HASP Student Payload Application for 2022

Payload Title: WANKA II - An evaluation of aerosol sensors in stratospheric conditions	
Institution: Universidad Nacional de Ingeniería	
Payload Class (Enter SMALL, or LARGE): SMALL	Submit Date: 07/01/2022

Project Abstract:
Wanka II is the continuation of the Wanka missions of the National Engineering University, whose main mission is to analyze the concentration of stratospheric aerosols, ozone and pollutant gases. The team proposes an improved version of the gas and aerosol sensor suite based on the flight of the first Wanka mission performed on the HASP 2021 flight, as well as an increased amount of thermo-vacuum testing for the different subsystems during its development. The Wanka II team is advised by engineer Luis Fernando Suarez Salas, from the sub directorate of Atmospheric Sciences and Hydrosphere of the Geophysical Institute of Peru (IGP), who provides expert advice on operations and characteristics of the sensors to be installed on the payload.
The payload will weigh less than 3 kg, its dimensions will be 150 mm x 15 mm x 300 mm, it will require 8,188 watts of power and a downlink bandwidth of 109 bps.

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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:

Faculty Advisor Signature:

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1. Payload Description

The Wanka II mission is a project developed by peruvian undergraduate students from the "Universidad Nacional de Ingeniería" and the "Pontificia Universidad Católica del Perú", with the collaboration of engineers from the Geophysical Institute of Peru. Its main objective is the development of a payload capable of measuring concentration of stratospheric aerosols using low-cost sensors and to measure different parameters as ozone and polluting gas concentration. This mission continues the activities of the Wanka mission, launched on HASP 2021, moving forward on the launch that was successful. We are considering improvements at some subsystems, better equipment and more pre-launch tests.

Fig.1. Wanka II mission logo

1.1 Payload Scientific / Technical Background

1.1.1 Mission Statement

The main objective of the Wanka II mission is to develop a payload able to measure stratospheric aerosol parameters using low-cost commercial sensors. The payload will measure the concentration of stratospheric aerosols using two kinds of low-cost commercial light-scattering-based particle matter (PM) sensors. One sensor is the Plantower PMS 5003, in this mission we are using two sensors together to improve measurement precision and our need to acquire reliable data and with better algorithms to obtain particle number and concentration. The other sensor is a Sharp GP2Y1010AU0F, which acquired data successfully in the past launch. They will work after air is heated up to a temperature where sensors work optimally. Finally, if the mission is successful, it will be the second step in the development of payloads for stratospheric aerosol parameters measurement designed and implemented by Peruvian undergraduate students at an affordable cost.

1.1.2 Mission Background and Justification

During the last decade the interest in the study of stratospheric aerosols has increased, mainly due to their increase since 2000, and their potential applications to control global warming due to its negative effect on the Earth's radiative forcing. They are usually considered as the particles suspended in a gas, without a constant composition [1]. They affect the earth's radiative budget, absorbing and scattering the radiation that enters or leaves the planet. Working directly or indirectly, affecting the radiative properties and the lifetime of the clouds [3]. However, there is a lot of imprecision regarding the effect that they cause in the radiative forcing as it is shown in Fig. 2, where the aerosol parameters indicate high uncertainty. Stratospheric aerosols are found from the end of the tropopause up to a maximum height that depends on the sedimentation and evaporation process generated by the increase in temperature with the altitude, and are mainly composed by stratospheric sulfur from different gaseous molecules as sulfur dioxide (SO_2), carbonyl sulfide (OCS) and sulfuric acid (H_2SO_4), the ones that are produced mainly due to volcanic injections of SO_2 and aerosols.

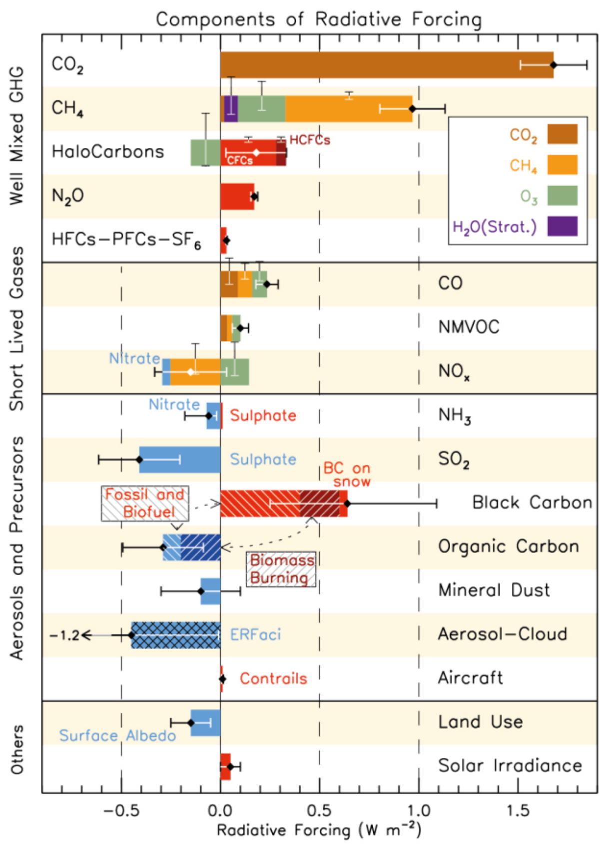


Fig. 2. Components of Earth's radiative forcing with their corresponding uncertainty (Source: Adapted from [2, Fig. 8.17]).

There are different ways to measure stratospheric aerosol parameters: in situ, ground based and space based. Space based missions use mainly satellites, as CALIPSO, which provides backscattering profiles assuming a static lidar ratio for all the latitudes and longitudes, or the SAGE missions that calculate backscattering coefficients using coefficient extinction and use data provided by ground-based systems to verify its algorithms. Ground based measurements use powerful lidar systems. There are many places in the world with this instrument, such as Mauna Loa in the USA or the Observatorie de Haute-Provence in France [3], and different instruments that can acquire this data as the Raman lidar or ceilometers [4]. One of the ceilometers used to measure these parameters is the CL31, which works at 905 nm, a wavelength where the molecular scattering is very weak, usually below the sensitivity of the instrument. [5]

In situ measurements are the most affordable way to measure stratospheric aerosol parameters, they can be sent to the stratosphere using balloons, and its payload can be composed by commercial sensors and actuators. They are not supposed to replace the other techniques, but can provide highly complementary information, and can be built by students from different academic years [6]. One of these missions is Compact Optical Backscatter Aerosol Detector (COBALD), which provides high precision measurements of optical parameters as the Backscattering coefficient at 455 nm and 940 nm, but cannot work during the day [4]. Another mission is developed by High-Altitude Balloon for Outreach and Research (HARBOR), which measures aerosol and gases concentration using low-cost commercial sensors [7].

1.1.3 Mission Objectives

The Wanka II mission has three main scientific objectives:

- Measurement of stratospheric aerosol concentration using low-cost commercial dust sensors. The data acquired will be compared with the data obtained after processing the Calipso satellite measurements to obtain stratospheric aerosol concentration [8], in order to confirm the reliability of the data acquired by our mission.
- Evaluate the performance of PM sensors under stratospheric conditions, using different sensors to know the humidity, temperature and pressure to which they are exposed, and calculate their correlation with the data provided by the PM sensors.
- Evaluate the performance of low cost ozone and temperature sensors under stratospheric conditions, comparing the data with theoretical information and the one provided by the SHADOZ/NASA network.

1.2 Payload Systems and Principle of Operation

To control the stratospheric aerosol concentration, a constant aerosol flux will be necessary. To achieve this, a system as shown in Figure 3 will be implemented.

The aerosols will be blown by a fan located at the top of the payload to a temperature and humidity control cavity, then the aerosol flow will pass through the flow sensor to the two PMS 5003 sensors, which will measure the mass concentrations of PM1.0, PM2.5, PM10, then the flow will pass through the dust sensor GP2Y1010AU0F where the concentration of PM 2.5 particles will be measured. Finally the gas sensor MQ135, will measure the composition of ozone present in the circuit. This system will have a closed control circuit to obtain a stable particle flow.

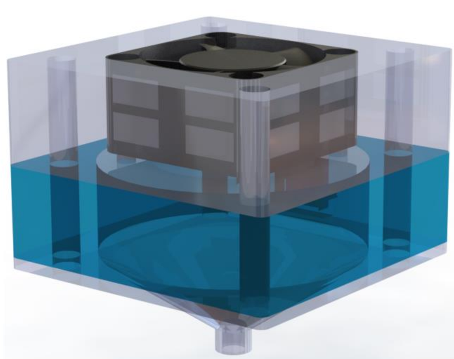
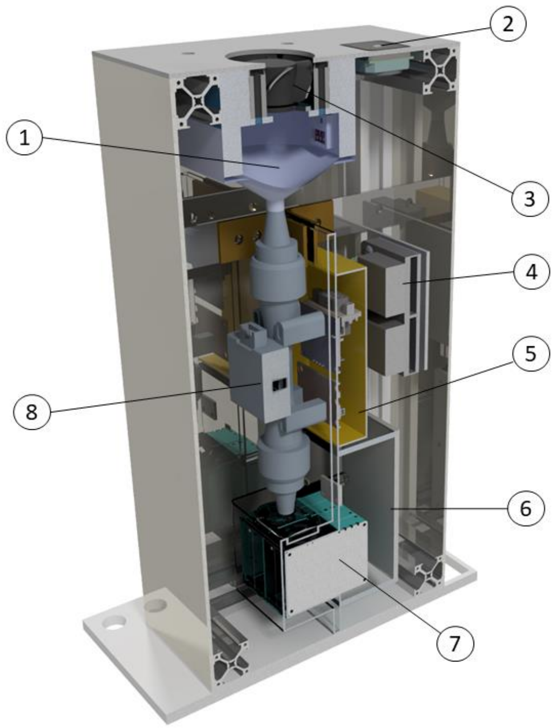


Fig 3. Module for air flow through the cooler with temperature and humidity sensor SHT31.

The design of 3 assembled pieces (see Fig. 3) printed in PETG for the air flow through a cooler placed on the surface of the payload; internally a SHT31 sensor is placed which is screwed and supported by the intermediate piece, this piece also has a hole in the bottom of the sensor for the connections of the 4 pins of the sensor.

The lower part is connected to a hose for air circulation to the PMS sensors. The heating pads, used for the internal heating of the payload, will be connected to a MOSFET to consume less current and will be powered by a 5V supply to reach an optimal temperature of the sensors.



Item	Name
1	Incoming air monitoring cavity
2	GPS antenna
3	Axial fan
4	Voltage converter
5	Microcontroller cavity
6	Aerosol monitoring cavity
7	Particulate matter sensor
8	Flow sensor

Fig 4. Parts of the payload WANKA

1.3 Major System Components

Wanka II is composed of two major subsystems, the ones that will measure the backscattering coefficient and the concentration of the aerosols. Two additional subsystems will be considered, a system to transmit the critical parameters by telemetry and to save data in a micro-SD module and a system to acquire GPS data. The payload will acquire GPS data using a commercial module, to acquire this data independently, but also it will receive it from HASP, to ensure correct data acquisition during the flight, and to verify that the data acquired by the module within the payload is correct.

1.3.1. Aerosol concentration sensor system

a. Components: PMS5003 sensor, GP2Y1010AU0F Dust Sensor, Heating pad, SHT31 temperature and humidity sensor, K-5S-O3-20 Ozone sensor, AWM5000 flow sensor.

b. Purpose: Measurement of stratospheric aerosol concentration at different heights and places.

c. Resource: The flow sensor operates at 10V, the BME280 operates at 3.8V, the rest of the sensors and actuators operate at 5V and the Heating Pad uses an analog voltage from 0V to 5V.

d. Description: This system will measure stratospheric aerosol concentration using PMS sensors, low cost commercial dust sensors and ozone sensor. For sampling, an axial fan and a flow sensor will be used to control the flow for proper operation of the sensors and to optimize their energy consumption. To achieve a temperature at which the sensors can operate, the outside air will be heated by two heating pads, all inside a cavity made of Polyethylene terephthalate glycolate (PETG), a thermoplastic polyester that offers significant chemical and mechanical resistance. In this way we control the air inlet and outlet for a correct sampling.

1.3.2. GPS data acquisition system

a. Components: GPS NEO-6M module (includes receiver and antenna)
b. Purpose: Acquire latitude, longitude, altitude and time data.
c. Resource: GPS NEO-6M module runs on 5V.
d. Description: This system will acquire latitude, longitude and altitude to generate a complete profile of the aerosol parameters after the flight, and also a time stamp to be included in the data. The GPS antenna will be located at the level of the payload lid to improve data acquisition. The GPS receiver will be inside the box containing the data management module.

