HASP Student Payload Application for 2012

Payload Title: HELIOS (Hydrogen-alpha Exploration with Long Infrared Observation Systems of the Sun)

Payload Class: (check one) ☐Small ☑Large	**Institution:** University of Colorado at Boulder	**Submit Date:** 16 December, 2011

Project Abstract:

Team HELIOS recognizes the unparalleled opportunities offered by balloon flights for research and experimentation. HASP is especially unique in its scale and facilities available for student purposes. To maximize float-time research, Team HELIOS proposes to observe the Sun in the Hydrogen-Alpha and Infrared wavelengths utilizing customized optics and an Attitude Determination and Control System (ADCS). Through post-flight analysis of images in these wavelengths, valuable data on solar phenomena can be ascertained and the accuracy of the ADCS verified. High-altitude balloon platforms provide an incredibly accessible location for astronomical observatories, avoiding both the crippling costs of orbiting satellites and the atmospheric interference of ground based operations. The team is comprised of a Project Manager, Systems Engineer, and four Section Heads, along with Project Advisor Lia Matthews and CASA Director James Green. Over the course of nine months, Team HELIOS shall meticulously design, construct, and test a Large 20kg payload capable of assessing the feasibility of these systems in the rugged high-altitude environment.

Team Name: Team HELIOS	**Team or Project Website:** http://spacegrant.colorado.edu/index.php/current-projects/hasp

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Dr. T Gregory Guzik
Department of Physics and Astronomy
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Dear Dr. Guzik

Thank you for taking the time to read our proposal, and for considering our payload for the 2012 flight of the HASP platform. We look forward to hearing from you as the selection process nears. The results from the previous University of Colorado at Boulder HASP teams of 2008 (DIEHARD), 2009 (BOWSER), and 2010 (SPARTAN-V) were valuable in determining the feasibility of high altitude observatories. This year's HASP team offers the opportunity to extend this research into wavelengths outside the visible spectrum, as well as continue research into balloon based pointing systems. Our research provides the opportunity to work with experts such as Dr. James Green, Principle Investigator of the Cosmic Origins Spectrograph, and to extend our work into facilities such as CASA (Center for Astrophysics and Space Astronomy). The HASP platform is the most suitable device to test our imaging systems in high altitude environments and to compare them to similar orbit and ground based imaging devices. Thank you for providing this opportunity for student driven research.

Sincerely the 2012 team,

Gabrielle Massone Project Manager	Glenda Alvarenga Systems Engineering Lead
Vincent Staverosky Science Lead	J.J. Busse ADCS Lead
Greg McQuie Computer and Electrical Lead	Jake Broadway Structure and Thermal Lead

HELIOS

Hydrogen-Alpha Exploration with Long Infrared Observation Systems

HASP | 2012

Proposal

Project HELIOS
Project Advisor: Lia Matthews

Project Manager: Gabrielle Massone **Systems Engineer**: Glenda Alvarenga

Science Lead: Vincent Staverosky

Structure Lead: Jake Broadway

Attitude Determination and Control Lead: J.J. Busse

Computer and Electrical Lead: Greg McQuie

Colorado Space Grant Consortium

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1.0 Mission Objective

Team HELIOS (Hydrogen-Alpha Exploration with Long Infrared Observation Systems), shall design and construct a payload that utilizes an Attitude Determination and Control System (ADCS) and a Solar Hydrogen-Alpha InfraRed Camera (SHAIRC) to collect high-resolution images of the Sun throughout flight. Our primary mission objectives include:

- To observe and analyze solar phenomena with the SHAIRC imaging system
- To characterize the motion of the HASP platform
- To develop an ADCS capable of:
  - Tracking the motion of the Sun through the sky
  - Counteracting changes in motion of the balloon
  - Orienting the SHAIRC towards the Sun when in line-of-sight
- To verify the accuracy of the ADCS with the images collected
- To determine the feasibility of high-altitude balloon observatories
- To provide a data point in the design and development of high altitude balloon based observatories

The imaging system, SHAIRC, shall focus on the Sun and collect images in the InfraRed and Hydrogen-Alpha light wavelengths. Through post-flight analysis, SHAIRC images can be used to analyze solar phenomena and verify the accuracy of the pointing system.

1.1 Mission Premise

Observations of the Sun currently rely on ground-based observatories or orbiting telescopes such as SOHO and TRACE. Though both have returned invaluable information, they are hindered by factors such as atmospheric interference or prohibitive costs and accessibility. Balloon based observatories offer a uniquely accessible but cost efficient alternative that circumvents these issues.

The HASP Platform ascends beyond 99.5% of the Earth’s atmosphere, achieving an exceptionally high-altitude while avoiding costly rocket fuels or any hazardous chemicals. Should a high-altitude observatory prove viable, it would dramatically reduce construction and operation costs. Previous CU Boulder payloads have employed similar imaging systems in an effort to explore potential star and exoplanet observation; however, what compromised some accuracy was lack of effective control systems. In the spirit of continuity, our mission intends to further refine their objectives and supplement the imaging system with a fully functional attitude determination and control system capable of coping with the extreme environment and unpredictable variances in platform movement. This will be accomplished by both characterizing and compensating for the motion of the balloon. Post-flight, accuracy of the system will be verified by analysis of the solar images.

A HASP payload provides distinct opportunities over traditional orbiting satellites. A lack of costly operations ensures any technological breakthroughs during flight may be quickly adapted and implemented by future missions. This experiment is intended to illustrate the feasibility, quality, and cost efficiency of a balloon based ADCS and imaging system.

1.2 Photometry

The SHAIRC system offers a unique combination of InfraRed and Hydrogen-Alpha imaging designed to maximize data analysis post-flight. Invisible to the naked eye, InfraRed wavelengths occur between 740nm and 3000nm and are typically interpreted as heat. Comprising a large part of solar radiation, InfraRed emission varies significantly across the solar surface and atmosphere, indicating different elements, atmospheric absorption, Sunspots, and other characteristics. Hydrogen-Alpha wavelengths occur in the visible spectrum at approximately 658nm, but are normally overwhelmed by surrounding wavelengths, becoming effectively “washed-out” in unfiltered cameras. The light wavelength is emitted when a hydrogen electron falls from its third to second lowest energy level; due to the abundance of hydrogen in the Sun, Hydrogen-Alpha imaging offers an exceptional amount of insight into solar activity. Often used to study the activity of the solar chromosphere, it is also indicative of Sunspots and other solar anomalies. Currently, it is often employed in observations of nebula, stars, and other cosmic bodies, lending a large variety of potential applications should it prove viable on a balloon platform.

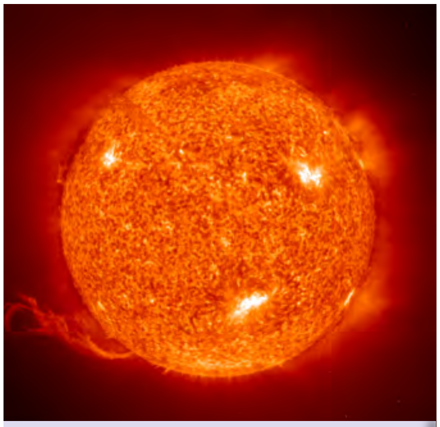


Figure 1.1 Hydrogen Alpha Image of the Sun

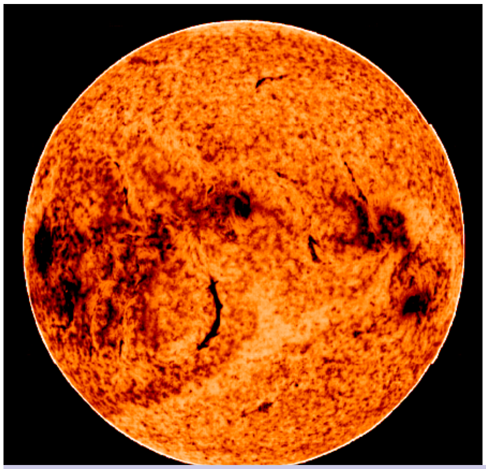


Figure 1.2 Infrared Image of the Sun

The primary goal of utilizing the SHAIRC system is to verify that the attitude control system is capable of controlling the orientation of the imaging system, while simultaneously characterizing solar phenomena. The SHAIRC system will be verified through extensive ground testing to fully calibrate the appropriate exposure times. To aid in this task a monochrome video camera with a programmable exposure time and frames per second will be used to fully determine the appropriate exposure time for the wavelengths we will be working with. The telescope will be oriented towards the Sun via the ADCS.

