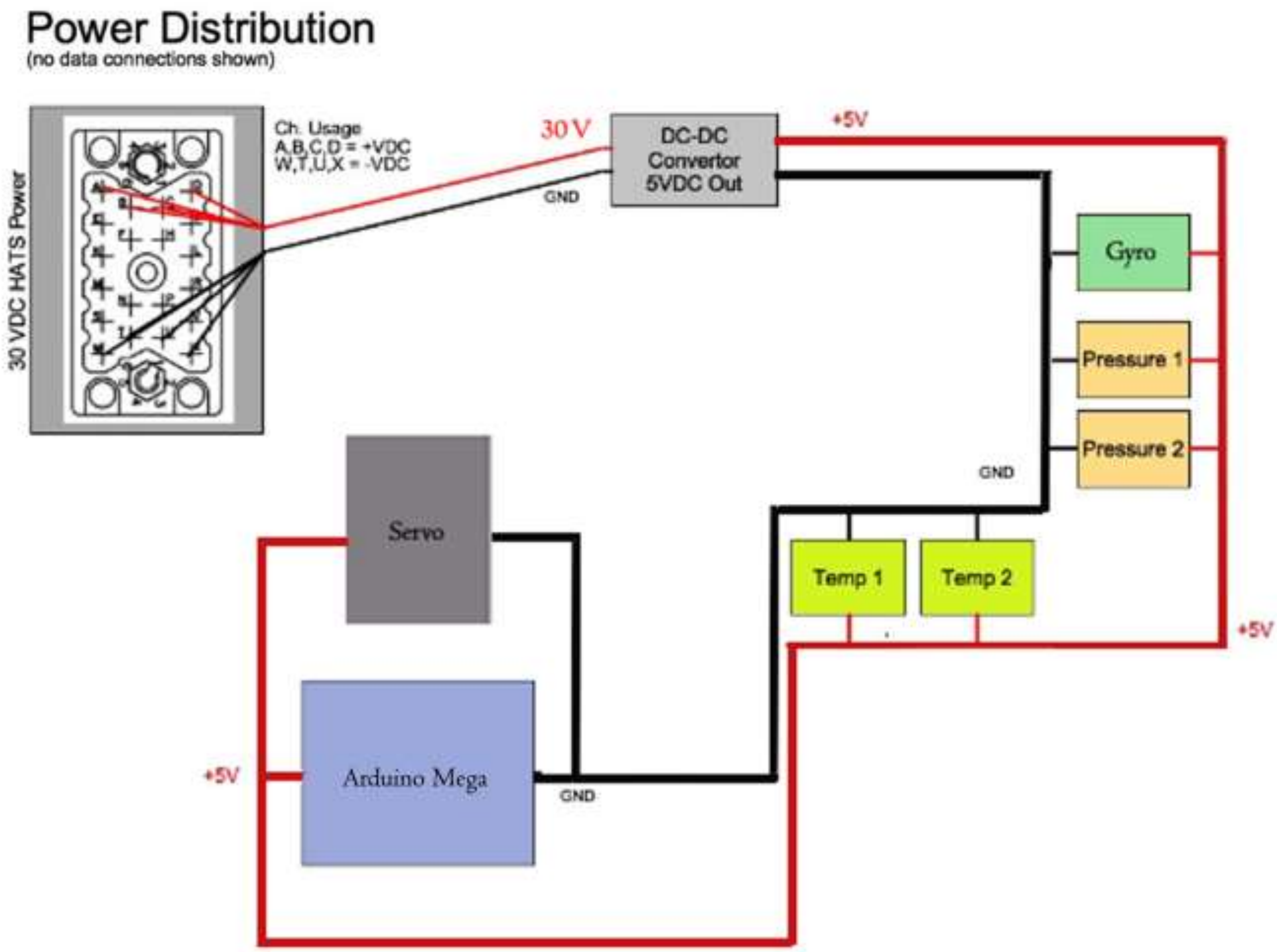


Figure 7 Power Distribution Drawing of Primary Electrical System Components

Software System

The software system of the payload includes the Arduino programing system. The Arduino Mega will be used to regulate the motion of the solar tracker through the analog input data of four photo resistors and digital 360 degree one axis servo. Data input received from the photo resistors on the highest light intensity will be relayed through the Arduino to move the servo, rotating the platform to the servo location of highest light intensity. The data output from the solar panels will be relayed through current sensors then to the Arduino to log voltage and current output of the solar panels. Temperature, pressure, and gyroscope data will be logged for post flight analysis. The temperature sensor will also be regulating the thermal conditions of the payload to mitigate overheating risks. See Figure 8 for a drawing of data handling in the software system of the payload.