1.3.3. Data management system

Because the payload will receive commands in RS232 protocol, the MAX3232 module will be used, this module will convert the RS232 signal to TTL format so that it is logically compatible with the Arduino Mega. Through this module will be sent the downlink stream from the payload, as well as it will receive the uplink commands

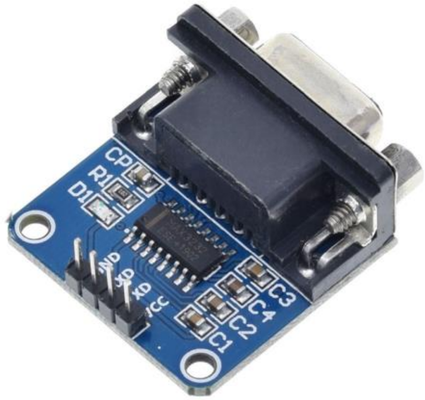


Fig 5. MAX3232 Converter Module - RS232 to TTL

Also, for data storage, a micro sd memory module will be used, which receives the information through SPI protocol.In the micro sd memory, all the information provided by the pressure and temperature sensors, both PMS5003 and the ozone sensors will be recorded, as well as the location information provided by the GPS.

Fig 6. Micro SD Card Memory reader module

1.4 Mechanical and Structural Design

The main structure is based on a geometry that resembles a parallelepiped 15 cm deep, 15 cm wide and 30 cm high. The structure is composed of 7075 aluminum sheets on the lateral faces and a thermal blanket as thermal insulation on the inside, the structure also contains a removable bottom face and top face which are assembled to the body by bolts allowing easy access to the electronic sub-modules.

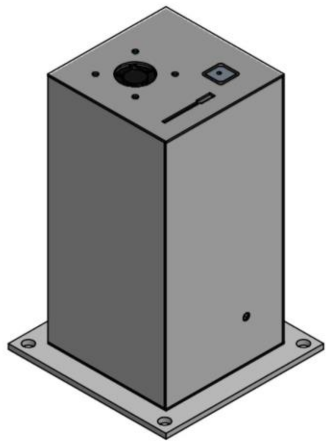


Fig. 7. Structural Design

Given its high hardness and low density, aluminum 7075 was chosen as the structural material. To ensure that the payload remains intact and bonded to the mounting plate, a vertical shock of 10 g and a horizontal shock of 5 g were applied on a finite element simulation in the commercial software Ansys Structural.

In Fig.8 it can be seen the total deformation, Fig 9 shows the stresses under which the payload will be and Fig 10 shows the safety factor product of these loads.

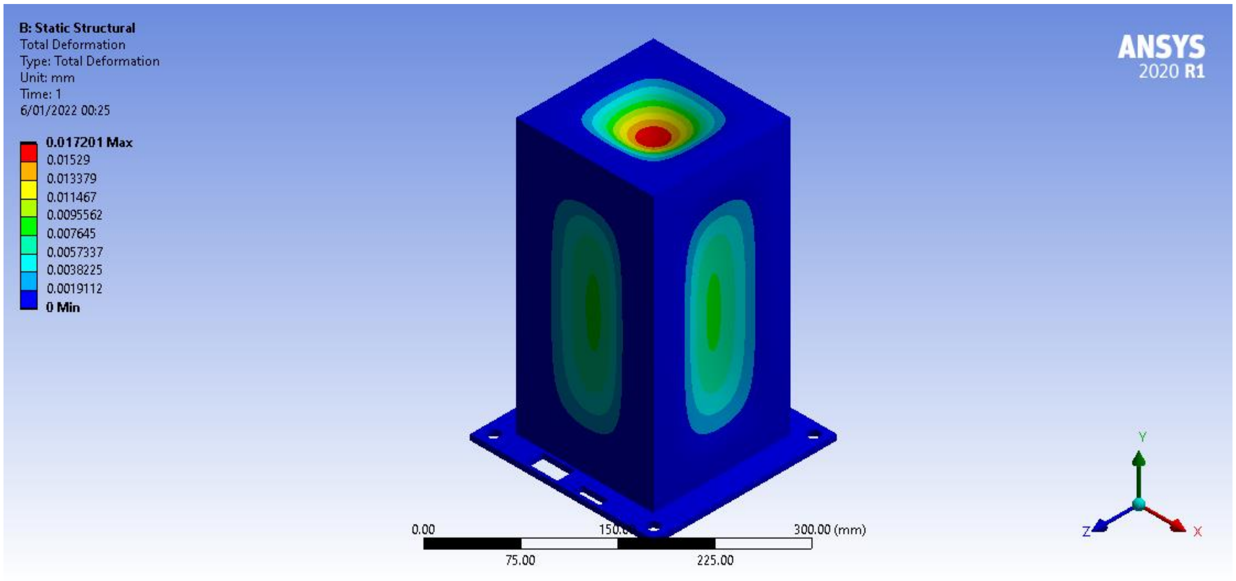


Fig. 8. Total deformation under a 10 g vertical and 5 g horizontal shock.

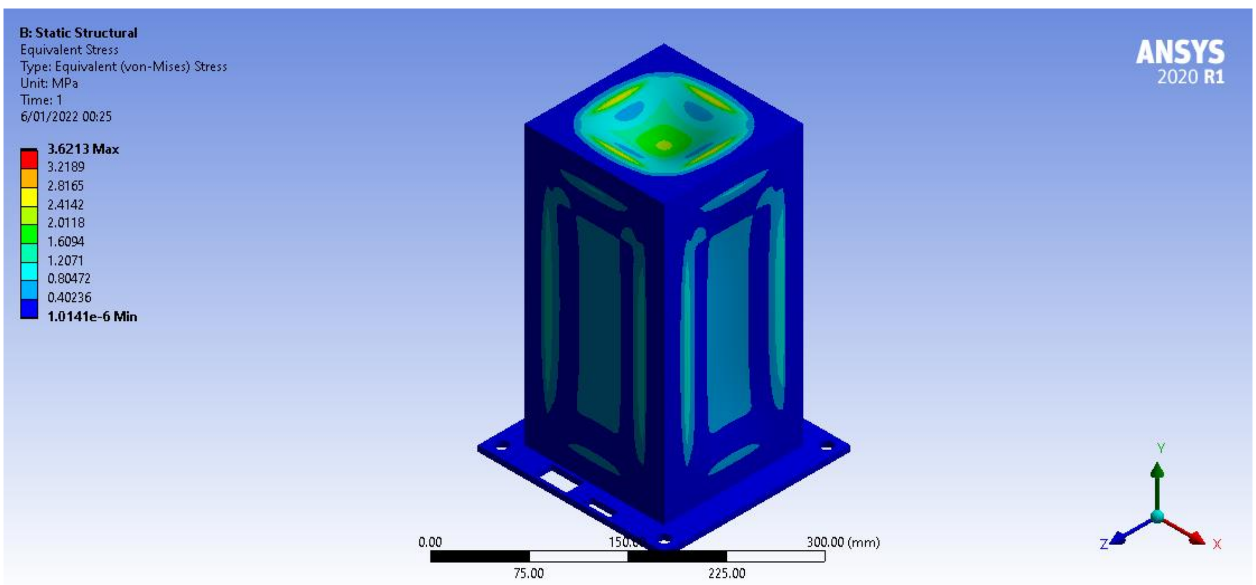


Fig. 9. Stress equivalent to the mechanical structure under a 10 g vertical and 5 g horizontal shock.

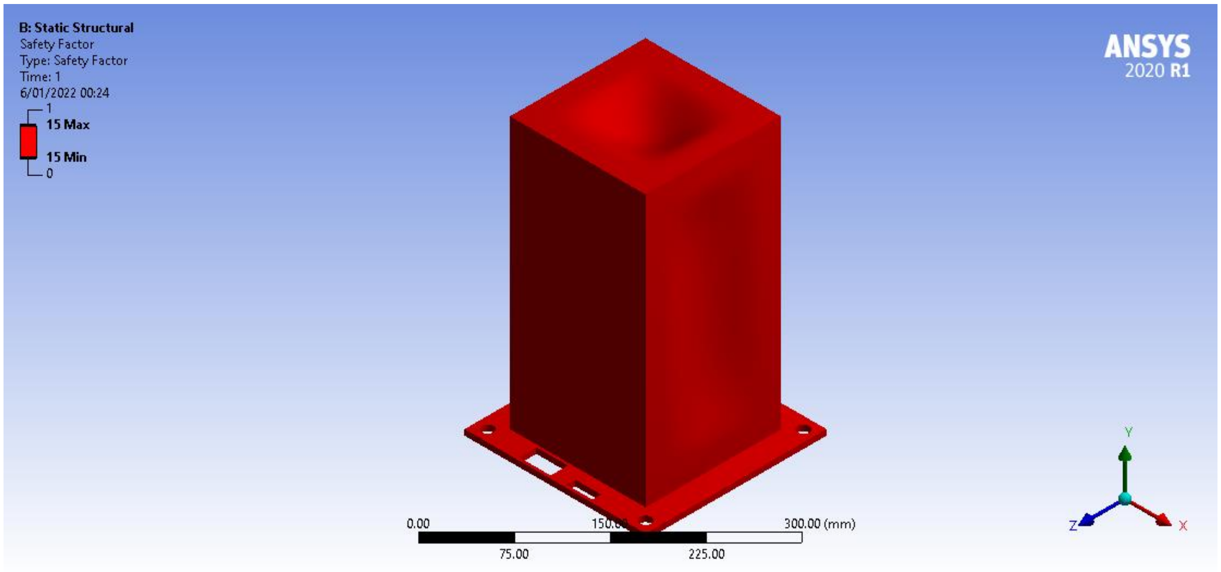


Fig. 10. Safety factor under a 10 g vertical and 5 g horizontal shock.

A minimum safety factor of 15 will guarantee that the structural design and its material chosen will remain intact and attach to the mounting plate.

Figure 11 shows how the payload will be attached to the HASP mounting plate. As shown in Fig. 11, the bolts will secure the payload and the HASP plate mounting plate. A detail of the attachment section is shown in Fig. 12 .

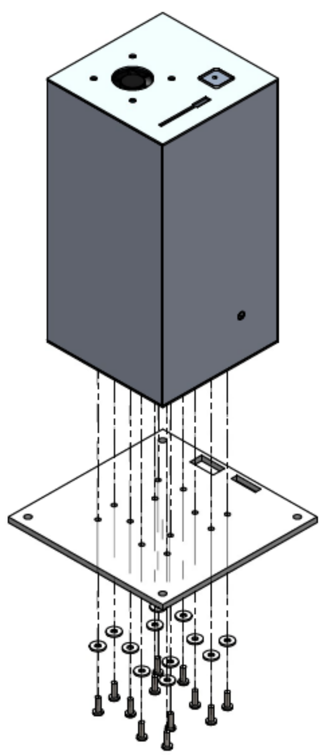


Fig. 11. Payload mounting plate interface.

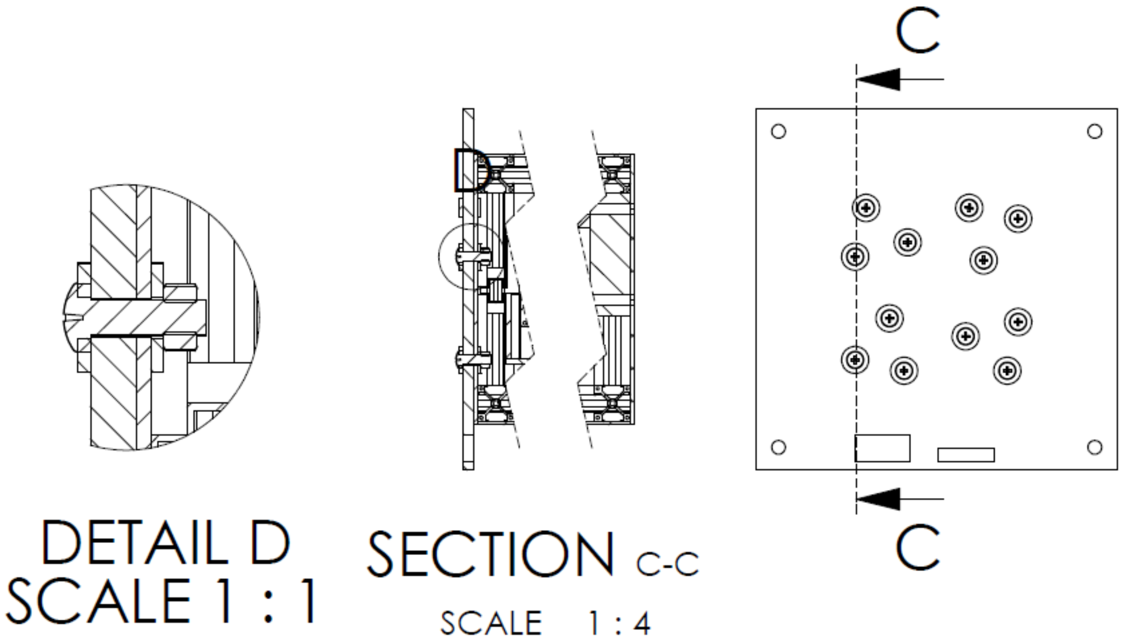


Fig. 12. Fastener cross section.

