HASP Student Payload Application for 2016

Payload Title: Ozone Sensors Payload and its Applications (OSPA).		
Payload Class: (circle one) Small Large	**Institution:** University of North Florida (UNF) And University of North Dakota	**Submit Date:** 12-17-2015

Project Abstract:

UNF-UND team have successfully flown payloads on the HASP balloon flights since 2008 and measured the ozone gas profile in the stratosphere. The ozone profiles measured by sensors payloads were nearly matched with the expected profile. Based on the success, experience and the few known technical issues of the previous payloads, the UND-UNF team proposes the HASP 2016 flight for the development of improved version of payload to measure ozone profile using high sensitive and selective ozone gas sensor arrays and also to measure pollutant gases in the atmosphere and troposphere. The output of the proposed payload will help us for the development of free flying small gas sensors payload instrument for meteorological weather balloon, rocket or sub orbital space vehicle and may be used at Antarctica for the long duration of balloon flight. The new version of eight nanocrystalline ITO thin film gas sensors array and eight nanocrystalline alpha phase of silver tungstate thin film gas sensors array will measure oxidizing ozone gas, while eight nanocomposite SnO_2+ITO thin film gas sensors will detect the pollutant gases such as smog, CO, CO_2, methane in the atmosphere and troposphere. These thin film sensors have higher sensitivity, good selectivity and stability and also faster response time. Temperature controller will be used to control operating temperature of all gas sensors at about 302 K. Three sensors boxes will be mounted on the three sides of rectangular payload body. The new UV light photodiode will be mounted just below ozone gas sensors box in order to measure amount of photovoltage generated by UV light, which will support the science concept of generation of ozone gas in the presence of UV light. This concept will help us understanding the effect of darkness or shadow on the gas sensors and decrease of ozone gas concentration at the night time. In addition, new pressure sensor will measure the low pressure about 1 mbar. GPS will measure the altitude throughout the flight without any blockage of transmission. Ozone and pollutant gas sensors will be fabricated and calibrated by the students' team at UNF and also tested at UND. The modified version of developed payload may use to fly on the long duration of balloon flight at Antarctica, which is our dream and long term goal.

Team Name: OSPA		Team or Project Website: N/A	
Student Team Leader Information:		Faculty Advisor Contact Information:	
Name:	Brittany Nassau (Leader),	Dr. Ronald Fevig	Dr. Nirmalkumar G. Patel
Department:	Engineering	Space Studies	Physics
Mailing Address:	University of North Florida 1 UNF Drive	University of North Dakota Clifford Hall, Room 512 4149 Uni. Ave Stop 9008	University of North Florida 1 UNF Drive
City, State,	Jacksonville, FL 32224	Grand Forks, ND 58202	Jacksonville, FL 32224
Email:	Brittany.Nassau@gmail.com	rfevig@space.edu	npatel@unf.edu
Office Phone:	904-620-1670	701-777-2480	904-620-1670
Cell Phone:	904-495-1765	520-820-3440	904-200-2855
FAX:	904-620-1989	701-777-3711	904-620-1989

HASP2016 Proposal

Ozone Sensors Payload and its Applications (OSPA)

Submitted by

University of North Florida (UNF) and University of North Dakota (UND)

UNF Students Team:
Brittany Nassau (Leader), Ken Emanuel (Consultant),
Jesse Lard, Chris Farkas, Caleb Grantham, Joseph Silas, Matthew Linekin,

UND Student:
Chris Follette

Faculty Advisors:
Dr. Ronald A. Fevig (UND) and
Dr. Nirmalkumar G. Patel (UNF)

Proposal Index

1. Project Summary

The UNF and UND team have successfully flown payloads on the HASP balloon flights since 2008 and measured the ozone gas profile in the stratosphere. The measured ozone profiles were nearly matched with the theoretical expected profile. Based on the success of last few flights and the few known technical problems of these payloads, the UNF-UND team proposes the HASP 2016 flight for the development of improved version of payload to verify generation of ozone and measure ozone profile in the stratosphere and also to detect the pollutant gases in the atmosphere and troposphere. The output of the proposed payload will help us for the further development of free flying small gas sensors payload instrument for meteorological weather balloon, rocket and suborbital space vehicle.

