HASP Student Payload Application for 2021

<table>
<tr><td colspan="3">Payload Title:
Sub-Millimeter Water Wave Spectrometer (WWASP)</td></tr>
<tr><td colspan="3">Institution: Arizona State University (ASU)</td></tr>
<tr><td colspan="2">Payload Class (Enter SMALL, or LARGE): Large</td><td>Submit Date: 01/08/2021</td></tr>
<tr><td colspan="3">Project Abstract: Based on our understanding of life on Earth, water is a critical component for life to develop and evolve. Submillimeter wavelength water spectroscopy provides a method of investigating a protoplanetary disk for water through detecting water vapor emission lines and is a good indicator of whether a newly forming planetary system has this fundamental molecule in the accretion disk. These water vapor lines cannot be reliably detected from ground-based telescopes due to the water content in the Earth's atmosphere, forcing observations to rely on space telescopes such as the Hubble Space Telescope (HST) and James Webb Space Telescope (JWST). As getting time on these telescopes is expensive and difficult, finding a reliable alternative method for imaging newly forming star systems would allow for a less expensive and more frequent analysis of these systems. Project WWASP will provide an opportunity to answer the scientific question: is the transparency of the Earth's Atmosphere near the frequency of the 557 GHz rotational ground state line of water vapor sufficient for researchers in the future to launch a stratospheric balloon mission to detect water in a protoplanetary disk? To support this endeavor, Team WWASP seeks to measure the Earth's atmospheric transparency as a function of frequency in a high altitude balloon flight aboard the NASA High Altitude Student Payload (HASP) mission. By taking these measurements, WWASP will provide data to test atmospheric transparency models against ground-based telescope data, as well as provide a justification for future missions to use atmospheric balloons when analyzing the water vapor emission spectra of a protoplanetary disk. WWASP will complete this goal through the use of a tipping radiometer and spectrometer to detect and measure the atmospheric water line at 557 GHz. The Jet Propulsion Laboratory (JPL) has supplied the mission with the submillimeter receiver system, a quad-core computer and a Smart Power Supply Unit (PSU). A camera will be mounted for visual confirmation, and a blackbody calibration system for the spectrometer to ensure accurate data.</td></tr>
<tr><td colspan="2">Team Name:
WWASP</td><td>Team or Project Website:
N/A</td></tr>
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Flight Hazard Certification Checklist

NASA has identified several classes of material as hazardous to personnel and/or flight systems. This checklist identifies these documented risks. Applying flight groups are required to acknowledge if the payload will include any of the hazards included on the list below. Simply place an (x) in the appropriate field for each hazard classification. **Note:** Certain classifications are explicitly banned from HASP (grey filled items on table below) and the remaining hazards will require additional paperwork and certifications. If you intend to include one of the hazards, you must include detailed documentation in section 3.8 of the application as required by the HASP Call for Payloads.

This certification must be signed by both the team faculty advisor and the student team lead and included in your application immediately following the cover sheet form.

Hazardous Materials List

Classification	Included on Payload	Not Included on Payload
RF transmitters		X
High Voltage		X
Pyrotechnics		X
Lasers		X
Intentionally Dropped Components		X
Liquid Chemicals		X

Cryogenic Materials		**X**
Radioactive Material		**X**
Pressure Vessels		**X**
Magnets		**X**
UV Light		**X**
Biological Samples		**X**
Li-ion Batteries		**X**
High intensity light source		**X**

Student Team Leader Signature: Jessica Berkheimer

Faculty Advisor Signature: ___ ____

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1. Payload Description

1.1 Payload Scientific / Technical Background

Team WWASP seeks to fly an innovative submillimeter receiver and spectrometer aboard the NASA HASP mission for purposes of measuring atmospheric transparency as a function of frequency. The submillimeter water-wave spectrometer has been provided by Arizona State University and NASA JPL as part of a Senior Capstone Project, a project that is dedicated to ensuring undergraduate students receive hands-on experience in developing, designing, and building an experiment.

1.1.1 Mission Statement

Project WWASP will provide an opportunity to answer the scientific questions: is the transparency of the Earth's Atmosphere near the frequency of the 557 GHz rotational ground state line of water vapor sufficient for researchers in the future to launch a stratospheric balloon mission to detect water in a protoplanetary disk? Because these water vapor lines cannot be reliably detected from ground-based telescopes due to the water content in the Earth's atmosphere, researchers are forced to rely on space telescopes such as the Hubble Space Telescope (HST) and the James Webb Space Telescope (JWST). However, being granted time on these telescopes is expensive, difficult, and extremely competitive. Project WWASP will aim to pave a path to find a reliable alternative method for imaging water emission in newly forming star systems. This project will focus on the critical component of measuring water vapor in the Earth's atmosphere.

The data collecting cycle will begin once flight altitude has been reached. The cycle will begin by taking a blackbody reference temperature, followed by a sky-position tilt. A sub-millimeter radiometer will receive input from optics into the waveguide feed horn to measure water vapor near 557 GHz. Every 10 seconds, the angle of the mirror will be adjusted and spectra will be collected and recorded by the computer and timestamped. By doing this we will ensure accuracy of when, and where each spectrum is taken. WWASP will also have an optical camera onboard that will be used to aid in interpreting the orientation of the radiometer. For the radiometer's data to be accurate, the team will need to know if something is obstructing the view of the instrument. Each data collecting cycle will be systematically taking house-keeping data.. House-keeping data will consist of receiving position/altitude versus time from HASP telemetry, monitoring the payload clock, ambient temperatures of critical components on board the payload, and a reference temperature of the calibration blackbody to verify that the payload is running properly. House-keeping data will be taken every 10 seconds and reported every 10 minutes. By the completion of the flight, we will have spectra of the sky, spectra of the blackbody, and pre-launch calibration data. We will then take this data and make plots of the atmospheric transparency as a function of frequency, and atmospheric transparency as a function of time.

The WWASP Team is responsible for the payload build, interfacing, and full system testing. System testing before launch will take place at Arizona State University using a thermal vacuum chamber. Currently, the team has developed a plan to test every instrument and component to ensure that they all work under the environmental stresses of flight (e.g. heat, cold, pressure, etc.). Only after all subsystems have been tested will they be assembled into a single payload, which will then finally be followed by the entire system being subjected to the same thermal vacuum experience.

If chosen to fly on the HASP gondola, the collected data will be analyzed to demonstrate that balloon-borne observations of water are indeed possible for future missions. In addition, the flight will also justify that the computer and electronics can perform with precision and efficiency for the future JPL/ASU ASTHROS balloon mission.

1.1.2 Mission Background and Justification

Ground-based telescopes are a great choice to build relative to a space-based telescope as they are typically much less expensive. They are also typically bigger, much less expensive and easier to upgrade. Space-based telescopes on the other hand are much more expensive to build, harder to upgrade and repair. So one might wonder as to why even build a space-based telescope but there is a catch. Ground-based telescopes can only detect wavelengths the Earth's atmosphere lets through. The rest of the electromagnetic spectrum is blocked by the atmosphere. That's where space-based telescopes come into play, they can detect x-rays, gamma rays, and even UV-rays from cosmological events that would otherwise be blocked by the atmosphere. Balloon borne telescopes allow near space observations at a cost far lower than space missions. That is where HASP Student Payload comes into play. This project will determine if the atmosphere is transparent enough to measure spectral lines from water vapor using a balloon borne telescope. Previously, all water observations have been done only from space. If the atmosphere is transparent enough, it would permit low cost future missions focused on water observations.

1.1.3 Mission Objectives

Project WWASP will accomplish the following goals: (1) Taking spectra while looking through the Earth's atmosphere, (2) Measure the transparency at numerous angles, (3) Plot the data as transparency vs. frequency.

Furthermore, Team WWASP expects to accomplish the following with Project WWASP: (1) Flight test the submillimeter receiver system, (2) Flight test electronics for the ASTHROS balloon mission (computer and control board for the receiver), (3) Demonstrate that balloon-borne observations of water are indeed possible for future missions.

Figure 1 shows our predicted value for atmospheric opacity for tau of 1.0, which was calculated using a monte Carlo simulation. The simulation produced a temperature error of ± 1.0 K and the error on tau is ± 0.03. The six data points obtained were calculated at every 10 degrees of elevation between 20 and 70 degrees. A 0.03 error on tau is sufficient for us to achieve our science goals. A 1K measurement accuracy in antenna temperature is achievable with a measurement time of a few seconds at each mirror position.