The use of both Infrared and Hydrogen-Alpha imaging serves a dual purpose. First, solar phenomena can be observed and examined through two simultaneous wavelengths, allowing for correlations between heat, activity, composition, among other variables. Second, it provides an inherent redundancy; should one camera experience an unexpected occurrence or observance, the event can be doubly analyzed and more easily confirmed or disproved. The feasibility of the imaging system will be verified by comparison to the images of ground facilities dedicated to solar research. Finally, the images can be analyzed to assess the true accuracy of the ADCS relative to the reported values to determine correct function of the system.

Mission Requirements

Type	
G	Goal
O	Objective
F	Function
P	Performance
DC	Design Constraint
HC	HASP Constraint

Type	Requirement	Goal
G	0.0	Team HELIOS shall design and construct a payload that utilizes an Attitude Determination and Control system and a Solar Hydrogen-Alpha InfraRed Camera (SHAIRC). The ADCS shall be responsible for characterizing the motion of the HASP platform and maintaining payload focus on the Sun throughout flight. The imaging system, SHAIRC shall focus on the Sun and collect images in InfraRed and Hydrogen-Alpha light wavelengths. Through post-flight analysis, SHAIRC images shall also verify the accuracy of the ADCS. By comparing ground and orbiting telescope images collected during flight with SHAIRC results, we shall determine the feasibility of an advanced balloon-based imaging system.

Type	Requirement	Objective	Reference
O	1.0	Team HELIOS shall comply with all HASP requirements	HC
O	2.0	Team HELIOS shall use an attitude determination and control system to track and focus on the Sun during flight.	G
O	3.0	Team HELIOS shall gather and analyze images of light coming from Hydrogen-Alpha emissions as well as near- infrared wavelengths.	G
O	4.0	Team HELIOS shall have electrical and power systems	G

		to support science and ADCS throughout the mission.	
O	5.0	Team HELIOS shall maintain a temperature which allows for optimal use of onboard systems for the flight duration.	G
O	6.0	Payload shall house a command and data processing system capable of monitoring and controlling all systems in flight	G
O	7.0	Team HELIOS shall remain within strict budget and schedule constraints	G

Type	Requirement	Objective	Reference
O	**1.0**	**Team HELIOS shall comply with all HASP requirements**	**HC**
DC	1.1	The Payload footprint shall not exceed 38cm X 30cm.	HC
DC	1.2	The Payload height shall not exceed 30cm unless with an exemption.	HC
DC	1.3	The Payload shall be able to withstand a 10 g vertical force and 5 g horizontal force.	HC
DC	1.4	The payload shall have a twenty-pin EDAC 516 interface to the HASP system power and analog downlink channels.	HC
DC	1.5	The payload shall draw no more than +30 VDC or 2.5 amps and shall convert the provided +30 VDC to the necessary voltages required inside the payload.	HC
DC	1.6	The payload shall allow for four discreet command functions from HASP payload using EDAC 516-020 interface. One shall be for powering the payload on. One shall be for powering the payload off.	HC
DC	1.7	The payload shall allow for a serial downlink functioning at 4800 baud.	HC
DC	1.8	The serial up-link shall allow for 2 bytes per command.	HC
DC	1.9	The payload shall use a DB9 connector, RS232 protocol, with pins 2, 3, and 5 connected.	HC
DC	1.10	The payload shall transmit data packages that show the payload’s health status using unique header identification.	HC
DC	1.11	The payload shall integrate with the existing HASP mounting template design	HC

Type	Requirement	Objective	Reference
O	**2.0**	**Team HELIOS shall use an attitude determination and control system to track and focus on the Sun for up to 20 hours of flight.**	**G 0.0**
F	2.1	The Payload shall characterize the motion of the HASP Platform	O 2.0

P	2.1.1	Team HELIOS shall monitor changes in pitch and yaw	F 2.2
F	2.2	Team HELIOS shall use a mechanical system to orient SHAIRC in the direction of the Sun.	O 2.0
P	2.2.1	SHAIRC shall be able to pitch to approximately 70º to maintain Sun in field of view.	F 2.3
P	2.2.2	The ADCS shall accommodate for thermal effects on materials	F 2.3

Type	Requirement	Objective	Reference
O	**3.0**	**Team HELIOS shall gather and analyze images of light coming from Hydrogen-Alpha emissions (656nm) and Infrared emissions (750-1400 nm).**	**G**
F	3.1	SHAIRC shall collect solar images and video in the InfraRed wavelength	O 3.0
P	3.1.2	Shall utilize an infrared filter to obtain light wavelengths between 700 nm and 1400 nm	F 3.1
P	3.1.3	Shall utilize a camera capable of collecting high resolution solar infrared images	F 3.1
P	3.1.4	Payload shall allow for data storage for captured InfraRed images.	F 3.1
F	3.2	SHAIRC shall collect solar images and video in the Hydrogen-Alpha wavelength	O 3.0
P	3.2.1	Shall utilize a Hydrogen-Alpha filter to obtain a light wavelength of 656.28 nm	F 3.2
P	3.2.2	Shall utilize a camera capable of collecting high resolution solar Hydrogen-Alpha images	F 3.2
P	3.2.3	Payload shall allow for data storage for captured Hydrogen-Alpha images.	F 3.2
F	3.3	SHAIRC shall collect light and diffract the image to create two sub-images, one focused towards the InfraRed imager and the other focused towards the Hydrogen-Alpha imager.	O 3.0
P	3.3.1	The payload shall have two cameras mounted behind the main telescope that correspond to each wavelength.	F 3.4

Type	**Requirement**	**Objective**	**Reference**
O	**4.0**	**Team HELIOS shall have a electrical and power system to achieve the desired science data product and support the infrastructure of ADCS, CDH, Thermal, and Structure**	**G**
F	4.1	The payload shall be powered by HASP for the life of the flight	O
P	4.1.1	The payload shall use no more than 30 VDC at 2.5 amps to power components.	HC
P	4.1.2	The payload shall use large enough gauge wire for	F 4.1

		power transfer on different bus lines for powered components.	
F	4.2	The payload shall have a twenty-pin EDAC 516 interface to the HASP system power and analog downlink channels.	HC
P	4.2.1	Pins A, B, C, and D shall be connected and designated as power.	O
P	4.2.2	ADCS system and SHAIRC shall be able to connect to these pins for power support.	F 4.2
F	4.3	Pins M, T, U, and X shall be connected and designated as power ground.	O
F	4.4	Pins F and N shall be connected and designated as the discrete commands for powering on and off the payload.	O
F	4.5	Pins K, L, M and R shall be connected and designated as analog downlink to HASP command. K and M act as signal, while M and R act as the respective returns.	O
F	4.6	Pins 2, 3 and 5 shall be connected and designated as received data, transmitted data and signal ground, respectively.	O
P	4.6.1	SHAIRC data storage system shall be able to connect to the motherboard computer.	F 4.6
F	4.7	The payload shall use the RS232 protocol (8 bits, no parity bit, 1 stop bit, no control flow).	O

Type	**Requirement**	**Objective**	**Reference**
O	**5.0**	**Team HELIOS shall maintain a temperature which allows for optimal use of onboard systems throughout flight.**	**G**
F	5.1	SHAIRC system shall be insulated and decoupled from internal component heat	O 5.0
P	5.1.1	The SHAIRC support structure shall be insulated to mitigate effects of payload heat on infrared sensors	F 5.1
F	5.2	Internal components shall remain within operating temperatures between -80 C to 60 C	O 5.0
P	5.2.1	Internal Structures shall use heat sinks to dissipate excess heat	F 5.2

Type	**Requirement**	**Objective**	**Reference**
O	**6.0**	**Payload shall house a command and data handling system capable of monitoring and controlling all systems in flight**	**G**
F	6.1	Command and Data Handling system shall monitor and execute ADCS functions	O 6.0
F	6.2	Command and Data Handling shall facilitate control	O 6.0

		over the payload	
P	6.2.1	Team HELIOS shall be able to turn payload on and off,	F 6.2
P	6.2.2	Team HELIOS shall be able to communicate with SHAIRC.	F 6.2
F	6.3	Command and Data Handling system shall accept power from the power system	O 6.0