Data from the sensors and the solar panels will be downlinked using heritage software from HATS 1.0 interface. The HATS 1.0 software code will need minor changes in order to function with the alterations of HATS 2.0. Assuming the limit of 4800 bauds, this translates to 480 bits per second or 60 bytes per second. Table 6 shows the estimated logging and relay rates at high resolution, which are subject to change as testing on the system progresses. The changes will abide to the limit of 4800 bauds in placed by H.A.S.P program.

Table 6 Estimated downlink and Data Logging Details

Component	Ground Relay Rate [Hz]	SD Logging Rate [Hz]	Data Type [bytes]	Total [Bytes per second]
Pressure 1	1	20	8	160
Pressure 2	1	20	8	160
Temperature 1	1	30	8	240
Temperature 2	1	30	8	240
Gyroscope	0	20	8	160
Solar 1	1	10	8	80
Solar 2	1	10	8	80
Solar 3	1	10	8	80
Total SD Data Logged				1200 Bytes per second
Total Ground Relay	Allowed:	60 Bytes per second	**Estimated:**	**56 Bytes per second**

Note that the analog inputs will not require 8 bytes (typical is 8 bits), but it is overestimated to allow for flexibility in case there is a need for a digital conversion.

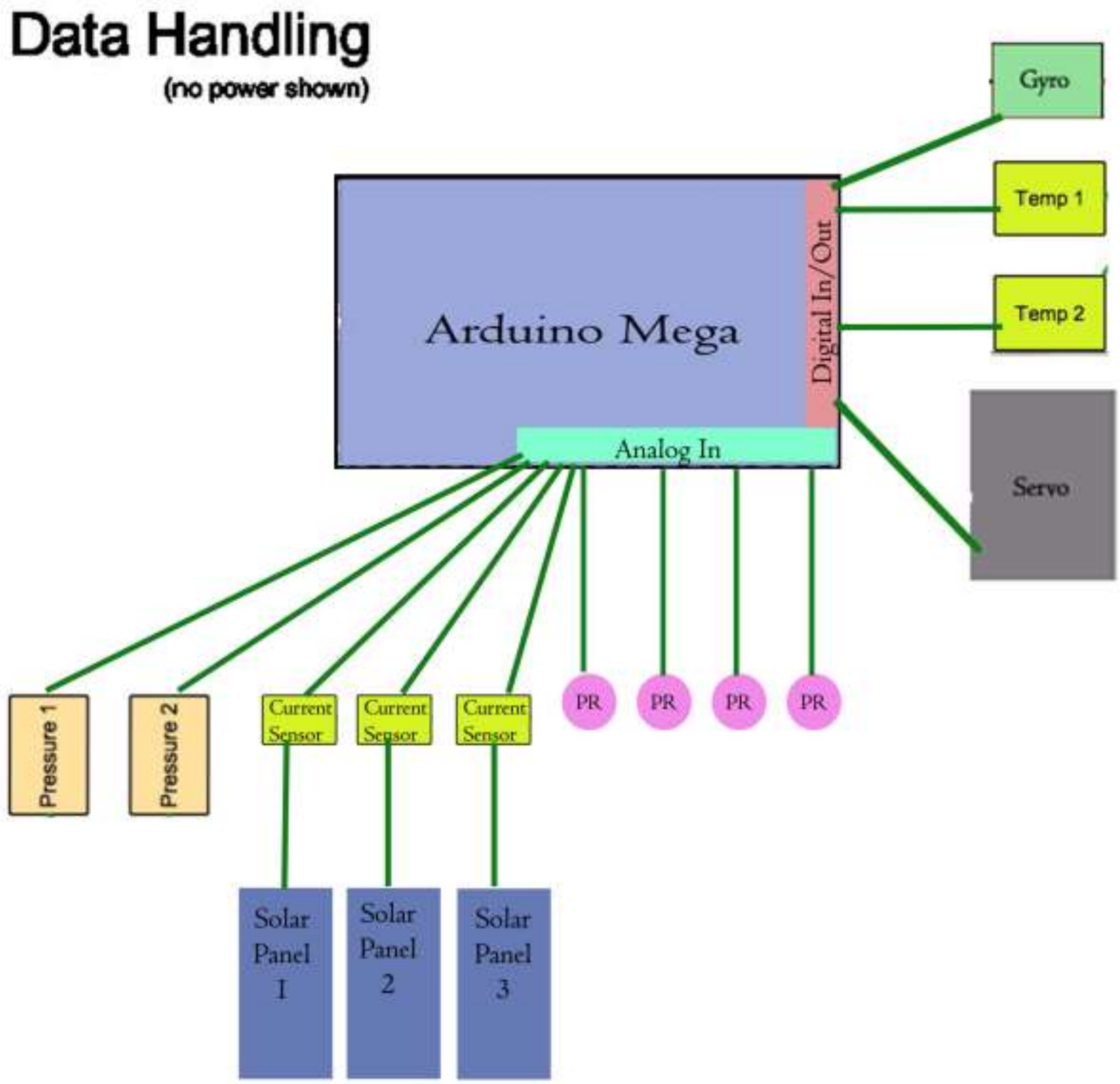


Figure 8 Data Handling Diagram

Thermal Management

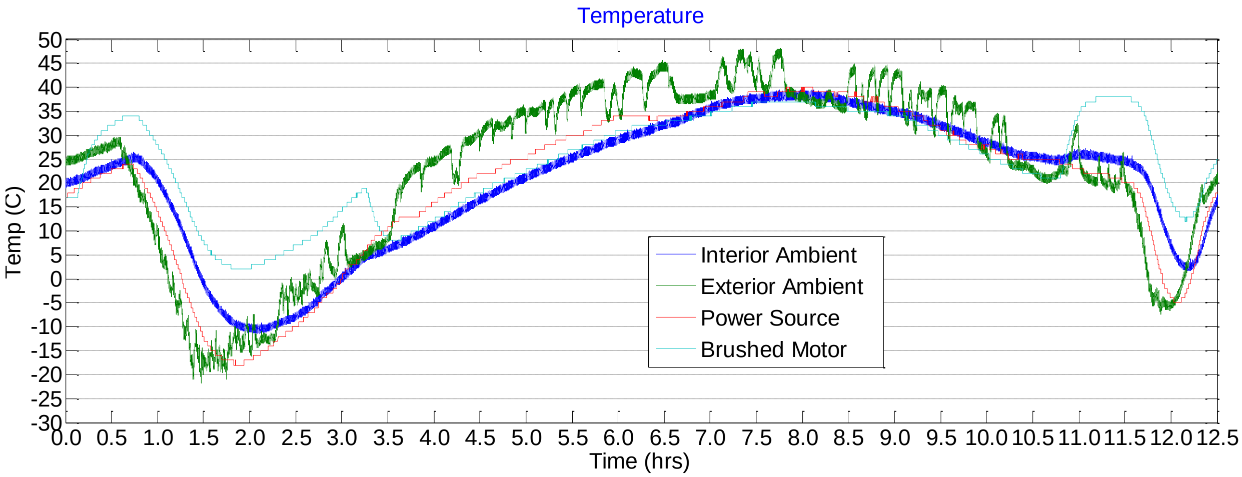


Figure 9 HATS 1.0 Temperature Data

The exterior temperature during flight ranges from 40˚C to -70˚C from ascent to descent. It is important that the payload system is capable of maintaining functionality during this flux for data collection. HATS 1.0 encased the majority of electronics in an aluminum box to resolve this constraint using excess motor heat and a set of 2 W resistors to maintain an interior temperature range allowing functionality of the electronics encased. HATS 2.0 will be using a similar design to insulate the temperature sensitive components if initial cold tests return results requiring insulation. A temperature sensor inside the electronics box will monitor and relay to ground, the interior temperature to maintain an idealized temperature of 40˚C to -20˚C. If test data exhibits the need for further insulation, the aluminum box encasing will be rebuilt with a lower thermally conductive material such as carbon fiber or Balsa wood. Overheating is predicted to pose more of an issue to the payload from previous flight data analysis. Without the motors implicated in HATS 1.0, HATS 2.0 is not posed with a 6 W excess heat internally. In the case of overheating, electronics will be powered down temporarily to re-establish safe temperatures with the exception of minimal electronics required to power the system on and off. Overheating will also be resolved by increasing surface area and volume of the electronics structure in the vertical direction with a height wavier permitted for purposes listed in Waiver Request section. The extra volume and surface area will allow heat to dissipate to the structure to prevent overheating.

