HASP Student Payload Application for 2022

Payload Title: HADHR (High Altitude Deuterium to Hydrogen Receiver)

Institution: Arizona State University (ASU)

Payload Class (Enter SMALL, or LARGE): LARGE

Submit Date: 01/07/2022

Project Abstract: The origins of Earth's water is a key component to understanding the history of Earth and the Solar System. Limb-sounding can offer a cost effective alternative to astronomical space observatories that can measure the atmospheric Deuterium to Hydrogen (D/H) ratio and provide insight into the history of Earth's atmospheric water. Using a submillimeter wave receiver and spectrometer, HADHR will record emission lines of HDO, H_2O, H_2O-17, and H_2O-18 between a 500-600 GHz range. This data will then be analyzed by the AM Atmospheric Modeling software using a reverse retrieval method and a D/H ratio will then be calculated. The calculated D/H will then be compared with data collected from the Atmospheric Chemistry Experiment - Fourier Transform Spectrometer (ACE-FTS) to determine the accuracy of the retrieval method and will also be compared to Vienna Standard Mean Ocean Water (VSMOW) and various cometary water data collected from NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) mission to determine the origins of Earth's atmospheric water. NASA's Jet Propulsion Laboratory (JPL) is providing the mission with the submillimeter receiver system, a fanless industrial computer, and a Smart Power Supply Unit (PSU). A blackbody calibration system for the spectrometer will also be included to ensure accurate data.

Team Name: HADHR

Team or Project Website: N/A

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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
Lasers (Class 1, 2, and 3R only) Fully Enclosed		X
Intentionally Dropped Components		X
Liquid Chemicals		X
Cryogenic Materials		X
Radioactive Material		X
Pressure Vessels		X
Pyrotechnics		X
Magnets less than 1 Gauss		X
UV Light		X
Biological Samples		X
Batteries	X	
High intensity light source		X

Student Team Leader Signature:___ J. Petersen __

Faculty Advisor Signature: ___ ___________________

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1. Payload Description

1.1 Payload Scientific / Technical Background

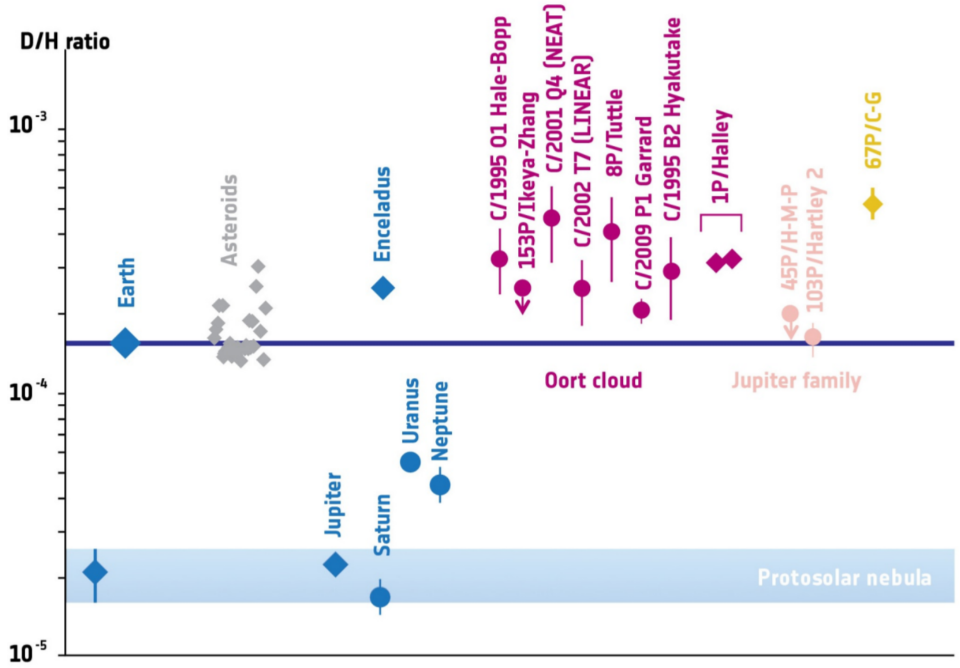
Project HADHR's (High Altitude Deuterium to Hydrogen Receiver) primary goal is to fly a submillimeter wave receiver and spectrometer - provided by Arizona State University and NASA JPL - aboard the HASP heavy-lift balloon for the purposes of measuring the D/H (Deuterium to Hydrogen) ratio within the atmosphere. These measurements will be compared to the D/H ratio measured by orbiting satellites. We will adhere to every constraint and guideline presented by the HASP CFP 2021-2022 document and specifically, the constraints and requirements listed under the Large Student Payload section within the document. Project HADHR is dedicated to ensuring that undergraduate students receive hands-on experience in the wide variety of developmental, design and manufacturing processes and procedures when building an experiment.

Project HADHR's payload design is based off of a previous HASP team's payload, WWASP (Sub-Millimeter Water Wave Spectrometer). Upon reaching the end of Project HADHR's timeline, the payload will have gone through design iterations in order to best fit the goals that the team has set out to accomplish. The payload will have completed its flight onboard the heavy-lift balloon where it will have fulfilled its purpose and provide adequate data for analysis and for Project HADHR to answer its science questions.

1.1.1 Mission Statement

Project HADHR will use limb sounding to gather data about the D/H ratio of the stratosphere and above to an accuracy of ± 12.5% . These error bars were determined by using the Figure 1 below, and these error bars will allow the D/H ratio of the upper atmosphere to be distinguishable from Vienna Standard Mean Ocean Water (VSMOW), asteroids, and comets (*Deuterium-To-Hydrogen Ratio In The Solar System, 2014)*. This accuracy will allow the following scientific questions to be answered: (1) How does the D/H ratio measured by atmospheric limb sounding compare to the D/H ratio measured by orbiting earth observing satellites? (2) How does the D/H ratio of the stratosphere compare to the D/H ratio of VSMOW? (3) How does the D/H ratio of the upper atmosphere compare to the D/H ratio that has been observed in various asteroids and comets?

Figure 1: D/H ratio of the solar system compared to Earth.



1.1.2 Mission Background and Justification

Determining the D/H ratio of the upper atmosphere, comets, and planets is difficult using ground based telescopes due to the emission line of H_2O being optically thick in the lower atmosphere. This means that the brightness of the emission line of H_2O washes out the emission lines of HDO, H_2O-17, H_2O-18, and other spectra that are needed to accurately determine the D/H. Satellites have been used to measure the D/H ratio of Earth's atmosphere, Jupiter, Saturn, and other planets (Pierel et al., 2017, Hallis, 2017, Randel et al., 2012). The Atmospheric Chemistry Experiment Fourier Transform Spectrometer (ACE-FTS) mission collected data about the D/H ratio in the upper troposphere and lower stratosphere (UTLS), and the data collected by HADHR will be compared the data from ACE-FTS. This comparison will be done to determine if balloon missions can return the same level of accuracy about the D/H ratio as earth observing satellites. If the data collected by HADHR is comparable to the data that was collected by ACE-FTS, it would show that less expensive balloon missions can return the same data about the D/H ratio in Earth's stratosphere as more expensive satellite missions.

The Stratospheric Observatory for Infrared Astronomy (SOFIA) has also been used to determine the D/H ratio of comets as well as observing the D/H ratio of Venusian atmosphere (Lis et al., 2019, SOFIA Quick Guide, 2021). Due to the SOFIA mission being one of the most expensive NASA projects, as well as not meeting scientific expectations, the NASA FY2022 budget recommends the cancellation of SOFIA (*NASA FY 2022 Budget Estimates,* 2021; *FY 2022 Budget Request: Deep Space Exploration Systems,* 2021*; NASA FY 2022 Budget Request,* 2021). While Project HADHR will not be observing comets or other planets, it will help provide information about far infrared observations for future infrared telescope missions.

1.1.3 Mission Objectives

The following are the mission objectives for Project HADHR: (1) Determine the D / H ratio of the stratosphere by observing the brightness of the emission spectra of Deuterium (HDO), H_2O, H_2O-17, and H_2O-18 to within +/- 12.5%. The frequencies that will be used to observes the emission spectra are shown in Table # (2) Take measurements of the listed spectra at 6 separate angles between +10^o and +70^o from horizontal. The angles that will be used are shown in Table #. (3) Compare the D/ H ratio of the stratosphere that is observed by earth observing satellites, and the D/H ratio of comets, to the D/H ratio that this mission observes.

Table 1: Frequencies for the Emission Spectra

Emission Lines	Frequency (MHz)
HDO	537792, 539935
H_2O	504482
H_2O-17	507935
H_2O-18	537337, 539895

Table 2: Observation Angles

Observation Angles
+10^o
+20^o
+30^o
+40^o
+50^o
+60^o
+70

1.2 Payload Systems and Principle of Operation

The primary component of our payload contains the radiometer which will be continuously taking data while in flight of sub-mm spectra, to which we'll derive water and HDO concentrations in addition to the angle of elevation above the horizon. By using a submillimeter receiver, spectrometer, and a tilting radiometer, HADHR will take 12 second observations of the calibration target as well as 12 second observations of the atmosphere. Observations for the atmosphere will be taken at six predefined angles, each at 10-degree intervals between +10 and +70 degrees. Minimum integration time at a predefined angle is 227 seconds, totalling a required 15 minutes for each angle. With this method two LO Frequencies will be observed, one at 538636 MHz to measure H_2O-18 and HDO emission lines and the other at 506208 MHz to measure H_2O and H_2O-17 vertical alignment emission lines. The tilt and motion of the mirror will be controlled via a stepper motion which runs off a driver operated by an Arduino microcontroller. A SYS-405Q Fanless Industrial Computer and SMART PSU are provided to us by the Jet Propulsion Laboratory (JPL). Collected data will be stored in the SYS-405Q Fanless Industrial Computer, and this computer will be connected to a 24V DC-DC converter that is directly to HASP power. While the Smart Power Supply Unit (PSU) will also be connected to the 24V DC-DC converter providing power for all other components on the payload. The computer will talk with the Smart PSU that controls the receiver through RS-485 serial interface, (an industrial specification that defines the electrical interface and physical layer for direct communication with electrical devices). The RS-485 allows to connect systems of the payload supporting multiple devices in electrically noisy environments via cabling.

Additionally, there will be a calibration subsystem for the radiometer to compare raw data to a known blackbody 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 and the atmosphere will provide us with the data we need to extrapolate the D/H ratio as well as subtract any background noise generated by the payload. Collected data will be run through the retrieval science software in order to plot and analyze our results.

Furthermore, we will downlink an example spectrum every ten minutes to ensure proper collection of data. Moreover, to ensure that each subsystem can operate to assumed parameters within the expected environment, tests will be performed on each subsystem, but also as a whole once the payload has been assembled.

Figure 2: Block Diagram

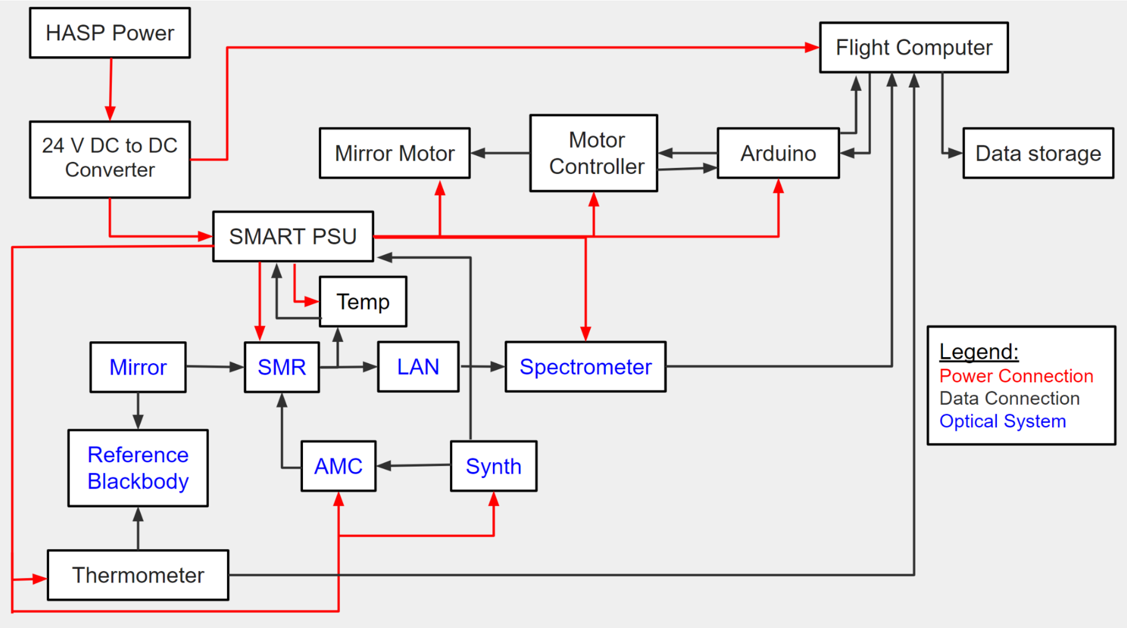


Figure 3: Concept of Operations Graphic

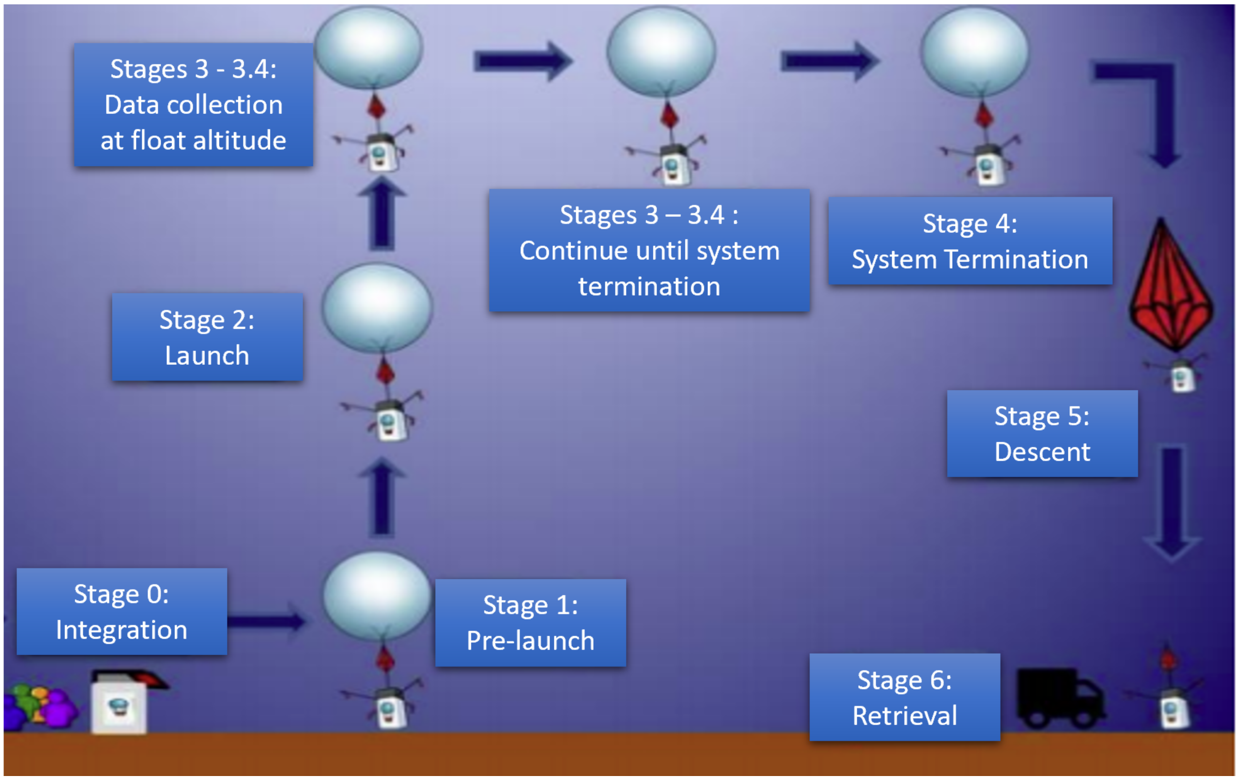


Table 3: Concept of Operations

Stage of Operation	Stage Description
0: Integration	The payload will be integrated onto the HASP gondola and the SMART PSU will be connected to the HASP power system.
1: Pre-launch	All onboard systems will be powered on and perform calibration tests to ensure that they are working correctly. This includes homing the mirror above the calibration target, taking temperature measurements of the calibration target, and transmitting the measured temperature and other system status information back to the ground receiver. Data collection starts once the instrument is powered on. Stages 3 - 3.4 detail the individual steps needed to complete a single observation for one angle.
2: Launch	The balloon is launched and begins its ascent to float altitude.
3: Data Collection	Data collection starts once the payload is powered on before launch, and will continue making observations at a rate of one observation per second until the end of the mission. Each observation will be time tagged, as well as being tagged with the position of the mirror. This will allow for removal of data that is captured while the mirror is in motion, and sorting the remaining data by the time it was captured. Data will be collected at two separate LO frequencies which are 538636 MHz and 506208 MHz, with each LO frequency being observed at 6 predefined angles between +10° and +70° from the horizontal. Each data taking cycle, consisting of pairs of 12 second observations of a sky angle and the blackbody target, takes approximately 6 minutes to complete for the full set of 7 angles. After a complete cycle, the LO will switch to the second frequency and the process will repeat. We will continue alternating LO frequencies in this manner throughout the flight. After a given pair of LO frequencies is complete (approximately once every 12 minutes), we will telemeter down one example spectrum, pausing the normal housekeeping telemetry while the example data is transmitted.
3.1: Calibration of Spectrometer	The mirror moves to the home position and a 12 second observation of the calibration target is made by the sub-millimeter spectrometer.