The detailed planes of the structural design and the modified mounting payload plate can be found in the appendix.

1.5 Electrical Design

This section should describe your preliminary electrical design including sensors, sensor interface, controllers, data acquisition, storage, telemetry, and power supply system. Preliminary electrical schematics are required here.

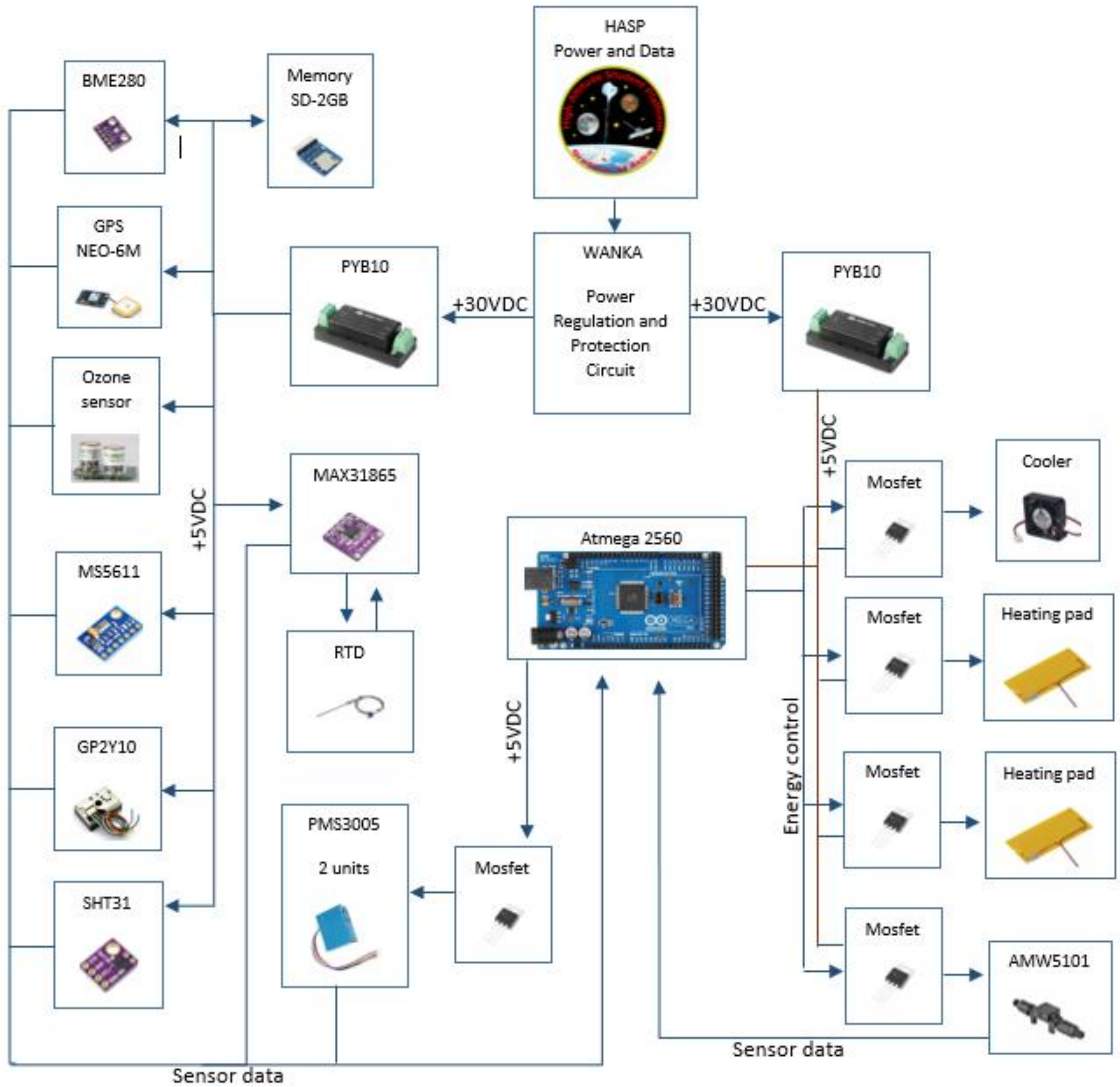


Fig. 13. Preliminary diagram of Wanka

1.5.1 PMS5003

A particle sensor that uses laser scattering to detect particle concentration size, the laser beam is class IIIa/3R and will reflect light from any particle present on a detection plate. The detection plate measures the reflection as a pulse, and the pulse length determines the particle size, while the number of pulses determines the particle count. These particle counts are used to calculate the mass concentrations of PM1.0, PM2.5 and PM10. This sensor is widely used in air pollution assessment around the world. Its manufacturer is Plantower, based in China. [9] For the stratospheric aerosol monitoring mission it is proposed to use 2 PMS5003 sensors, with each laser counter alternating 5-second readings for 120 seconds and taking the mean value. This configuration is used by the manufacturer Purple Air in their PA-II devices, these devices were tested by AQ-SPEC and documented in [10] the tests were performed in field and laboratory conditions, obtaining an accuracy (PM 2.5) higher than 95% considering relative humidity and temperature parameters, comparing the measurements with a reference instrument, obtaining also a high correlation between the measurements. This equipment also showed a high performance in the evaluations in urban environments carried out by [11].

For these reasons we consider that by using two PMS5003 sensors we will be able to obtain a reliable low-cost system for aerosol measurement. The WANKA team proposes a system to maintain a stable flow of aerosols through the PMS5003 sensors, the proposed methods will be subjected to thermo-vacuum tests, in this way we will ensure that the device has the right conditions to perform measurements of aerosol number concentrations and sizes.

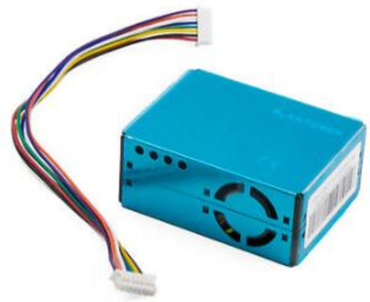
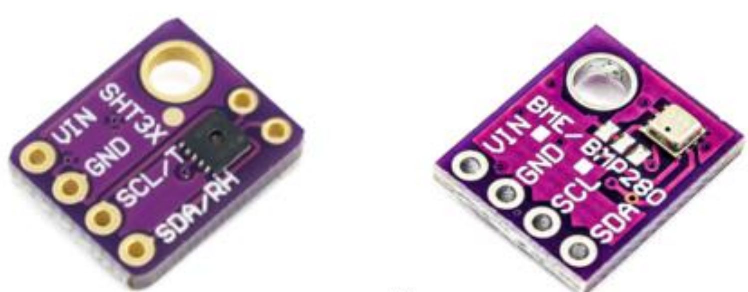


Fig. 14. Air quality sensor PMS5003.

1.5.2 SHT31 - Relative humidity and temperature sensors:

Due to the internal design of the payload, two sensors will be used; the SHT31 and the BME280. These sensors use the I2C serial communication protocol, which is the reason for the desire to differentiate them. In the air quality sensing compartment, the BME280 sensor will be located, which will allow us to know the temperature and humidity changes of the volume to be analyzed. The SHT31 will be placed in the controller and heating pads compartment, which will be in charge of measuring the temperature at which it is located and perform the thermal control, to preserve the integrity of the equipment. The SHT31 and the BME280 are similar in their operation and connectivity, as both of them use the I2C protocol. [12]



a) b)

Fig. 15. Humidity and temperature sensors, a) SHT31, b) BME280.

1.5.3 MS5611 - Pressure and temperature sensor:

To measure the pressure in the air quality sensing compartment, due to previous experience and its good performance, the MS5611 will be used. This sensor has a good accuracy at low power consumption, so it will be used as an indicator for the control of non-critical systems; its connection to the microcontroller is two power pins and two for the I2C communication protocol.[13]

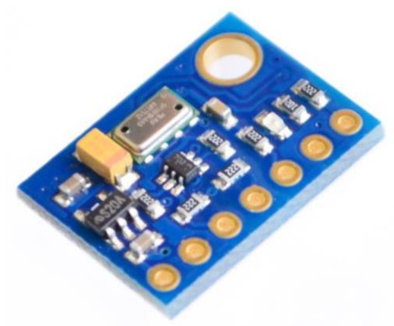


Fig. 16. Pressure and temperature sensor MS5611.

1.5.4 GPS Module:

It is important to know the location of the payload at all times during the flight, for this purpose it will use the NEO-6M GPS module, with an operating frequency of 5Hz, high sensitivity of 165 dBm and communication with the controller by UART serial port.[14]

Fig. 17. NEO-6M GPS module with antenna.

1.5.5 Heating pad:

These DC powered heating pads are perfect for near-body heating applications. They get warm to the touch but not too hot as long as you provide the appropriate voltage. Simply apply 5VDC to the wire leads and within minutes, the pad will begin to warm up.[15]

These heating pads are constructed using a mesh of Polyester filament and Micro Metal Conductive Fiber folded into a protective Polyimide Film. The fact that these are low power, flexible and draw little power makes them ideal for things like hand-warmers and other heated garments.

Heating pad features:

- Operating voltage: 5 V DC
- Operating current: 750 mA (6.5 Ω)
- Dimensions: 5 x 10 cm

Figure. 18. Heating pad

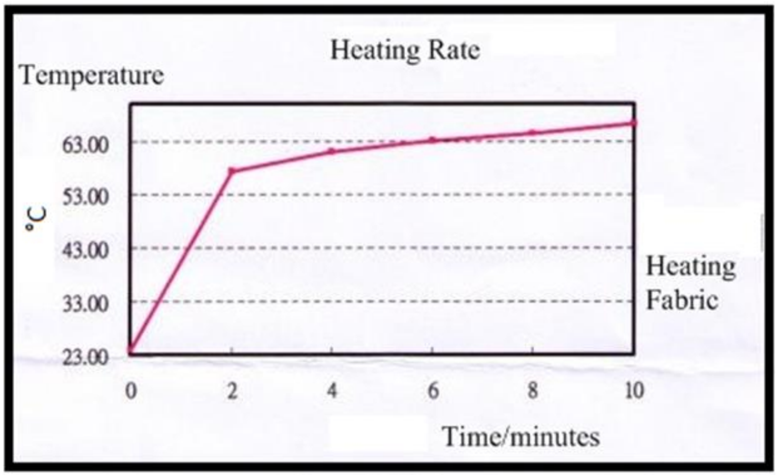


Figure. 19. Temperature(°c) vs. time(minutes) curve

1.5.6 INA219-Voltage and Current Sensor:

The INA219 allows simultaneous measurement of voltage and DC current in the range of 0 to 26 volts and 0 to 3.2 amps via an I2C interface. The module incorporates an internal shunt resistor for current measurement of 0.1 ohms and 1%.

The INA219 is characterized by measuring current on the positive side of the load, unlike other meters that are connected on the negative side, generating a false ground in the circuit or load to be measured. The INA219 operates from –40°C to 125°C. Also the INA219 has an internal 12-bit ADC that provides a resolution of 0.8 mA over a range of 3.2A. It is possible to increase the range by changing the shunt resistor.[1] [16]

Fig. 20. INA 219

1.5.7 RTD PT100 Temperature sensor (3-wire):

The 3-wire Pt100 RTD is the most typical construction of the Platinum resistance temperature sensor. It is a platinum coil with a value of 102 Ohms at 0°C and a positive temperature coefficient, in other words the Ohm value increases with increasing temperature. This will be used to measure the temperature outside the payload. We will use a Pt100 RTD sensor, due to its good performance at low temperatures, high accuracy and almost linear variation of its resistance as a function of temperature. [17]

Specific characteristics:

- Working range: -100℃ to +400℃.
- Connection: 3 wire
- Cable length: 1m
- Dimensions: D5mm x L100mm
- Thread diameter: 8mm/0.31"
- Probe material: stainless steel
- Waterproof (sensor part, not cable)

Fig. 21. RTD PT100 TEMPERATURE SENSOR (3-WIRE)

1.5.8 Max38165:

The MAX31865 transmitter module provides a simple and reliable way to obtain temperature measurements from PT100 RTD sensors. The module reads the resistance of the PT100 sensor and converts this analog signal into digital data to be interpreted by a microcontroller. [18]

Device features

- Operating voltage: 3 – 5.5VDC
- Power-Supply Current: 3.5mA (max)
- Resolution: 15 bits (0.03125ºC)
- Accuracy: 0.5ºC
- Conversion time: 21ms (max.)
- Interface: SPI
- Has mounting holes
- Dimensions: 28mm*25.3mm*3mm

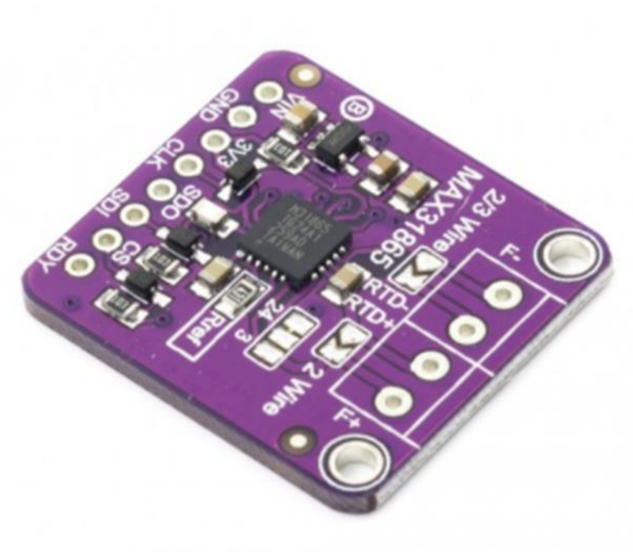


Fig. 22. Max38165

1.5.9 Step Up XL6009 DC/DC Booster DC/DC voltage regulator:

This DC-DC voltage regulator will be used to connect an input voltage of 5v to then obtain an output voltage of 10V. This voltage will power the flow sensor.[19]

- Step up XL6009 characteristics.
- Input voltage: 3V-32V (optimum voltage 5V-32V).
- Output voltage: 5-35V Adjustable
- Maximum input current: 4A (recommended to use heatsink)
- Maximum output current: 3A
- Approximate efficiency: 94%.
- Working frequency: 400KHz

- Operating Temperature Range: -40 to +85 degrees Celsius
- Dimensions: 43mm x 21mm x 14mm

Fig. 23. Step Up XL6009 DC/DC Booster DC/DC Voltage Regulator.