Type	**Requirement**	**Objective**	**Reference**
O	**7.0**	**Shall remain within budget and schedule constraints**	**G**
F	7.1	Every purchase and expense shall be documented	O 7.0
P	7.1.1	All receipts and purchase orders shall be kept.	F 7.1
F	7.2	Major design phases and deadlines shall be planned and documented	O 7.0
P	7.2.1	Schedule shall include deadlines for each week of the design and construction process	F 7.2
P	7.2.3	Schedule shall include all design document revisions and presentations	F 7.2
P	7.2.2	Schedule shall include all regular team meetings at pre-coordinated times	F 7.2

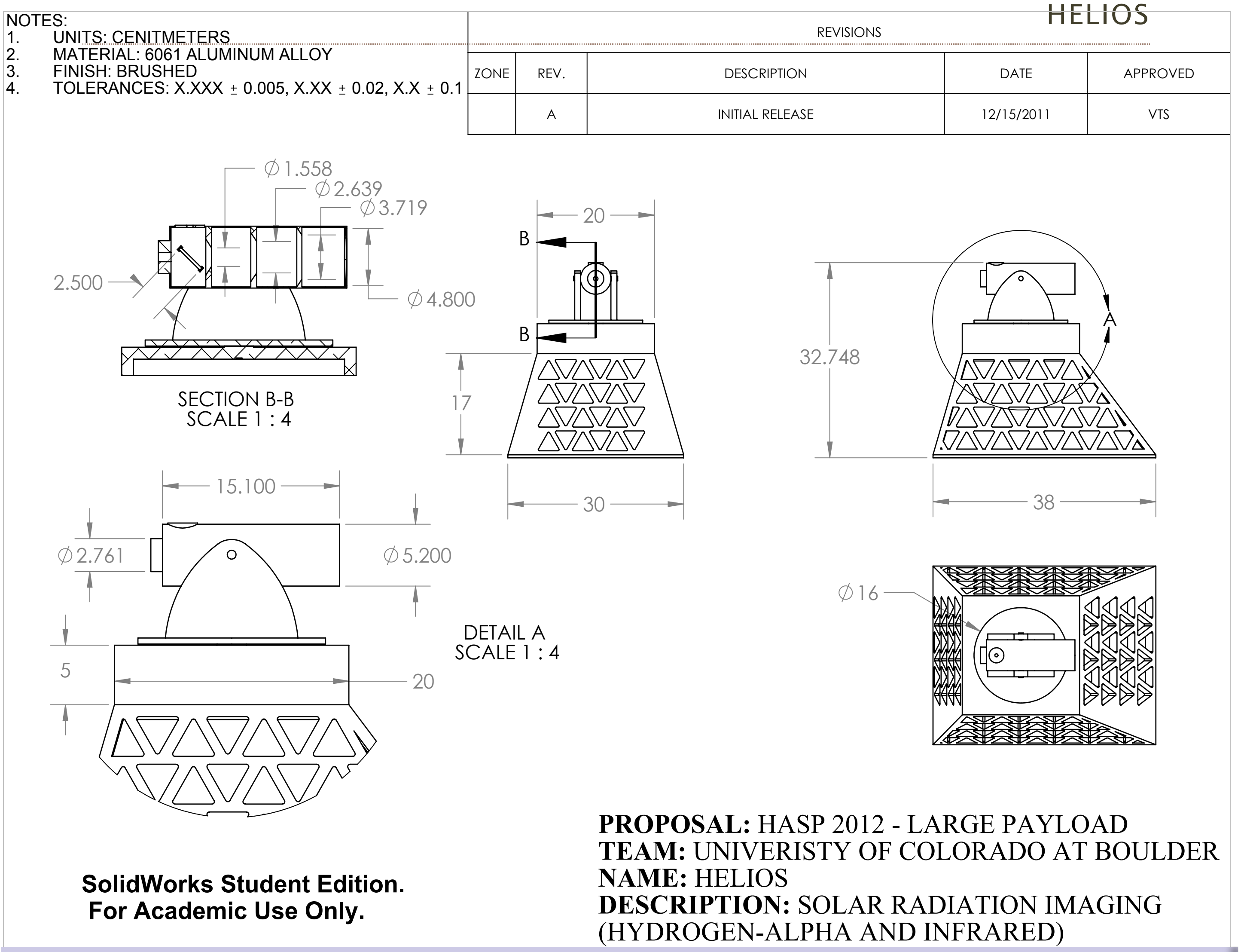
2.0 Design Overview

The primary design of HELIOS consists of three main sections: the SHAIRC imaging system, the ADCS control, and the processing unit and power distribution system. The SHAIRC imaging system is a mirror-based telescope that uses a dichroic beam splitter to separate the Hydrogen-Alpha and Infrared wavelengths and direct them into their respective cameras. The ADCS is a two-axis control system. The ADCS will adjust the azimuth elevation of the SHAIRC; the imaging system is mounted on a circular plate with a full 360-degree range of rotation. The combination of these two elements will allow SHAIRC to observe the entire sky and ensure the sun is kept within the field of view is possible during any given orientation. The processing unit and power distribution system will be located underneath the imaging system, separated from the ADCS system. This section will have the computer, as well as all power conditioning hardware. All of these separate sections will be connected through the machined aluminum structure that shall maintain the structural integrity of HELIOS throughout launch, float, and landing. The design of HELIOS is most suited for a **Large 20kg Payload, situated in any of the four large payload spots.**

2.1 Structural Design

The HELIOS payload consists of three major substructures, each primarily constructed of ¼ inch aluminum panels. We request that the base of the payload will be bolted to a 30x38, ¼ inch aluminum mounting plate, rather than the traditional ¼ inch PVC mounting plate. (See 2.8 Special Requests). This allows for more favorable thermal conductive properties, improving the cooling of vital components. The first segment of the structure measures 30x38x20 cm, and houses the central computing and data storage system, electronics, and power board. The second segment of the structure measures 30x38x10 cm and houses all wiring and necessary motorized components for the ADCS and SHAIRC systems. This segment is primarily open, providing an additional thermal barrier between the heat-producing computing elements and the heat-sensitive imaging systems. On top of this resides the third substructure, comprising the SHAIRC and associated gear systems. The height of the telescope shall not exceed 10 cm above the top of the second substructure.

Figure 2.1 Structure conceptual design



NOTES:
1. UNITS: CENITMETERS
2. MATERIAL: 6061 ALUMINUM ALLOY
3. FINISH: BRUSHED
4. TOLERANCES: X.XXX ± 0.005, X.XX ± 0.02, X.X ± 0.1

REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED
	A	INITIAL RELEASE	12/15/2011	VTS

PROPOSAL: HASP 2012 - LARGE PAYLOAD
TEAM: UNIVERISTY OF COLORADO AT BOULDER
NAME: HELIOS
DESCRIPTION: SOLAR RADIATION IMAGING (HYDROGEN-ALPHA AND INFRARED)

Figure 2.2 Detailed Dimensions of the HELIOS Aluminum Structure

2.2 Solar Hydrogen-Alpha InfraRed Cameras (SHAIRC)

The SHAIRC imaging system is designed to focus on the Sun, and collect images in the Hydrogen-Alpha and Infrared wavelengths. The system is comprised of a telescope that observes the sun and then splits the focus image by wavelength via a dichroic filter with 99.9% image retention; each solar image is reflected and sent to its corresponding monochrome video camera. The first camera will be capable of collecting high-resolution solar infrared images. The second camera will be capable of collecting solar images in the hydrogen-alpha wavelength using a hydrogen-alpha filter. To avoid any smearing of the images due to the movement of the HASP payload, the monochrome cameras will be filming during the duration of float, and storing their images on a high-capacity solid state drive.

Splitting the focused image by wavelength necessitates the use of a 700 nm Dichroic Longpass Filter that transmits infrared from 725-1600 nm and reflects the 656 nm Hydrogen-Alpha wavelength at a 90-degree angle. Video cameras will be secured at 90 degrees relative to each other, and the dichroic filter positioned at 45 degrees. Two wavelength-specific filters positioned in the path of each "split" light beams then further refine the camera image, absorbing extraneous light.