3.2: Transition	The mirror moves to one of the six defined angles between +10 and + 70 degrees from horizontal.
3.3: Measurement	Once the mirror has moved to the correct angle, the spectrometer will make a 12 second observation at the required LO frequency.
3.4: Return to Calibration	After the 12 second observation at the correct angle is completed, the mirror will move to the home position and the observation process will start again. After a complete observation pair, we will telemeter the last complete line of housekeeping data, saved onboard once per second.
3.5: LO frequency switch	After 7 pairs of 12 second observations have been made at each mirror angle, we will command the Microlambda synthesizer to switch LO frequencies and repeat steps 3.1 to 3.4 for all mirror angles at the new LO frequency. After a complete pair of LO frequencies are complete, we will telemeter a single example spectrum. We will pause housekeeping transmissions during this step and resume housekeeping transmissions when the example spectrum transmission is complete. Steps 3.1-3.5 will repeat throughout the mission.
4: System Termination	Data collection stops and instrument shutdown occurs 5 minutes before HASP power system shutdown.
5: Descent	The balloon pops and the gondola begins its descent back to the surface.
6: Retrieval	After landing, the gondola is retrieved by HASP personnel.
7: Data Analysis	The collected data will be downloaded from the onboard storage system; it will then be analyzed using the reverse retrieval method that is incorporated with the *am Atmospheric Model* to determine the D to H ratio in the stratosphere. After the D to H ratio has been determined, it will then be compared to the D to H ratio that has been measured by earth observing satellites, as well as the D to H ratio that has been measured on comets.

1.3 Major System Components

1.3.1 Submillimeter receiver

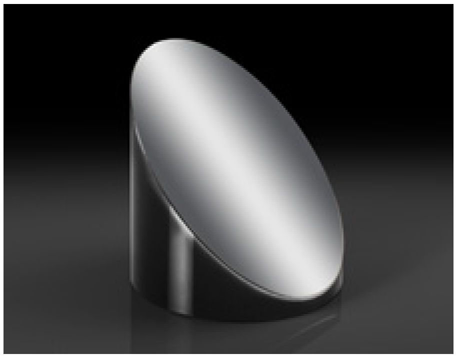
NASA JPL has provided a sub-millimeter receiver for the WWASP payload is a system consisting of three components that come from JPL pre-assembled. The first component is the Integrated Schottky Diode Receiver Module which will have the input from the optics into the waveguide feed horn and an SMA output for the intermediate frequency. It also contains two mixers, but we 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.

1.3.2 Optics

One mirror will be used for the calibration system and for the radiometer. The mirror will be attached to a motor that will allow it to alternate between the radiometer and the blackbody. The data collected includes a known temperature reflected from a beam from the blackbody. The mirror will also be aligned with the radiometer to collect data from emission lines between a 500-600 GHz range.

During the WWASP flight, the original mirror was lost during payload retrieval. This original mirror had a 4 inch focal length and diameter and was not securely attached to the payload due to its size and limitation of space within the payload frame. To correct this issue, the replacement mirror will be an inch smaller in diameter. The concave mirror that will be used will be 3 inches in focal length and diameter in order to fit within the limited space of the payload frame. The current mirror considered for use is a protected aluminum off-axis parabolic mirror with a diameter of 76.20 +0.00/-0.38 millimeters. The effective focal length of the mirror is 76.20 millimeters. This mirror is shown below in Figure 3. The motor controlling the mirror will be a Nema 34 Stepper motor. We will redesign the mirror mount to ensure the mirror is not lost on landing. A shock test will be performed on the payload after assembly to ensure that the mirror is secured adequately.

Figure 4: 76.20 x 76.20 EFL 90° Protected Aluminum 100Å Off-Axis Parabolic Mirror



1.3.3 Computer and PSU

The overall purpose of the computer for this flight will be to analyze the data that is recorded from the onboard systems and then store and compile that into a data file. The model that will be used is the SYS-405Q Fanless Industrial Computer which will be able to imprint a code that is based on a HASP team that flew in 2021, WWASP. However, it will need to be adjusted to fit our goal for this experiment. It is also necessary that none of the data is lost or overwritten during the duration of the flight. This code will undergo a series of tests before the payload is launched to confirm it is functioning properly. JPL has also provided the smart PSU printed circuit board that has dimensions 9.5 X 9.5 with a thickness of 1.4". The purpose of this is to take the HASP bus voltage of 28-30 V from the DC to DC converter and distribute the necessary voltage for the receiver, amplifiers, synthesizers, and other electronic components. However, the PQA50 DC to DC converter that is being used is able to bring this down to 24 V for the computer and the smartPSU. The smart PSU will also communicate with the synthesizer. More testing will be done to determine the true power and voltage draw from the PSU as well as the computer and an effort will be made to have the power distributions as efficient as possible. The printed circuit board will have voltage/current readouts for all ports and also has electrostatic discharge protection (ESD).

Housing: The housing of the SYS-405Q is lightweight aluminum which provides durability with less unnecessary weight. The exterior has a coat finish that is resistant to scratches adding to its overall durability. The composition of durable interior and exterior allows the computer to withstand industrial applications and reduces field service.

Memory: This system supports a range of three different sizes of factory-installed DDR3L SRAM memory (2GB, 4GB, 8GB)

Battery: This system uses a singular CR-2032 or CR 2025 battery with a voltage of 3.0 V for either battery. This provides the SYS-405Q board with standby power for the real-time clock and GPS.

Power: This system obtains power through the J5 connector and the main supply to the board is +10-50 V DC.

Watchdog Timer: This system is also equipped with an advanced watchdog timer (WDT) which is used to guard against software shutdowns or lockups. This timer is adjustable between 1 second to 255 minutes.

Operating Temperature: The operating temperature for this system is fanless -40 C to +85 C and requires a minimum airflow of 200 LFPM that is above 80 C if the input voltage is above 24 V DC. The storage temperature: -50 C to +95 C

Figure 5: SYS-405Q Fanless Industrial Computer with Quad-Core Intel® Atom™ Processor

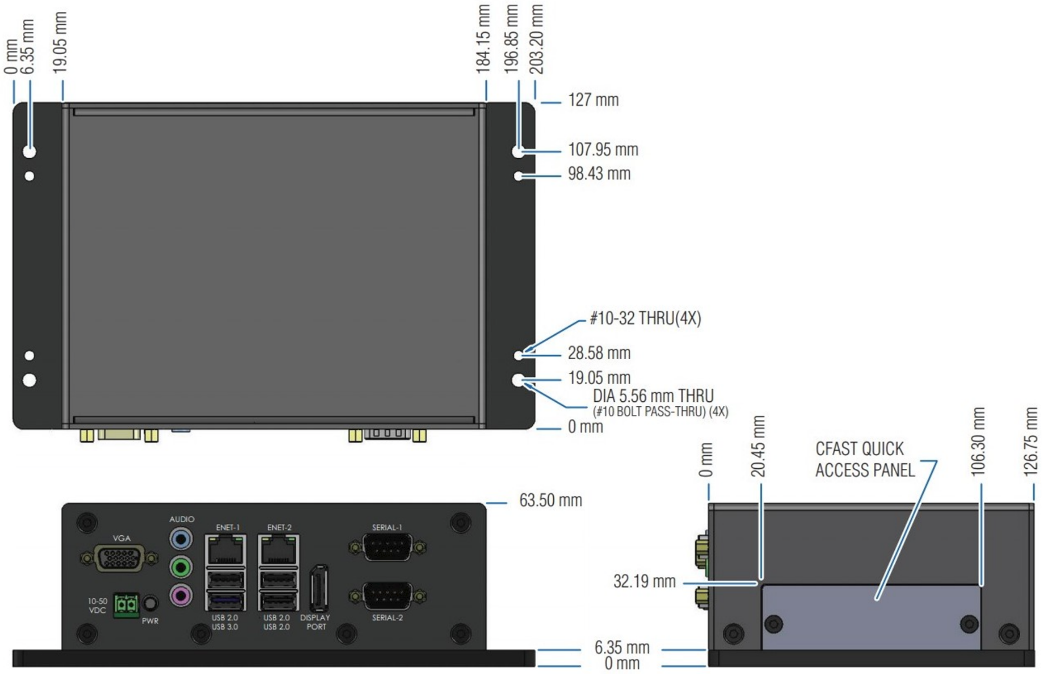


Figure 6: SYS-405Q top connections

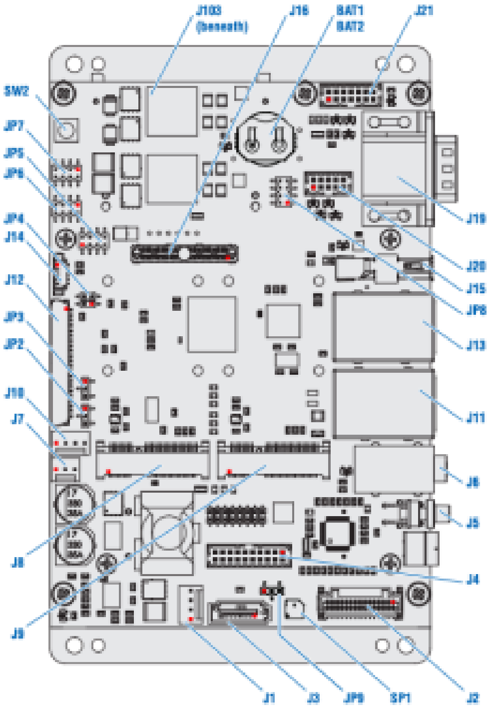
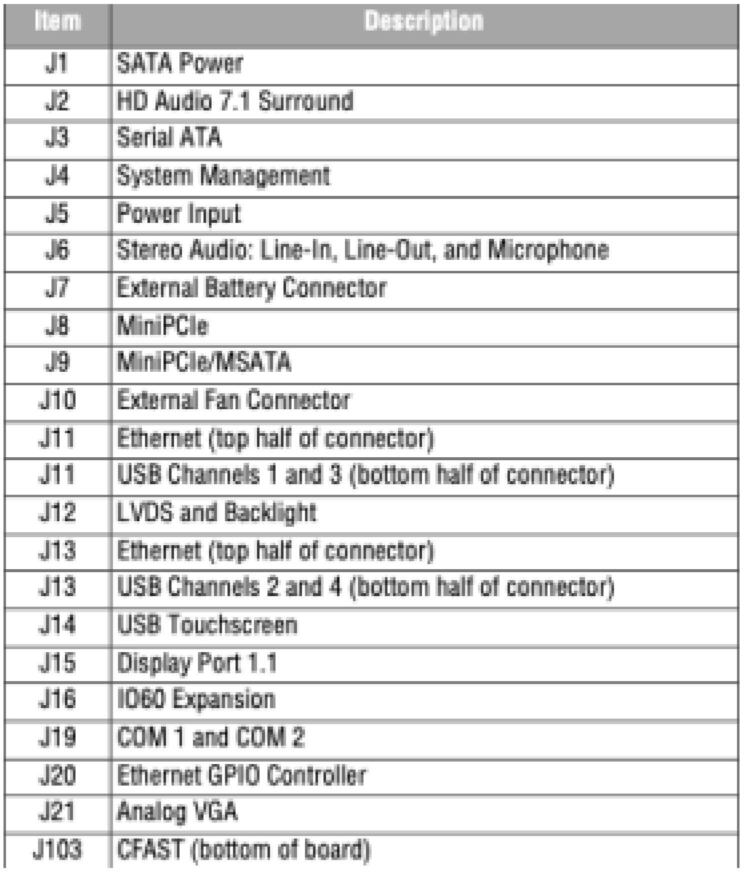
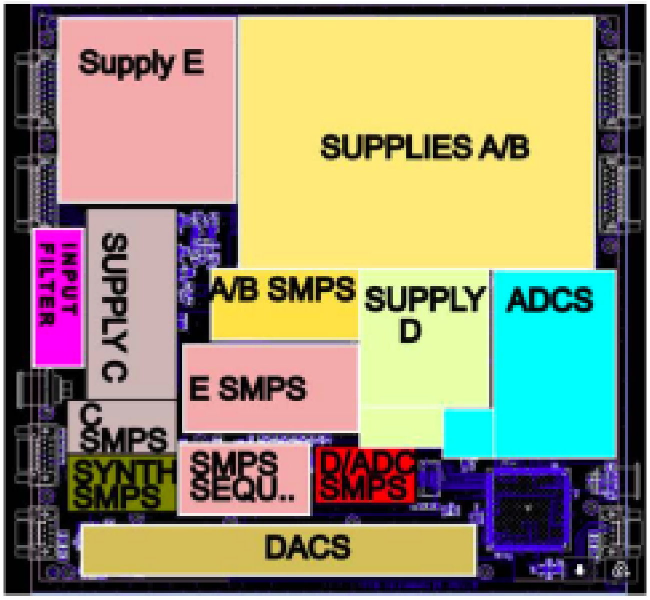


Table 4: Connector Descriptions



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)

Figure 7: Smart PSU



1.3.4 Calibration

Calibration target for the submillimeter receiver will be a blackbody. Also, it will need to be the same size or larger than the 3-inch diameter mirror. It will be either the same blackbody plus thermometer flown last year or very similar to last years but smaller including a thermometer. The blackbody is an aluminum plate covered in Stycast epoxy mixed with coarse silicon carbide grit.