1.5.10 Ozone Sensor:

The K-5S-O3-20 module incorporates several gas sensors with unified interfaces precisely calibrated at the factory. In addition to a resolution of up to 0.1ppm, all these features allow the collection of extensive data on the presence of aerosols present in the stratosphere. It has digital output and analog voltage output for ease of use.

Fig. 24. Módule Ozone sensor K-5S-O3-20

1.5.10.1 Method of Calibration

The calibration in the vacuum chamber of the gas sensors will be done considering the variables: flow in the sensor, chamber pressure, chamber volume and temperature inside the chamber.

Direct comparison tests will be performed by varying each one of the parameters keeping the other parameters constant or trying to monitor them. The data collected will be used to adjust the values using approximations for the programming of the sensors through the microcontroller.[20]

[6]

1.5.11 Dust sensor

This sensor performs the measurement of particle concentration PM of 2.5 micrometers, the dust sensor GP2Y1010AU0F was chosen. Such a sensor has a linear relationship between the output voltage and the density of the dust sensor between 0 and 0.5 $mg/m3$.

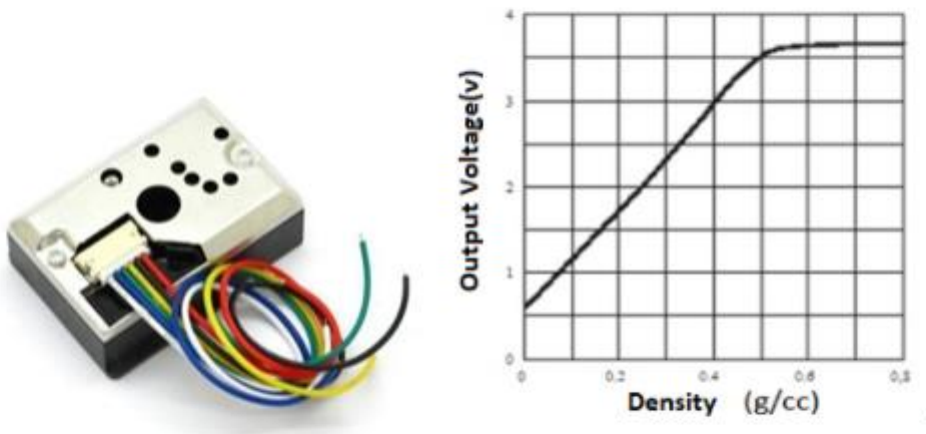


Fig. 25. Dust sensor GP2Y1010AU0F sharp and output curve

1.5.12 Flow sensor

To measure the inlet air flow through the pipe, we consider Honeywell's AWM5000 series flow sensors that can make in-line measurements and are equipped with a linearization circuit to have a linear relationship between voltage and flow as shown below.

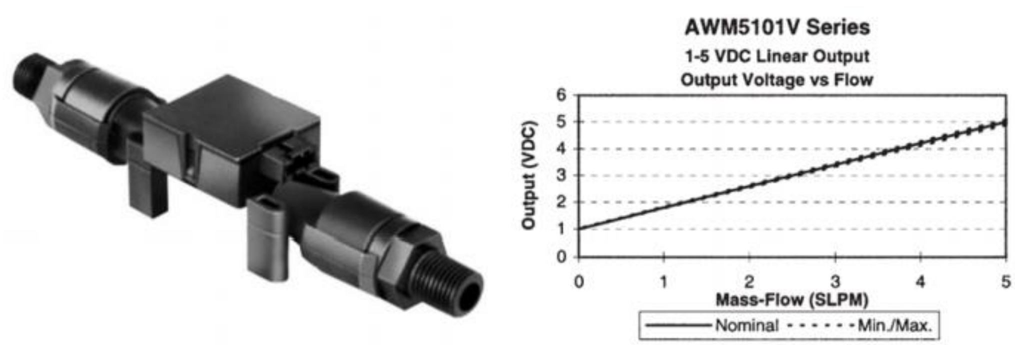


Fig. 26. WM5000 series sensor and output curves

According to the working range of the vacuum pump, from this series, we select the AWM5101VN sensor which has a flow range from 0 to 5 SLPM. The obtained analog output voltage is converted into digital values with the ADC module of the microcontroller. [5] [21]

1.5.13 PBY10 DC-DC converter

Two PYB10 converters will be used to distribute the power, as each can transfer up to 8W. These converters will be connected to the EDAC port via an overcurrent protection (fuse). They will set the input voltages from 30V to 5V to power the electronic components. Their main characteristics are: [22]

- Input voltage: 9 V -36 V.
- Number of outputs: 1 - 2
- Output voltage: 3.3V, 5V, 12V, 15V, 24V.
- Maximum output power: 8 W
- Operating temperature: -40 ° C to 85 ° C

Fig. 27. PBY10 DC to DC converter

1.5.14 Arduino mega:

The Arduino Mega is a development board based on the ATmega2560 microcontroller used for programming and control of the entire system; it was chosen for its ease of use, available libraries and low power consumption. It has 54 digital inputs/outputs (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs, a 16Mhz crystal, USB connection, DC power jack, ICSP connector, and a reset button.[23]

Fig. 28. Arduino mega

1.5.15 Electronic fan:

For the circulation of the stratospheric particles a fan will be used, which will be placed in a 3D printed piece (See fig 3.) in the upper part of the structure, this fan has the following features:

Features:
Rated voltage: 5V DC
Rated current: 100mA

Fig 29. DC fan brushless hydraulic bearing

1.5.16 Module SD and Micro SD memory:

SD memories are the most used for portable devices, for its large capacity and small size, due to its high demand are easy to get in different capacities and prices. These features give us a good storage alternative for use in Arduino, especially when we need to store large amounts of information.[24]

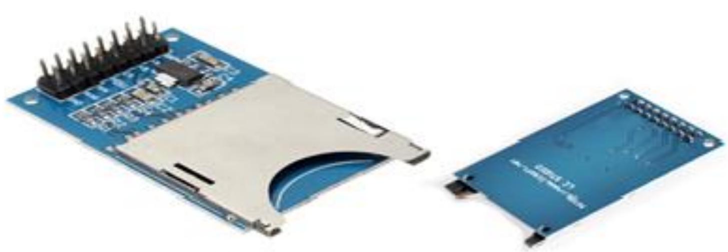


Fig. 30. SD module

1.6 Thermal Control Plan

This section will discuss the payload operating temperature range and the implementations that will be made to ensure that the payload remains operational.

The payload systems used are sensitive to low temperatures where their optimum temperature range is in the -10°C to 65°C range. However, the temperature range that the payload is exposed to during its trajectory to the stratosphere is -70°C to 24°C, so it is necessary to implement a thermal control system.

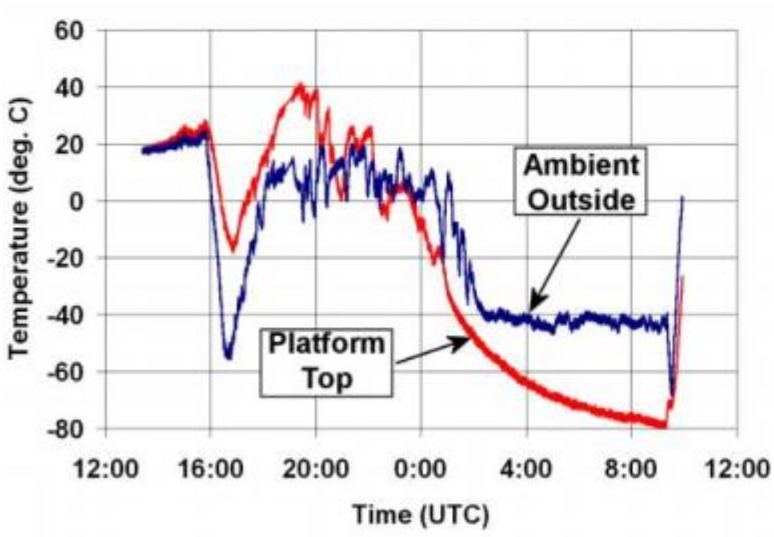


Fig. 31. Typical temperature during flight. (Source: HASP 2021 CFP)

1.6.1 Passive Control

The passive thermal control implemented in our payload consists of a Mylar thermal blanket coated with a BoPET (Biaxially Oriented Polyethylene Terephthalate) polyester film with a silver emissivity of 0.02; and 7075 aluminum reflective faces with a thermal conductivity of 134W/K°m, which will be coated with white epoxy to achieve high emissivity.

1.6.2 External thermal simulation

Parameters considered:

- External temperature: -60 °C
- Solar Radiation: 1380 w/m^2
- Air convection coefficient: 5 W/m^2K
- Air pressure: 0.7 atm
- External structure material: aluminum 7075
- Launch location: Fort Sumner, New Mexico, USA
- Launching coordinates: 13 S 569788 3815642 (UTM)

For the simulation, the number of faces exposed to solar radiation was taken into account; the incidence of radiation on a lateral face and on the lid of the project was taken into account. This is due to the fact that radiation does not necessarily fall on all the faces exposed to the environment. As a result, it can be observed that in the incident faces to the solar radiation there is a maximum temperature value of 40.6 °C and that in the unexposed or more distant faces the minimum temperature value is 21.1 °C, this indicates that externally, the project will be maintained at a temperature above 20 °C. Due to the external conditions and the low air flow, the values are not very high. The point chosen for the incidence of radiation is relative, since the project rotates in conjunction with the platform that supports it.

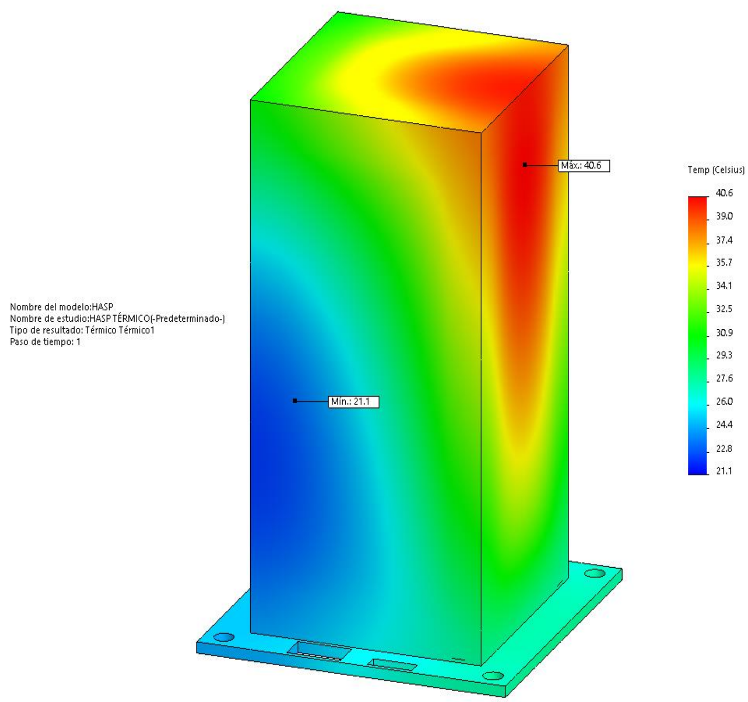


Fig. 32. External view of the analysis of the radiation temperature distribution over the external structure in SolidWorks® software.