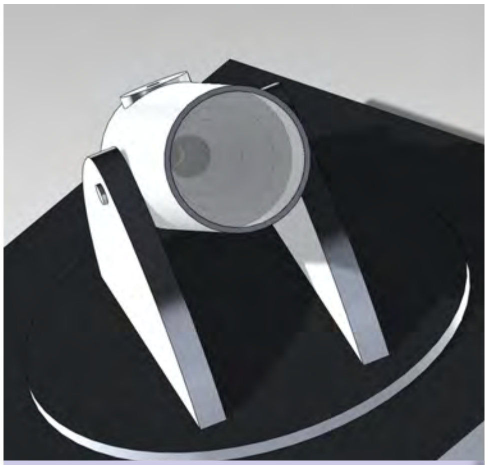


Figure 2.3 SHAIRC mounted on a rotating platform

The Sun occupies approximately 0.5 x 0.5 degrees of the Earth sky. Our telescope will magnify the Sun to a resolution of 200x200 pixels, which allows the smallest common Sunspots (1500 km in diameter) to be resolved at 2-6 square pixels. Larger solar prominences in the chromosphere (up to 50,000 km in diameter) can be resolved at 10-14 square pixels. Using a 1024x768 pixel camera, this would allow for a 2.5-degree margin in horizontal alignment and a 2-degree margin in vertical alignment for the ADC system. If the ADCS system ultimately is less accurate than predicted, higher resolution cameras can be used to increase the allowable margin.

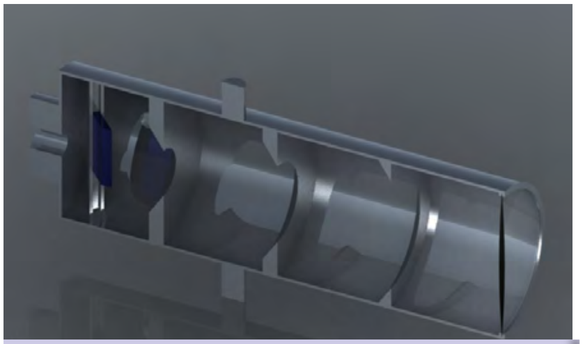


Figure 2.4 SHAIRC Cross-Section Illustrating baffling

Light intensity in Earth's orbit is estimated to be 1360 W/m^2. The heightened intensity - relative to light intensity on the Earth's surface – allows for decreased exposure times. Through extensive ground testing and data analysis, the most appropriate exposure time and frames per second rate will be established.

The telescope will also incorporate a system of baffles. Light reflecting off the inside of the telescope tube will reduce the effectiveness of the scope by producing glare, reflections, and ghosts. Baffles placed inside the telescope casing will correct these aberrations by intercepting reflected light and keeping it from the eyepiece. This improves the quality of the image by only allowing parallel light rays to reach the camera sensors.

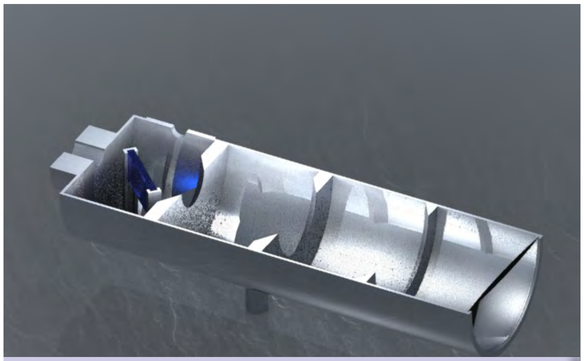


Figure 2.5 SHAIRC Cross-Section Illustrating Internal Components

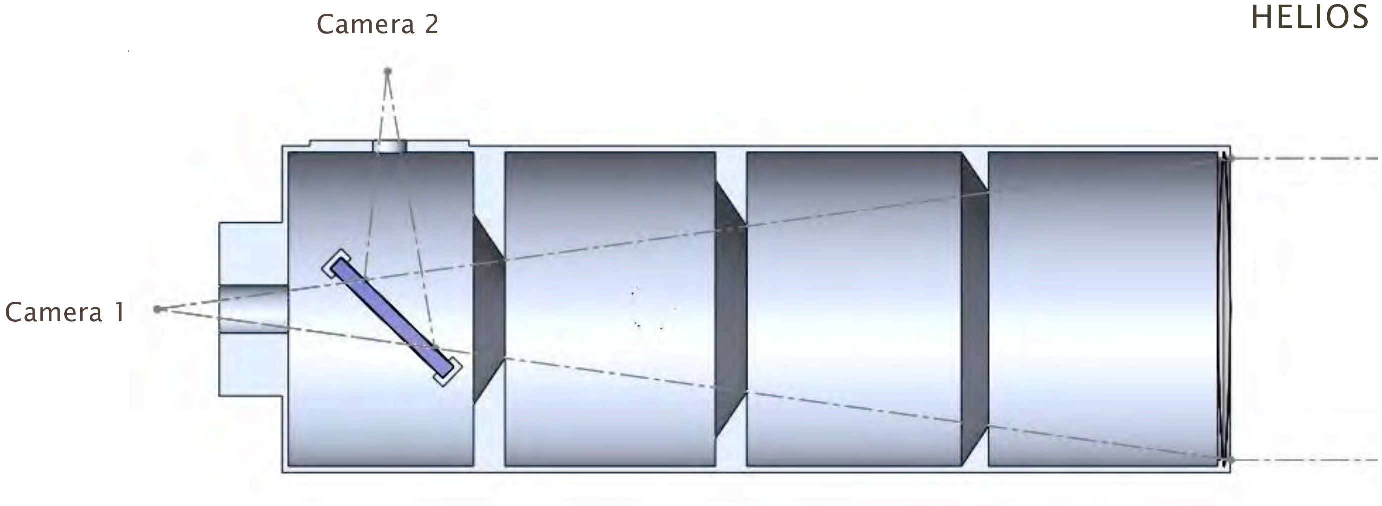
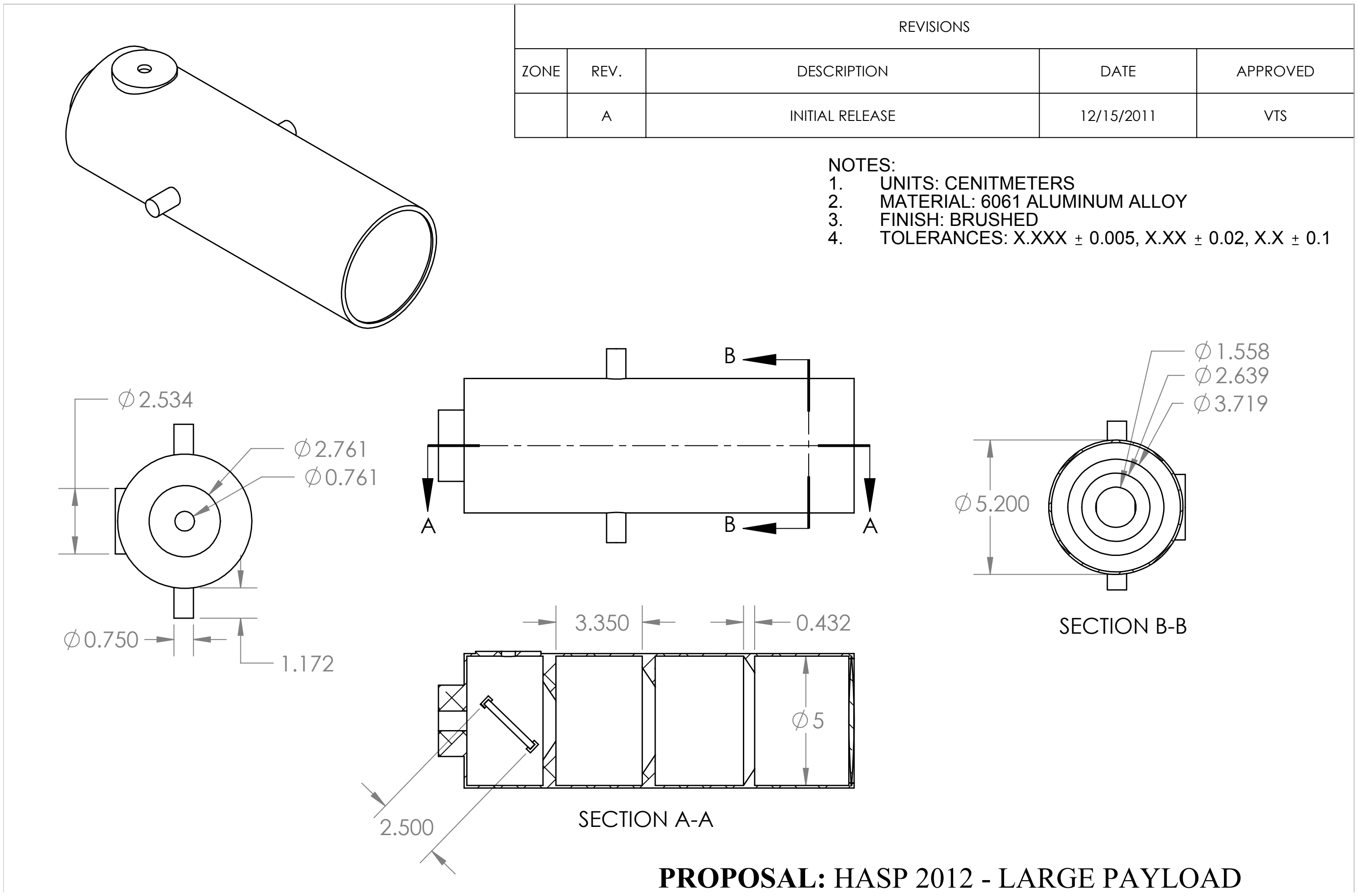


Figure 2.6 SHAIRC Internal Layout features a dichroic filter that splits incoming light from the aperture perpendicularly according to wavelength.



REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APPROVED
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NOTES:
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PROPOSAL: HASP 2012 - LARGE PAYLOAD

Figure 2.7 SHAIRC Dimensions illustrate the expected size and ratios of the telescope design.

2.3 Attitude Determination and Control

The ADCS is responsible for maintaining the Sun within the field of view of the SHAIRC system. Due to obstructions in solar observation caused by the HASP balloon, surrounding payloads, and the horizon line, the system will have a limited range of movement along two axes to track changes in azimuth of the Sun. First, the SHAIRC shall be able to pitch upwards and downwards from -10 degrees to 60 degrees from horizontal. Past 60 degrees, the expanded HASP balloon obstructs the field of view. The system will also be capable of rotating 360 degrees to capture the Sun as it rises and sets in two different directions.

Attitude determination shall be dependent on a series of sensors intended to track changes in the Sun's position and monitor platform movement. To accomplish this, several instruments will be employed in a closed feedback loop:

- Photodiode Array: 8-12 photodiodes arranged at strategic positions around the SHAIRC and shall track the Sun through changes in relative voltage intensity. Values from each photodiode are compiled by the computer and analyzed to determine the area of greatest intensity. There will also be a series of photodiodes set up in a quadrant evenly spaced around the aperture of the telescope (when all diodes have the same optimal current ratio it will indicate the telescope is focused at the Sun)
- Image Analysis: depending on computer processing speed, images may be analyzed during collection to assess position of the Sun in the field of view.
- Accelerometer: 1-2 accelerometers will measure changes in platform movement, and alert the computer to any changes that may alter the field of view
- Gyroscope: responsible for measuring oscillations, the gyroscope will primarily focus on changes in yaw that affect the field of view.
- Magnetometer: depending on accuracy, a magnetometer may be employed to determine initial pointing direction and calibrate the system.

Data from each sensor and analysis tool will be processed by the on-board flight computer and translated to actuators to control movement of the SHAIRC. Actuators consist of primarily motorized gears, designed from materials with a low Coefficient of Thermal Expansion (CTE) to maintain a high degree of accuracy. Stepper motors shall facilitate all motion via a system of tensioned gears. The components are tensioned to avoid slipping and malfunction should issues with thermal expansion arise. Following each change in position, data from the sensors are re-evaluated to assess whether subsequent changes are needed.

Feedback Loop

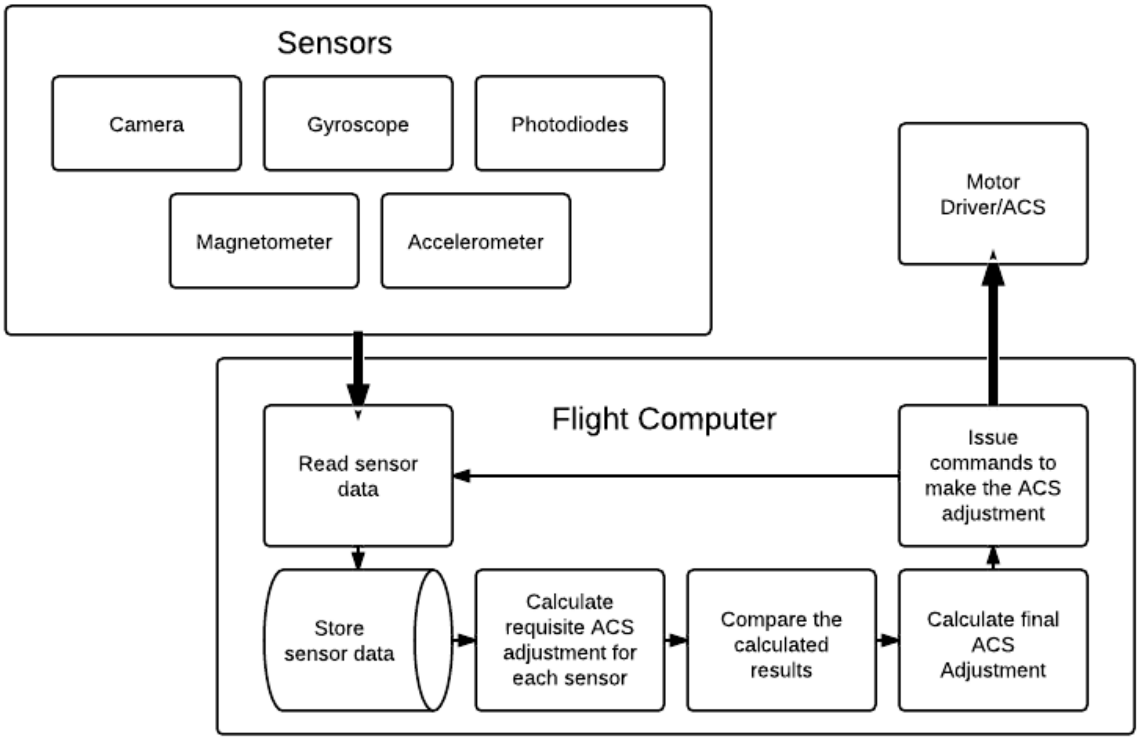


Figure 2.8 Attitude Determination and Control System Feedback Loop

The Sun moves approximately 15 degrees per hour across the sky; additionally, the HASP Platform experiences one period of side-to-side oscillation roughly every 5 minutes, according to data obtained by the CU Boulder SPARTAN-V mission. Counteracting these changes in two axes necessitates a control system capable of processing sensor data quickly enough to track at this speed. Additionally, all ADCS adjustments and sensor data shall be recorded for post-flight analysis. Potentially, this data will allow us to fully characterize the motion of the balloon at that altitude, and further refine the ADCS systems.

In order to maintain the Sun within the field of view, the ADCS system must have a margin of 2.5 degrees horizontal and 2-degrees vertical. Ideally the system would prove even more accurate following extensive testing and calibration throughout development. However, should the tolerance be beyond these limits, the resolution of the SHAIRC system could be adjusted to compensate.