Figure 1 – Science Overview

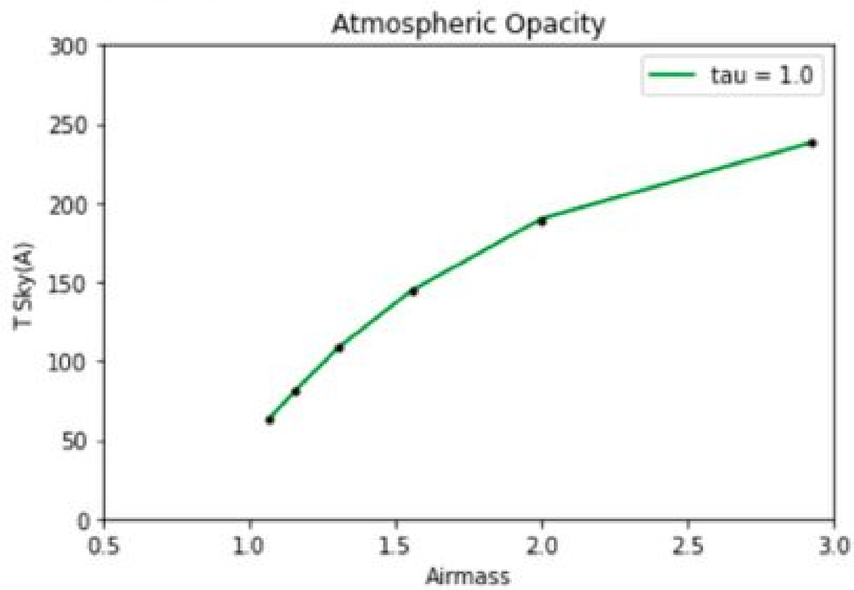


Table 1: Calculated Air Mass as a Function of Elevation

Degree of Elevation	Air Mass
20	1.0642
30	1.1547
40	1.3054
50	1.5557
60	2.0000
70	2.9238

1.2 Payload Systems and Principle of Operation

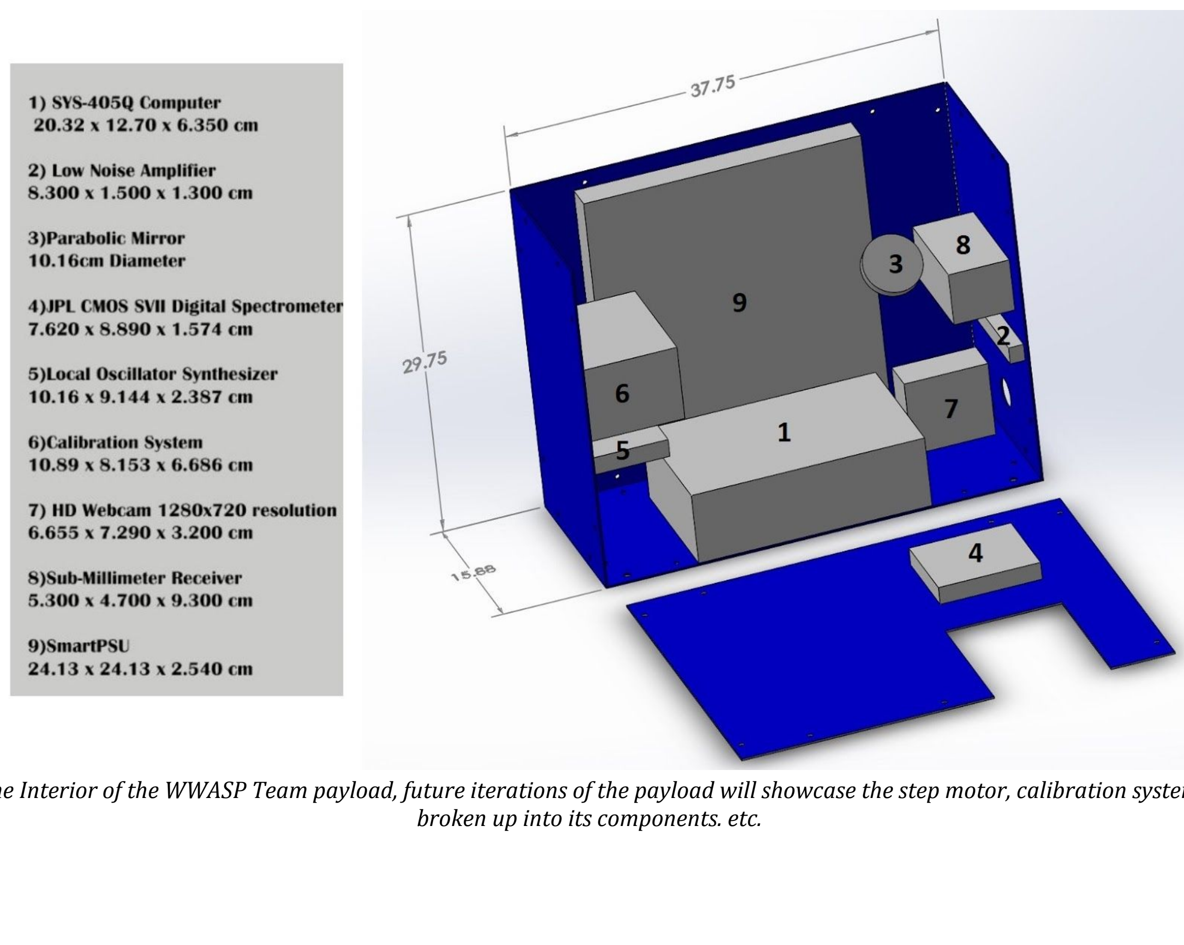
The heart of our payload contains the radiometer which will be continuously taking data while in flight of both the atmospheric water density and the angle of elevation above the horizon. By using a submillimeter receiver, spectrometer, and a tilting radiometer, WWASP will take spectra in 10-degree increments, every 10 seconds, of the 557 GHz water line. A stepper motor with a driver operated by an Arduino microcontroller will control the tilt and motion of the mirror. Data will be collected and stored in a SYS-405Q Fanless

Industrial Computer with Quad-Core Intel® Atom™ Processor. The computer will be connected directly to HASP power. The Smart Power Supply Unit (PSU) will also be connected directly to HASP power and will provide power for all components on the payload, with exception of the computer. Both the computer and SMART PSU have been provided by the Jet Propulsion Laboratory (JPL). The provided computer will talk to the Smart PSU that controls the receiver through RS-485 serial interface. RS-485 is an industrial specification that defines the electrical interface and physical layer for point-to-point communication of electrical devices. The RS-485 standard allows for long cabling distances in electrically noisy environments and can support multiple devices on the same bus.

Additionally, we have a calibration subsystem for the radiometer to provide context for the raw data due to the Radiometer only providing a voltage difference. This calibration subsystem will allow the radiometer signal to register off a blackbody system of known temperature before taking data from the atmosphere outside. The voltage difference between the known blackbody temperature and the atmosphere will provide us with the data we need to extrapolate atmospheric transparency as well as subtract any background noise generated by the payload.

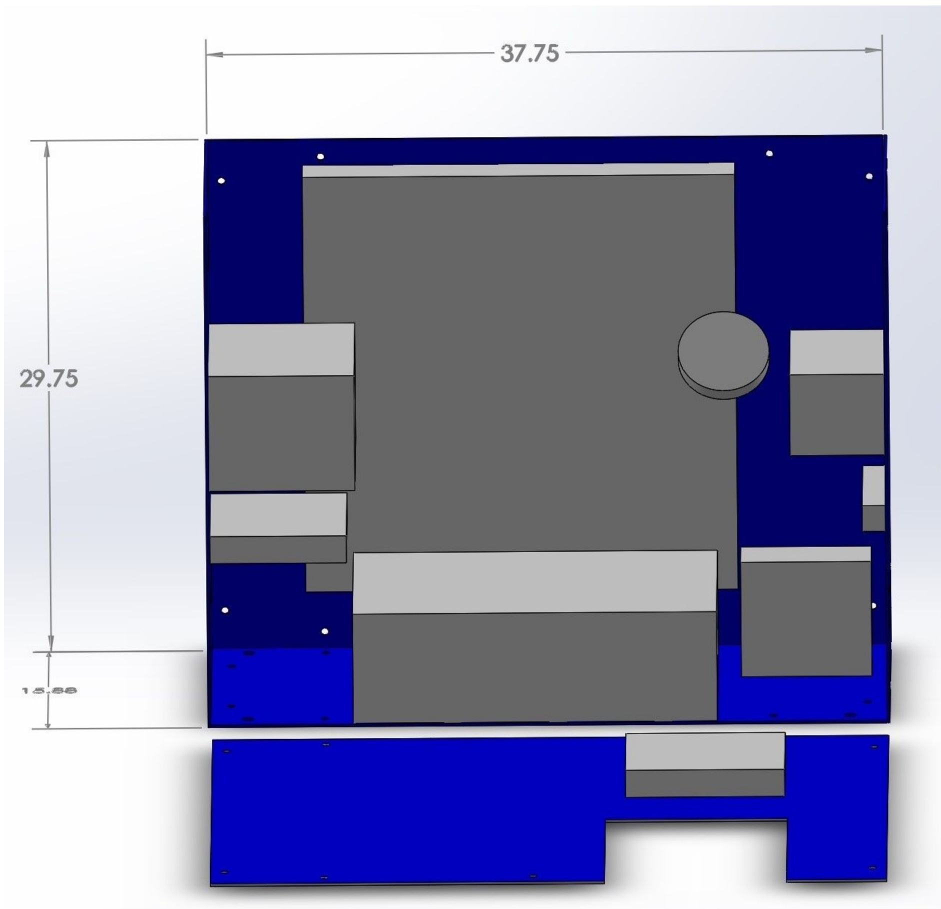
Furthermore, there will also be a camera for visual context so that we may be certain that any measurements taken at some specific time spot are accurate and not blocked by any foreign object. Tests to ensure that each subsystem can perform in a vacuum environment will be performed on each subsystem, but also as a whole once the payload has been assembled.