New version of 8 Nanocrystalline Indium Tin Oxide (ITO) thin film gas sensors will be used to detect ozone gas. In addition, 8 newly developed nanocrystalline alpha phase of silver tungstate (α- Ag_2WO_4) thin film gas sensors will be used to detect ozone gas, Improved version of 8 nanocomposite SnO_2+ITO thin film gas sensors will be used for detection of pollutant gases such as smog, CO, CO_2, methane in the atmosphere and troposphere. The operating temperature of all gas sensors will be maintained constant at 302 K using a temperature control circuit. Three sensors boxes will be mounted on the three sides of rectangular payload body. New ultra violet photodiode will be mounted just below ozone gas sensors box in order to measure amount of photovoltage generated by UV light, which will support the science concept of generation of ozone gas in the presence of UV light. This science concept will help us understanding the effect of any dark shadow on the gas sensors, particularly at the time of sunset and also how much ozone gas concentration decrease at the night time. In addition, a temperature sensor to measure the temperature, new pressure sensors to measure the low pressure. The tested GPS will measure the altitude throughout the flight without any blockage of transmission. GPS antenna will be mounted outside of the payload for the better performance. Payload data communication will be performed by the HASP communication link. Measured data will be monitored in real-time mode and converted into the plots by the LabVIEW software program. The other software will also allow us to convert RAW files directly into one EXCEL file.

Gas sensors will be fabricated and calibrated with ozone gas in the low pressure chamber at UNF and also tested at UND. Then, gas sensors and other transducers will be integrated with the electronics circuit and software to complete the payload. The developed sensor payload will meet all the requirement of the HASP such as weight, size, power, communication and thermal vacuum test for the balloon flight. Furthermore, the surface topography of the sensors before and after the flight will be studied using a scanning electron microscope (SEM), and the chemical composition of the surface of the sensors will be analyzed by an energy dispersive analysis of x-rays (EDAX) at UNF. This student project may be supported by both Florida and North Dakota Space Grant Consortia.

2. Significance of Project

Nanocrystalline oxide semiconductor thin films gas sensor arrays technology (U. S. Patent Pending) and ITO-QCM (Quartz Crystal Microbalance) sensor platform technology (Patented) are being developed by Dr. Patel at the University of North Florida (UNF) for the detection of toxic gases, explosive materials and chemical warfare agents with support of the Edgewood Chemical Biological Center, US Army Laboratory, APG, and the U.S. Department of Defense. Nanocrystalline gas sensors have also been used for the detection of ozone gas in the stratosphere. Nanocrystalline indium tin oxide (ITO) gas sensors were successfully tested and calibrated with ozone gas at the Kennedy Space Center (KSC) and at the UND during 2008-2009. UNF team is improving the performance of ozone sensors by changing its fabrication conditions and modifying its surface structure every year after HASP balloon flight. These sensors were successfully tested on HASP 2008 to 2015 flights (Ambler *et al,* 2008). We have made step by step improvement of sensors, hardware, and software every year. UNF ozone sensors were also used by the students of Louisiana State University, University of Central Florida, Iowa State University and Taylor University for their weather balloon projects.

The proposed development and fabrication of different types of gas sensors and payload have several unique features. ITO gas sensor arrays have higher sensitivity and stability because of the nanocrystalline thin film structure. Earlier reported work on tungsten oxide sensors for the detection of ozone gas (Hansford *et al*., 2005) required a high operating temperature of about 450°C to detect ozone, while the UNF developed nanocrystalline ITO sensors arrays operate at the room temperature and do not require a heater, which ultimately saves power requirements and space, and also minimizes the possibility of an accidental fire. The UNF developed alpha phase of silver tungstate thin film gas sensors have better sensitivity and selectivity for detection of ozone gas at low pressure, while nanocomposite SnO_2+ITO thin film gas sensors have better selectivity for detection of pollutant gases such as smog, CO, CO_2, SO_2 and methane, etc. UNF developed gas sensors arrays are very small in size, have low weight and low power consumption, which meets the payload requirements for the space applications. These gas sensors can easily be integrated with microcontroller electronic circuits. Compared to the conventionally costly spectroscopic and other reference methods for the detection of ozone, our gas sensors payload has low cost and low weight for the rapid detection of gases in the troposphere and stratosphere.

3. Work Plan for the Proposed Science Experiment

3.1 Pervious Flight

The proposed work is in continuation of the previous flight. Overview of output of the last HASP 2015 flight is given in fig.1 (a). The flight picture and ozone profile are also shown in fig. 1(a).