System components not included in the insulating box such as the solar panels, servo, and photoresistors are rated and will be tested to operate in the full flux of the exterior temperatures. There will be cold tests performed on the HATS 2.0 system in order to ensure that the system can maintain functionality throughout the temperature flux exposed. Components will be individually tested and then tested as a system to pinpoint sources of potential error. In addition to the cold tests, a thermal vacuum test will be needed to analyze the heat dissipation at low pressure and temperatures.

Prototyping and Analysis

HATS 2.0 performed some baseline tests to understand the concept of solar energy better. On an Arizona NASA Space Grant balloon payload launch, the Aerospace STEM Challenges to Educate New Discoverers (ASCEND!) team invited HATS 2.0 to integrate a 5V solar panel to an Arduino Due as a sensor to measure the voltage changes relative to the altitude. The purpose of the test is to determine the behavior of a solar panel as well as to learn how to use a solar panel as a sensor as oppose to a power supply. The 5V solar panel was an of the shelf product from Fry's Electronics.

Figure 10

The data from this baseline test returned unchanged values for the voltage output from the solar panel. The 5V solar panel remained unchanged at 4.092 V. It was previously tested in the dark with flashlight so therefore, the functionality of the code or solar panel is excludable relative to the data return. 30 points of data, 15 from beginning and 15 from end are included in Figure 11. Possible interpretations of the data include a need for higher resolution sensor or a need for higher voltage solar panels. Possible solutions include analog to digital converter and higher voltage solar panel.

Time	T(degC)	Pressure(P	Alt(m)	w(mV)	w(deg/s)	Solar(mV)
3.77	26.56	95985	454.3	494	-5	4092
3.91	26.57	95985	454.3	515	8	4092
4.05	26.59	95986	454.21	513	7	4092
4.19	26.6	95982	454.56	508	4	4084
4.34	26.61	95986	454.21	512	6	4040
4.48	26.62	95982	454.56	507	3	3988
4.62	26.63	95988	454.04	501	0	3960
4.76	26.63	95983	454.48	499	-2	4032
4.91	26.64	95985	454.3	494	-5	4092
5.05	26.64	95985	454.3	484	-12	4092
5.19	26.64	95987	454.13	490	-8	4092
5.34	26.65	95983	454.48	497	-3	4092
5.48	26.65	95985	454.3	501	0	4092
5.62	26.65	95987	454.13	506	2	4092
5.77	26.65	95985	454.3	498	-2	4092
9905.7	31.2	96838	380.38	501	0	4092
9905.86	31.2	96839	380.3	502	0	4092
9906.02	31.2	96839	380.3	508	4	4092
9906.18	31.2	96839	380.3	503	0	4092
9906.34	31.2	96837	380.47	512	6	4092
9906.5	31.2	96843	379.95	504	1	4092
9906.66	31.2	96844	379.86	507	3	4092
9906.82	31.2	96840	380.21	515	8	4092
9906.98	31.2	96834	380.73	511	6	4092
9907.14	31.2	96838	380.38	513	7	4092
9907.3	31.2	96838	380.38	506	2	4092
9907.46	31.2	96842	380.04	503	0	4092
9907.63	31.2	96837	380.47	500	-1	4092
9907.79	31.2	96834	380.73	497	-3	4092
9907.95	31.2	96836	380.55	506	2	4092

Figure 11 ASCEND! Fall 2012 Data. Right Column shows solar panel voltage output in mV

The next step in prototyping and analysis of the design include testing the sensitivity of the photoresistors and maneuverability of the servo to rotate to the photoresistor. A concern regarding the design was the stability of the payload and the ability of the servo to rotate fast enough. Data in Figure 12 from last year's HATS 1.0 flight show that the rotational speed of the payload in the majority and higher altitudes of the flight is stable.