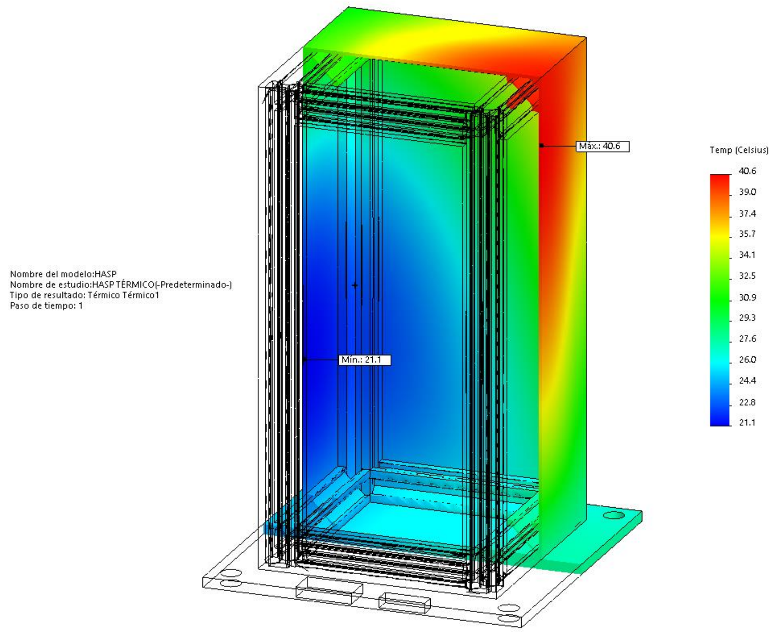


Fig. 33. Internal view of the analysis of the temperature distribution by radiation on the external structure in the SolidWorks ® software.

1.6.2 Internal thermal simulation

Parameters considered:

- External temperature: -60 °C
- Aluminum emissivity: 0.03
- Isotropic Thermal Conductivity of aluminum 7075: 120 W/mK
- Isotropic Thermal Conductivity of Polyethylene terephthalate glycol (PETG): 0.25 W/mK
- Isotropic Thermal Conductivity of electronic components:0.16 W/mK
- Launch location: Fort Sumner, New Mexico, USA
- Launching coordinates: 13 S 569788 3815642 (UTM)

For the internal simulation, two situations have been considered:

In the first scenario, the external temperature of the environment is 24ºC and there is heat transfer by natural convection of the air and conduction by each of the components. This case simulates the thermal conditions to which the payload will be subjected at the beginning of the launch. In the second scenario, the outside temperature is minus 60ºC and there is a heat transfer by radiation and conduction, this case simulates the thermal conditions to which the payload will be subjected in the stratosphere.

The temperature range within the payload is greater than 22ºC and maximum temperatures of 24ºC when the load is at a critical temperature of 24ºC and the heating pads are turned off to maintain a temperature.

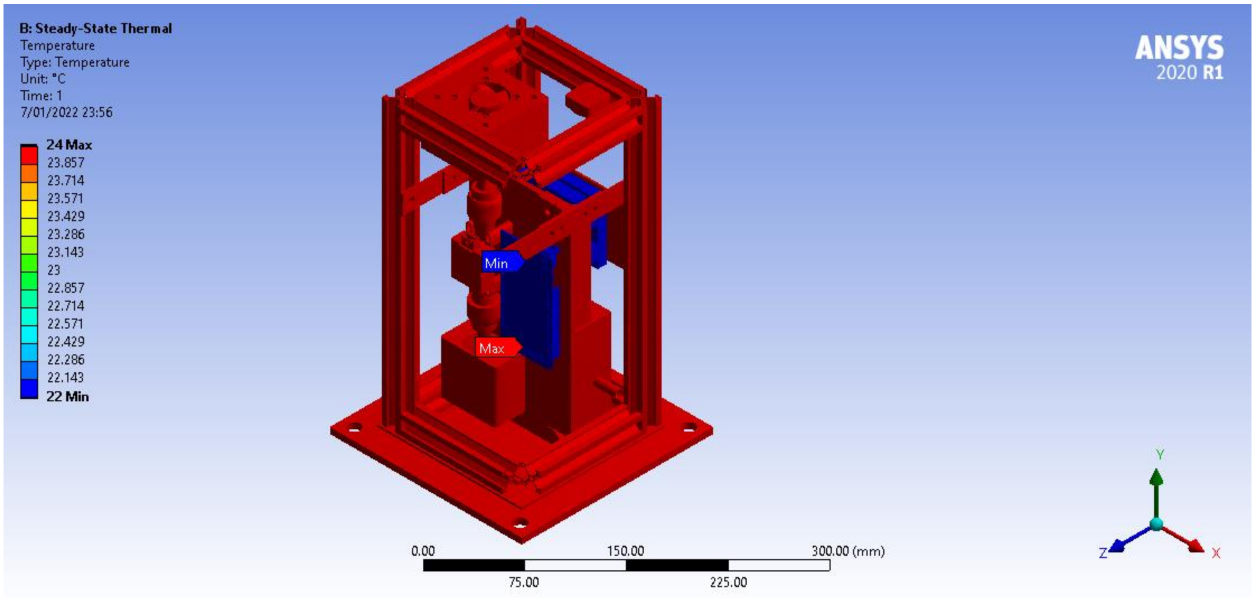


Fig. 34. The internal temperature of the payload considering an external temperature of 24ºC and the heating pad turned off.

The temperature range within the payload is greater than -10ºC and maximum temperatures of 42ºC when the load is at a critical temperature of -60ºC and the heating pads are turned on to maintain a temperature.

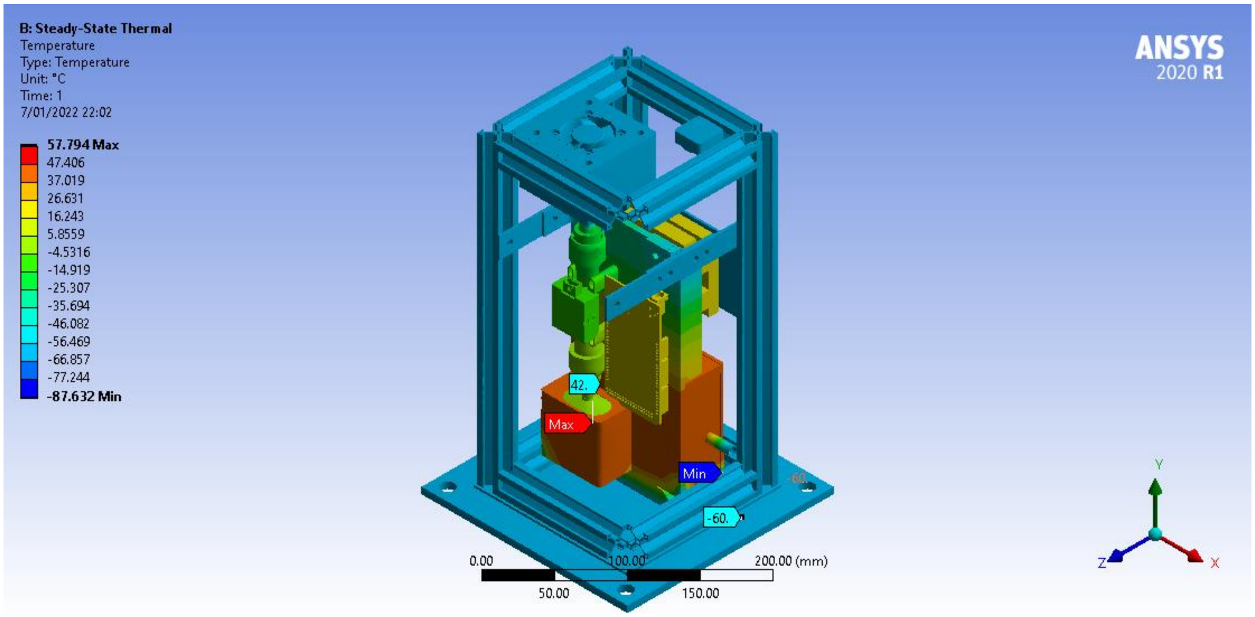


Fig. 35. The internal temperature of the payload considering an external temperature of -60ºC and the heating pad turned on.

1.6.3 Active Control

For active thermal control, two heating pads positioned at the base of the sensor box will be used, which will be controlled by a temperature sensor that will send the information to a microcontroller to regulate the on and off of the heating pads by means of the Intelligent PD control (see Fig. 36); in addition, a structural support printed in PETG has been designed for the cooler.

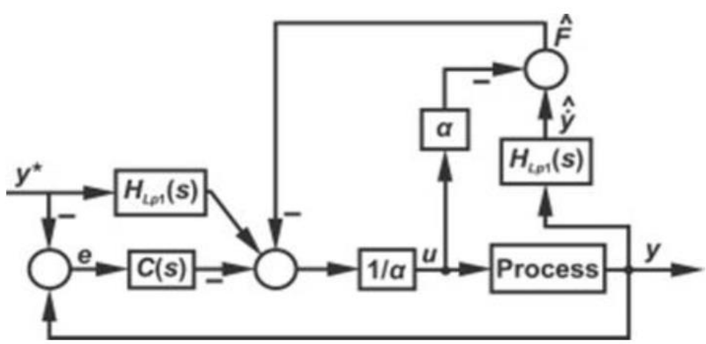


Fig. 36. iPD Control System [22] [25]

2. Team Structure and Management

2.1 Team Organization and Roles

The payload will be built by a team of students and alumni led by Martin Santos Salazar Macalupu who will be responsible for team management, monthly reporting and teleconferencing. Martin Salazar's engineering responsibilities will focus on the joint work of design, simulation and implementation of the different payload modules.

Luis Suarez Salas from the Subdirección de Ciencias Atmosféricas e Hidrosfera del Instituto Geofísico del Perú (IGP) is the advisor of the Wanka team and provides expert advice on operations and characteristics of the sensors to be installed in the payload.

2.1.1 Electrical section

The person in charge of the area will be María Nimia Muñoz Diaz, graduated in Physics Engineering from the Universidad Nacional de Ingeniería, who will be in charge of the development and implementation of the hardware and software reading, storing and transferring data.

The team is formed by:

Role	Name	Academic year	Institution	Contact information
Electronic team leader	María Nimia Muñoz Diaz	Graduate	Universidad Nacional de Ingeniería Lima-Perú	maria.munoz.d@uni.pe +51 951-048-134
Power distribution.	Miguel Morales Gonzales	Graduate	Universidad Nacional de Ingeniería Lima-Perú	miguel.morales.g@uni.pe +51 924-482-219
PMS	Lucas Nicolas Taipe Ramos	5	Universidad Nacional de Ingeniería Lima-Perú	ltaiper@uni.pe +51 920-594-837
Gas sensor programming	Michael Jean Pierre Quiquia Martinez	4	Universidad Nacional de Ingeniería Lima-	mquiquiam@uni.pe +51 946-227-847

			Perú	
Micro controller	Dario Adolfo Huanca Paredes	5	Pontificia Universidad Católica del Perú Lima-Perú	dario.huanca@pucp.edu.pe +51 957-742-086

2.1.2 Mechanical section

The team leader will be Antony Josel Dávila Paredes, a Mechanical Engineering graduate from the Universidad Nacional de Ingeniería, who will be in charge of the design and fabrication of the payload's general structure as well as the passive and active thermal protection and control system.

The team is formed by:

Role	Name	Academic year	Institution	Contact information
Mechanical team leader	Josel Dávila Paredes	Graduate	Universidad Nacional de Ingeniería Lima-Perú	adavilap@uni.pe +51 937-720-697
Structural design and manufacture	Julver Renaldo Marrufo Palli	5	Universidad Nacional de Ingeniería Lima-Perú	jmarrufop@uni.pe +51 917-315-573
Air flow system design and manufacture	Gaus Abdul Gonzales Sáenz	4	Universidad Nacional de Ingeniería Lima-Perú	ggonzaless@uni.pe +51 918-520-714
Thermal and mechanical simulation.	Michael Richard Celestino Cajavilca	Graduate	Universidad Nacional de Ingeniería Lima-Perú	michael.celestino.c@uni.pe +51 951-448-382
Structural simulation and CAD design	Zedrix Augusto Quispe Carrillo	4	Universidad Nacional de Ingeniería Lima-Perú	zaquispec@uni.pe +51 965-069-548

Heat transfer and flow simulations.	Giusep Alexander Baca Bernable	Graduate	Universidad Nacional de Ingeniería Lima-Perú	gbacab@uni.pe +51 997-218-987

2.1.3 Monitoring and data processing section

The person in charge of this area will be Germain Rosadio Vega, a 9th cycle student of the Faculty of Science at the National University of Engineering, this area will be responsible for developing a graphical interface for monitoring and displaying in real time the measurements of the various sensors incorporated in the payload, this will allow us to monitor the proper functioning of the sensors and take almost immediate action in case the payload is subjected to conditions that jeopardize the mission. The next task of the team will be to process the payload sensor data obtained during the entire launch, comparing them with data measured from other reference sources, and their respective visualization in the report.