2.4 Software

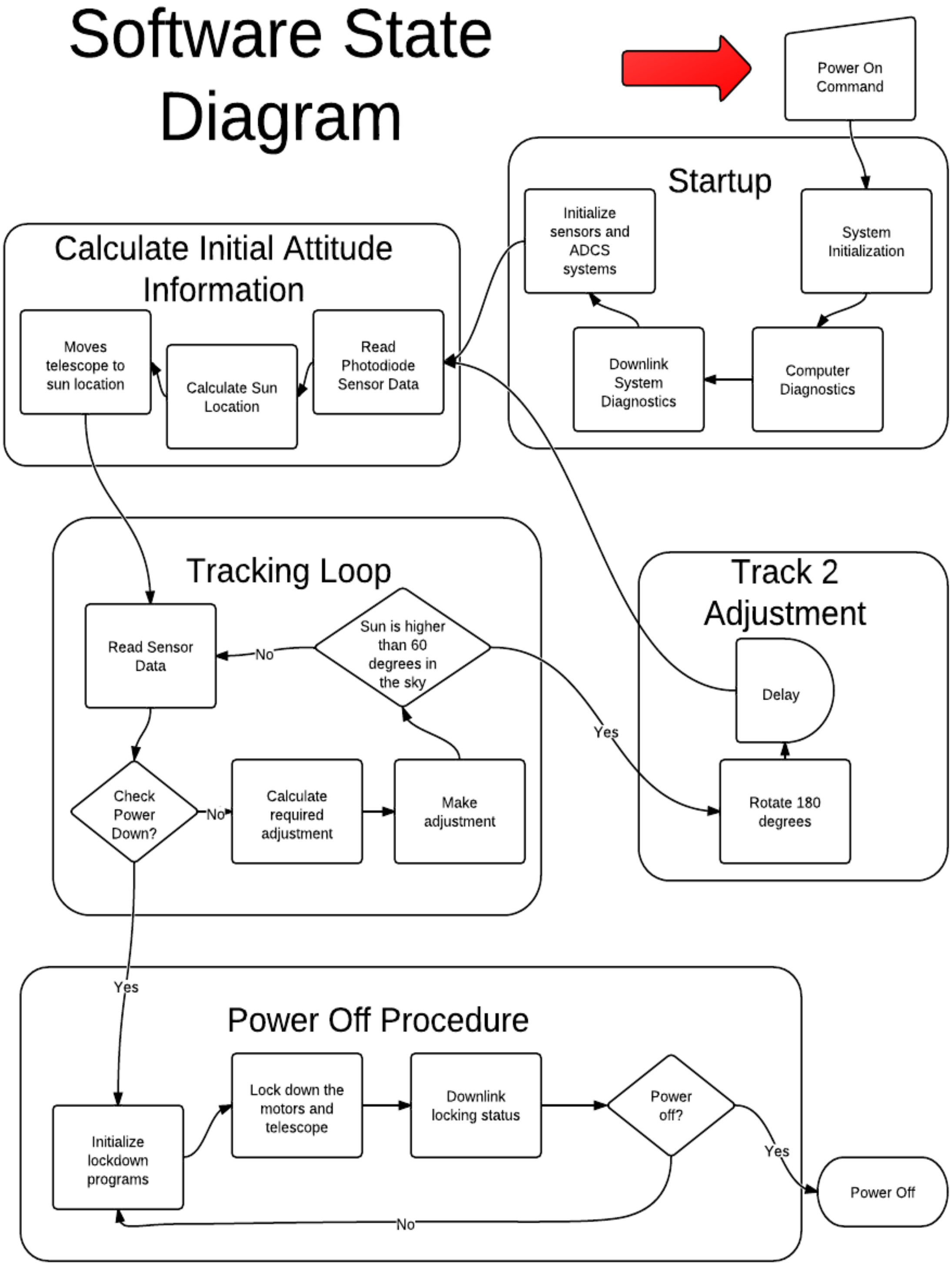


Figure 2.9 Software State Diagram describes all major phases of software operation

The software system has five subroutines that make up the payload control system. Upon receiving the power-on command, the computer system performs system diagnostics. The computer will check that all sensors are operational and that the ADCS is functional. The computer then proceeds to calculate the initial attitude information by reading sensor data and calculating where the sun is in relation to HASP. Then the tracking loop is entered, sensor data is read, the required adjustment is calculated, and the SHAIRC system is moved to point at the sun. If the sun is has an azimuth elevation higher than 60 degrees, the computer enters the track 2 adjustment. The computer enters sleep mode and delays until the sun passes over the top of the balloon and back into view. The computer will then recalculate attitude information and reenter the tracking loop. At the end of the flight, the computer will check for the power down command and enter the power down procedure. The motors and telescope will be locked down, the locking status will be downlinked, confirmed by the ground team, and the power will be shut off.

2.5 Computer and Data Handling

The command and data dandling system will consist of three components: A flight computer, a data storage system, and a secondary microcontroller. HELIOS will have a full motherboard and CPU onboard for data handling. This computer will run off of a modified, low resource, Linux kernel and will be used in all data processing, communication and ADCS control. This motherboard will be attached to a secondary analog to digital microcontroller that will be used to interface the main flight computer to all of the sensors that will be used to make ADS calculations and to monitor system health. The final element of the computer and data handling system is a solid-state drive. This drive will be used for the storage of all flight sensor data and will record all flight information with the exception of SHAIRC images. The electrical power for these devices should not exceed 25W even under extreme loads. This computer and data handling system will also be the direct interface to the HASP downlink/uplink communication lines.

2.6 Power and Electrical System

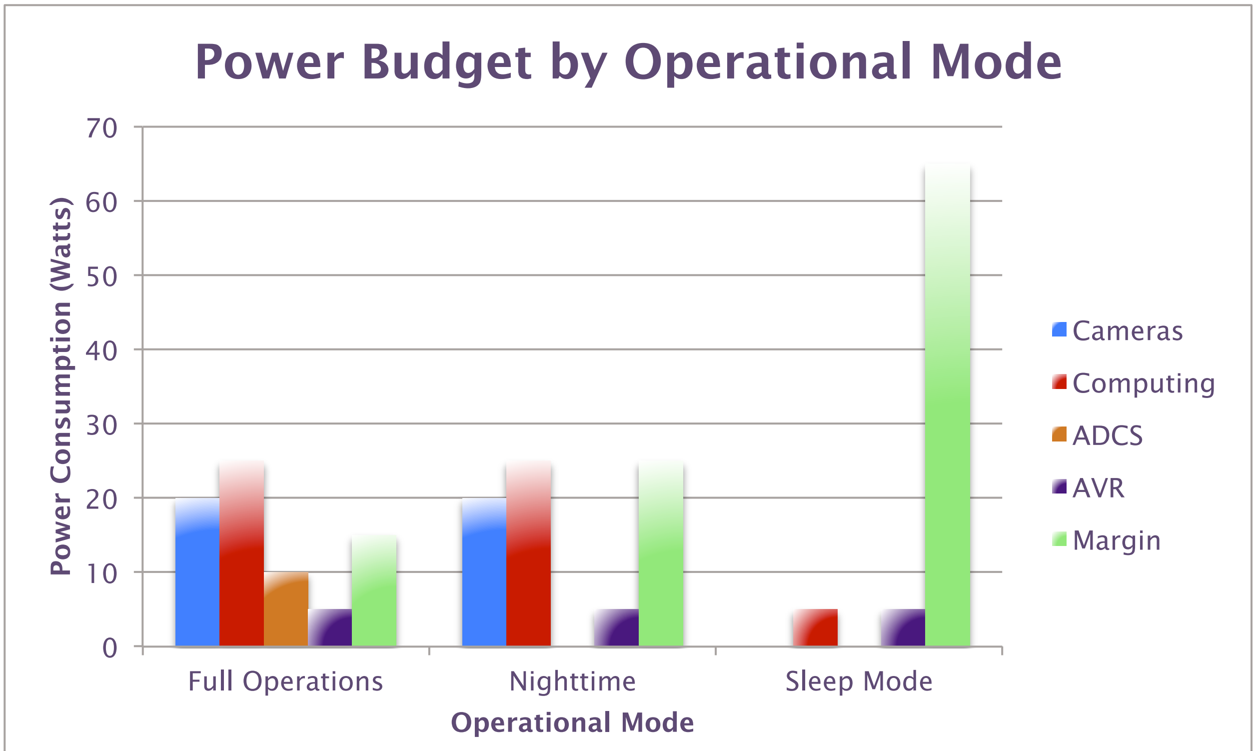


Figure 2.10 Graph of Power Consumption illustrates dynamic power needs through different stages of flight

30V DC will be taken directly from the HASP platform and run through a power board to condition and distribute the voltage. Four major sub-systems are allocated the majority of power: cameras and imaging, computing, AVR, and ADCS. Of the 75W allotted, a 30% margin of 15W has been reserved for unanticipated power needs such as lower efficiency in components or resistance in the circuit. Should additional power be required, extra batteries shall be used.

Component	Mass (Kg)
Total Structure	7.2
Solid State Drive	0.8
Computer System	1.5
ADCS	3
DMK21 AU04 Cameras x2	.6
Telescope	3.2
Aluminum Mounting Plate	1.1
Total Weight	**17.4**

Table 2.1 Mass Budget shows allocated weights for each major component. The estimated Total Weight is currently 2.6 kg below the 20kg limit.