Figure 2 – Payload Architecture/Arrangement Angled View



The Interior of the WWASP Team payload, future iterations of the payload will showcase the step motor, calibration system broken up into its components. etc.

Figure 3 – Payload Architecture/Arrangement Side View



A side view of the Interior of the WWASP Team payload.

Figure 4 – Block Diagram

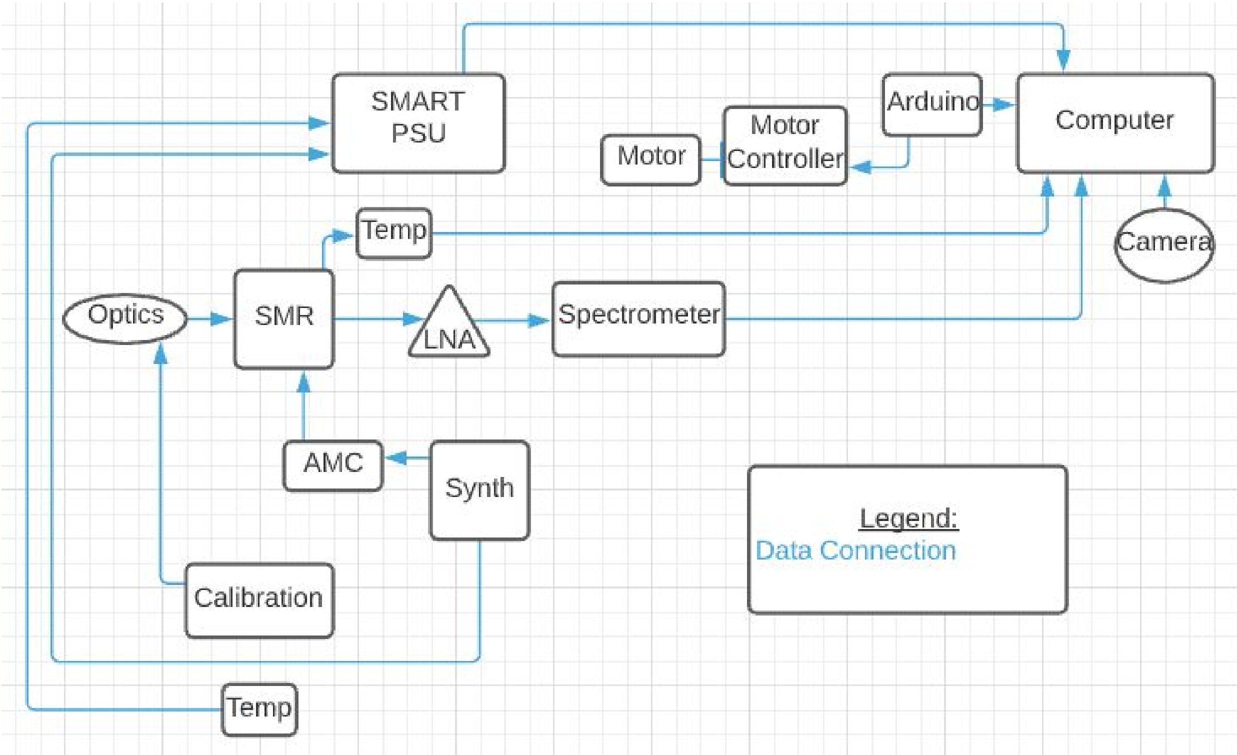
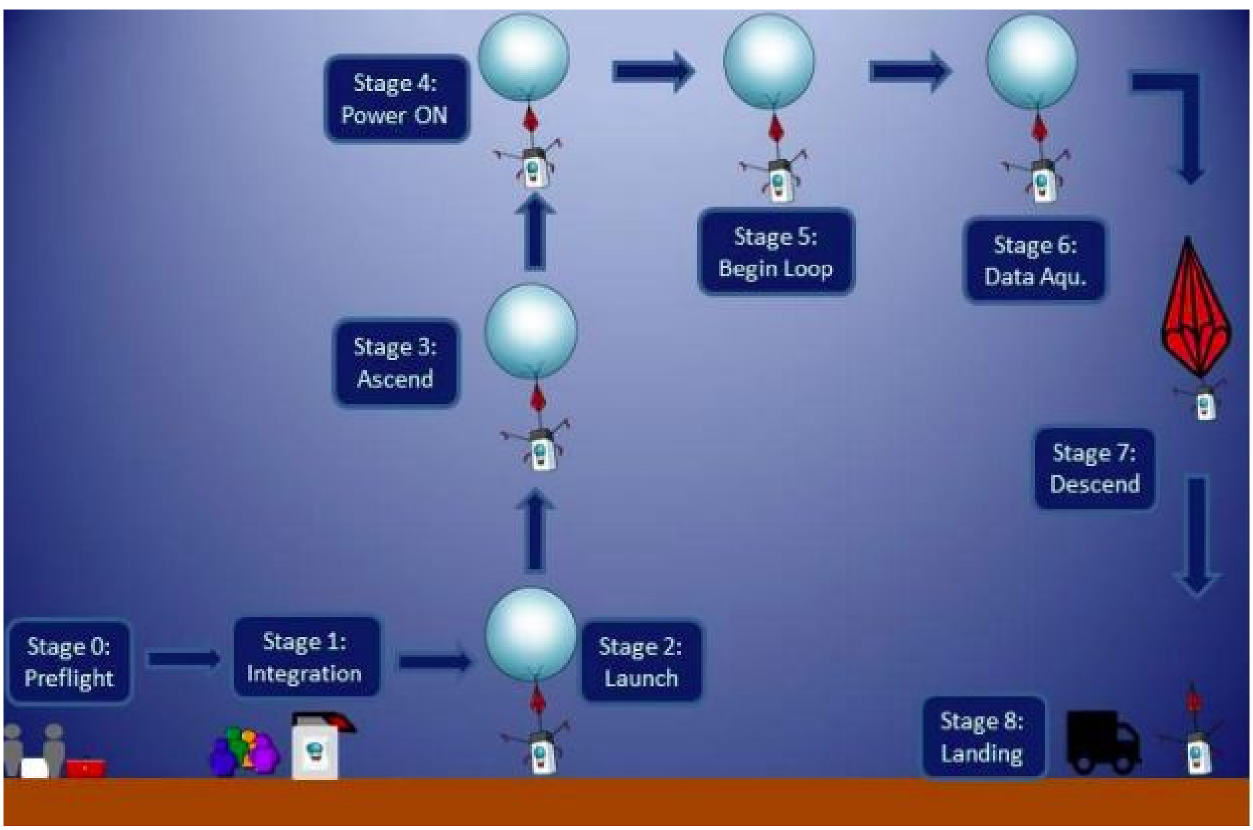


Figure 5 – Concept of Operations



The above figure represents a cartoon version of our concept of operations. Each stage is described in detail in the accompanying table below.

Table 2 – Description of Concept of Operations

Stage Number/Title	Description
Stage 0: Preflight	The payload will be calibrated followed by a series of system diagnostic tests to ensure that every subsystem and instrument inside the payload is functional.
Stage 1: Integration	The payload will be integrated on the gondola with the other payloads. The Computer and the SMART PSU will be plugged into the HASP system.
Stage 2: Launch	The entire gondola will launch and begin ascending.
Stage 3: Ascent	The gondola will ascend into the stratosphere where it will remain for most of the flight until it reaches the end of its journey.
Stage 4: Power ON	The HASP flight system will provide power and the payload will turn on. The motor inside our payload that runs the mirror will immediately begin running and will begin taking a blackbody reference. Our computer will begin by listening in for the GPS time and Position Data that we will be requested every 10 seconds.
Stage 5: Begin Loop	Once our computer receives the blackbody spectra, the data acquisition loop in our code will begin. The loop starts by tilting the mirror 10 degrees above the horizon and taking a spectrum. Once the data has been received, the code will then cycle through each sub-system to record and store the house-keeping data from each of the instruments. Subsystems -Sub-Millimeter Receiver: The receiver will be continuously taking in data and it will alternate between calibration data and atmospheric data. - Calibration System: The motor will be continuously running while power is provided to the system. The calibration system will read out a blackbody reference spectra that differentiates between the calibration process and the atmospheric observation process. The thermometer will be reporting the temperature of the blackbody during flight to provide context to the radiometer calibration system. - Spectrometer and Imaging: The spectrometer and the camera will have the same measurement cadence of 10 seconds. This was done to line up the orientation data to the radiometer data so that we can provide context to where the mirror is pointing. After each of these subsystems reports their information and the data is stored the loop will end until it is reactivated again by the GPS data string. This process repeats itself every 10 seconds