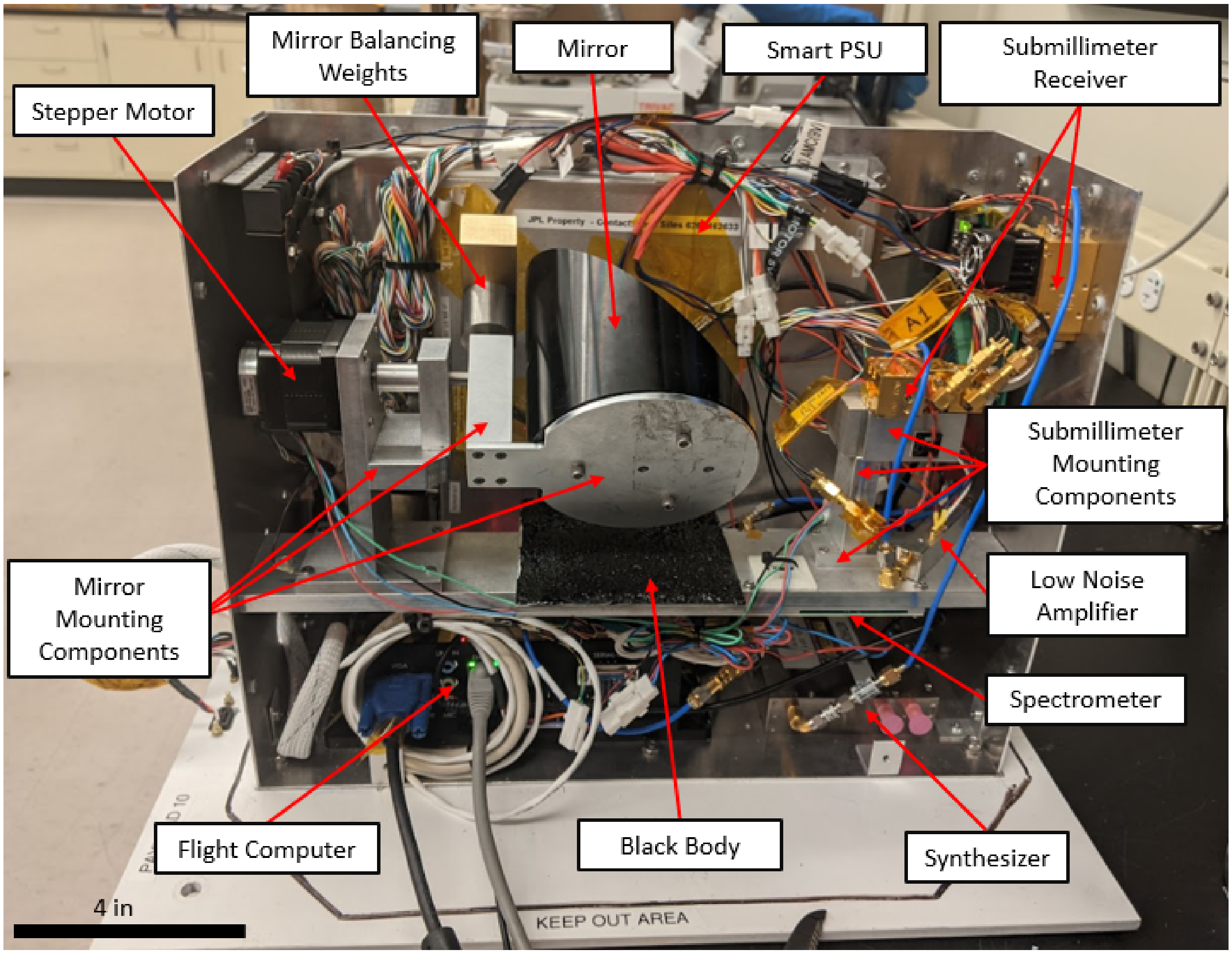
1.3.5 Reverse Retrieval Method

The *am atmospheric model* tool allows for comparison between measured and modeled spectrums. Using the *fit estimator* function within *am* allows for this comparison by comparing the weighted residual differences between both spectrum through the direct search method via the downhill simplex method. By using the direct search method for the fit estimator function, we acquire more accurate residuals, with possible derivatives which may be discontinuous in the fit variables. Through using the *fit estimator* between our modeled *am* atmosphere for emission levels of specified compounds to within +/- 12.5%. and the data collected with HADHR, we'll be able to approach answering our science questions asked.

1.4 Mechanical and Structural Design

Mechanical Design and Layout

Figure 8: Locations of components inside WWASP Payload



The mechanical design and layout of the payload is near-similar to the payload the previous HASP team, WWASP, flew with a few minor modifications to better suit our mission, and to accomplish our science objectives. In the bottom area - delimited by the Mirror & Motor Mounting Plate, Blackbody Calibration Target, and the Submillimeter Receiver on the right - we have on the left, the SYS-405Q Computer fastened and sunk to the bottom plate using 4 #10 10-32 thru and 4 #10 Bolt Pass-Thru connectors in order to secure it to the payload.

To the right of the SYS-405Q, the MLVS-0520 Synthesizer is located. It is fastened and sunk to the bottom plate using 4 #4-40 x .200 DP Helicoil threaded insert. The position of the synthesizer is relevant to the position of the Submillimeter Receiver and the components associated with it because it provides the Synthesizer with the most direct approach and least obstructed path for the connections between the two.

Moving vertically up the payload, we encounter the Mirror & Motor, Calibration Target and the Submillimeter Receiver Mounting Plate. Located on the left side of the plate, the Mirror & Motor Mounting plate is located and is fastened and sunk to the plate and the walls of the payload using 3 8-32 TPI SHCS and 4 1/4-20 bolts and screws. This component as a whole, as well as components that comprise the assembly will be updated and modified by the members of project HADHR by changing the height of the mirror, and motor so that the focal point of the mirror will be better aligned with the Submillimeter Receiver. The axis of rotation about the mirror and the motor will be raised or lowered in order to better suit the needs of certain components and our mission. The mirror has been reduced in size from 101.4mm x 101.4mm to 76.2mm x 76.2mm (4in to 3 in) . We will redesign the mirror mount and receiver mount to accommodate this smaller mirror and take advantage of the added space gained from its shorter focal length.

In the middle of the plate, underneath the mirror is the Blackbody Calibration target. This is attached to the plate by a glue so as to not obstruct the surface of the target with any type of thru-connectors. The size of the target is directly correlated with the size of the mirror. Since the mirror is being decreased in size, so will the calibration target area. The perimeter of the target needs to be greater than the circumference of the mirror.

Moving onto the right side of the plate. There is the Submillimeter Receiver and its associated components: AMC, Receiver Diode, and H-Plane Waveguide. The AMC is fastened and sunk to the plate using 4 #4-40 UNC 2B screws. The H-Plane Waveguide is fastened and sunk to the AMC and to the receiver using 8 Flange UG-378/U-M (0.11 cm radius) screws. The members of project HADHR will need to adjust the vertical position of the entire Submillimeter Receiver as it is directly correlated to the focal point, and thus directly correlated to the position of the mirror and its attached components.

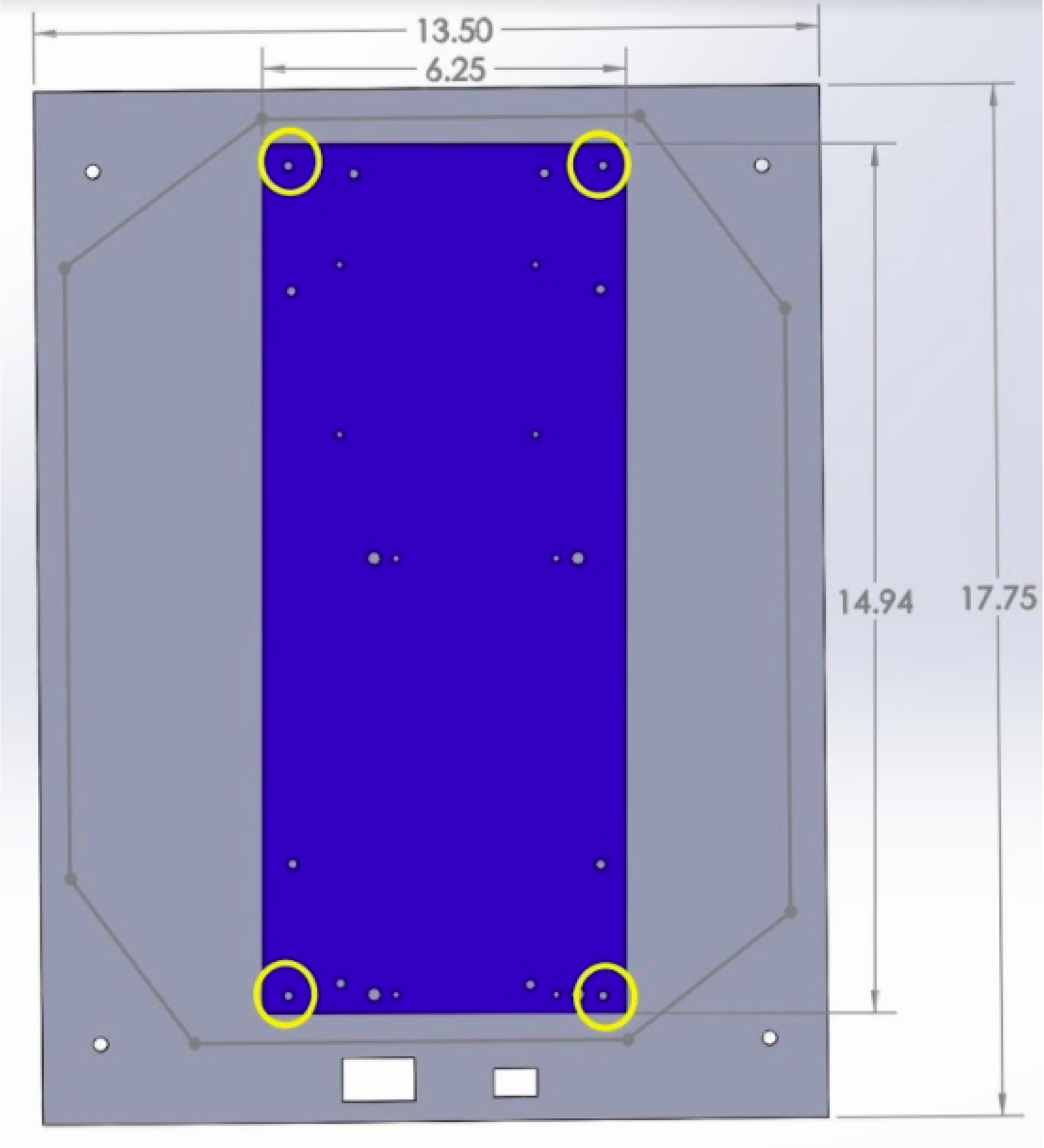
Packaged onto the right side of the plate is the Spectrometer, and this has been fastened and sunk to the right wall of the payload using 4 #4-40 threads. The position of this may need to change depending on the tolerances of the Submillimeter Receiver.

Located in the back, the Smart PSU has been fastened and sunk to the wall using 4 #4-40 screws. The position of this instrument was chosen due to its size, its importance to the entirety of the mission, as well as other factors like thermal and electrical reasons.

Types of Materials Used

The types of materials used vary from component to component throughout the payload. The team members of project HADHR could not decide with the components that have been provided to us by JPL and ASU what types of materials were used, and so there is not a clearly defined list of what comprises these components. However, every structural component like the plates for the walls, the mounting plates for the Motor, Mirror, and Submillimeter receiver were made out of primarily 6061-T6 Aluminum. It has been concluded that all of the material types that flew on project WWASP operated without issue and were able to withstand the various temperature, pressure and mechanical load ranges.

Methods of Attaching the Payload to Plate



The yellow circles on the four corners of the drawing indicate where the payload will be attached to the mounting plate. The mating method will use x4 10-32 screws and nuts that will secure the payload to the mounting plate.

Expected Stress and Methods of Stress Mitigation

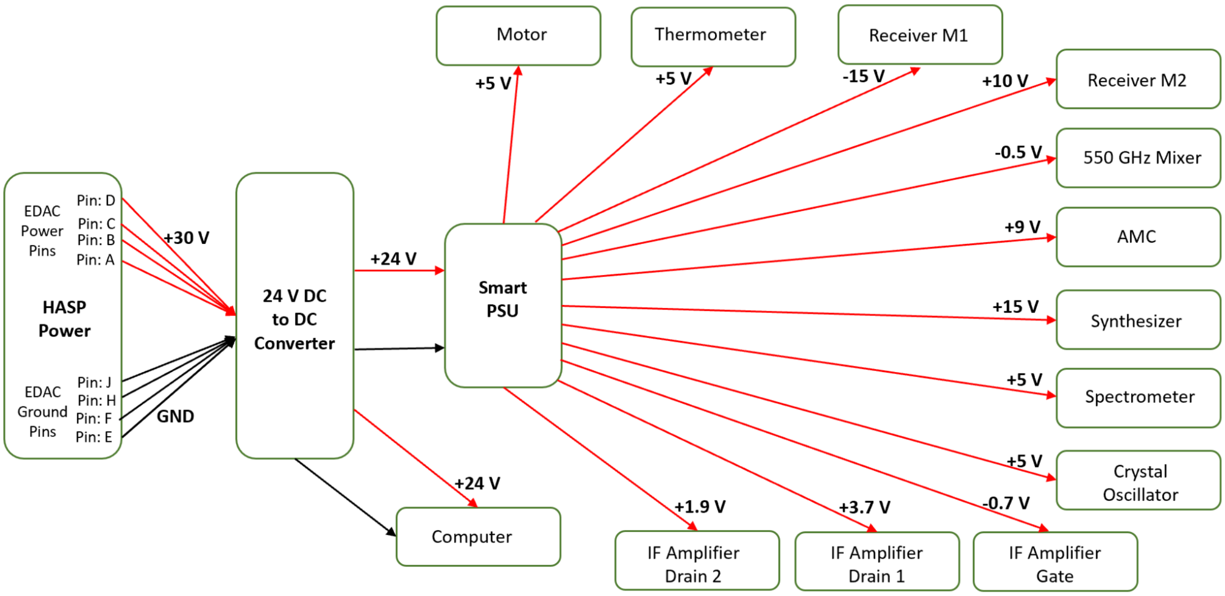
The payload and all subsequent components that will be flying have been proven to be able to withstand the external and internal stresses encountered during the flight based off of the previous HASP team, WWASP. This does not remove the need to appropriately test the payload and all subsequent components; the payload shall at a minimum undergo tests that will provide the insurance required by HASP of being able to withstand both a 10g vertical and 5g horizontal shock loads. The mechanical connections throughout the payload will be verified with tests; replacing key components with mock mass/volume models and conducting drop tests from a height calculated that will simulate the 10g vertical and 5g horizontal shock loads. If the calculation for the height that will simulate these loads is too difficult to produce, then FEA analysis will be conducted using Siemens NX. Project HADHR is adamant about providing a margin of safety that will need to be determined, but will require the payload and all subsequent components and subsystems to undergo tests that will put the payload and all subsequent components and subsystems under greater-than-to-be-expected shock loads.

The members of project HADHR will need to conduct trade studies for the different types of methods of stress mitigation that will provide the highest level of stress mitigation while considering factors such as mass and volume constraints.

1.5 Electrical Design

As mentioned in section 1.2, we will be utilizing a Smart Power Supply Unit (PSU) provided to us by JPL which will be connected directly to draw power from HASP which will then be distributed to the various components that need electrical power on board. The flight computer will be connected to a 24V DC to DC converter. The flight computer will also have another 3V battery to provide standby power for real time clock and the GPS. Apart from the flight computer, there are instruments which need power, they are : Motor (with Arduino and Driver Board), Camera, Thermometer, Receiver M1, Receiver M2, 550GHz mixer, AMC, Synthesizer, Spectrometer, Crystal Oscillator, IF Amplifier Gate, IF Amplifier Drain 1 and IF Amplifier Drain 2. All these instruments will get their power from the PSU, which in turn will receive its power directly from HASP via a 24V DC to DC convertor. The power distribution is shown in Figure 9 below.