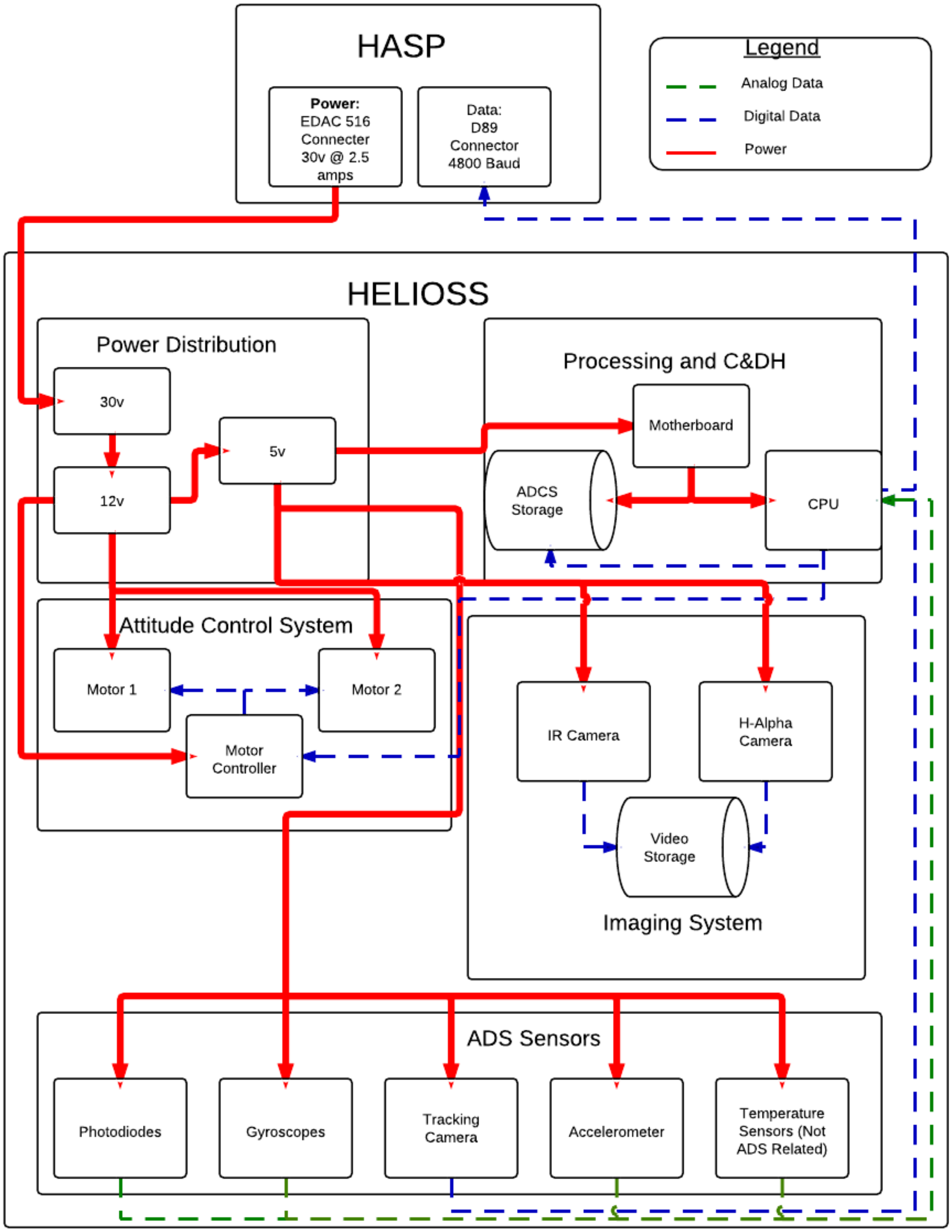


Figure 2.11 Functional Block Diagram illustrates power and communication relationships between systems

2.7 Thermal System

To ensure the success of HELIOS, the internal temperature of the payload shall remain within the operational range of all payload components. The heat generated from the processor unit as well as the voltage converters will be significant enough to prevent the internal temperatures of the payload from falling below the operational range of any of the components, and therefore it is anticipated that no heater will be required. To ensure that the internal temperature does not rise above operation limits, causing overheating and possible computer shutdown, this excess heat must be removed from the payload so that continuous data recording may be achieved.

The possibility of overheating necessitates the application of heat sinks to the processors with thermal epoxy. As the ambient pressure at an altitude of 120,000 feet will be too low to allow for convection, the heat sinks used shall directly conduct the thermal energy from the payload to the structure of the HASP platform where it will be radiated to space. These heat sinks therefore avoid reliance upon fluid passing over them and will function in the near-vacuum environment in which they shall operate. As such, the payload shall use the structure of the HASP platform itself for heat storage and therefore distribute excess thermal energy away from the processor elements, avoiding over-heating and shutdown of the system.

Additionally, the infrared camera will require cooling to ensure there is no interference from the ambient temperatures. This will require the application of additional heat sinks to the infrared system that will conduct the heat directly to the structure of HELIOS and therefore to the HASP platform. An array of temperature sensors located throughout the payload will monitor and alert the computer system to excessively hot areas; the computer system will then downlink this information, and the ground-team will assess what actions to take.

2.8 Special Requests

2.8.1 Aluminum Integration Plate

In order to ensure the success of HELIOS, the payload must be kept within operational temperature limits. To provide a better thermal short to the HASP platform – where excess thermal energy will be conducted to the gondola – we request that the PVC mounting plate provided be exchanged for an aluminum counterpart of the same dimensions and form. We will incur the extra weight caused by this exchange, and have the facilities and materials at CU Boulder to machine the plate ourselves; the machine shops include a CNC machine that would allow us to machine the plate to a high degree of accuracy. The addition of this plate will greatly improve conduction of heat from the processor units and other heat-producing mechanisms away from temperature sensitive components, reducing the likelihood of overheat and system failure.

If this request is not granted, HELIOS shall design heat sinks that apply directly to the structure of HASP. This would complicate integration with the platform, but will not ultimately endanger the success of our mission. The primary purpose of the Aluminum Integration Plate is to simply ease the integration process and reduce the risk of thermal failures during float.

2.8.2 Height and Width Extension

The success of Team HELIOS's mission is dependent on extended solar observation. In order to ensure that project HELIOS can retain the Sun within its field of view for the longest amount of time possible, we request an increase in the height of our payload of approximately 10 cm. This increase would minimize line of sight interference caused by surrounding payloads when the Sun rises or sets on the opposite side of the platform. Since the orientation of the platform cannot be guaranteed, the mission favors an extended 360-degree perspective to observe the Sun at all azimuths. The increase in height would allow a field of view virtually unobstructed by any obstacle save for the balloon directly above.

If the increased height request is not granted, the primary mission of HELIOS could still be conducted in a more constrained manner. The primary impact would be an inability to view the Sun at sunrise and sunset, where azimuth elevation is negative; this eliminates the possibility of comparing solar images with atmospheric interference and those without.

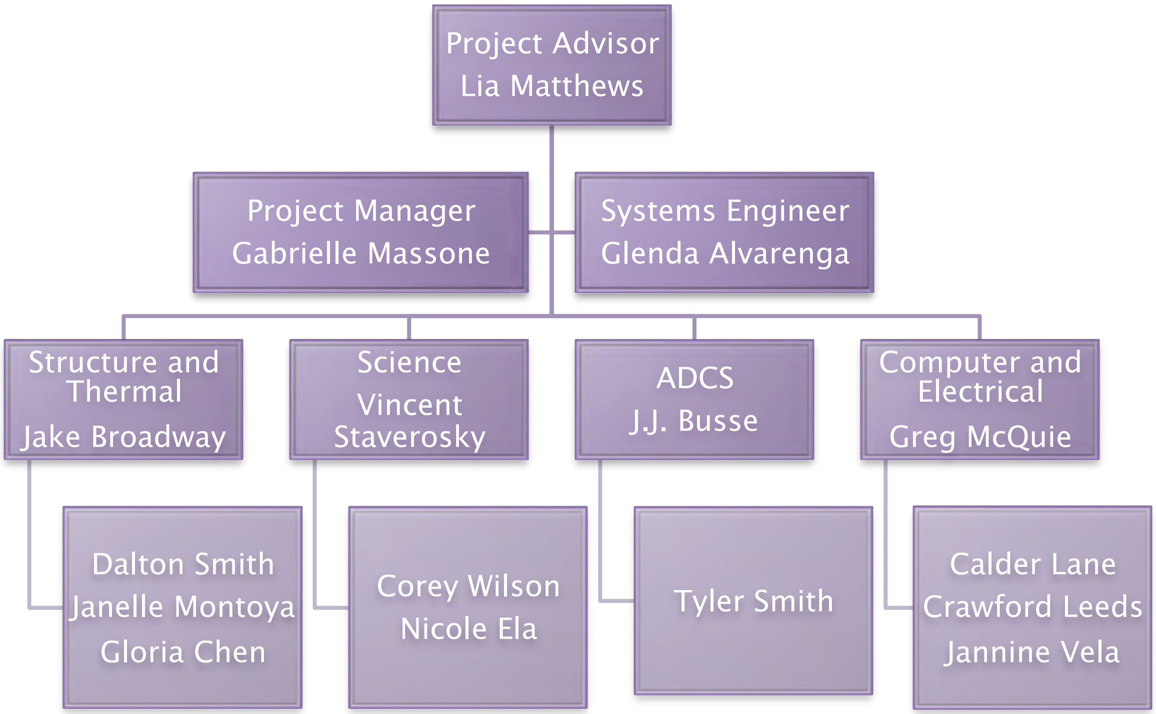
If the height increase is granted, Team HELIOS also requests a slight increase in telescope length, beyond the 30x30cm footprint allotted. HASP guidelines allow for booms and other extensions up to 3ft beyond the payload footprint. In order to improve our chances of imaging various features of the sun (i.e. sunspots, prominences, etc...) the angular resolution or ability to discern small details must be maximized. This is more easily accomplished by increasing the aperture size of the telescope. However, increasing the aperture also affects the focal ratio of the system. As a consequence of a small focal ratio, more light is allowed to reach the sensors, increasing the risk of damage from over-exposure. Compensating for this requires an increased focal length, and thus a longer telescope. A telescope measuring 8cm longer would allow for an aperture twice as large, doubling the angular resolution and rendering the solar images twice as crisp. Additionally, since the primary body of the structure and footprint would remain 30x38cm, a width allowance would not affect the process of integration.