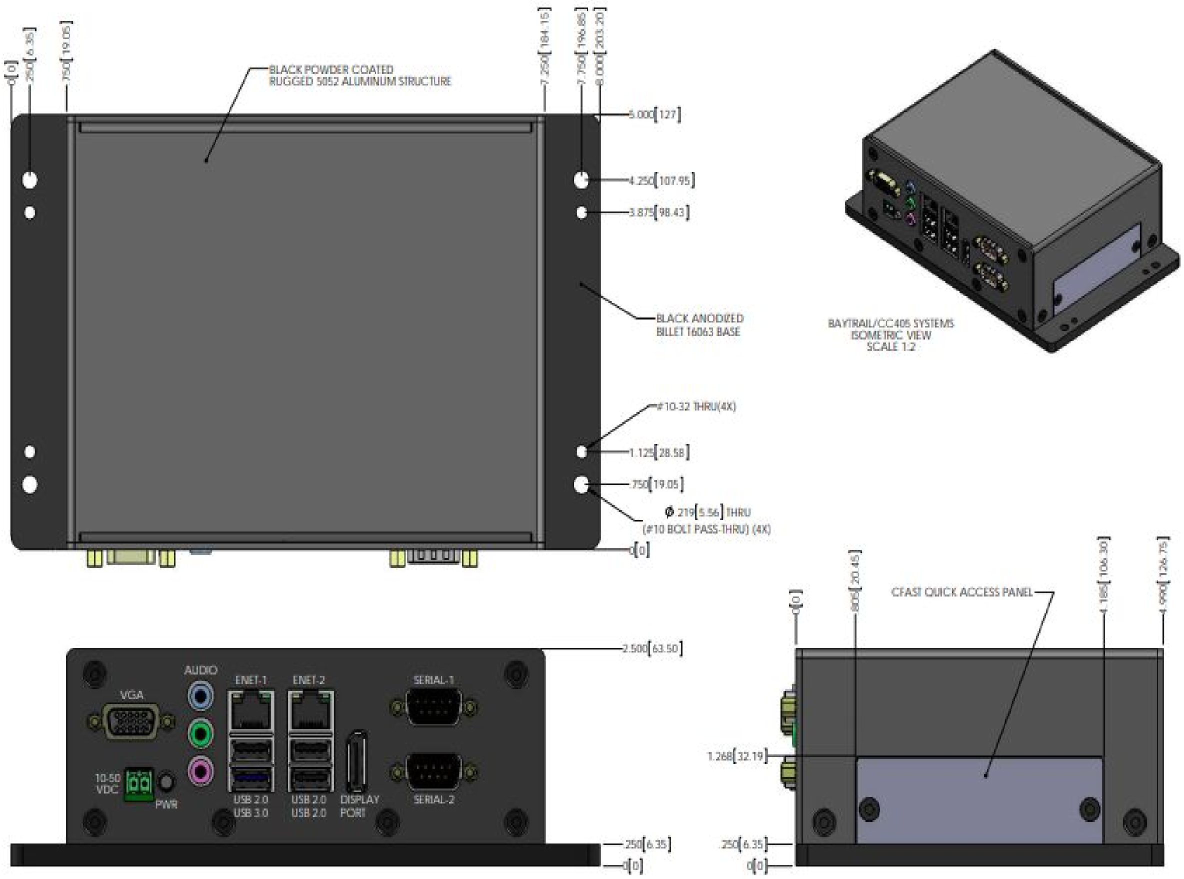
Stage 6: Data Acquisition	The payload will continue the data acquisition loop throughout the entire flight. Additionally, we will be downlinking information from our payload to the ground every 10 minutes to ensure that our payload is powered on and functioning properly. Our downlink package includes receiving position/altitude versus time, monitoring the payload clock, ambient temperatures of critical components onboard the payload, and a reference temperature to verify that the payload is running properly. Students will be monitoring the downlink packages to ensure the payload is functioning properly. If any components are reporting issues of overheating, a student will request to HASP that the power be shut off then turned back on again.
Stage 7: Decent	The balloon holding the gondola will pop and the entire system will begin the descent.
Stage 8: Landing	The gondola has landed somewhere in Arizona and a team will be dispatched by HASP for retrieval.

1.3 Major System Components

1.3.1 Computer

The general purpose of the computer will be to analyze the data from all sensors and compile it into a data file, and store it for post-flight analysis; this analysis is of critical importance. Team WWASP intends to inscribe a code for the computer that will ensure the data which is being stored will not be erased or written over in the case of a power reset on HASP. This code will be run through a series of tests on the computer before launch. The computer is supplied by JPL.

Figure 6 – SYS-405Q Fanless Industrial Computer with Quad-Core Intel® Atom™ Processor



Housing – Made of lightweight aluminum, the enclosure provides ample durability without adding unnecessary weight to the system. Its exterior has a black powder coat finish that resists scratches and fingerprints. With its durable exterior and fanless interior, the SYS-405Q is able to survive in industrial applications and reduce field service.

Memory – The SYS-405Q supports 2G, 4G, or 8GB of factory-installed DDR3L SRAM memory.

Battery - The SYS-405Q uses a single CR-2032 or CR-2025 battery. The nominal voltage of either battery is 3.0 V. This battery, or alternatively, an external battery connected to the SYS405Q board provides standby power for the real-time clock and GPS.

Power - The SYS-405Q draws power through the J5 connector. The main supply to the board is +10-50 V DC.

Watchdog Timer - Advanced watchdog timer (WDT) that can be used to guard against software lockups. The timer is programmable from 1 second to 255 minutes.

Operating Temperature - Fanless -40 °C to +85 °C (-40 °F to +185 °F); SYS-405-3845 requires a minimum airflow of 200 LFPM above 80 °C (176 °F) if input voltage (VCC) is above 24 V DC. • Storage temperature: -50 °C to +95 °C (-58 °F to +203 °F)

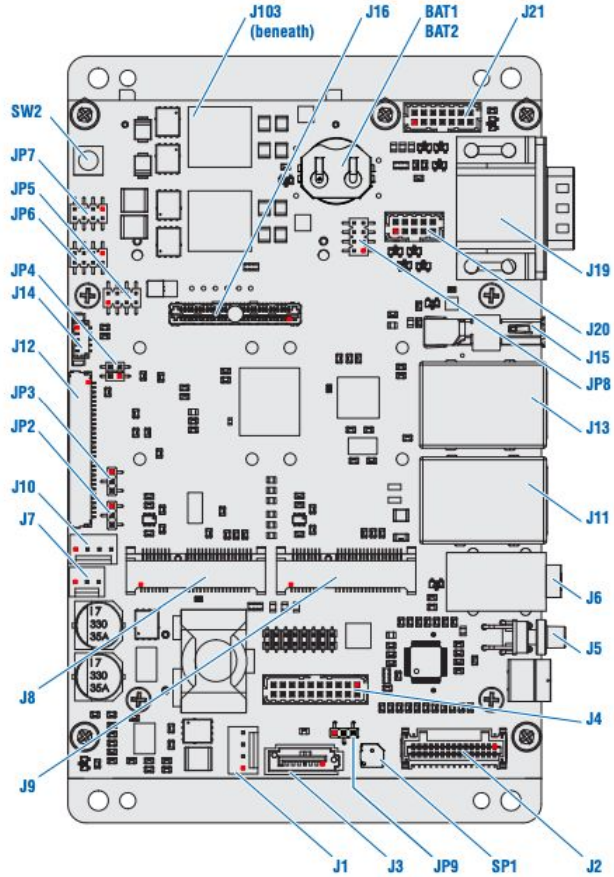
Table 3 - The SYS-405 system adheres to the following specifications and requirements.
SYS-405 Specifications

Electrical	
V_{CC}	10 to 50 V DC ±5%, 15 Watts (maximum)
MTBF	14.5 Years
Battery: CR-2032	Chemical System: Li/MnO_2 Nominal Voltage: 3 V Rated Capacity: 225 mAh
Mechanical	
Mechanical Enclosure Dimensions	8 x 5 x 2.5 inches (203.2 x 127 x 63.5 mm)
Weight	2.65 lbs (1.20 kg)
Environmental	
Temperature	-40 °C to +85 °C (-40 °F to +185 °F)
Humidity (RH)	5% to 95% non-condensing
Mechanical Shock Testing	MIL-STD-202G, Method 213B, Condition A 50g half-sine, 11 ms duration per axis, 3 axis
Random Vibration Testing	MIL-STD-202G, Method 214A, Condition D .1g/Hz (11.95g rms), 20 minutes per axis, 3 axis
RoHS Compliant	Yes
Operating Systems	
Runs 32/64-bit Windows, Linux, and other x86-compatible operating systems.	