Translated with www.DeepL.com/Translator (free version)

Role	Name	Academic year	Institution	Contact information
Data analysis team leader	Germain Rosadio Vega	5	Universidad Nacional de Ingeniería Lima-Perú	grosadiov@uni.pe +51 997-813-640
Data analysis	Ramiro Gustavo Tintaya Quispe	Graduate	Universidad Nacional de Ingeniería Lima-Perú	rtintayaq@uni.pe +51 954-154-873
Telemetry and command control	Lucas Nicolas Taipe Ramos	5	Universidad Nacional de Ingeniería Lima-Perú	ltaiper@uni.pe +51 920-594-837
Data processing	Gilmer Daniel Andreé Rosales Fernández	Graduate	Universidad Nacional de Ingeniería Lima-Perú	gilmer.rosales.f@uni.pe +51 910-240-861

2.2 Timeline and Milestones

Wanka management		
	START	END
New members integration	20-Sep-21	27-Sep-21
General meeting/Designation areas	27-Sep-21	4-Oct-21
Application due	1-Jan-22	6-Jan-22
Draft PSIP	1-Apr-22	15-Apr-22
Preliminary PSIP report	15-Apr-22	29-Apr-22
Final Draft PSIP	29-Apr-22	10-Jun-22
Final PSIP	10-Jun-22	24-Jun-22
FLOP Draft 1	19-Jun-22	4-Jul-22
FLOP Final draft due	2-Jul-22	12-Jul-22
Final FLOP documents due	12-Jul-22	22-Jul-22
Student Payload Integration at CSBF	25-Jul-22	29-Jul-22
Target Flight Ready/Target lunch date and flight operation/Recovering, packing and return Shipping	7-Sep-22	11-Sep-22
Final Flight/Science Report Due	24-Nov-22	9-Dec-22

Mechanical team		
	START	END
Study of the phenomenon and mechanical simulations	6-Jan-22	10-Jan-22
Manufacture of the metal structure	10-Jan-22	19-Feb-22

Thermal layer implementation	19-Feb-22	21-Mar-22
Temperature/Vacuum tests	21-Mar-22	20-Apr-22
Trouble shooting	20-Apr-22	20-May-22
Vacuum tests	20-May-22	16-Jun-22
Final mechanical test	16-Jun-22	25-Jul-22

Electronic Team		
	START	END
Component management	7-Jan-22	6-Feb-22
Sensor Programming and wiring	7-Feb-22	9-Mar-22
Sensor testing and calibration	9-Mar-22	13-Apr-22
Sensor testing	13-Apr-22	28-Apr-22
PCB printing and component soldering	28-Apr-22	18-May-22
Electronic components integration	18-May-22	22-Jun-22
Electronic tests	22-Jun-22	4-Jul-22
Sensor final test	19-Jun-22	25-Jul-22

2.3 Anticipated Participation in Integration and Launch operations

Before integration	1. Heat and fluid transfer analysis. 2. General structure and thermal control implementation. 3. Thermal vacuum testing and calibration of sensor modules. 4. Coupling of the sensor modules into the overall structure. 5. Final thermo-vacuum test.
Integration	1. Mount the payload module in the HASP. 2. Connect the HASP power connector. 3. Connect the HASP serial connection. 4. Read initial values for the system test. 5. Troubleshooting.
Pre-flight operations and tests	1. Connect the HASP power connector. 2. Connect HASP serial connection. 3. Check payload ground and payload size. 4. Test thermo vacuum and communications test. 5. Vibration/impact test of 10g vertical and 3g horizontal.
Flight operations	1. Data logging via sensors.
Post-flight operations	1. Complete payload checkout. 2. Removal of sensor modules from payload. 3. Test each module independently. 4. Data processing and analysis. 5. Final flight report due.

3. Payload Interface Specifications

3.1 Weight Budget

Item	Quantity	Mass(g)	Method of measurement	Uncertainty(g)
SHT31	1	0.75	According to instrumental measure	+-0.5
BME280	1	0.75	According to instrumental measure	+-0.5
MS5611/gy-63	1	1	According to instrumental measure	+-0.5
INA 219	1	2	According to instrumental measure	+-0.5
INA 219	1	2	According to instrumental measure	+-0.5
GPS-NEO6M	1	18	According to instrumental measure	+-0.5
Max3816 with RTD	1	39	According to instrumental measure	+-0.5
K-5S-O3-20	1	4	According to datasheet	Not specified
Micro SD Socket	1	7	According to instrumental measure	+-0.5
GP2Y101010AU 0F	11	17	According to instrumental measure	+-0.5
Electronic fan	1			
PMS5003	1	29	According to instrumental measure	+-0.5
PMS5003	1	29	According to instrumental measure	+-0.5
Flow sensor with step up	2	62	According to instrumental measure	+-0.5
Heating pad	1	4	According to instrumental measure	+-0.5
Heating pad	1	4	According to instrumental measure	+-0.5
Max3232	1	4	According to datasheet	Not specified
5 Mosfet	1	10	According to datasheet	Not specified
PYB10	1	47	According to instrumental measure	+-0.5
PYB10	1	47	According to instrumental measure	+-0.5

Mechanical design				
Aluminum side plates	4	974	Weighed on scales	+-0.5
Aluminum top plates	1	115	Weighed on scales	+-0.5
Aluminum base plates	1	123	Weighed on scales	+-0.5
Extruded aluminum profile 20x20x296mm	4	538	Weighed on scales	+-0.5
Extruded aluminum profile 20x20x106mm	8	385	Weighed on scales	+-0.5
Horizontal PETG bar	2	14	Weighed on scales	+-0.5
PETG Corner Angle Joint Bracket	4	11	Weighed on scales	+-0.5
PETG inner cover	1	36	Weighed on scales	+-0.5
PETG support	1	19	Weighed on scales	+-0.5
PETG PCB holder	1	139	Weighed on scales	+-0.5
PCB box	1	20	Weighed on scales	+-0.5
Mylar thermal blanket	1	11	Weighed on scales	+-0.5
TOTAL		2708.5		

3.2 Power Budget

Two PBY10 converters are connected to the 30V pins of the EDAC through a 0.5A fuse to protect the payload. These converters will distribute the 15 watts that the HASP provides as it is shown in figure 38. The first PBY10 transmits 2.693 W and the second PBY10 transmits 6.495 W, transmitting a total power of 9.188 W. The power consumption of each component is explained in Table 1. Power consumption of each sensor. The sensors that require 3.8 and 10V are the BME280 and Sensor flow respectively, the voltage of 10v is obtained by a step up converter, this component converts from 5 V to 10 V and the other voltage of 3.8V will be provided by the arduino mega. Also MOSFETs have been used to control the on/off switching of some sensors and actuators(heating pad, flow sensor and PMS5003).

Item	Voltage(V)	Average current(mA)	Current (mA)	Power (W)	Comments
SHT31	5	0.528	0.53	2.65m	Humidity and temperature sensor
BME280	3.8	3.6	3.6	13.68u	Pressure, Temperature and Humidity Sensor
MS5611/gy-63	5	1.37	1.4	7m	Pressure sensor
INA 219	5	0.713	0.72	3.6m	Voltage and current sensor
INA 219	5	0.68	0.72	3.6m	Voltage and current sensor
GPS-NEO6M	5	60.44	66	330m	Global positioning system
Max3816 with RTD	5	2.95	2.97	14.7m	
MQ131	5	124	125	622m	Ozone sensor
Micro SD Socket	5	3.3	3.35	17m	Memory
GP2Y101010AU0F	5	1.6	1.83	9.15m	particle sensor
Electronic fan	5	43	49	245m	Fan
PMS5003	5	38.33	52.6	263m	Air quality sensor
PMS5003	5	38.33	52.6	263m	Air quality sensor
Flow sensor with step up	5	29	33	145m	Flow meter
Heating pad	5	590	625	3.125	
Heating pad	5	590	625	3.125	
Max3232	5	1	1	5m	
K-5S-O3-20	5	200	200	1	Ozone and gas sensor
5 Mosfet	5	1.4	1.4	7m	
TOTAL				9.188	

3.3 Downlink Serial Data

The downlink stream will contain most of the information provided by the sensors of this mission, as it is intended to be a backup in the extreme case that the mission's internal memory fails.
As specified in the HASP, our small payload will send the data stream at a baud rate of 1200 with the parameters of 8 bits, no parity and a stop bit.
In Table 8, the string structure was configured as suggested in the interface manual.
In the information packet, information such as internal and external temperature, pressure, the aerosol concentration data obtained by the PMS5003 and GP2Y1010AU0F sensors and the O3 concentration are included.

This data package has a size of 203 bytes, and will be sent each 15 seconds, this results in 109 bits per second. which was calculated as it was stated in the Call for Payloads.

Byte	Bits	Description
1	0-7	Record Type Indicator
2-5	0-31	Timestamp(seconds since January 1,1970)
6-9	0-31	Timestamp(nanoseconds past the last second)
10-12	0-23	Record size
13	0-7	Least significant 8 bits of the record checksum
14	0-7	Start of heading (SOH)
15	0-7	Start of text (STX)
16-21	0-47	BME280 humidity in ASCII
22-27	0-47	BME280 temperature in ASCII
28-35	0-63	GY-63 pressure in ASCII
36-41	0-47	GY-63 temperature in ASCII
42-46	0-39	GP2Y1010AU0F data in ASCII
47-51	0-39	PMS1 particles > 0.3um/0.1L in ASCII
52-55	0-31	PMS1 particles > 0.5um/0.1L in ASCII
56-59	0-31	PMS1 particles > 1um/0.1L in ASCII
60-62	0-23	PMS1 particles > 2.5um/0.1L in ASCII
63-64	0-15	PMS1 particles > 5um/0.1L in ASCII
65-66	0-15	PMS1 particles > 10um/0.1L in ASCII
67-69	0-23	PMS1 1.0 concentration (Standard particle)
70-72	0-23	PMS1 2.5 concentration (Standard particle)
73-75	0-23	PMS1 10 concentration (Standard particle)
76-78	0-23	PMS1 1.0 concentration (Under atmospheric environment)
79-81	0-23	PMS1 2.5 concentration(Under atmospheric environment)

82-84	0-23	PMS1 10 concentration(Under atmospheric environment)
85-89	0-39	PMS2 particles > 0.3um/0.1L in ASCII
90-93	0-31	PMS2 particles > 0.5um/0.1L in ASCII
94-97	0-31	PMS2 particles > 1um/0.1L in ASCII
98-100	0-23	PMS2 particles > 2.5um/0.1L in ASCII
101-102	0-15	PMS2 particles > 5um/0.1L in ASCII
103-104	0-15	PMS2 particles > 10um/0.1L in ASCII
105-107	0-23	PMS2 1.0 concentration (Standard particle)
108-110	0-23	PMS2 2.5 concentration (Standard particle)
111-113	0-23	PMS2 10 concentration (Standard particle)
114-116	0-23	PMS2 1.0 concentration (Under atmospheric environment)
117-119	0-23	PMS2 2.5 concentration(Under atmospheric environment)
120-122	0-23	PMS2 10 concentration(Under atmospheric environment)
123-127	0-39	Honeywell flow sensor in ASCII
128-133	0-47	RTD temperature in ASCII
134-139	0-47	SHT31 humidity in ASCII
140-145	0-47	SHT31 temperature in ASCII
146-148	0-23	INA219(1) current in ASCII
149-151	0-23	INA219(2) current in ASCII
152-155	0-31	INA219(1) voltage in ASCII
156-157	0-31	INA219(2) voltage in ASCII
158-168	0-87	GPS-module Latitude in ASCII
169-179	0-87	GPS-module Longitude in ASCII
180-188	0-71	GPS-module time in ASCII
189-190	0-87	GPS-module date in ASCII
191-195	0-39	K5SO3 O3 ppm in ASCII

196-200	0-39	K5SO3 analog value.
201	0-7	End of text (ETX)
202	0-7	Carriage return (CR) in ASCII
203	0-7	Line Feed (LF) in ASCII

Here it is shown an example of the string as it will be used in the launch.

19999312021961;75.77;190;5;80.24;10.52;1001.22;10.60;0.53;2.5;3.0;10;5;13;15;23;12;13;0.72;-5.51;15.82;02.52;0.32;0.15;29.5;3.5;-12.016667;-77.050369;03;11;44;07;01;2021;1201;2.5

3.4 Uplink Serial Commanding

According to the experience of Wanka I, the uplink commands have been reduced. This time, only independent commands for switching the heating pads on and off, for temperature control, as well as the control of the fan on and off for airflow control will be used.
Finally, we will control the power supply of the flow sensors and both PMS7003 sensors, in case of failure or erroneous reading.