Figure 9: Power Distribution for Components



1.6 Thermal Control Plan

Our initial payload will be a box with a white, painted exterior and an unpainted, shiny interior. Since the white paint reflects solar radiation and allows IR to be radiated away, the payload is then able to release heat more efficiently. With the inside of the payload, the shiny interior allows for heat to reflect around evenly throughout the payload, keeping temperatures inside stable. To further help with the temperature regulation, all of the components will be heat sunk to the walls of the payload, which causes the payload box to act as a radiator to space. The thermal environment that the HASP payloads must endure ranges from both extreme cold and heat. Since we are using most of the previous instruments from the WWASP team, we were able to use their temperature data for each system in the payload. The table below shows both the minimum and maximum operating temperatures and recorded temperatures of each instrument during the flight.

Table 5: Thermal Operational Ranges for Components

Instrument	Minimum Operating Temperature	Maximum Operating Temperature	Minimum Recorded Temperature	Maximum Recorded Temperature
Blackbody	-55°C	+155°C	-30.375°C	+58.188°C
Computer	-40°C	+85°C	N/A	N/A
Synthesizer	0°C	+80°C	0°C	+88.23°C
Low-Noise Amplifier	-40°C	+85°C	N/A	N/A
Parabolic Mirror	-100°C	+100°C	N/A	N/A
Stepper Motor	-20°C	+50°C	N/A	N/A
Smart PSU	-40°C	+85°C	-15.216°C	+71.983°C
Stepper Motor Driver	-40°C	+85°C	-2.688°C	+86.062°C
Submillimeter Receiver	-100°C	+85°C	N/A	N/A
Thermometer	-55°C	+150°C	N/A	N/A

Looking at the temperatures from the table, the lowest recorded temperature during flight was about -30℃ and the highest recorded temperature during flight was about +88℃. With this in mind, we were able to come up with an operational temperature range for our payload, which was -50℃ to +80℃. This range was chosen with the important components, such as the synthesizer and receiver, operational temperatures in mind. Since components like these are the most important components in the payload, making sure they do not overheat is crucial. Another reason this range was chosen was so the payload can also survive the temperature range of thermal vacuum testing. From the temperature data collected from the previous team, the synthesizer was the instrument that reached the highest temperature in the payload, which was about 88.23℃. With the synthesizer reaching such a high temperature, this can cause other instruments, as well as the synthesizer itself, to overheat and break during flight.

The current plan to reduce the heat in the payload is to heatsink the synthesizer. We currently have two methods on which we could heatsink the synthesizer. Our first method, which will be tested first, will be to heatsink the synthesizer to a side panel of the payload. If the temperature of the synthesizer, as well as the instruments, is too high, then we will heatsink the synthesizer using our second method. Our second method is to heatsink the synthesizer using copper, which will transfer the heat from the synthesizer to a radiator. Aside from the synthesizer, we also plan to make sure the instruments in the payload are not too crowded, so that heat does not build up quickly.

2. Team Structure and Management

2.1 Team Organization and Roles

Table 6: Team Roles and Responsibilities

Name	Academic Year	Role	Email	Phone
Timothy Petersen	Senior	Team Lead / Systems Engineer	trpete11@asu.edu	480-826-8573
Aidan Earley	Senior	Mechanical Engineer	aearley1@asu.edu	206-734-8572
Maitreya Sonawane	Senior	Electrical Engineer	msonawan@asu.edu	480-738-2843
Dustin Church	Senior	Flight Software Engineer	ddchurch@asu.edu	331-223-3188
Ricardo Rodriguez	Senior	Thermal Engineer	rrodr104@asu.edu	623-337-1789
Caitlin Gilbert-Kroen	Senior	Optical Engineer	cagilbe4@asu.edu	928-323-2933
Trey Callands	Senior	Calibration Engineer	tcalland@asu.edu	602-672-2289
Dakota Kornau	Senior	Science Software Engineer	dkornau@asu.edu	480-521-4997
Prof. Chris Groppi	Advisors	Faculty Advisor	cgroppi@asu.edu	480-965-6436
Dr. Jose Siles		JPL Technical Advisor	jose.v.siles@nasa.jpl.gov	626-316-2633

Table 6 shows the current roles of all team members for the Fall 2021 and no changes are expected to be made for the Spring 2022 semester. By keeping each team member on the same subsystem(s) throughout the project it will allow for an easier transition from the instrument development stage to the final construction, assembly, and testing stages. A more detailed explanation of the roles and responsibilities of each team member are given in the paragraphs below.

Timothy Petersen is the team lead and systems engineer for project HADHR, and oversees the scheduling, logistics, budgeting, and requirement tracking of this project. He also ensures that all milestones are met, all necessary documentation is completed on time, attends all monthly teleconference meetings, and all other necessary documents or presentations are completed by the expected deadlines.

Aidan Earley is the Mechanical Engineer for project HADHR and oversees the mechanical design, iteration and final assembly of the payload. They ensure that all mechanical tolerances, requirements and constraints are adhered to and are in charge of documentation behind all mechanical aspects of the project.

Maitreya Sonawane is the Electrical Engineer for project HADHR and oversees the electrical components and power distribution. They will also help in budgeting.

Dustin Church will be the Flight Software Engineer and will be in charge of the code to ensure that the onboard systems are running properly. He will develop, run and test this code to run in order to get accurate data. He will also create this code in a way that allows for no data to be lost or overwritten during the data collection process.

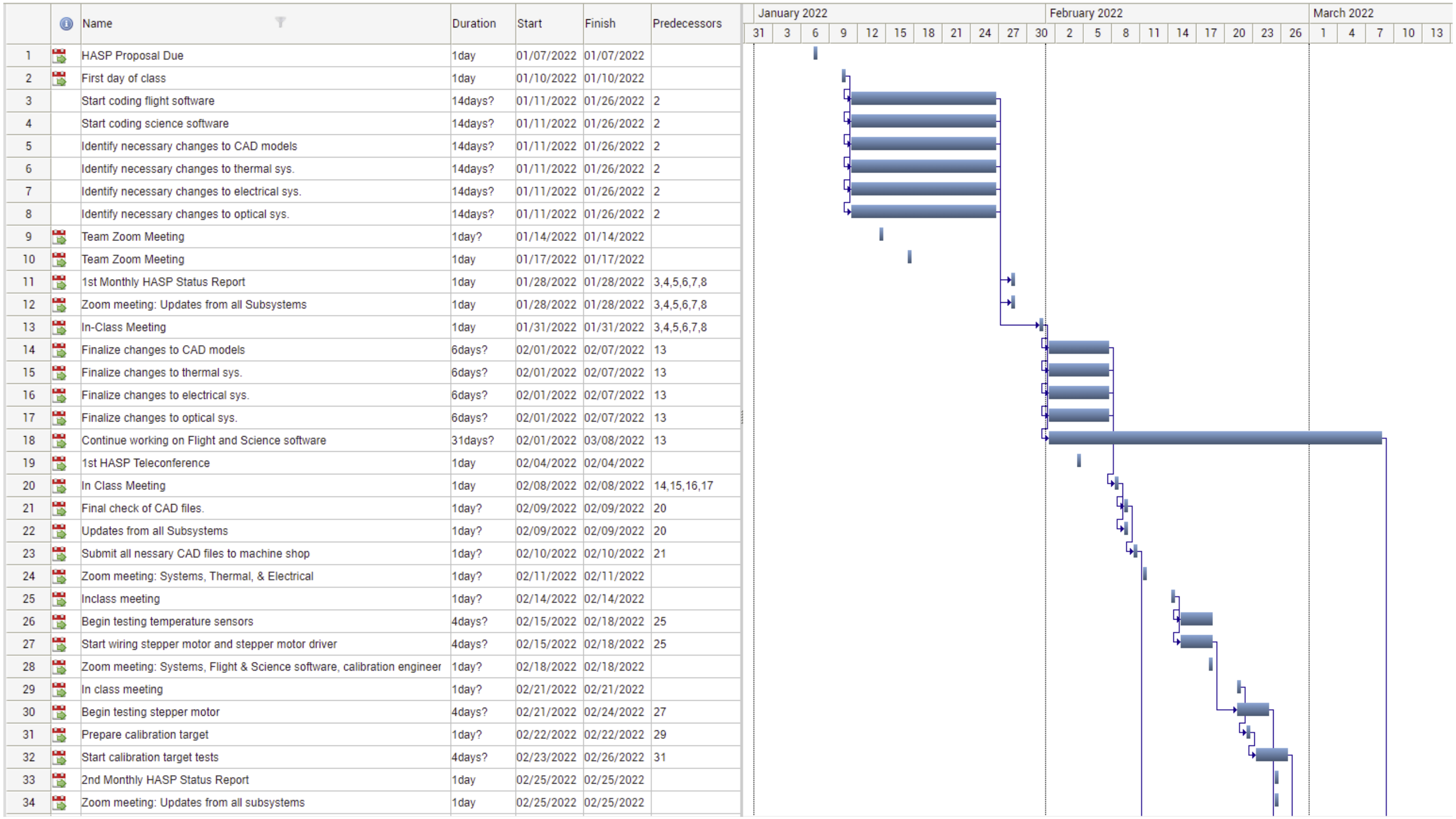
Ricardo Rodriguez is the Thermal Engineer for project HADHR, and oversees that the payload stays within its operational temperature. This includes measuring the temperature of each instrument to make sure it is within its operational temperature, as well as fixing any problem which involves an instrument from either getting too hot or too cold.

Caitlin Gilbert-Kroen is the Optical Engineer. They will oversee the placement of the mirror in relation to the blackbody and the radiometer along with the attachment to the motor.

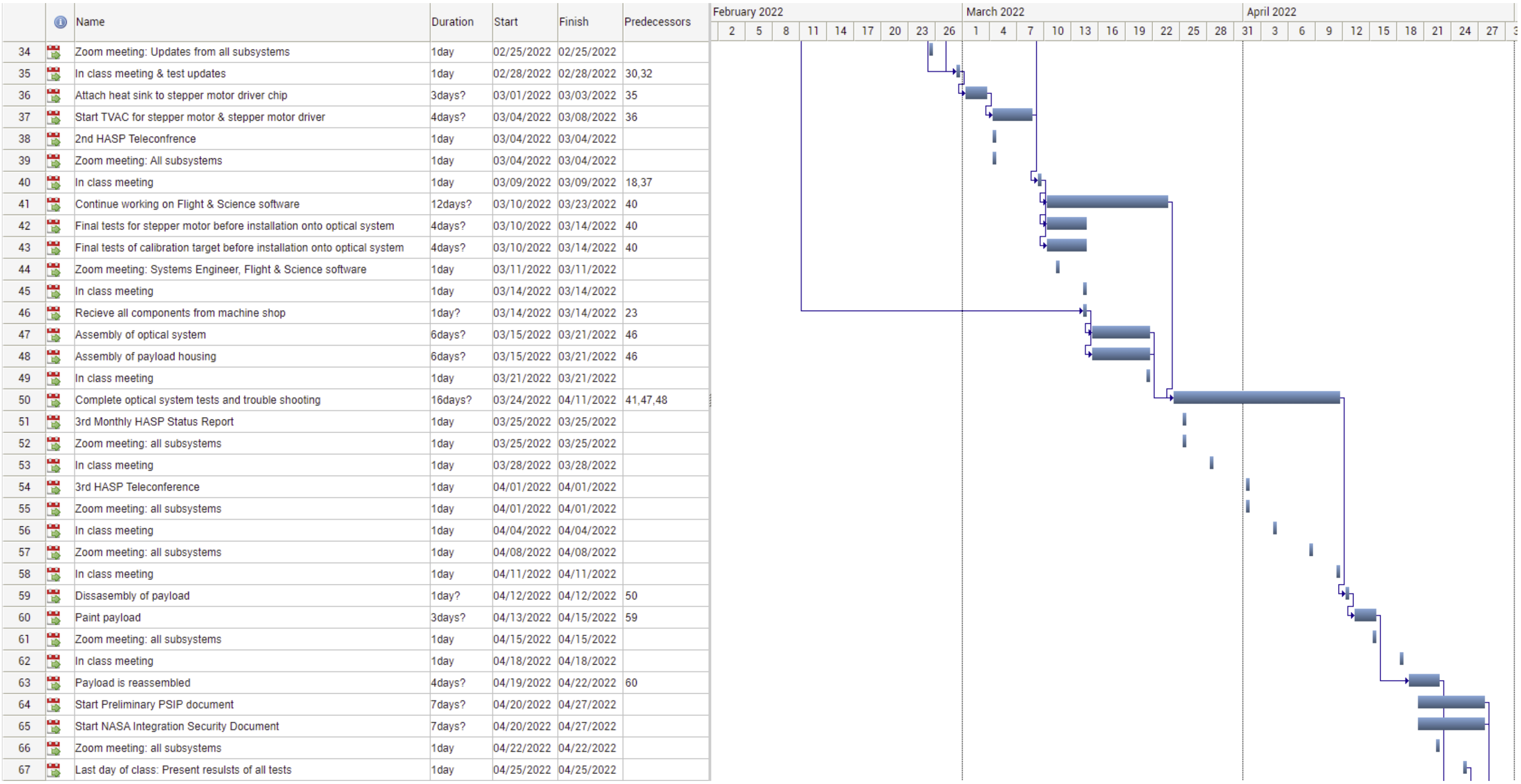
Trey Callands is the Calibration Engineer. He will oversee the Calibration of the Submillimeter Receiver and the home position of the mirror.

Dakota Kornau is the Science Software Engineer for HADHR. Their responsibility is to oversee the science software involving the retrieval process for desired data in addition to the analysis of this data. They ensure that the reading can integrate with the *AM atmospheric modeling* software and that results are accurately calculated/displayed.