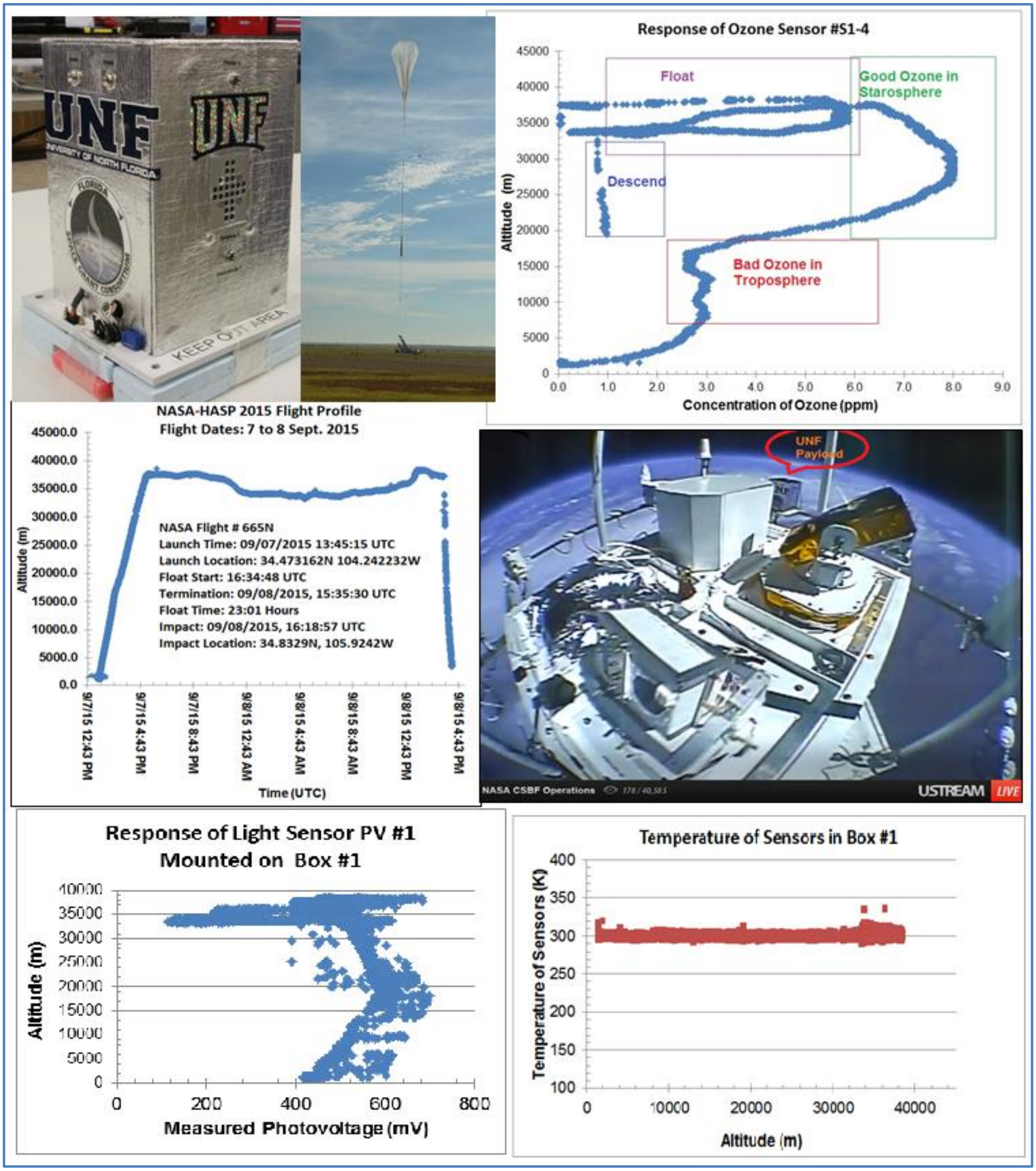


Fig. 1(a) HASP 2015 payload, launch, profile, response of sensor, payload in the stratosphere, response of light sensor and temperature stability of sensors box #1

3.2 Proposed Work Plan

Based on the success and few known technical problems with the HASP balloon flights made during previous flights, the UND-UNF team proposes a HASP 2016 flight with following new objectives for the measurement of ozone profile in the stratosphere using improved version of the gas sensors payload.