Name	Command ID	Description
Fan OFF	F5x01	Turning off the fan.
Fan ON	E5x02	Turning on the fan.
HP 1 OFF	D5x03	Turning off the Heating Pad 1.
HP 1 ON	C5x04	Turning on the Heating Pad 1.
HP 2 OFF	B5x05	Turning off the Heating Pad 2.
HP 2 ON	A5x06	Turning on the Heating Pad 2.
HP1-HP2-ON	95x07	Turning on both heating pads.
HP1-HP2 OFF	85x08	Turning off both heating pads.
FLOW OFF	75x09	Turning off the airflow sensor
FLOW ON	65x0A	Turning off the airflow sensor.
PMS1 OFF	55x0B	Turning off the PMS5003(1) sensor.
PMS2 ON	45x0C	Turning on the PMS5003(1) sensor.
PMS2 OFF	35x0D	Turning off the PMS5003(2) sensor.

PMS2 ON	25x0E	Turning on the PMS5003 (2) sensor.
PMS1_2 OFF	15x0F	Turning off both PMS5003 sensors.
PMS1_2 ON	F5x11	Turning on both PMS5003 sensors.

3.5 Analog Downlink

This mission does not require analog downlink information.

3.6 Discrete Commanding

This mission does not require discrete commanding.

3.7 Payload Location and Orientation Request

Most of the experimental targets are independent of the physical location in the HASP nacelle. WANKA successfully flew on the 2021 HASP mission at position 5 on the platform, which is suitable also for the 2022 flight (see Fig. 37). The payload mounting is not orientation dependent, as the sensors are mounted vertically.

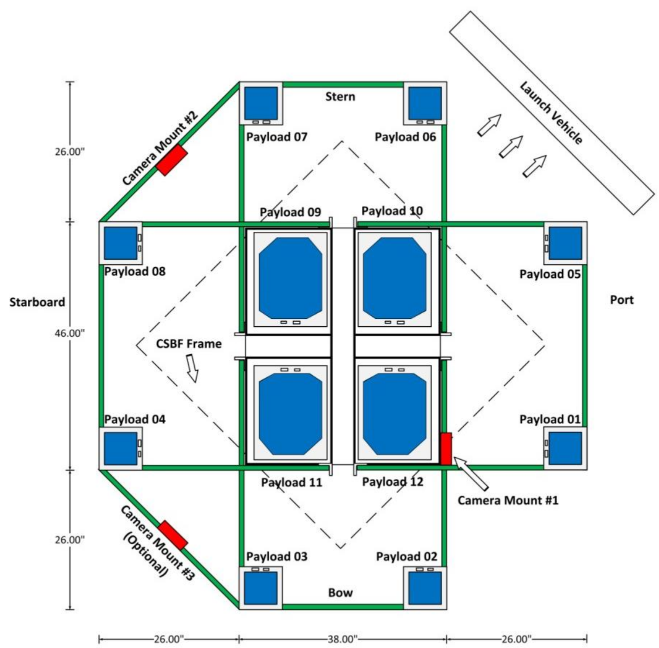


Fig. 37. Top down view of the HASP student payload positions [26]

3.8 Special Requests

There is no special request.

4. Preliminary Drawings and Diagrams

4.1 Power Distribution Diagram

The Fig 38. Power Distribution Diagram shows the connection diagram of the sensors and actuators for their respective functions. In the first part you can see the interface (the EDAC connector) that offers the HASP to power our circuit and that will be connected to the PYB10 converters to then feed all the electronic components.
The description of the diagram, the red line that represents the connections to the 5VDC, 10VDc and 3.8VCD, the black line that represents the connections to the GND and finally the blue line that represents the connections of data capture or sending.

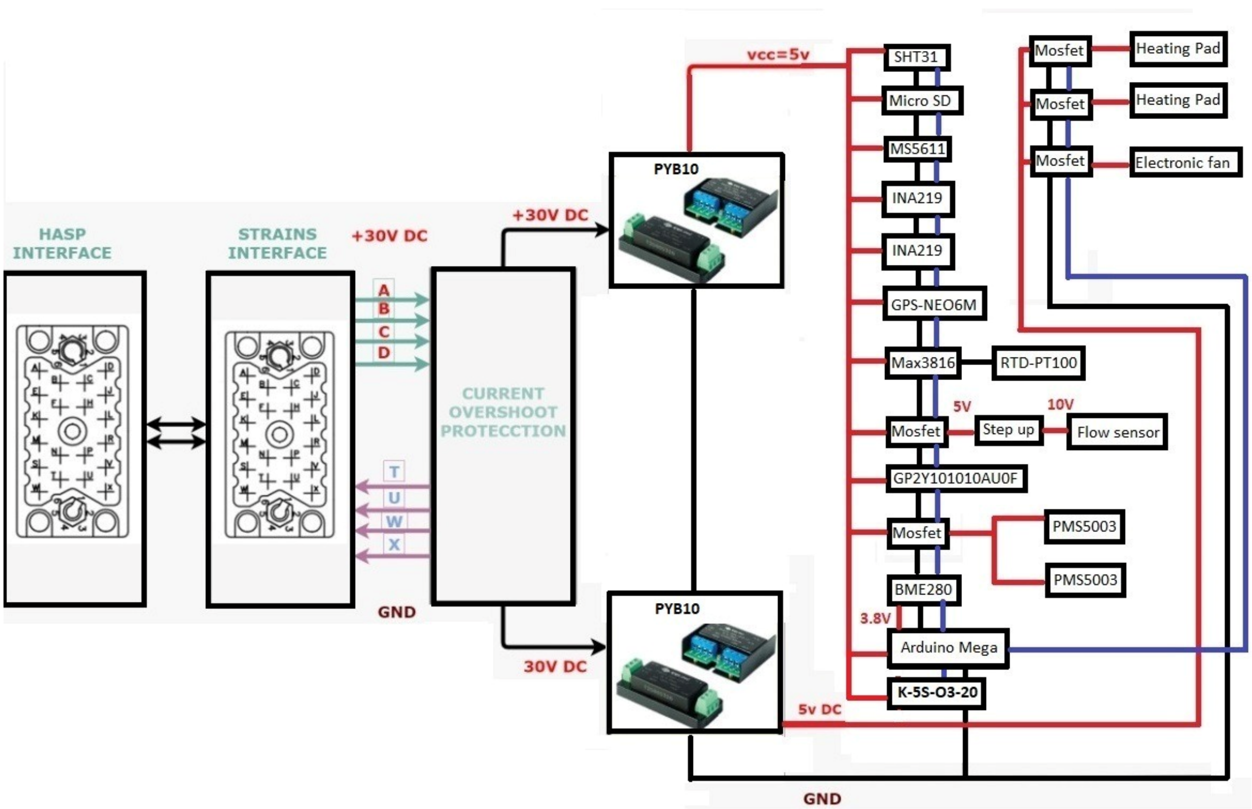


Figure 38. Power Distribution Diagram

4.2 Electrical components distribution

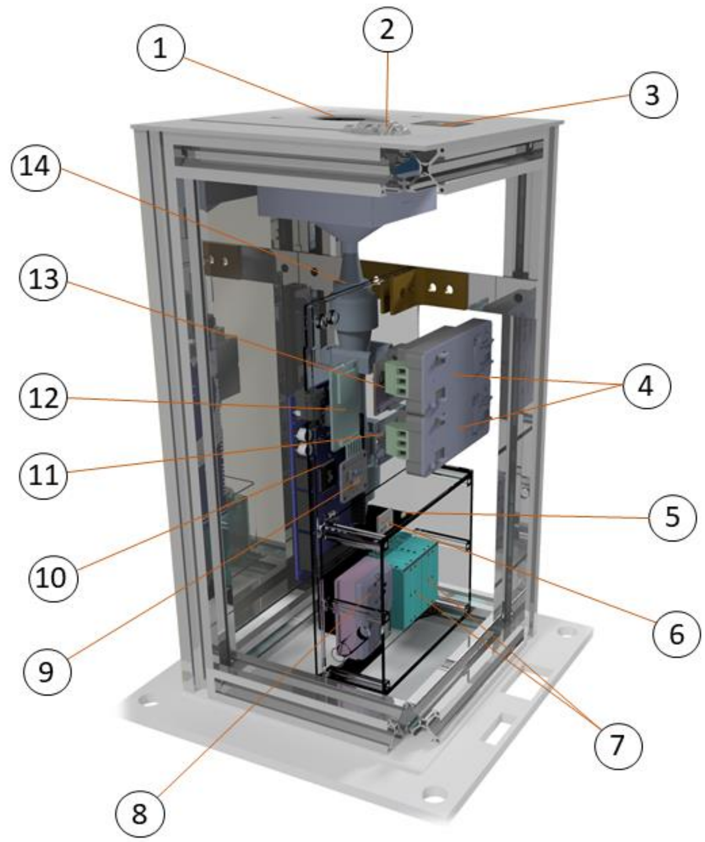


Fig. 39.view of the distribution of electrical components on the payload

Item	Name	Quantity
1	Electronic fan	1
2	RTD	1
3	GPS antenna	1
4	PYB10	2
5	MS5611/gy-63	1
6	BME280	1
7	PMS5003	2
8	GP2Y101010AU0F	1
9	INA 219	2