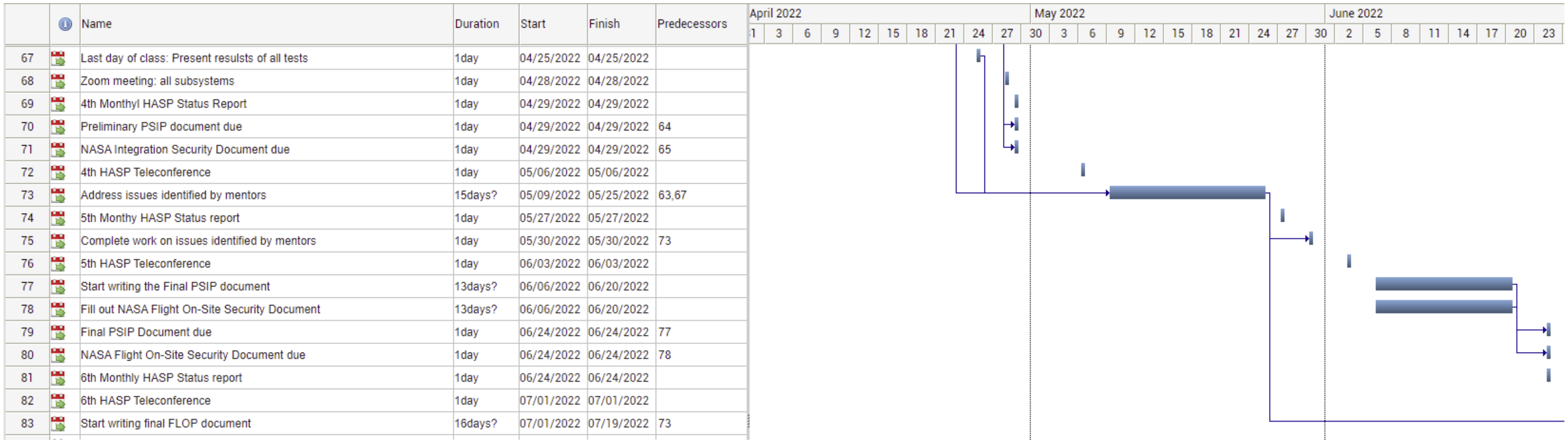
2.2 Timeline and Milestones



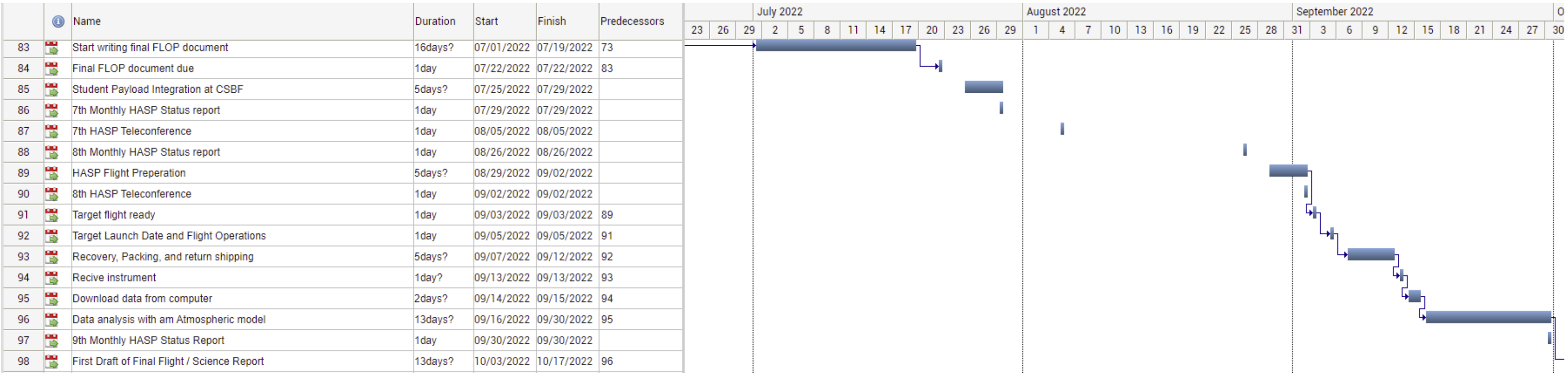
	Name	Duration	Start	Finish	Predecessors
1	HASP Proposal Due	1day	01/07/2022	01/07/2022	
2	First day of class	1day	01/10/2022	01/10/2022	
3	Start coding flight software	14days?	01/11/2022	01/26/2022	2
4	Start coding science software	14days?	01/11/2022	01/26/2022	2
5	Identify necessary changes to CAD models	14days?	01/11/2022	01/26/2022	2
6	Identify necessary changes to thermal sys.	14days?	01/11/2022	01/26/2022	2
7	Identify necessary changes to electrical sys.	14days?	01/11/2022	01/26/2022	2
8	Identify necessary changes to optical sys.	14days?	01/11/2022	01/26/2022	2
9	Team Zoom Meeting	1day?	01/14/2022	01/14/2022	
10	Team Zoom Meeting	1day	01/17/2022	01/17/2022	
11	1st Monthly HASP Status Report	1day	01/28/2022	01/28/2022	3,4,5,6,7,8
12	Zoom meeting: Updates from all Subsystems	1day	01/28/2022	01/28/2022	3,4,5,6,7,8
13	In-Class Meeting	1day	01/31/2022	01/31/2022	3,4,5,6,7,8
14	Finalize changes to CAD models	6days?	02/01/2022	02/07/2022	13
15	Finalize changes to thermal sys.	6days?	02/01/2022	02/07/2022	13
16	Finalize changes to electrical sys.	6days?	02/01/2022	02/07/2022	13
17	Finalize changes to optical sys.	6days?	02/01/2022	02/07/2022	13
18	Continue working on Flight and Science software	31days?	02/01/2022	03/08/2022	13
19	1st HASP Teleconference	1day	02/04/2022	02/04/2022	
20	In Class Meeting	1day	02/08/2022	02/08/2022	14,15,16,17
21	Final check of CAD files.	1day?	02/09/2022	02/09/2022	20
22	Updates from all Subsystems	1day?	02/09/2022	02/09/2022	20
23	Submit all nessary CAD files to machine shop	1day?	02/10/2022	02/10/2022	21
24	Zoom meeting: Systems, Thermal, & Electrical	1day?	02/11/2022	02/11/2022	
25	Inclass meeting	1day?	02/14/2022	02/14/2022	
26	Begin testing temperature sensors	4days?	02/15/2022	02/18/2022	25
27	Start wiring stepper motor and stepper motor driver	4days?	02/15/2022	02/18/2022	25
28	Zoom meeting: Systems, Flight & Science software, calibration engineer	1day?	02/18/2022	02/18/2022	
29	In class meeting	1day?	02/21/2022	02/21/2022	
30	Begin testing stepper motor	4days?	02/21/2022	02/24/2022	27
31	Prepare calibration target	1day?	02/22/2022	02/22/2022	29
32	Start calibration target tests	4days?	02/23/2022	02/26/2022	31
33	2nd Monthly HASP Status Report	1day	02/25/2022	02/25/2022	
34	Zoom meeting: Updates from all subsystems	1day	02/25/2022	02/25/2022	



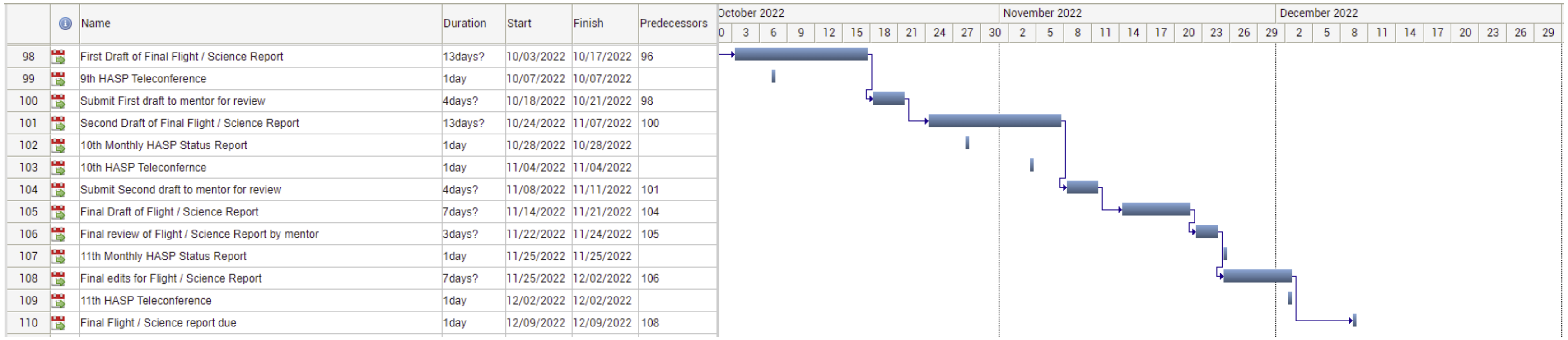
	ⓘ	Name	Duration	Start	Finish	Predecessors
34		Zoom meeting: Updates from all subsystems	1day	02/25/2022	02/25/2022	
35		In class meeting & test updates	1day	02/28/2022	02/28/2022	30,32
36		Attach heat sink to stepper motor driver chip	3days?	03/01/2022	03/03/2022	35
37		Start TVAC for stepper motor & stepper motor driver	4days?	03/04/2022	03/08/2022	36
38		2nd HASP Teleconfrence	1day	03/04/2022	03/04/2022	
39		Zoom meeting: All subsystems	1day	03/04/2022	03/04/2022	
40		In class meeting	1day	03/09/2022	03/09/2022	18,37
41		Continue working on Flight & Science software	12days?	03/10/2022	03/23/2022	40
42		Final tests for stepper motor before installation onto optical system	4days?	03/10/2022	03/14/2022	40
43		Final tests of calibration target before installation onto optical system	4days?	03/10/2022	03/14/2022	40
44		Zoom meeting: Systems Engineer, Flight & Science software	1day	03/11/2022	03/11/2022	
45		In class meeting	1day	03/14/2022	03/14/2022	
46		Recieve all components from machine shop	1day?	03/14/2022	03/14/2022	23
47		Assembly of optical system	6days?	03/15/2022	03/21/2022	46
48		Assembly of payload housing	6days?	03/15/2022	03/21/2022	46
49		In class meeting	1day	03/21/2022	03/21/2022	
50		Complete optical system tests and trouble shooting	16days?	03/24/2022	04/11/2022	41,47,48
51		3rd Monthly HASP Status Report	1day	03/25/2022	03/25/2022	
52		Zoom meeting: all subsystems	1day	03/25/2022	03/25/2022	
53		In class meeting	1day	03/28/2022	03/28/2022	
54		3rd HASP Teleconference	1day	04/01/2022	04/01/2022	
55		Zoom meeting: all subsystems	1day	04/01/2022	04/01/2022	
56		In class meeting	1day	04/04/2022	04/04/2022	
57		Zoom meeting: all subsystems	1day	04/08/2022	04/08/2022	
58		In class meeting	1day	04/11/2022	04/11/2022	
59		Dissasembly of payload	1day?	04/12/2022	04/12/2022	50
60		Paint payload	3days?	04/13/2022	04/15/2022	59
61		Zoom meeting: all subsystems	1day	04/15/2022	04/15/2022	
62		In class meeting	1day	04/18/2022	04/18/2022	
63		Payload is reassembled	4days?	04/19/2022	04/22/2022	60
64		Start Preliminary PSIP document	7days?	04/20/2022	04/27/2022	
65		Start NASA Integration Security Document	7days?	04/20/2022	04/27/2022	
66		Zoom meeting: all subsystems	1day	04/22/2022	04/22/2022	
67		Last day of class: Present resulsts of all tests	1day	04/25/2022	04/25/2022	



	ⓘ	Name	Duration	Start	Finish	Predecessors
67		Last day of class: Present resulsts of all tests	1day	04/25/2022	04/25/2022	
68		Zoom meeting: all subsystems	1day	04/28/2022	04/28/2022	
69		4th Monthyl HASP Status Report	1day	04/29/2022	04/29/2022	
70		Preliminary PSIP document due	1day	04/29/2022	04/29/2022	64
71		NASA Integration Security Document due	1day	04/29/2022	04/29/2022	65
72		4th HASP Teleconference	1day	05/06/2022	05/06/2022	
73		Address issues identified by mentors	15days?	05/09/2022	05/25/2022	63,67
74		5th Monthy HASP Status report	1day	05/27/2022	05/27/2022	
75		Complete work on issues identified by mentors	1day	05/30/2022	05/30/2022	73
76		5th HASP Teleconference	1day	06/03/2022	06/03/2022	
77		Start writing the Final PSIP document	13days?	06/06/2022	06/20/2022	
78		Fill out NASA Flight On-Site Security Document	13days?	06/06/2022	06/20/2022	
79		Final PSIP Document due	1day	06/24/2022	06/24/2022	77
80		NASA Flight On-Site Security Document due	1day	06/24/2022	06/24/2022	78
81		6th Monthly HASP Status report	1day	06/24/2022	06/24/2022	
82		6th HASP Teleconference	1day	07/01/2022	07/01/2022	
83		Start writing final FLOP document	16days?	07/01/2022	07/19/2022	73



	ⓘ	Name	Duration	Start	Finish	Predecessors
83		Start writing final FLOP document	16days?	07/01/2022	07/19/2022	73
84		Final FLOP document due	1day	07/22/2022	07/22/2022	83
85		Student Payload Integration at CSBF	5days?	07/25/2022	07/29/2022	
86		7th Monthly HASP Status report	1day	07/29/2022	07/29/2022	
87		7th HASP Teleconference	1day	08/05/2022	08/05/2022	
88		8th Monthly HASP Status report	1day	08/26/2022	08/26/2022	
89		HASP Flight Preperation	5days?	08/29/2022	09/02/2022	
90		8th HASP Teleconference	1day	09/02/2022	09/02/2022	
91		Target flight ready	1day	09/03/2022	09/03/2022	89
92		Target Launch Date and Flight Operations	1day	09/05/2022	09/05/2022	91
93		Recovery, Packing, and return shipping	5days?	09/07/2022	09/12/2022	92
94		Recive instrument	1day?	09/13/2022	09/13/2022	93
95		Download data from computer	2days?	09/14/2022	09/15/2022	94
96		Data analysis with am Atmospheric model	13days?	09/16/2022	09/30/2022	95
97		9th Monthly HASP Status Report	1day	09/30/2022	09/30/2022	
98		First Draft of Final Flight / Science Report	13days?	10/03/2022	10/17/2022	96



	ⓘ	Name	Duration	Start	Finish	Predecessors
98		First Draft of Final Flight / Science Report	13days?	10/03/2022	10/17/2022	96
99		9th HASP Teleconference	1day	10/07/2022	10/07/2022	
100		Submit First draft to mentor for review	4days?	10/18/2022	10/21/2022	98
101		Second Draft of Final Flight / Science Report	13days?	10/24/2022	11/07/2022	100
102		10th Monthly HASP Status Report	1day	10/28/2022	10/28/2022	
103		10th HASP Teleconfernce	1day	11/04/2022	11/04/2022	
104		Submit Second draft to mentor for review	4days?	11/08/2022	11/11/2022	101
105		Final Draft of Flight / Science Report	7days?	11/14/2022	11/21/2022	104
106		Final review of Flight / Science Report by mentor	3days?	11/22/2022	11/24/2022	105
107		11th Monthly HASP Status Report	1day	11/25/2022	11/25/2022	
108		Final edits for Flight / Science Report	7days?	11/25/2022	12/02/2022	106
109		11th HASP Teleconference	1day	12/02/2022	12/02/2022	
110		Final Flight / Science report due	1day	12/09/2022	12/09/2022	108

2.3 Anticipated Participation in Integration and Launch operations

As the payload has already been tested and flown, none of the original components will need to be retested. The payload in its entirety will be tested to determine its ability to function in low-pressure environments, to handle shocks equal to or greater than the limits proposed in the HASP documentation, and the ability to function under a range of temperatures and at various pressure ranges. The payload will be tested to ensure its ability to operate despite numerous power outages and fluctuating voltage. The payload will also undergo shock testing to affirm that the components are securely attached and will remain intact during flight. The payload's dimensions will be measured and the new components and integrated systems will be weighed to ensure compliance with HASP's guidelines.

The code will also be tested to ensure it can continue to collect data even with frequent power restarts. This code will be tested thoroughly before flight to ensure its ability to operate despite different trials that it may face during flight.

During launch, HADHR will provide personnel that will maintain the payload and ensure the experiment runs smoothly. They will monitor the downlink signals to ensure the payload maintains the expected temperature, that data collection faces as little error as possible, and will provide information upon request. After flight, they will collect the payload and return it to ASU for analysis.

Expected personnel that will attend the launch are JPL's Dr. Jose Siles, faculty advisor Dr. Christopher Groppi, and at least one student from the HADHR team (TBD). Expected integration procedure after the payload is secured to the HASP gondola will include connecting the computer and PSU to the HASP power supply. Afterwards, the connection between the ground-based computer and the payload computer will be tested and a downlink signal will be secured. The code's function to run in the event that HASP needs to turn the main power supply will be tested by taking a sample spectrum and turning the payload on and off again. The calibration system will be tested by taking a blackbody spectrum. The systems' ability to work together will be tested using a collection of preflight data. During flight, the payload's temperature will be monitored and personnel will collect data.