If the increase in width were not granted, the primary effect would be a smaller telescope, with smaller angular resolution. It would not compromise the mission objectives; however, it would somewhat limit the scope of the SHAIRC, a feature of HELIOS that would ideally be as refined as possible.

3.0 Management

Project HELIOS currently consists of 15 team members. Although the team dynamic encourages interdisciplinary work, each member maintains a core area of specialization and responsibility. The team will design, construct, and thoroughly test the payload to certify it will be ready for launch. Team HELIOS will also be working with various advisors and researchers to ensure deadlines and objectives are achieved throughout the development process.

3.1 Organization Chart



Because of the inherent difficulties in designing and constructing an attitude determination and control system, work on that aspect of the project will be supplemented by an interdisciplinary team consisting of members from each section. Additionally, we are actively recruiting members for the Spring Semester to support the existing sections. Due to the interrelated nature of the computing and electrical systems, one lead with prior experience in both areas was selected to manage those sections.

3.2 Team Contact Information

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3.3 Scheduling

In addition to scheduled meetings and conferences listed below, HELIOS will meet a minimum of once a week to accomplish project tasks, as well as check-in with faculty advisors. During these meetings, team members shall discuss the current state of the project, and each section shall submit progress reports to the Project Manager and Systems Engineer. From there, each sub-section shall meet at their own discretion, under the prerogative of their Section Head.

Date	Task	Notes
12/14/2011	Final Draft Proposal	Review all of proposal and ready it for final submission
1/16/2012	Student Payload Selection Announced	
1/27/2012	January status report due and teleconference	
1/30/2012	Submit Selection Response	Within two weeks of selection, a response to comments and information requests on the application must be submitted.
1/30/2012	Critical Design Review	Within two weeks of selection, a CDR will be presented to Space Grant and project affiliates.
2/24/2012	February status report due and teleconference	
3/30/2012	March status report due and teleconference	
4/20/2012	Preliminary PSIP due	PSIP - Payload Specification and Integration Plan

4/21/2012	SHAIRC Functionality	Telescope will have accurate calibration with monochrome cameras mounted.
4/21/2012	Structure Functionality	All structure machining and interfacing shall be completed.
4/25/12	ADCS Functionality	All control and determination systems shall properly work with testable environment.
4/27/2012	April status report due and teleconference	
5/1/2012	Pre-Preliminary Vacuum Testing	Test all subsystem at Space Grant vacuum chambers and/or CASA (Center for Astrophysics and Space Astronomy) facility.
May (TBD)	Preliminary vacuum test	Test at CSBF in Palestine, Texas
5/25/2012	May status report due and teleconference	
6/22/2012	Final PSIP document due	
6/29/2012	June status report due and teleconference	
7/27/2012	Final FLOP document due	FLOP - Flight Operation Plan
7/27/2012	July status report due and teleconference	
7/30/2012-8/3/2012	Student payload integration at CSBF	PIC with flight certification issued at this time
8/26/2012-8/30/2012	HASP flight preparation	
8/31/2012	Target flight ready date	
8/31/2012	August status report due and teleconference	
9/3/2012	Target launch date	
9/5/2012	Recovery and return	
9/28/2012	September status report due and teleconference	
10/26/2012	October status report due and teleconference	
11/30/2012	November status report due and teleconference	

Table 3.1 Schedule provides a detailed overview of the anticipated deadlines throughout the design process

4.0 Integration and Launch

Upon integration of HELIOS into the HASP Platform, all Section Heads, the Systems Engineer, and the Project Manager shall be present to supervise the process. A detailed checklist shall be employed to ensure each step follows proper integration procedure, and to assure all wires between the HASP Platform and HELIOS are connected appropriately. The CDH Section Head will test all communication equipment during integration to assess function.

4.1 Flight Procedures

Below is a rough estimation of flight times, altitudes, and expected operations at each anticipated flight event. The schedule assumes 10 hours of daylight following a morning launch; however, this value is expected to change +/- 4 hours depending on launch time and ascent rate. Payload function depends primarily on location and orientation of the Sun throughout flight.

Est. Time	**Est. Alt (m)**	**Flight Event**	**System Event**	**Event Sub-Tasks**
T -1 day	0	N/A	Pre-Launch Check	Lock Mechanical Systems
T – 1 day	0	HASP Integration	HASP Integration	Check all systems
T – 1hr	0	N/A	Flight Line Setup	
T = 0	0	Launch	N/A	Power Off
1hr	36,576	Max Altitude	Power Up	1. Initialization 2. Unlock Systems 3. Downlink Results and Analyze
1.5hr	36,576	Max Altitude	Initialize ADCS and SHAIRC	1. Uplink “GO” from ground 2. Orientation 3. Find Sun 4. Stop at relative max sensor voltage
1.75hr	36,576	Max Altitude	Track Sun, initialize SHAIRC	1. Track Sun with photodiodes 2. Monitor HASP Platform movement 3. Control motion of SHAIRC
4hr	36,576	Sun Above 60 degrees azimuth, obstructed by balloon	Rotate SHAIRC 180 degrees to anticipate Sunset	1. Initialize Platform Rotation 2. Power down if necessary – enter “sleep mode”
6hr	36,576	Sun Re-entering view	Re-initialize systems, commence solar observations	1. Initialization 2. Downlink Results 3. Uplink “GO” 4. Initialize ADCS and SHAIRC

10hr	36,576	Dusk	Star Observation	1. If viable, observe and image night sky 2. Shut Down ADCS – passive imaging
20hr	36, 576	Dawn	If still in flight, re-initialize solar observation	1. Initialization 2. Downlink Results 3. Uplink "GO" 4. Initialize ADCS and SHAIRC
20+hr	36, 576	Solar Observation	Observe Sun until reaches 60 degrees or descent commences	1. All systems operational
20+hr	36,576	Before Descent	All systems power off	1. Lock mechanical systems 2. Downlink Confirmation 3. Power-down CDH
20+hr	36,576	Begin Descent	All systems off	1. All systems powered off, ready for descent
20+hr	36,576	Landing	All systems off	All systems off

Table 4.1 Flight Procedures provides an overview of anticipated actions throughout the duration of float.

5.0 Conclusion

The primary goal of the HELIOS payload is to determine whether the use of InfraRed and Hydrogen Alpha solar imaging will gather accurate images at float altitude. The secondary goal will be to analyze solar aspects utilizing Infrared and hydrogen-alpha imaging and compare it to facility ground testing to verify the imaging is accurate. Analyzing solar aspects such as the Sun's chromosphere. By using the SHAIRC imaging and pointing system to follow the sun throughout flight, we will gather data confirming whether high-altitude balloon observatories are a more accurate and more cost-effective alternative to ground and orbit-based imaging systems.