10	Arduino Mega	1
11	NEO6M	1
12	Micro SD Socket	1
13	Max3232	1
14	Flow sensor with step up	1

4.2 Overall payload dimensions

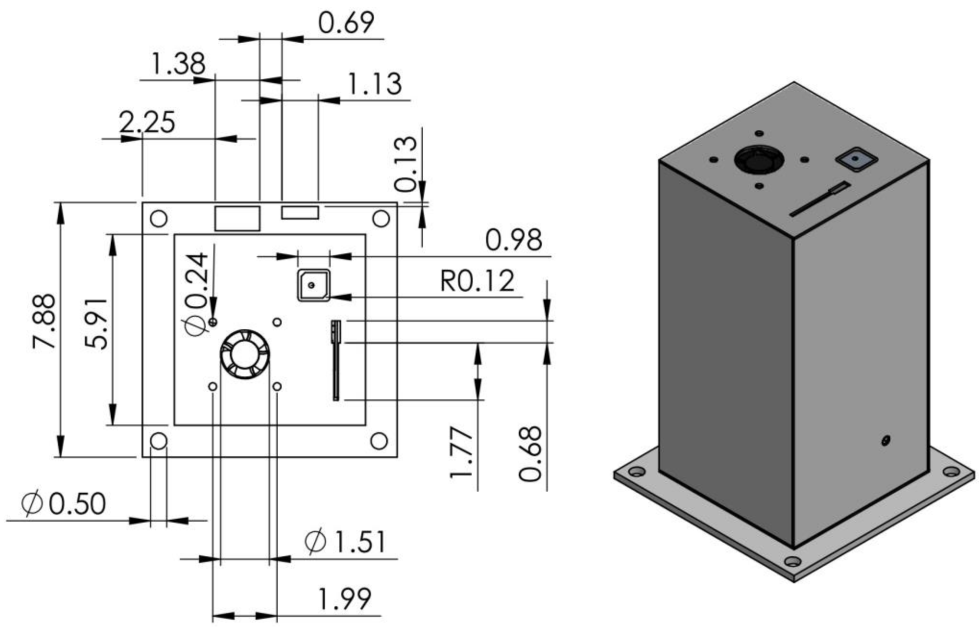


Fig. 40. Payload top view dimensions in inches

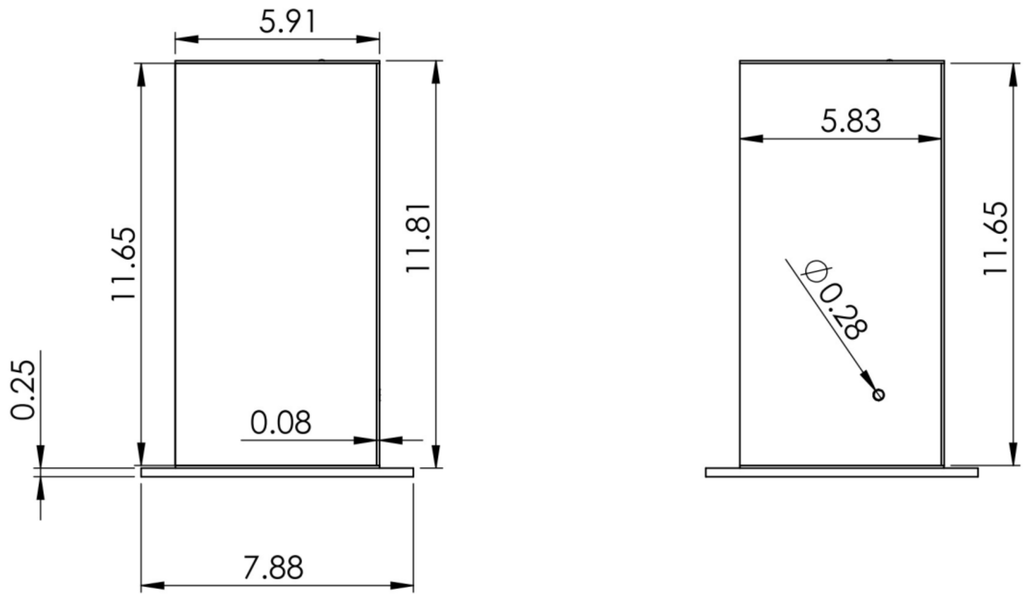


Fig. 41. Payload front view dimensions in inches

5. References

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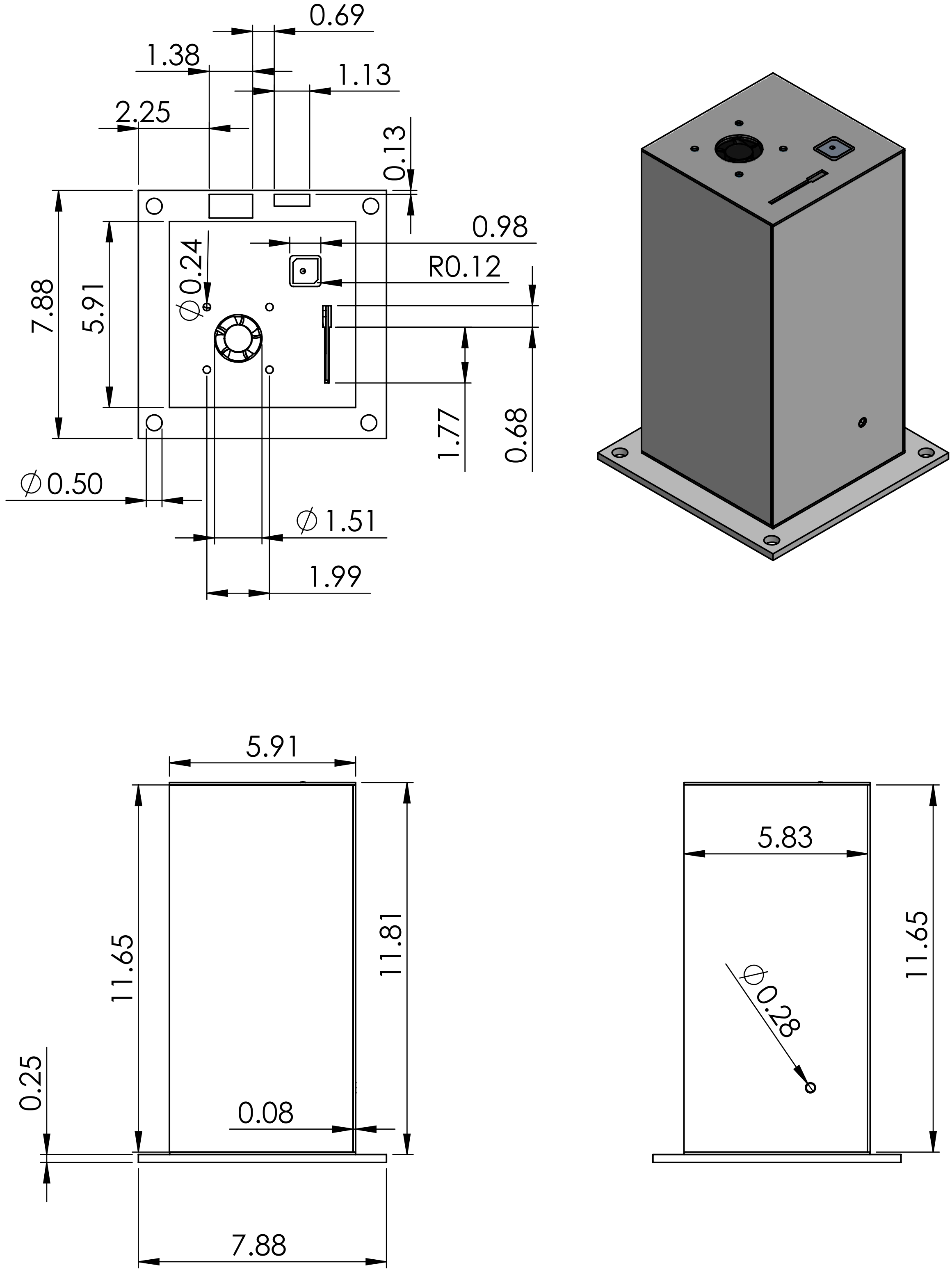
[25]12 HASP Student Payload Interface Manual (Version 10132021)

Appendix B: NASA Hazard Tables

Appendix B.3 Laser Hazard Documentation

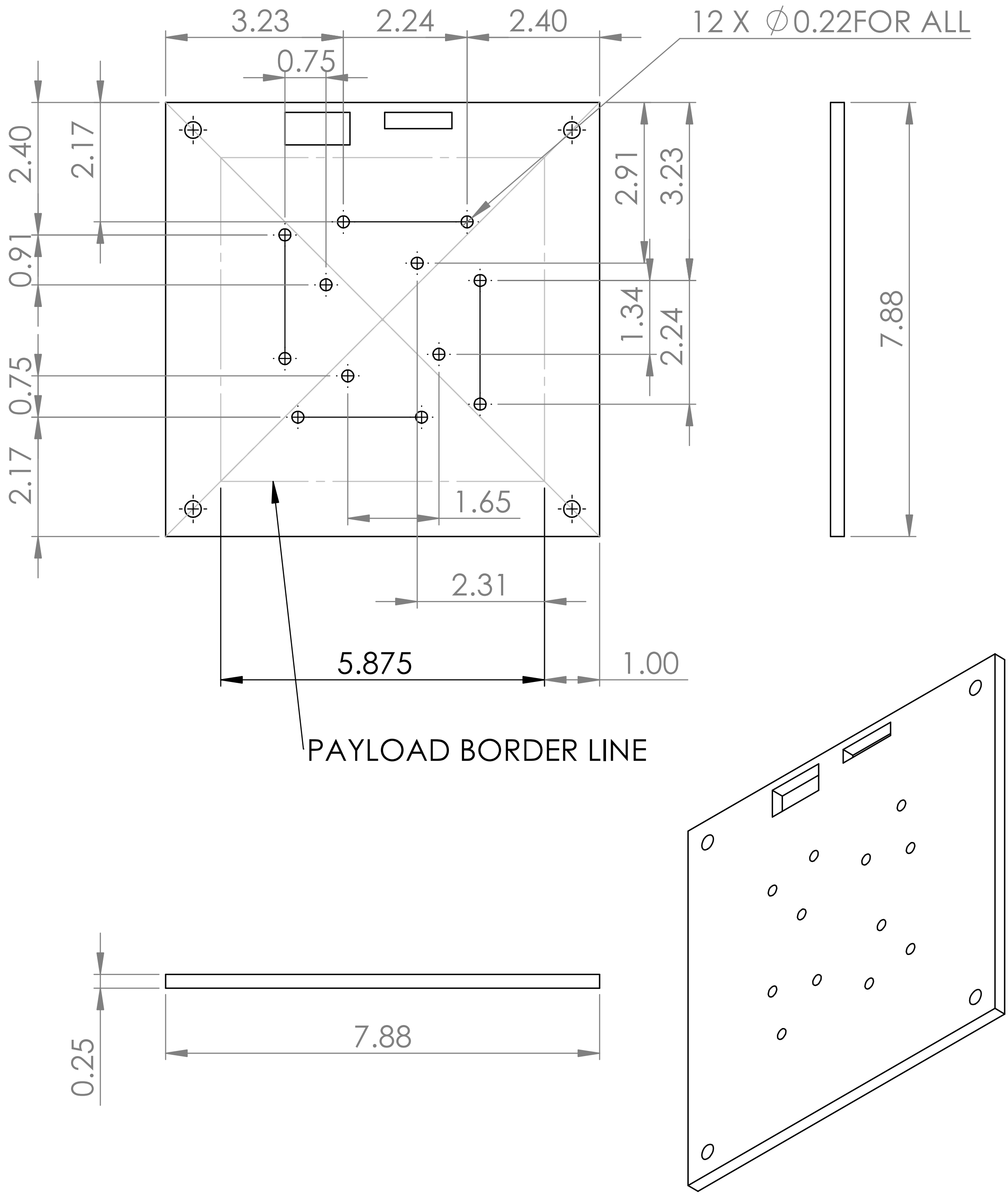
HASP 2022 Laser Hazard Documentation			
Manufacture Model		PMS5003	
Part Number			
Serial Number		B202008221421	
GDFC ECN Number			
Laser Medium		Air	
Wave Type		*Multiple Pulsed*	
Interlocks		*None*	
Beam Shape		*Circular*	
Beam Diameter (mm)	3.25	**Beam Divergence (mrad)**	74.965
Diameter at Waist (mm)	2	**Aperture to Waist Divergence (cm)**	0.475
Major Axis Dimension (mm)	3.25	**Major Divergence (mrad)**	276.012
Minor Axis Dimension (mm)	3.25	**Minor Divergence (mrad)**	74.965
Pulse Width (sec)	0.2	**PRF (Hz)**	0.5
Energy (Joules)	1 mJ per pulse	**Average Power (W)**	0.005
Gaussian Coupled (e-1, e-2)			
Single Mode Fiber Diameter			
Multi-Mode Fiber Numerical Aperture (NA)			



DRAWING NAME:

WANKA II

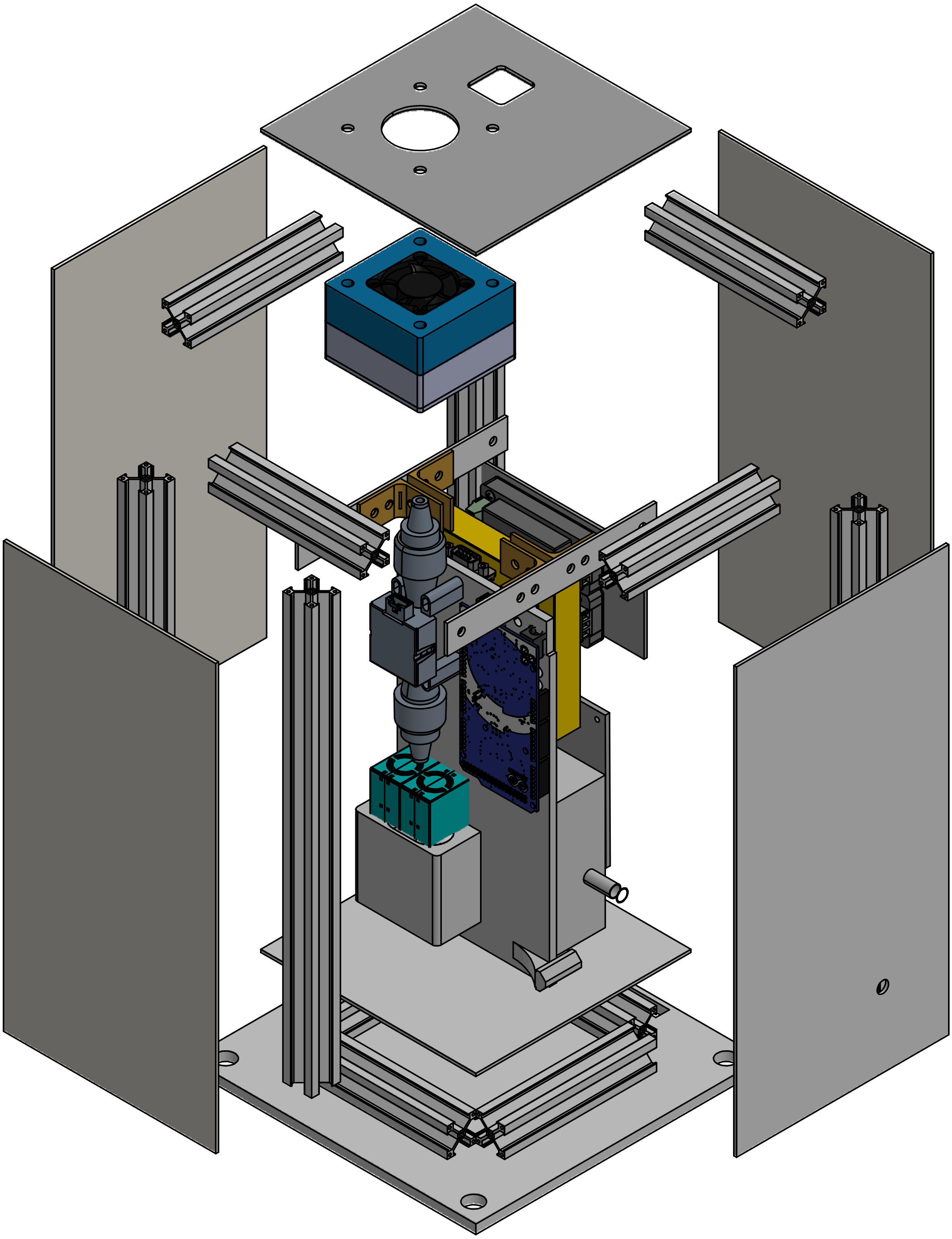
SCALE: 1:5	UNITS: INCH	1



DRAWING NAME:

PLATE INTERFACE

SCALE:1:5	UNITS: INCH	2



DRAWING NAME:

EXPLODED VIEW

SCALE: 1:3	UNITS: Inch	A4