Top view components

Figure 7 – SYS-405 Top Connections

The following figure illustrates the location of each connector, jumper, and switch on the top of the SYS-405.



Top view connectors

The following table provides connector descriptions.

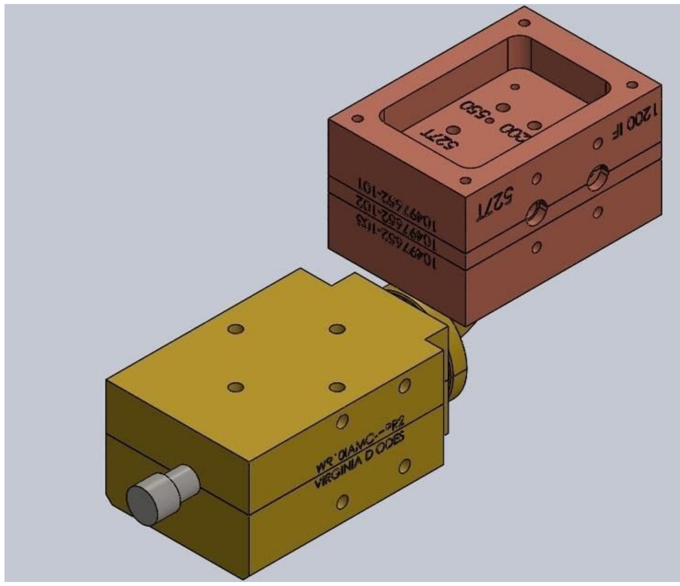
<u>Table 4 – Connector Descriptions</u>

Item	Description
J1	SATA Power
J2	HD Audio 7.1 Surround
J3	Serial ATA
J4	System Management
J5	Power Input
J6	Stereo Audio: Line-In, Line-Out, and Microphone
J7	External Battery Connector
J8	MiniPCIe
J9	MiniPCIe/MSATA
J10	External Fan Connector
J11	Ethernet (top half of connector)
J11	USB Channels 1 and 3 (bottom half of connector)
J12	LVDS and Backlight
J13	Ethernet (top half of connector)
J13	USB Channels 2 and 4 (bottom half of connector)
J14	USB Touchscreen
J15	Display Port 1.1
J16	IO60 Expansion
J19	COM 1 and COM 2
J20	Ethernet GPIO Controller
J21	Analog VGA
J103	CFAST (bottom of board)

1.3.2 Sub-Millimeter Radiometer

The JPL provided a sub-millimeter receiver for the WWASP payload is a system consisting of three components that come from JPL pre-assembled. The first component is the Integrated Schottky Diode Receiver Module which will have the input from the optics into the waveguide feed horn and an SMA output for the intermediate frequency. It also contains two mixers, but WWASP payload will only use one for the 550 GHz, and the sub-millimeter oscillator with 6x multiplication. The second component is a WR10AMC-I Compact Transmitter Module or otherwise known by its acronym, AMC. It will have 6x multiplication and will amplify the synthesizer signal from the Microlambda Wireless MLVS-0520 Synthesizer. This portion of the sub-millimeter receiver will need to be heat sunk to the payload very well for good heat dissipation. The last component of the Sub-Millimeter Receiver is the SWB-10090-HB WR-10 H Plane Waveguide Bend. Which will be used to connect the AMC to the receiver since the mechanical design of the AMC doesn't support being directly connected to the AMC.

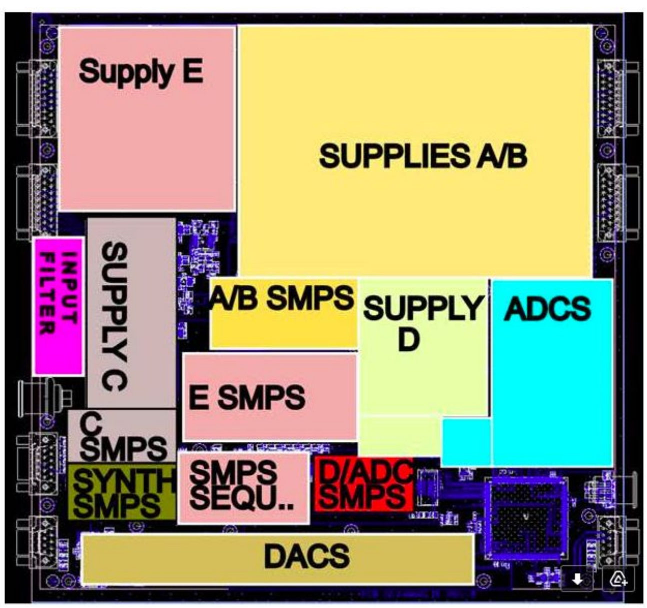
Figure 8 - Sub-millimeter radiometer



1.3.3 SMART PSU

The JPL provided Smart PSU is a 9.5 x 9.5 printed circuit board (PCB), with a case of 1-inch thickness. The board takes the HASP bus voltage 28V-32V and generates all the necessary voltages for the receiver, amplifiers, synthesizers and also talks to the synthesizer and has voltage/current readouts of all ports plus thermal sensors readout. The PCB also has electrostatic discharge (ESD) protection.

Figure 9 - SMART PSU



The following figure shows the power consumption of the PSU

PSU output	vout	vin	iout	ldo loss	delivered pwr	smps eff	smps pwr	pwr	current	Comments
supply A.0	-15	29	0.01	0.44	0.15	0.8	0.0725	0.3625	0.013942	Receiver M1 Multiplier
supply A.1	0	29	0	0	0	0.8	0	0	0	N/C
supply A.2	0	29	0	0	0	0.8	0	0	0	N/C
supply A.3	0	29	0	0	0	0.8	0	0	0	N/C
supply A.4	0	29	0	0	0	0.8	0	0	0	N/C
supply A.5	0	29	0	0	0	0.8	0	0	0	N/C
supply A.6	0	29	0	0	0	0.8	0	0	0	N/C
supply A.7	0	29	0	0	0	0.8	0	0	0	N/C
supply B.0	10	29	0.002	0.038	0.02	0.8	0.0145	0.0725	0.002788	Receiver M2 Multiplier
supply B.1	0	29	0	0	0	0.8	0	0	0	N/C
supply B.2	0	29	0	0	0	0.8	0	0	0	N/C
supply B.3	0	29	0	0	0	0.8	0	0	0	N/C
supply C.0	0	-6.6	0	0	0	0.75	0	0	0	N/C
supply C.1	0	-6.6	0	0	0	0.75	0	0	0	N/C
supply C.2	0	-6.6	0	0	0	0.75	0	0	0	N/C
supply C.3	0	-6.6	0	0	0	0.75	0	0	0	N/C
supply C.4	0	-6.6	0	0	0	0.75	0	0	0	N/C
supply D.0	-0.5	-3.5	0.001	-0.003	0.0005	0.75	-0.00117	-0.00467	-0.00018	557 GHz Mixer
supply D.1	-0.7	-3.5	0.001	-0.0028	0.0007	0.75	-0.00117	-0.00467	-0.00018	IF Amplifier Gate
supply D.2	0	-3.5	0	0	0	0.75	0	0	0	N/C
supply D.3	0	-3.5	0	0	0	0.75	0	0	0	N/C
supply E.0	15	16.8	1	1.8	15	0.88	2.290909	19.09091	0.734266	Synthesizer
supply E.1	9	10.8	0.4	0.72	3.6	0.88	0.589091	4.909091	0.188811	AMC
supply E.2	7	16.8	0.001	0.0098	0.007	0.88	0.002291	0.019091	0.000734	Arduino Motor Controller
supply E.3	15	16.8	0.22	0.396	3.3	0.88	0.504	4.2	0.161538	Motor
supply E.4	5	6.8	0.3	0.54	1.5	0.88	0.278182	2.318182	0.089161	Heater
supply E.5	1.9	3.8	0.029	0.0551	0.0551	0.88	0.015027	0.125227	0.004816	IF Amplifier Drain 1
supply E.6	3.7	4.8	0.038	0.0418	0.1406	0.88	0.024873	0.207273	0.007972	IF amplifier Drain 2
supply E.7	5	6.8	0.35	0.63	1.75	0.88	0.324545	2.704545	0.104021	Spectrometer
thermometers				0.00495				0.00495	0.00019	Thermometers
adc/dac/mcu				10				10	0.384615	ADC/DAC/MCU
				14.66985	25.5239		4.113585	44.00493	1.692497	
						diss brd	18.48103			
								0.88		
						diss unit+mains supply	24.48171	50.00561		

1.3.4 Imaging and Optics

An optical camera will be used to aid in interpreting the orientation of the radiometer. While an optical camera is not necessarily needed for the data collection process, we feel that for the radiometer's data to be accurate, the team will need to know if something is obstructing the view of the instrument. If a piece of equipment comes loose it could potentially throw off the measurements. The optical camera that is being considered is the ESCAM PVR006 HD webcam, which is around $26. It has a 75-degree field of view and has dimensions of 72 x 30 x 35 mm. This specific camera takes 5 volts for its power, is Linux compatible, and can be plugged into the computer via a USB 2.0 or a USB 3.0. The camera is operable in temperatures that range from -20°C - 60°C. We will test the quality of the camera at a range of appropriate temperatures and pressures to ensure it can operate in a near-space environment while providing a quality image.