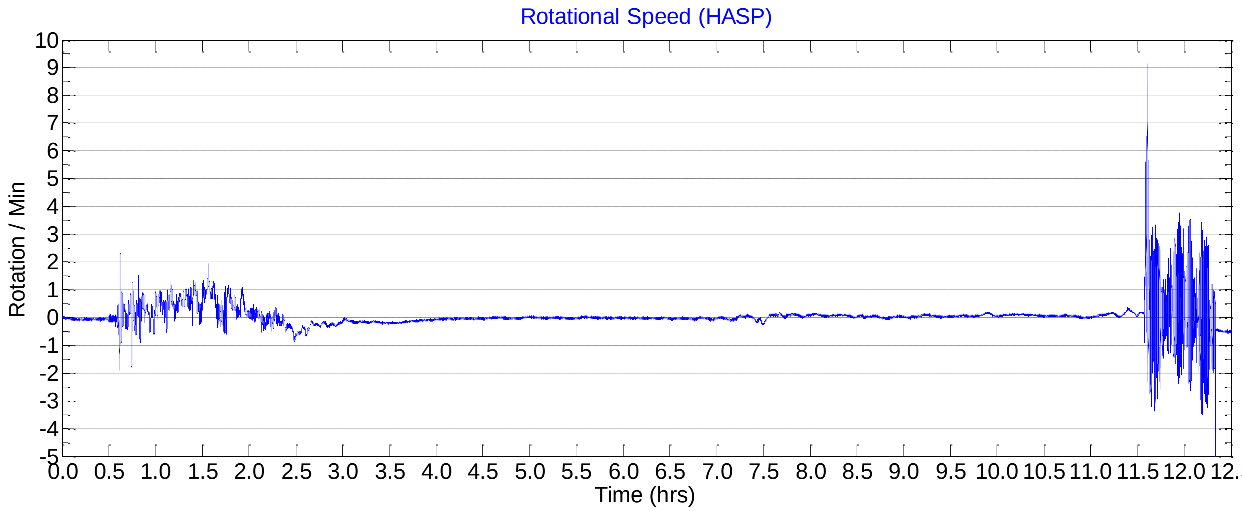


Figure 12 HATS 1.0 Payload Rotation Data

This relative stability in higher altitudes is predicted to be sufficient for the single axis 360˚ servo to track the sun accurately and efficiently.

Systems Level Testing

The system will be tested locally in addition to compliance with H.A.S.P testing requirements. All components of the payload system will be individually tested cost efficiently with air circulated cooler filled with dry ice to bring down temperatures to approximately -50˚C to simulate extreme cold temperatures of high earth altitude. Local full system payload tests will be performed in facilities available in the labs of faculty in School of Earth and Space Exploration.

A full system test will diagnose componential malfunctions and problems to be addressed. Figure 12 shows the flow chart for the functionality and success of the experiment. In the case that one or more components fail, a redundancy or substitution will need to be increased to increase the reliability of the payload system.