3. Payload Interface Specifications

3.1 Weight Budget

Measured weight of payload (not including payload plate)

Table 8: Weight Budget

Item	Mass(g)	Uncertainty(g)	Comments
SYS-405Q Fanless Industrial Computer[1]	1202.0	-	
Smart PSU*	500	-	
Arduino Board	5.8	+/- 0.1	
Stepper Motor with Controller	251.2	+/- 0.1	
Thermometer	6.3	+/- 0.1	3 thermometers
Synthesizer*	596.0	-	
Submillimeter Receiver*	450.0	-	
Low-noise Amplifier*	28.0	-	
Mirror	1400.0	+/- 0.1	
Calibration Blackbody	237.2	+/- 0.1	
Spectrometer	89.3	+/- 0.1	
Analog Downlink*	250.0	-	
DB9 DTE*	30.0	-	
EDAC Cable*	100.0	-	
Payload Housing • Payload Box w/ screws • Payload Supports	 2221.1 948.8	 +/- 0.1 +/- 0.1	
Miscellaneous Nuts, Screws, and wires*	0.6	+/- 12.0 - 24.0	(20 - 40) screws
TOTAL	~ 8.35kg		

*   Indicates estimated values, [1] Indicates value given by manufacturer datasheet

3.2 Power Budget

The measured current draw is at 30 VD. Currently, our total power is 55W, which is lower than the previous HASP team. This is due to a higher efficiency of the PQA50 24V DC to DC converter, and a lower power draw from the SmartPSU.

Table 9: Power Budget

Item	Voltage	Current (Amps)	Power (Watts)	Power Uncertainty (Watts)	Current @30 V (A=W/V)
Motor w/ Arduino & Driver Board	5.0	1.004	4.2	+/- 0.42	0.14
Submillimeter Receiver*					
● Receiver M1	-15	0.01	0.15	+/- 0	0.005
● Receiver M2	10	0.002	0.02	+/- 0	0.67 mA
● Mixer	-0.5	0.001	0.0005	+/- 0	0.017 mA
● AMC	9.0	0.4	3.6	+/- 0	0.12
Thermometer	5.0	0.001	0.005	+/- < 0.0005	0.095
Computer	10.0	1.5	15.0 (max)	+/- 0	0.5
PSU	28.0	0.3571	10.0	+/- 0	0.33
Synthesizer*	15.0	1.0	15.0	+/- 0	0.5
Spectrometer	5.0	0.35	1.75	+/- 0	0.0583
Crystal Oscillator	5.0	0.011	0.055	+/- < 0.0005	0.0018
IF Amplifier Gate	-0.7	0.001	0.0007	+/- 0	0.023 mA
IF Amplifier Drain 1	1.9	0.029	0.0551	+/- 0	0.00184
IF Amplifier Drain 2	3.7	1.00	0.1406	+/- 0	0.00468
DC-DC Converter	24	2.083	5.1	+/- 0.05	0.21
TOTAL		4.7	55.0	+/- 0.05	1.617

*   Indicates estimated values

3.3 Downlink Serial Data

HADHR intends to receive downlinks from the payload during the operation to verify that the payload is operating as intended. Listed data below will be transmitted from HASP through the serial link. The following will all be included in one data package and transmit 1 copy of telemetry for every pair of mirror moves(reference and sky,) at about every 30 seconds. Data package will include temperatures of the AMC, synthesizer, and SmartPsu as well as every voltage and current being used for the SmartPSU. Additional data in the package will include the timestamps, number of cycles the mirror has completed, and number of total measurements taken up to that point. We will use a python serial communications library set up for 4800 baud, 8 data bits, no parity, 1 stop bit and no flow control. Data will be transmitted using one of the two built in serial ports on the computer and will be interfacing with the HASP serial connection by wiring the DB9 pigtail as a NULL modem to our payload. The table below lists details of the data package that will be downlinked:

Table 10: Downlink Serial Data

Byte	Bit	Description
1-4	0-31	Timestamp (Seconds since 1/1/1970)
TBR	TBR	Runtime
TBR	TBR	Count
TBR	TBR	Bins
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
TBR	TBR	SmartPSU Current Readout
TBR	TBR	SmartPSU Voltage Readout
TBR	TBR	Other
14-15	0-15	Mirror cycle count
16-17	0-15	Number of spectra recorded
818*	6544	Total

* Total bytes for 11 lines from 9 kB files determined from WWASPs 10 kB files.

Our data package consists of 6544 bits that will be copied 1 time and streamed every 30 seconds making our average data rate 218.13 bits per second. Reviewing WWASPs files, there were approximately 195, 10 kB files worth of transmitted data. At 11 rows of data per file there's a total of 2145 rows or 1.95 MB worth of data being transmitted over the flight of HASP. With downlinking the same data package at the same transmission rate HADHR will result in the same total bytes transmitted.

Additionally, HADHR is looking into transmitting a single example spectrum at every full data cycle. At 12 seconds for 7 angles for both the reference and sky, a total time comes out as 2.8 minutes. Doubling time to take into account movement, a single cycle for a given LO frequency takes 5.6 minutes to complete. We will send a single spectrum every pair of LO frequencies every 11.2 minutes. A single spectrum is 52 kB, (416,000 bits.) At 4800 bps the spectrum will take 86.67 seconds to send down. Converting to binary and using lossless compression before transmission will reduce this data volume by about a factor of two, down to 22 kB and 36.67 seconds. . However, in order to perform this additional transmission will require stopping the normal telemetry while the spectrum is being sent, where normal telemetry will need to pick back up after. We will investigate methods of forward error correction (e.g Reed-Solomon coding) to make this transmission redundant to errors. We will also divide the data into segments of 128 spectral channels and transmit each segment sequentially to complete the 4096 channel spectrum If a segment is corrupted, we can still reconstruct the remaining spectrum but with a gap in frequency. The purpose of this spectrum is to check data quality during flight. It will not be used for science analysis, so gaps in the spectrum will not negatively impact our mission. All science analysis will be done with data recovered from the computer after landing.

Table 11: Downlink Spectrum Data, single transmission

Byte	Bit	Description
1-4	0-31	Timestamp
5-693	32-5575	Spectrum Data, bzip2 compressed binary
694-697	5576-5606	32 bit checksum
697	5606	Total

3.4 Uplink Serial Commanding

HADHR will use power on/off commands. There is no intention for additional uplink commands.

3.5 Analog Downlink

HADHR will not use analog downlink channels.

3.6 Discrete Commanding

HADHR will not need any additional discrete commands.

3.7 Payload Location and Orientation Request

The payload requires a large payload seat in either payload position 10 or position 11. These positions allow the mirror of the instrument to be in the correct orientation to gather the necessary data. Figure # shows the requested payload positions on the gondola. If needed, the payload can be reconfigured for position 09 and position 12 with advanced notice.

Figure 9: Requested Payload Positions

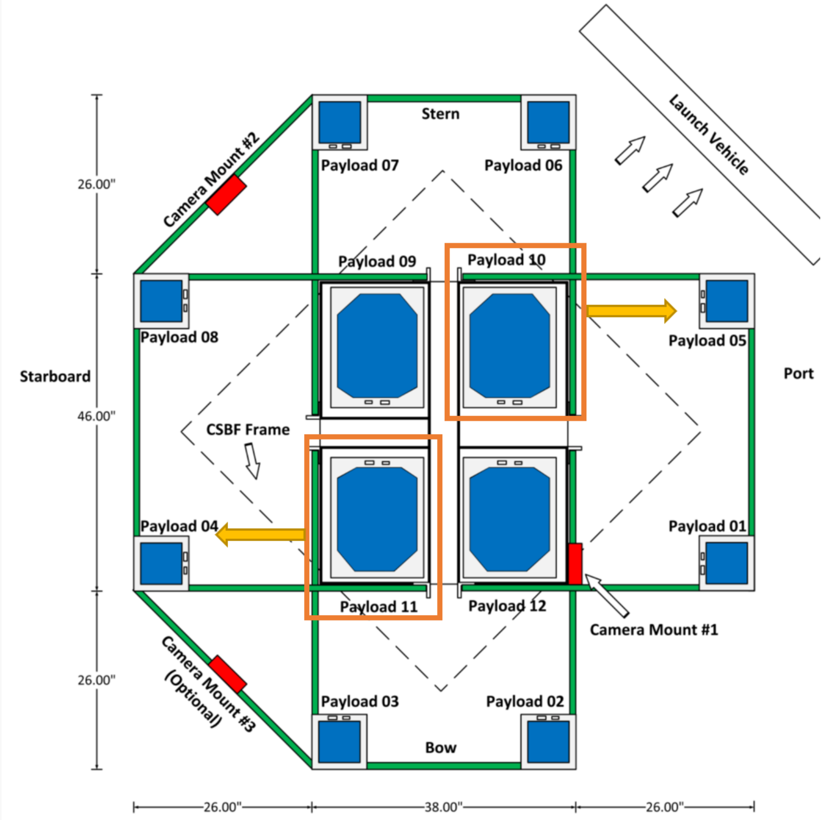


Figure 9: The desired payload positions are shown by the orange rectangles. The yellow arrows shows the orientation of the mirror on payload.

3.8 Special Requests

The SYS-405Q Fanless Industrial Computer uses a single CR-2032 or CR-2025 battery for the real-time clock. Specifications for both batteries are shown below in Table 11, with the information being provided by the batteries specification sheets as well as the manufacturer's safety data sheet.

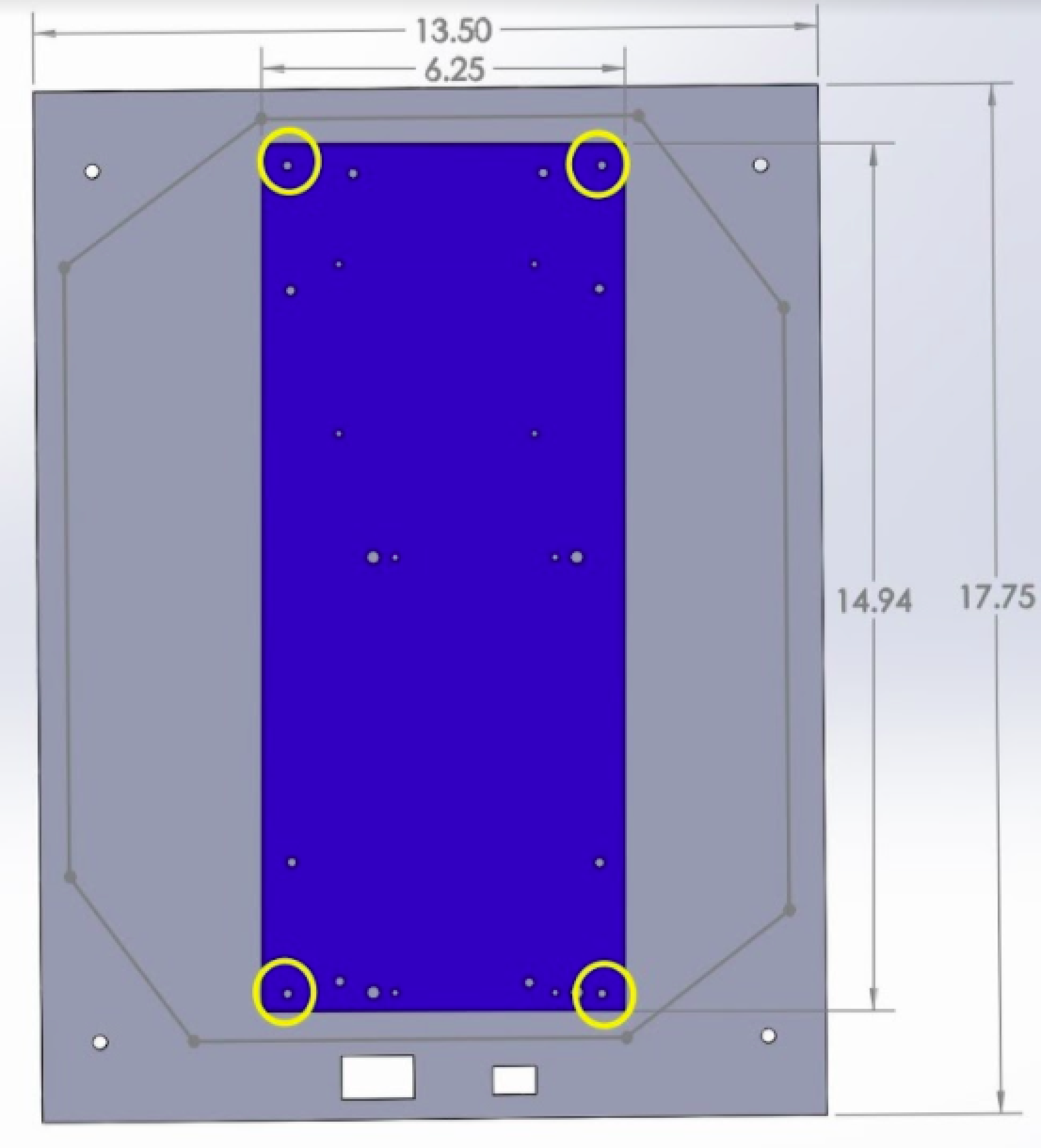
Table 11. Special Requests

Battery	CR-2032	CR-2025
Nominal Voltage (V)	3	3
Nominal Capacity (mAh)	225	165
Weight (g)	2.8	2.3
Operating Range: Min / Max (°C)	-30 / +85	-30 / +85
Positive Electrode Material	Manganese dioxide	Manganese dioxide
Negative Electrode Material	Lithium metal	Lithium metal
Lithium Content (g)	0.07	0.05

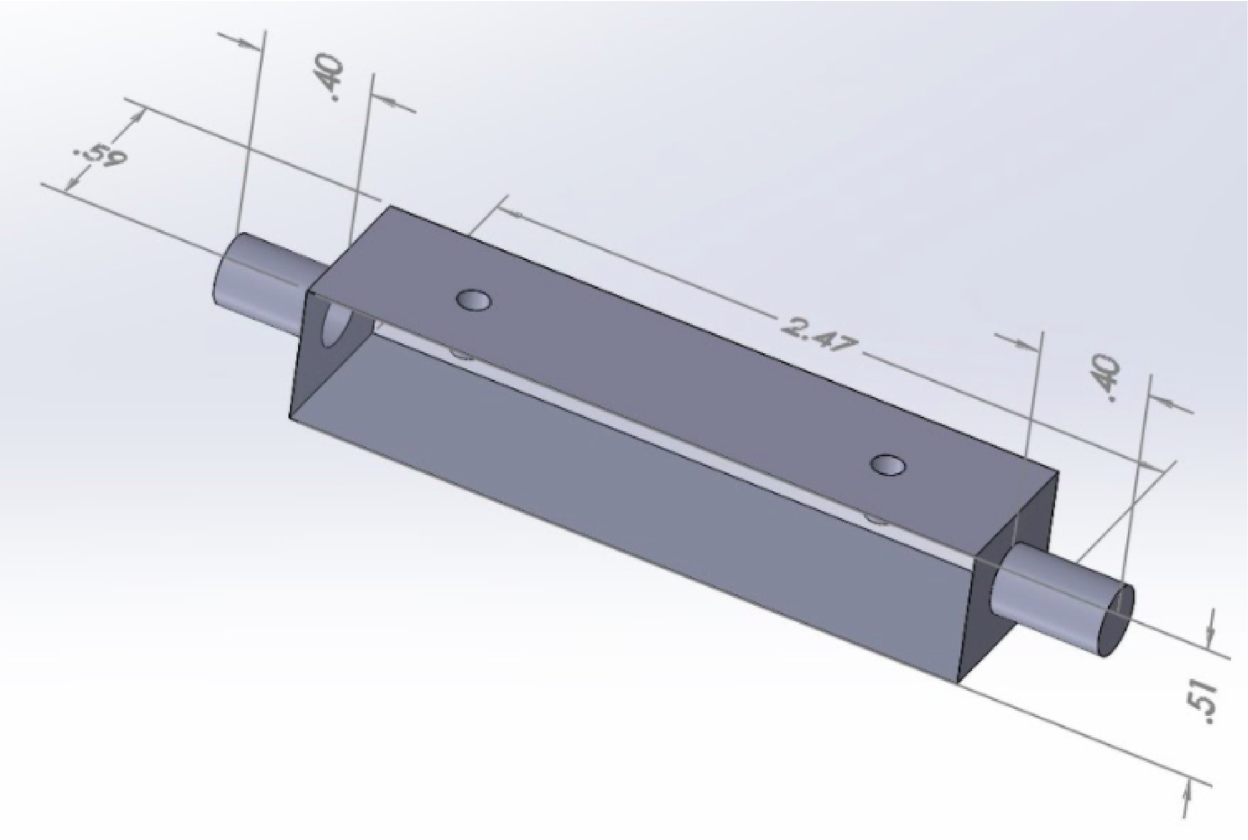
4. Preliminary Drawings and Diagrams

It is important to note that all drawings used in this section were used by the previous HASP team, WWASP and do not fully reflect the current status and dimensions of all parts. Namely the mirror, and the plates and the position of the mirror in relation to the submillimeter receiver. Accurate models will be provided and be completed well in advance of the launch date.