Figure 10 - ESCAM PVR006 HD webcam

A single mirror will be used for both the calibration system, and for the radiometer. The mirror will be connected and controlled by a motor, allowing it to alternate between the blackbody and radiometer. For the calibration system, the mirror will be tilted to direct a beam from the blackbody, of which a known temperature will be collected and stored. The mirror will then be tilted and aligned with the radiometer to collect a sky spectrum.

A concave mirror with a four-inch focal length is needed for this experiment due to the limited space inside the payload frame. The current mirror considered for use is an aluminum off-axis parabolic mirror with a diameter of 101.6 millimeters +0.00/-0.38. The mirror has an effective focal length of 101.6 millimeters. The motor used to control the mirror is a Nema 34 Stepper motor. The mirror will be tested to establish the accuracy of the focal length. A shock test will also be done once the payload is assembled to ensure that the mirror will be secure while in transport.

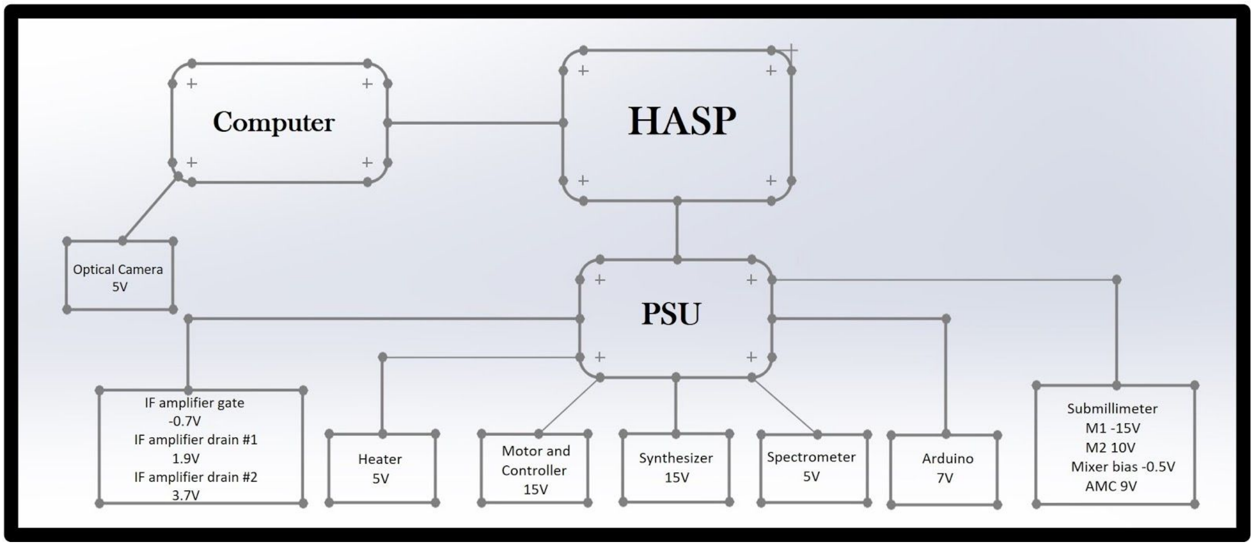
Figure 11 - 101.6 x 101.6mm EFL 90° Protected Aluminum 100Å Off-Axis Parabolic Mirror

1.4 Mechanical and Structural Design

The payload will have the dimensions of 15.9 x 11.7 x 6.25 inches of which the outer shell will be constructed of 0.06-inch thick aluminum sheets. Along the seams of the payload will be aluminum angle that is 0.5x0.5x2 inches which will unite all sides of the payload and also add more structural rigidity. The pieces for the aluminum sheeting exterior will be cut to size. The angle is in two-inch pieces so the entire payload does not flex as much, relative to the complete piece of angle, when landing. U-bolts will be attached to the outer shell of the payload by drilling holes and bolting them on with lock nuts while also weaving the U-Bolts through the payload plate. The payload plate and payload bolted together will ensure the force of the uplift will be distributed more evenly and not in one singular spot which would increase the chance of the payload becoming damaged. The landing is the other expected mechanical stress portion of the flight. A skeleton will be made for the payload utilizing aluminum angle around all the interior joints. Two-inch pieces will be used to make the payload more rigid as opposed to using 30cm pieces since the 2inch pieces will have more rigidity due to their smaller length. This will be essential as the payload lands since the angle will absorb most of the shock and ensure the payload does not flex so much that the payload or subsystem components break. A mechanical drawing of the payload is listed as Figure 1 in section 4 of this proposal.

1.5 Electrical Design

Figure 12 - Electric Flow Chart



The four +30V EDAC power wires and four ground wires will be attached to a terminal strip with the four power and ground wires bridged for current sharing. From there, the bus power will be distributed to the JPL SmartPSU and computer as shown in the power diagram above. The analog and discrete command wires and corresponding returns from the EDAC connector will not be used by WWASP.

1.6 Thermal Control Plan

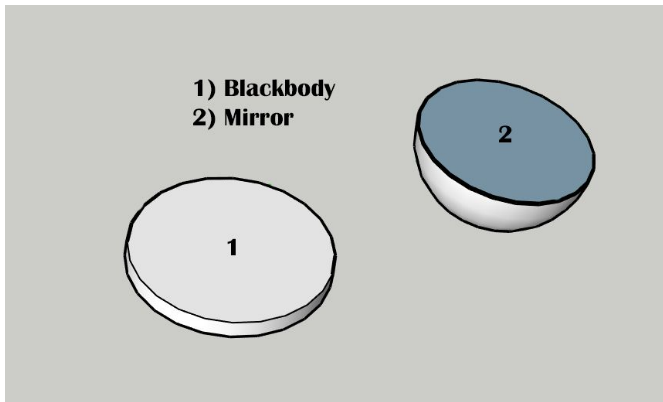
Currently, the team has developed a plan to test every instrument and component to ensure that they all work under the environmental stresses of flight (e.g. heat, cold, pressure, etc). Using one of the thermal vacuum chambers on the ASU campus, each item will receive either a pass or fail after being tested, determined by the capability of the part to meet system requirements while being stress tested. If the item passes this stress test, it will then proceed to undergo other various tests on simulated drops, power cycling, and more. If the item is a component to a larger subsystem (e.g. calibration), then all components that pass will be assembled together to be tested as a whole. If the item fails, however, the team will go back to the drawing board to find either an alternative part or a means of circumnavigating the issue that caused the failure. Important to note is that the who, what, and when will be noted for everything testing on the payload. For instance, when the computer is tested, the name of who tested this device, when they tested it, and what they tested it for will be recorded. This will ensure that everything is tested under circumstances of extreme heat. Only after all subsystems have been tested will they be assembled into a single payload, which will then finally be followed by the entire system being subjected to the same thermal vacuum experience.

The rest of the thermal control plan will be passive, starting with painting the outside of the payload white. This will reflect heat produced from the sun and keep the entire payload cool. After sunset, however, conditions may drop as low as -3 °C, and so heaters will be employed inside if it proves necessary for the payload to remain functional. Inside the payload, any instruments that produce heat (even if a minimal amount), will be thermally strapped to the payload frame directly using a thermally conductive material. This will mitigate and redirect any heat generated within the interior of the payload.

1.7 Calibration

The calibration subsystem exists to calibrate the sub-millimeter radiometer and eliminate noise from the receiver. The main components include a blackbody that will be approximately the same diameter as the mirror and a thermometer. Then a blackbody will be placed near the proximity of the rotating mirror so that it may be referenced repeatedly throughout the flight. A thermometer, read by the JPL Smart PSU board, will be epoxied directly to the blackbody to measure its temperature during flight.

Figure 13 - Blackbody Reference



Size comparison between the mirror and the blackbody we will need to construct. This is what blackbody will relatively look like and will have a diameter similar to that of the mirror at 10.16 cm.