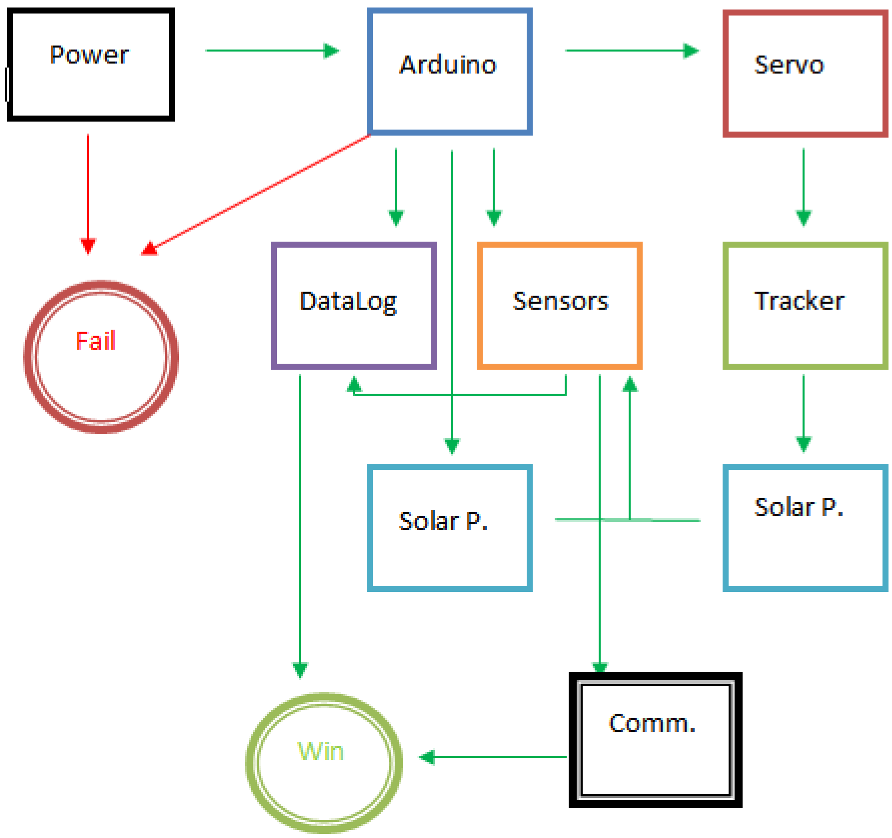


Figure 13 Systems Level Functionality Flow

From Figure 13, if the main power provided by H.A.S.P were to fail then it would result in a total system fail. A solution to this potential problem includes a lithium ion battery backup, connected directly to the Arduino. Options are being explored to mitigate this risk. A failure of the Arduino would also result in a total system failure. To mitigate this failure, extra precaution will be taken by the team by testing in maximum parameters of the Arduino.

Additional testing includes mounting the solar tracker system of the payload onto a 40 ft tethered large plastic helium balloon to test and calibrate the system. This resource is available through Dr. Ramon Arrowsmith's low altitude imaging group at the school of Earth and Space Exploration.