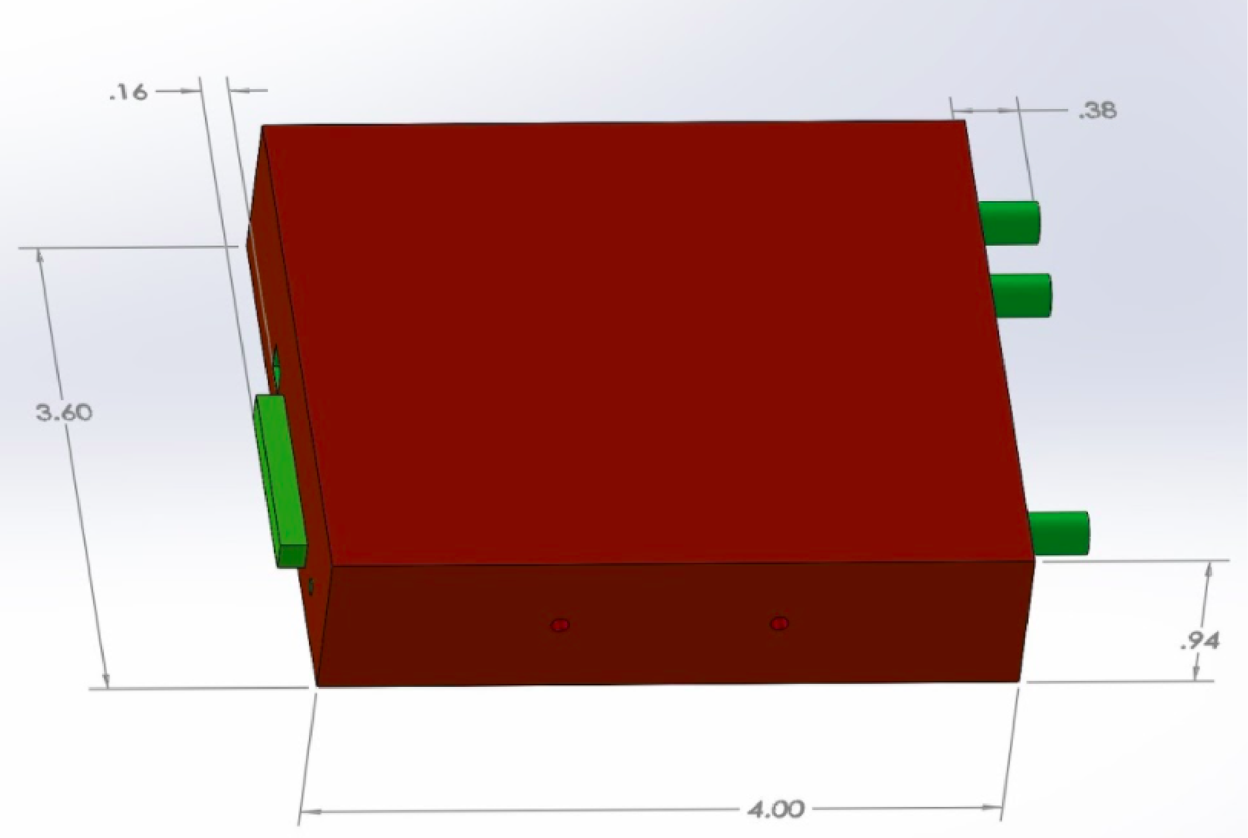
Bottom Plate to Mounting Plate



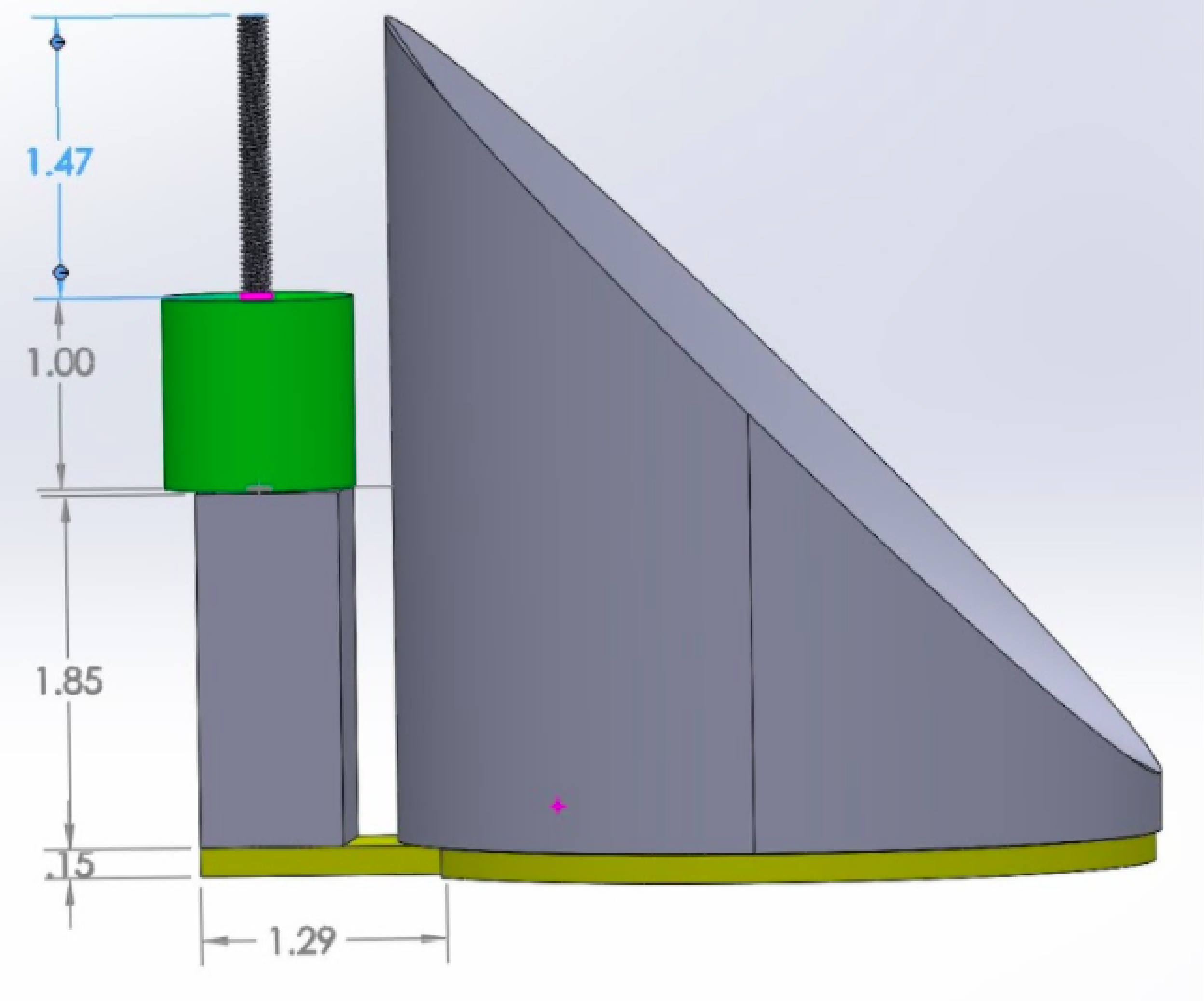
LNA



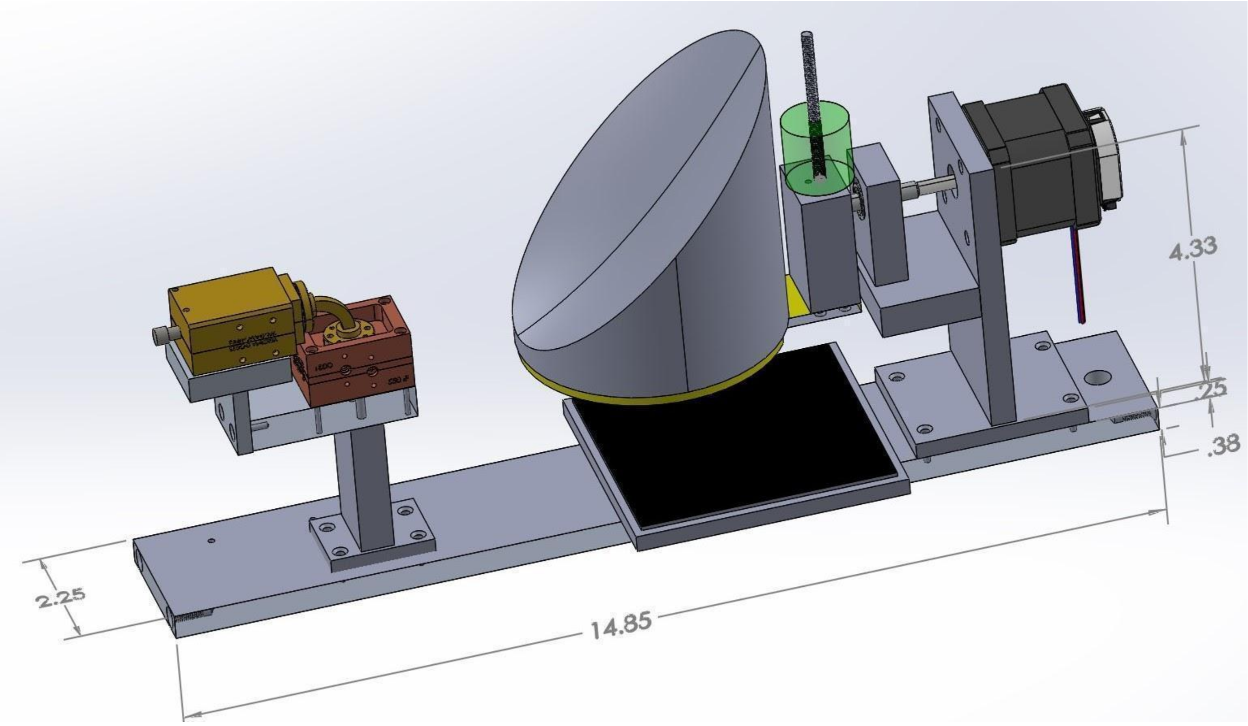
Synthesizer



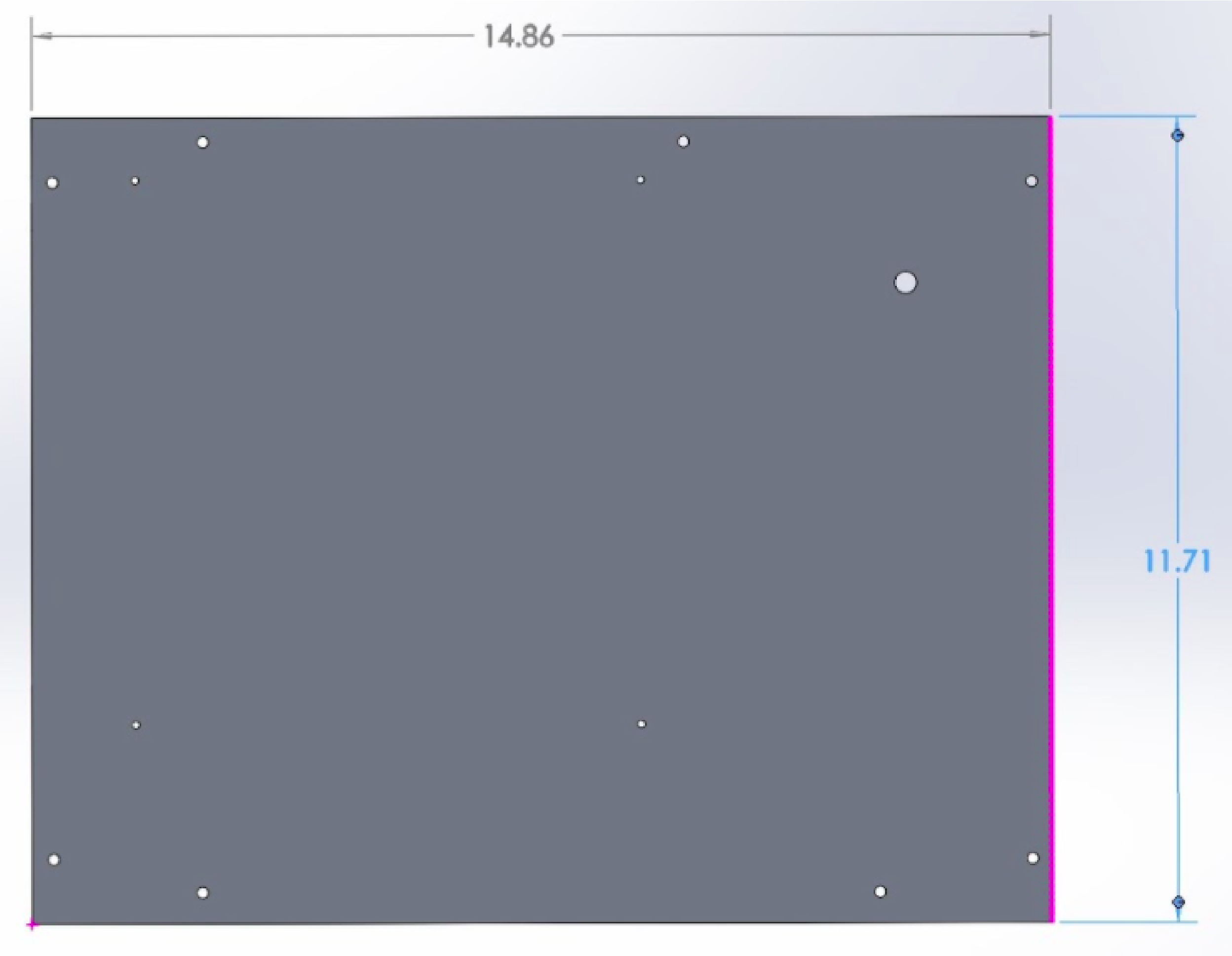
Mirror & Counterweight

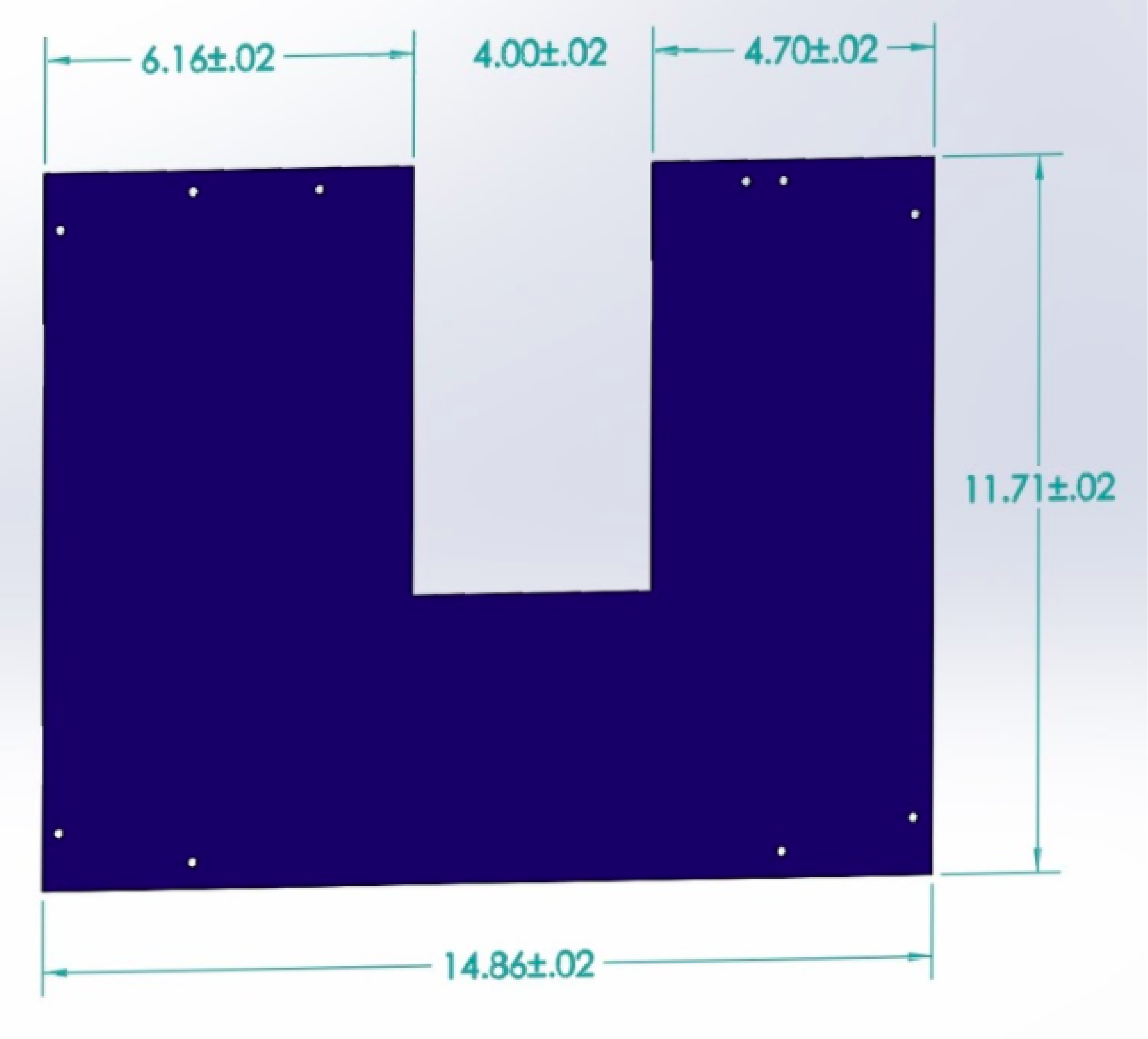


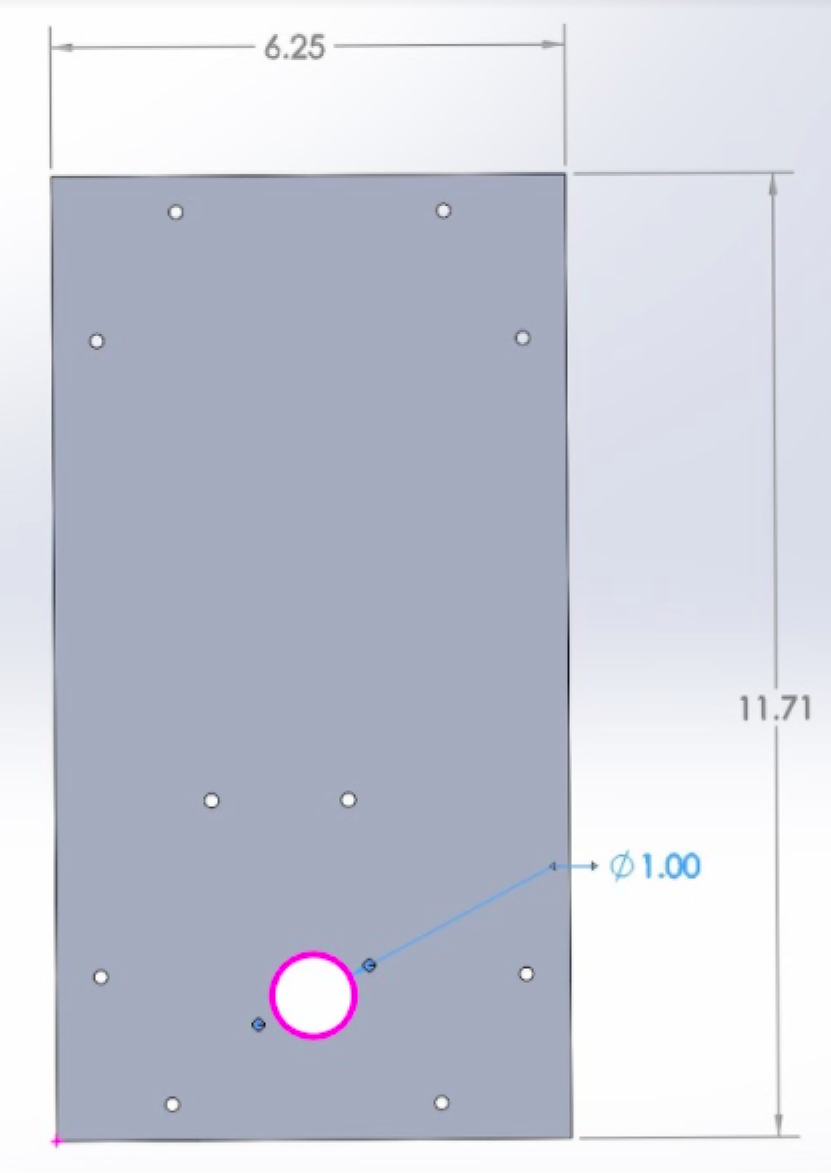
Motor, Mirror & Optical Mounting Plate

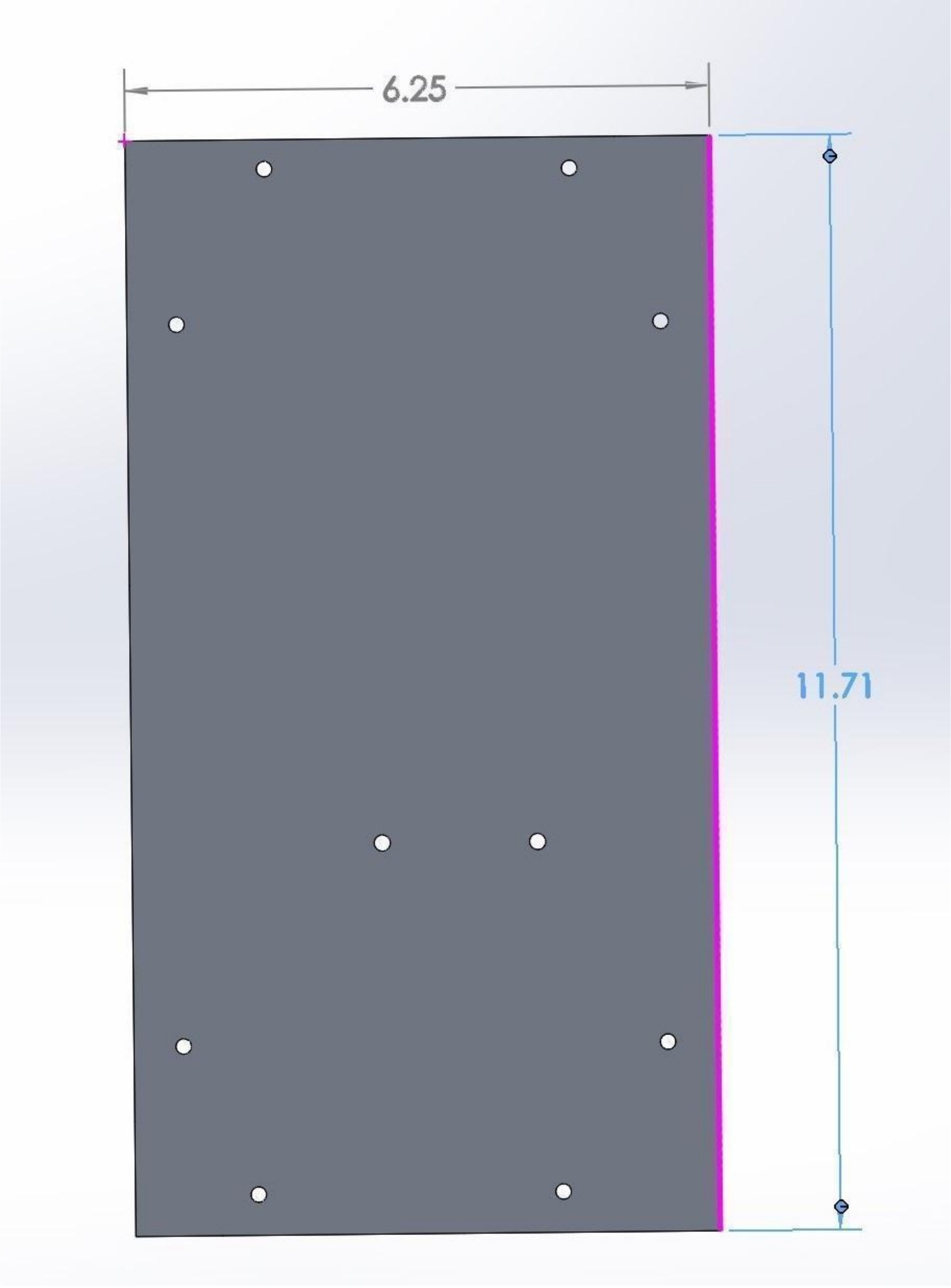


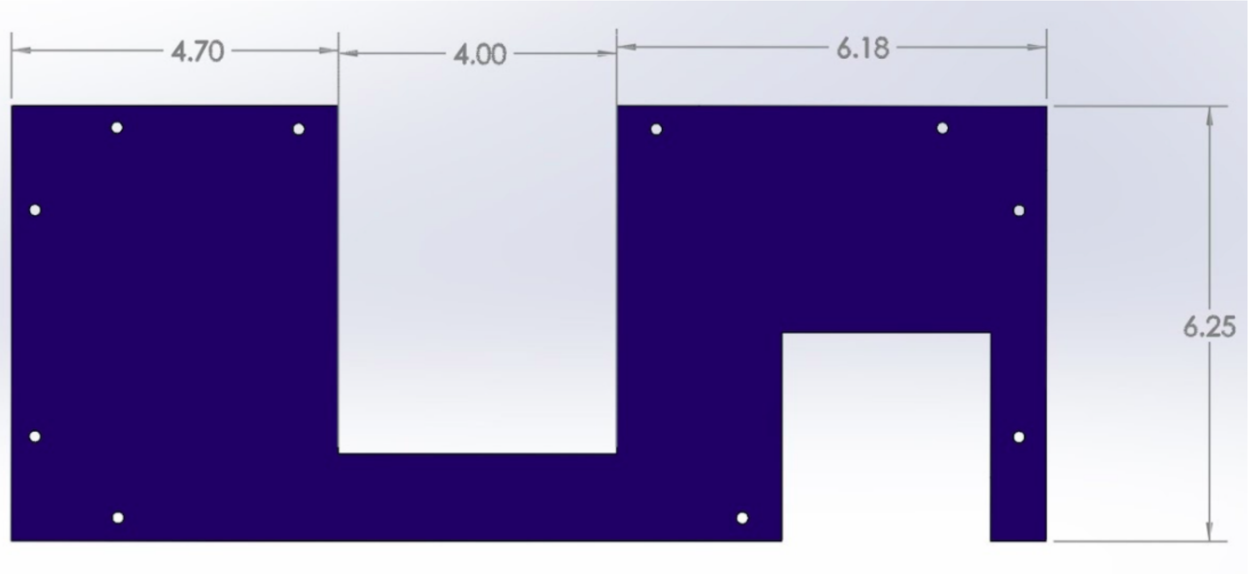
Panels




6.16±.02
4.00±.02
4.70±.02
11.71±.02
14.86±.02


6.25
11.71
Ø 1.00


6.25
11.71


4.70
4.00
6.18
6.25

5. References

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Appendix B: NASA Hazard Tables

Appendix B.1 Radio Frequency Transmitter Hazard Documentation

HASP 2022 RF System Documentation	
Manufacture Model	
Part Number	
Ground or Flight Transmitter	
Type of Emission	
Transmit Frequency (MHz)	
Receive Frequency (MHz)	
Antenna Type	
Gain (dBi)	
Peak Radiated Power (Watts)	
Average Radiated Power (Watts)	

Appendix B.2 High Voltage Hazard Documentation

HASP 2022 High Voltage System Documentation	
Manufacture Model	
Part Number	
Location of Voltage Source	
Fully Enclosed (Yes/No)	

Is High Voltage source Potted?	