2. Team Structure and Management

2.1 Team Organization and Roles

Name	Role	Email	Phone
Jessica Berkheimer	Team Lead, Science and Optics*	jberkhei@asu.edu	480-334-5104
Ruben Ortiz	Electrical Design, Weight and Power Budget	ruben.g.ortiz@asu.edu	262-909-5495
Kelsey Klingler	STM Manager	kmklingl@asu.edu	480-818-8478
Ewan Pringle	Calibration Engineer	epringl1@asu.edu	720-879-3828

Steven Sherman	Mechanical Engineer	ssherma6@asu.edu	401-749-0932
Prof. Chris Groppi	Faculty Advisor	cgroppi@asu.edu	480-965-6436
Dr. Jose Siles	JPL technical advisor	Jose.v.siles@nasa.jpl.gov	626-316-2633
Dr. Jonathan Kawamura	JPL technical advisor	Jonathan.h.kawamura@nasa .jpl.gov	818-653-3016

* = This role is subject to change depending on team member's workload

The above table depicts the roles that each team member will be performing for the 2021 Spring semester. A detailed breakdown of each member's responsibilities will be explained shortly, but first, it should be stated that most of these roles have already been overseen by their respective team members for the 2020 Fall semester too. By keeping each team member on the subsystem(s) they have been responsible for since nearly the beginning of this project, we hope that this will allow for a more seamless transition from the planning stage to its actual construction and testing. However, some responsibilities are predicted to be more demanding next year. Therefore, and as indicated by the * symbol above, some roles may be passed along to other team members who are either experienced in that subsystem or who have had a hand in its early creation.

Jessica Berkheimer will serve as the team lead, and will thus oversee logistics, budgeting, scheduling, ensuring milestones are met, paperwork (e.g. monthly HASP reports), and any mandated teleconferences or presentations. She will also be the head of the science role and the payload optics, which will require making certain that the construction and testing of anything engineering-related, including the optical camera and mirror, ties into the team's goals and requirements.

Ruben Ortiz will act as the electrical engineer/weight and power auditor. He will map out the power draw to all electrical components of the payload and ensure electrical components can be maintained by the supplied voltage provided by HASP as well as the maximum current draw of 2.5 amps. Additionally, he will audit the weights for all components, devices, and other support items (bolts, wires, fasteners, etc) to verify the total weight does not exceed the large payload limit of 20kg.

Kelsey Klingler will serve as the Science Traceability Matrix (STM) manager. The tasks for this includes keeping the STM up to date with the team's science goals and making sure the requirements for the experiments science goals are met so they can be accomplished. She will also be assisting with coding the computer and anywhere else that one of the team members may need assistance with a task.

Ewan Pringle will serve as the calibration engineer and will head the calibration and monitoring of the payload and its constituent parts. He will calibrate and ensure that the thermal aspects of the system, such as the thermometer, thermal testing, and blackbody calibration system, meet both HASP guidelines and payload requirements. He will also help resolve any unforeseen issues with the technical layout of the payload, including electrical, mechanical, and code-related problems that would impact the performance, safety, and results of the payload.

Steven Sherman will act as the Mechanical Engineer. He will map out the design of the payload and where all of its subsystems will go. He will also oversee the construction of the payload and determine what base components will be used to create said payload. Any stress testing or modification will be looked at and run by him as testing is commenced.

2.2 Timeline and Milestones

This section includes a list of key milestones (and associated dates) for the project and a Gantt chart timeline. The timeline should be a weekly schedule organized by major WBS elements.

Table 5: Timeline

Date	Event
December 18, 2020	HASP Application Development Q&A
January 8, 2021	HASP Proposal Due
January 11, 2021	In-class meeting; Safety training, order parts not already purchased over winter break and begin programming of payload.
January 18, 2021	No class (Holiday)
January 20, 2021	Team Lead and Systems Engineer meeting, begin subsystem design
January 25, 2021	In-class meeting; Begin design of calibration system and payload frame
January 29, 2021	1st HASP status report due
February 1, 2021	In-class meeting; Finish subsystem design, finish payload frame, begin design of radiometer housing
February 2, 2021	Team Lead and Systems Engineer meeting, begin orientation testing
February 3, 2021	In-class meeting; Finish design of radiometer housing and finish orientation testing, Begin camera testing
February 5, 2021	HASP Monthly Teleconference Meeting
February 8, 2021	In-class meeting; finish camera testing, submit for construction
February 15, 2021	In-class meeting; Begin and finish testing of temperature sensors
February 17, 2021	Team Lead and Systems Engineer meeting

February 22, 2021	In-class meeting; Begin computer testing, begin assembly of calibration system
February 26, 2021	2nd HASP status report due
March 1, 2021	In-class meeting; begin individual testing of subsystems
March 3, 2021	Team Lead and Systems Engineer meeting
March 5, 2021	HASP Monthly Teleconference Meeting
March 8, 2021	In-class meeting; work on code, continue testing of subsystems
March 10, 2021	Team Lead and Systems Engineer meeting
March 15, 2021	In-class meeting; finish individual testing of subsystems, begin assembly of payload
March 22, 2021	In-class meeting; Continue assembly of payload, and computer code
March 26, 2021	3rd HASP status report due
March 29, 2021	In-class meeting; Finish payload assembly and start tests
April 2, 2021	HASP Monthly Teleconference Meeting
April 5, 2021	In-class meeting; Finish payload tests and disassemble it, paint payload frame
April 12, 2021	In-class meeting; Finish painting and begin reassembly of payload
April 14, 2021	Team Lead and Systems Engineer meeting; begin round two of payload tests
April 19, 2021	In-class meeting; finish payload tests and present results
April 26, 2021	Last day of class
April 30, 2021	Preliminary PSIP document due, NASA Integration Security Document due, 4th HASP status report due
May 7, 2021	HASP Monthly Teleconference Meeting
May 10, 2021	Work on any issues proposed by mentors
May 28, 2021	5th HASP status reports due
June 4, 2021	HASP Monthly Teleconference Meeting
June 25, 2021	6th HASP status report due, Final PSIP Document due, NASA Flight On-Site Security Document Due

July 2, 2021	HASP Monthly Teleconference Meeting
July 23, 2021	Final FLOP Document due
July 26 – 30, 2021	Student payload integration at CSBF*
July 30, 2021	7th HASP status report due
August 6, 2021	HASP Monthly Teleconference Meeting
August 27, 2021	8th HASP status report due
Aug. 30 – Sept. 3, 2021	HASP flight preparation*
September 3, 2021	HASP Monthly Teleconference Meeting
September 4, 2021	Target flight ready*
September 6, 2021	Target launch date and flight operations
Sept. 7 – 11, 2021	Recovery, packing, and return shipping
Sept. 12 – 30 2021	Post launch data analysis*
Sept. – Nov., 2021	Monthly status reports and teleconferences
October 1, 2021	HASP Monthly Teleconference Meeting
November 5, 2021	HASP Monthly Teleconference Meeting
December 3, 2021	HASP Monthly Teleconference Meeting
December 10, 2021	Final Flight / Science Report due

* *indicates dates that may vary*

2.3 Anticipated Participation in Integration and Launch operations

We plan on testing our payload's ability to function in low-pressure environments, ability to handle shocks up to or greater than the limits proposed in the HASP documentation, and ability to function within the proposed range of temperatures while at low pressure. This will include tests of the individual parts, as well as the assembled payload. These tests will be done within the vacuum chambers at ASU, which will be capable of testing conditions analogous to the pressures found during HASP's expected flight.

These vacuum chambers will also allow us to perform thermal tests on each subsystem, as well as the assembled system. Overheating is the greatest concern. Rigorous tests will be done to make sure that the heat sinking is efficient enough on the SMR and the synthesizer to avoid overheating. Assuming the tests are a success, we will be able to add it to the integrated system, and then be able to thermally test the integrated system. If the system or subsystem fails the thermal test, we will remove it from the system and find an alternative part that will pass the thermal test and use it instead. The final version of this test will involve thermal testing of the entire integrated system with all of the subsystems to ensure that the entire payload will function at the expected temperature range during flight.

We will also be testing our code rigorously concerning its ability to function in the expected environment. We will ensure that the payload can operate with frequent restarts while continuing data collection from the last point to ensure the completion of our mission, as well as ensuring that the code will function as intended throughout the mission through frequent trials throughout the assembly process of the payload, as well as with the completed payload.

Finally, we will also be performing mechanical and physical tests. We will be weighing the components and the integrated systems to ensure that they align with HASPS guidelines, as well as measuring the payload's dimensions and ensuring that all systems are securely fastened to the payload. This will also include testing the experiment's ability to deal with power outages and fluctuating voltages, and the experiment's ability to function despite them.

During the launch, we will provide a few personnel to provide maintenance of the payload before launch and to ensure that the experiment runs smoothly during launch. The personnel will monitor the downlinked signals from the payload to ensure that the payload does not overheat, that data collection continues with as little error as possible, and to provide information upon request. We will also collect the payload when possible and return it to ASU for analysis.

Those expected to be present for the launch include, JPL's Dr. Jose Siles and Jonathan Kawamura, faculty advisor Dr. Christopher Groppi, and two students from the WWASP team (TBD). Once the payload is secured into place on the HASP gondola, our anticipated procedure during integration with HASP will be connecting the computer and the SMART PSU to the HASP power supply. Once the payload is connected to power, we will begin a series of prelaunch tests. We will test the connectivity of the ground-based computer to the payload computer, and also secure the downlink signal. We will then run a test on the code by taking a test spectrum, followed by turning the power to the payload off and back. This will establish certainty that the code runs as it should in the incident that HASP has to turn off the main power supply. We will test the calibration system by taking a blackbody spectrum. A preflight collection of housekeeping data will be collected to ensure that all systems are working together. Once the payload is launched, the flight operations will consist of collecting housekeeping data, monitoring the payload's temperature.