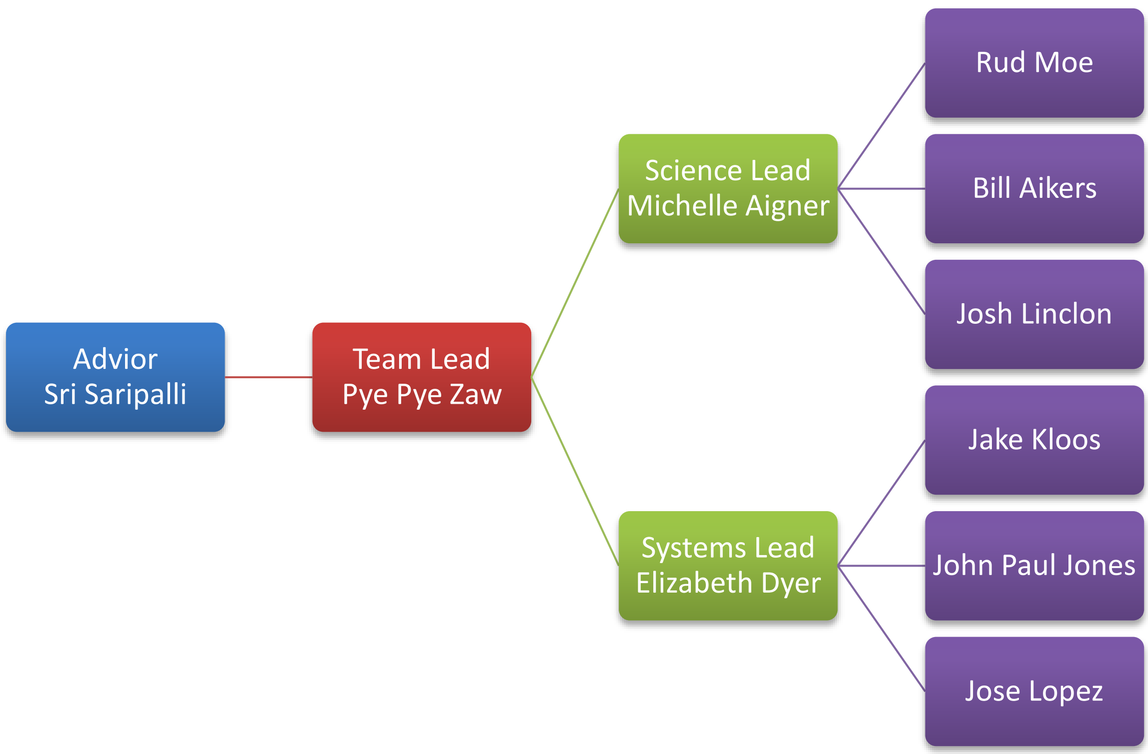
Risks

There are a few foreseeable risks that could complicate our payload and possibly jeopardize our science objectives. The primary risk that needs to be mitigated is the overheating of electronics. Since the atmosphere is so thin at such a high altitude, there is very little air mass to allow for efficient cooling by convection. To compensate for this, we will need to run vacuum tests on the payload, to see exactly how hot these electronics will be with less air density. To emulate the effect of the solar cells generating power, we could generate their maximum wattage using a resistor and power source. Once we know how hot the electronics are expected to be, we can then make the proper changes to the payload to correct for them. This could include adding in large surface area heat sinks to areas that get particularly hot. It is also possible that there is an electrical shortage or that one of the electrical components fails during the flight. To reduce these risks, the payload will be tested before flight, to make sure that all of the electrical components are working properly.

Project Management Plan

The HATS 2.0 team is comprised of nine senior design students from the school of Earth and Space Exploration at Arizona State University led by Pye Pye Zaw and advised by Professor, Dr. Sri Saripalli. The team has a stronger science background with some previous hands on experience in engineering. It will be a learning experience for the team to design and build a payload to participate with H.A.S.P.

Work Breakdown Structure



The team is broken down into science and an engineering team to maximize efficiency and productivity. The science team is led by Michelle Aigner and the engineering team is led by Elizabeth Dyer. The teams are broken down into specialties and relevant interests.