Output Voltage	
Power (W)	
Peak Current (A)	
Run Current (A)	

Appendix B.3 Laser Hazard Documentation

HASP 2022 Laser Hazard Documentation			
Manufacture Model			
Part Number			
Serial Number			
GDFC ECN Number			
Laser Medium			
Wave Type		*(Continuous Wave, Single Pulsed, Multiple Pulsed)*	
Interlocks		*(None, Fallible, Fail-Safe)*	
Beam Shape		*(Circular, Elliptical, Rectangular)*	
Beam Diameter (mm)		**Beam Divergence (mrad)**	
Diameter at Waist (mm)		**Aperture to Waist Divergence (cm)**	
Major Axis Dimension (mm)		**Major Divergence (mrad)**	
Minor Axis Dimension (mm)		**Minor Divergence (mrad)**	
Pulse Width (sec)		**PRF (Hz)**	
Energy (Joules)		**Average Power (W)**	
Gaussian Coupled (e-1, e-2)		*(e-1, e-2)*	
Single Mode Fiber Diameter			
Multi-Mode Fiber Numerical Aperture (NA)			

Appendix B.4 Pressure Vessel Hazard Documentation

HASP 2022 Pressure Vessel Documentation	
Description	
Maximum Operating Pressure (PSIG)	
Fluids (GN2, Air, etc)	

Appendix B.5 Battery Hazard Documentation

HASP 2022 Battery Hazard Documentation	
Battery Manufacturer	Panasonic
Battery Type	CR-2032 or CR-2025
Chemical Makeup	Li/MnO_2
Battery modifications	*No*
UL Certification for Li-Ion	