3. Payload Interface Specifications

3.1 Weight Budget

The following table summarizes each unique part and device planned to be implemented to the payload. If a part device contains multiple identical components, a number value will be listed next to the Part/Device. The units for weight are in grams and are projected to be within the weight parameter of 20 kg. A final entry of miscellaneous components such as wires and fasteners are estimated and may vary. The preliminary projection demonstrates the payload is well under the 20 kg limit.

Table 6: Weight Budget

Part/Device	Weight (g)	Uncertainty (g)
Computer	1202	± 120
PSU	500	± 250
Payload Box with Supports	6660	± 666
Arduino	32	± 3
Motor with Control Stepper	500	±250
Thermometer	1	± 0.1
Optical Camera	380	± 38
Synthesizer	596	± 60
Spectrometer	100	± 10
Submillimeter	450	± 45
Low-Noise Amp	28	± 3
Analog Downlink	250	± 0.5
Mirror	1136	± 100
Calibration blackbody	500	±250
DB9 DTE	30	± 3
EDAC Cable	100	± 50
Miscellaneous	2000	± 1000
Total	**14465**	**± 2849**

3.2 Power Budget

The following list summarizes each individual device on the payload that requires power to operate. The power uncertainties are minimal. The EDAC connector will interface the Smart PSU directly with HASP for power distribution, while the SYS 405Q computer for data will obtain power directly from HASP. The SYS 405Q will provide power for the optical camera while the Smart PSU will act as the "power system" for all other devices.

Table 7: Power Budget

PSU connected devices			
Part/Device	**Current (A)**	**Power (W)**	**Power Uncertainty**
Arduino Motor Controller	0.001	0.02	± 0.002
Motor	0.2	4.2	± 0.4
Thermometer	0.005	0.005	± < 0.001
Heater	0.09	2.3	± .2
Synthesizer	0.7	19.1	± 1.9
Spectrometer	0.1	2.7	± 0.3
Submillimeter Receiver M1 Receiver M2 557 GHz Mixer AMC	 0.01 0.003 -0.0002 0.2	 0.4 0.07 -0.005 4.9	 ± 0.04 ± 0.001 ± < 0.001 ± 0.5
IF Amplifier Gate	-0.0002	-0.005	± <0.001
IF Amplifier Drain 1	0.005	0.1	0.01
IF Amplifier Drain 2	0.008	0.2	0.02
ADC/DAC/MCU	0.4	10	± 1
Total	1.7	44	4.4
Computer			
Part/Device	**Current (A)**	**Power (W)**	**Power Uncertainty (W)**
SYS 405Q	0.3	10	± 1
Optical Camera	0.16	0.8	±0.006

Payload Total	2.16	54.8	5.406

3.3 Downlink Serial Data

We intend to receive downlinks from our payload during operation to ensure that the payload is on and operating correctly. This data will be transmitted to HASP through the serial link, and will contain the data listed below. For the sake of redundancy, the data will be transmitted 3 times every 1 minute. The data contained in the downlink will include the temperatures of the AMC, synthesizer, and SmartPsu. It will also contain the timestamp, the number of complete cycles the mirror has undergone, and the number of measurements we have recorded so far. We will use a python serial communications library set up for 1200 baud, 8 data bits, no parity, 1 stop bit and no flow control. We will transmit our data using one of the two built in serial ports on our computer. We will be interfacing with the HASP serial connection byu wiring the DB9 pigtail as a NULL modem to our payload. The table below lists the details of our data package that we will be downlinking. For redundancy, we will be sending three copies of our data package every 60 seconds.

Table 8: Downlink Serial Data

Byte	Bit	Description
1-4	0-31	Timestamp (Seconds since 1/1/1970)
5-6	0-15	Record Size
7	0-7	Checksum
8-9	0-15	AMC Temperature Readout
10-11	0-15	Synthesizer Temperature Readout
12-13	0-15	SmartPSU Temperature Readout
14-15	0-15	Mirror cycle count
16-17	0-15	Number of spectra recorded

Our data package consists of 136 bits that will be copied three times and streamed every 60 seconds making our average data rate 6.8 bits per second.

3.4 Uplink Serial Commanding

We do not intend to use any additional uplink commands beyond the usual power on/off commands. We will request GPS time and position data from HASP once per minute through the serial interface.

3.5 Analog Downlink

WWASP will not use analog downlink channels

3.6 Discrete Commanding

WWASP will not need any additional discrete commands.

3.7 Payload Location and Orientation Request

Any large payload seat will work for WWASP. WWASP will be oriented with the mirror cutout shown in section 4, figure 1 pointing to the outside of the gondola.

3.8 Special Requests

Presently the team has no special requests that they would like to make from the HASP facilitators.

4. Preliminary Drawings and Diagrams

The payload will have a rectangle cutout measuring 5 x 4 inches on the top and side panel to allow the mirror a tilt range of 20 to 70 degrees.

Figure 14 - Wasp Payload comparison with payload max dimensions (dimensions in inches)

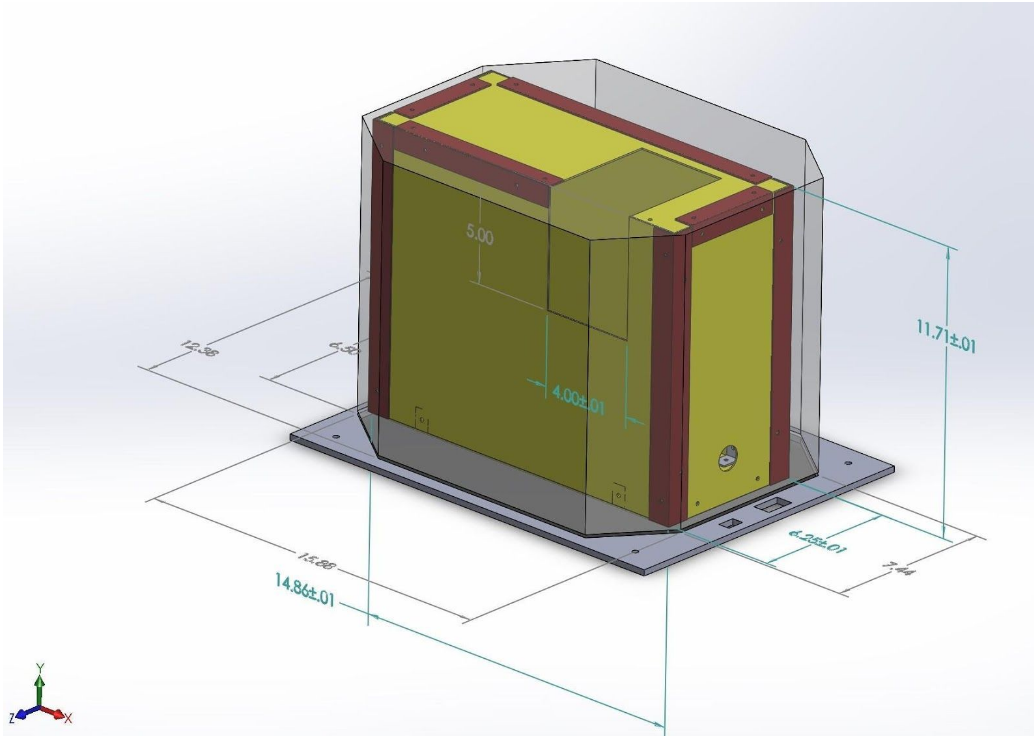
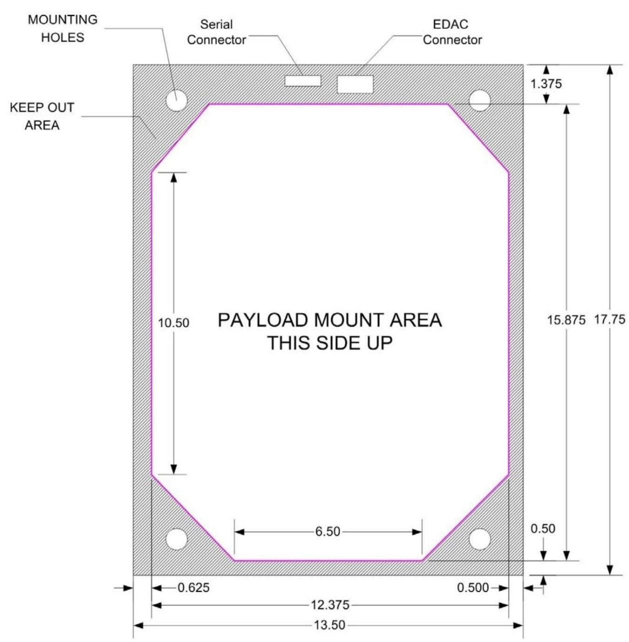


Figure 15 - Large Payload Frame



5. References

Appendix