Schedule

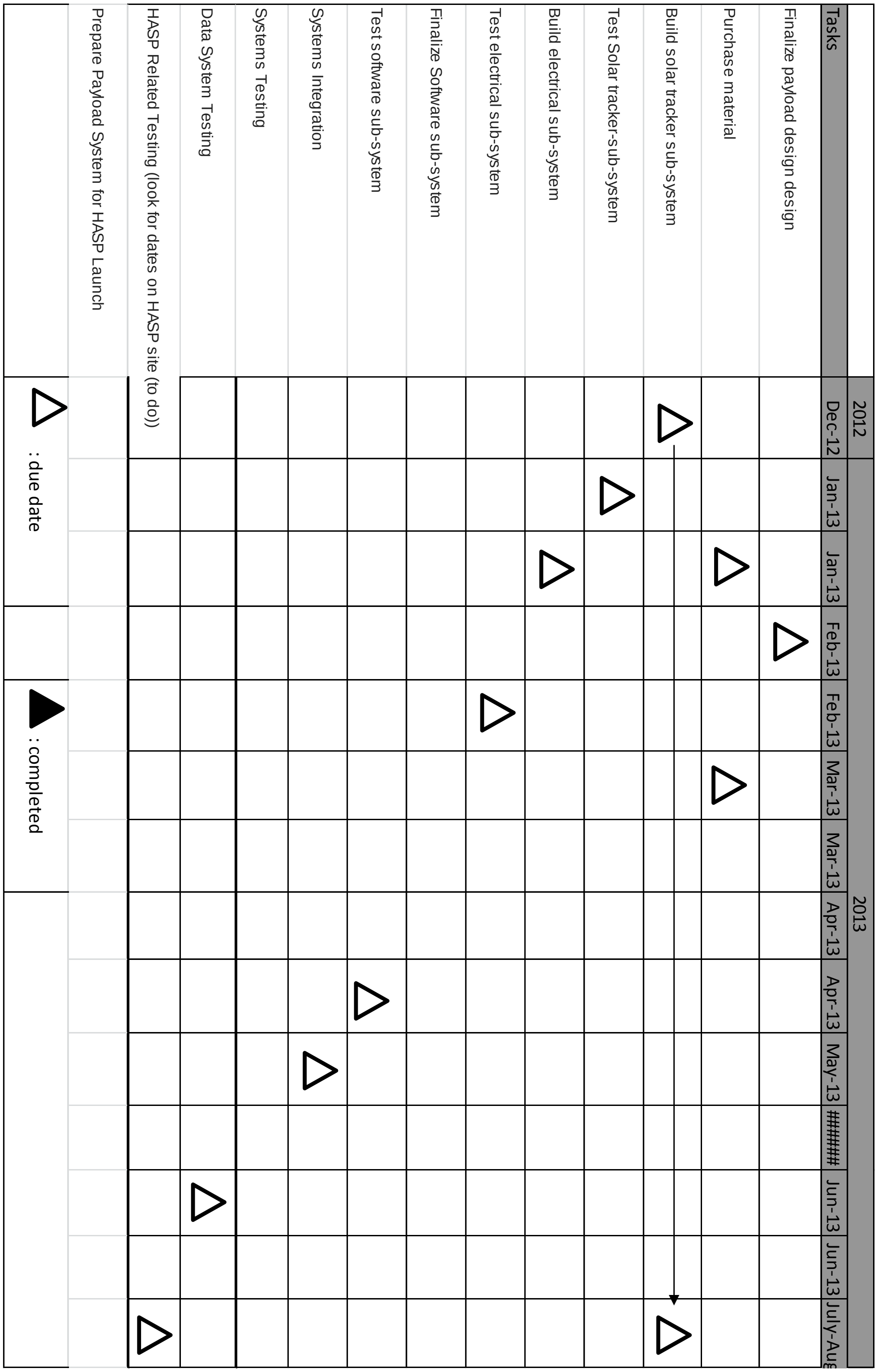


Figure 14 Milestone Scheduel

Budget

The build cost is fully funded by *School of Earth & Space Exploration* Grant up to $5,000. However, the total budget for HATS 2.0 is estimated to be much less. There is a 15% buffer in the budget for unexpected increases in costs due to availability. In addition, components of the HATS 1.0 such as the regulator, SD cards, and sensors will likely be reused thus lowering the cost. Reuse of certain components from HATS 1.0 will ensure reliability and reduced the cost of the project significantly. The budget of primary components is given in Table 2.

Table 7 Estimated Project Budget

Item	Supplier	Estimated Cost	#	Total cost	Notes
Servo - Large Full Rotation	Sparkfun	$13.95	1	$13.95	1 axis, 360 degrees
Triple-Axis Digital-Output Gyroscope - ITG-3200	Sparkfun	$ 24.95	1	$ 24.95	
Digital Temperature Sensor Breakout - TMP102	Sparkfun	$5.95	2	$ 11.90	
Arduino Mega 2560 R3	Sparkfun	$58.95	1	$ 58.95	
12 V Solar Panels (appx cost)	N/A	$30.00	3	$ 90.00	Frys, wildgame, radioshack
1/4" Aluminum Plate	McMaster	$29.00	1	$ 29.00	Top and Tracker
Voltage Regulator (5 V)		$1.00	1	$ 1.00	
Serial to USB cable	Frys	$25.00	1	$ 25.00	HASP to Arduino I/O
SD Data Card	Frys	$54.00	2	$ 108.00	
CdS Photoresistors (5-Pack)	RadioShack	$3.69	4	$14.76	
Fresnel Lens	Hobby Tool	$10.00	1	$10.00	
				Estimated Budget	**$445.64**

In the case that the $5000 budget does not cover travel, ASU NASA Space Grant will assist to transportation cost to payload integration/testing and launch.

Waiver Request

In order to get data that most accurately represents the solar tracker collection method it is necessary that the Fresnel lens and the photoresistors be elevated above the platform so that they are unimpeded by adjacent payloads of the HASP gondola. The necessary height that is required for the photoresistors and Fresnel lens will depend on the height of the instrumentation of the adjacent large payloads. The precise height of these components is still currently unknown; however, the solar array must be positioned at or above tallest element of the contiguous payloads.

If the light-dependent components from HATS 2.0 and instruments in the neighboring payloads are both stationed at the maximum allowed height (30cm), then at certain angles sunlight will be blocked from reaching the HATS sensors. For this reason it is important to have the option, if necessary, to break the height restraint and raise the payload above the potential obstructions. Because the experiment juxtaposes three different solar collection methods, inaccurate readings in one method will result in a less reliable comparison of solar efficiency at high altitudes.

While the photoresistors and the Fresnel lens would operate more effectively at an increased height, it is important to note that the scientific objectives of this mission will not be entirely compromised if the height waiver is not granted. The photoresistors are designed to orient the tracker towards the highest concentration of sunlight. If other payloads are blocking sunlight the system may be less efficient but the device will reorient and data collection will still be possible.

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