(i) New and improved version of gas sensors

New version of 8 nanocrystalline ITO thin film gas sensors (Box#1) will be used for detection of ozone gas. Improved version of 8 nanocrystalline α- Ag_2WO_4 (alpha phase of silver tungstate) thin film gas sensors (Box#2) will also be used for the measurement of ozone gas profile in the stratosphere, while new version of 8 nanocomposite SnO_2 + ITO thin film gas sensors (Box#3) will be used for the measurement of pollutant gases such as smog, CO, CO_2, methane in the atmosphere and troposphere. Students of UNF will fabricate ITO thin film gas sensors using an electron beam deposition method. Three sensors boxes (#1, 2 and 3) will be mounted on the three sides of rectangular payload body. We did not able to use α- Ag_2WO_4 sensors in the previous flight due to constrain of time and some issue of reproduction of alpha phase of silver tungstate.

We are interested to develop new ozone sensors having smaller in size for better performance. We may be able to fabricate nano size gas sensors and use it in the next flight. We have recently placed a purchase order of Electron Beam Lithography (www.raith.com) and hopefully it will be installed in our Scanning Electron Microscope (FEI, Quanta 200D) during spring 2016.

All ozone gas sensors will be tested and calibrated simultaneously in the low pressure chamber in order to minimize the experimental error for the trend line equations of the plots for converting the electrical resistance values into the concentration of ozone in the part per million (ppm). The pressure and temperature inside the test chamber will be maintained same as in the stratosphere. Reducing gas sensors will be tested and calibrated with combination of few reducing gases.

Each sensors box will have 8 gas sensors, 1 flexible heater, 1 temperature sensor and 1 mini fan. Three sensors boxes will be mounted on three side of cubic payload body. Gas molecules can enter in the sensor box through perforated holes on the payload body. Fan will protect the surface of sensor by blowing away dust particles in the atmosphere and ice particles in the troposphere. Temperature of ozone gas sensors will be maintained nearly constant at about 304±5 ^{o}K using the temperature controller. Flexible heater (MINCO or OMEGA make) and temperature sensor (Analog Device TMP 36) will be mounted on the back side of gas sensors.

(ii) New UV light sensors

We have recently purchased UV light photodiodes and will be used to improve the spectral response. New GaP (FGAP71) UV photodiode was purchased from http://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=285&pn=FGAP71.

This photodiode has wavelength range 150 to 550 nm and peak wavelength of 440 nm, which is shown in Fig. 1(b).

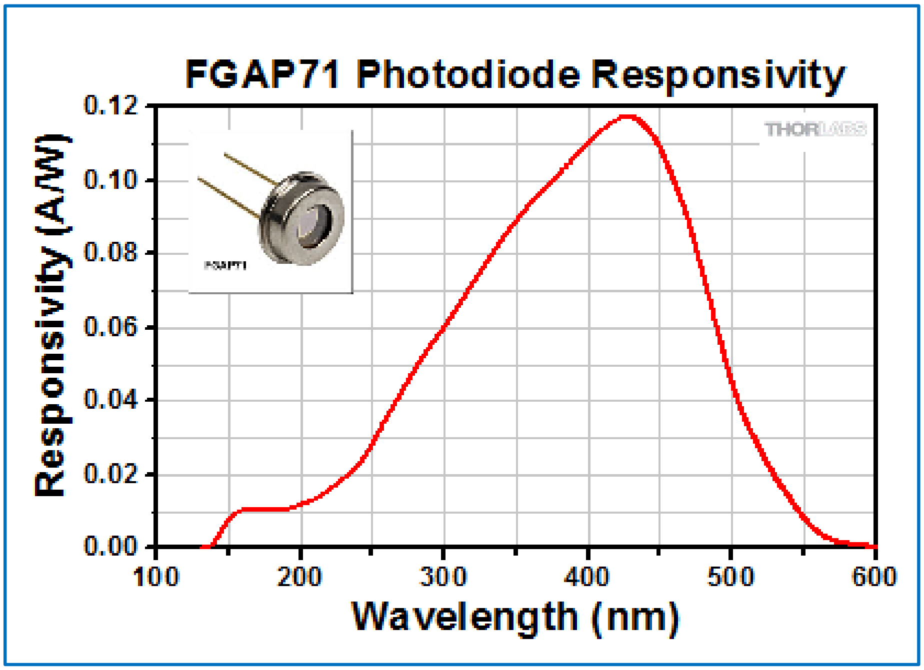


Fig. 1(b) Response of FGAP photodiode (Courtesy: www.thorlab.com)

Photodiode will be mounted just below the gas sensors box on each side of the payload body. The photodiodes will support the verification of science concept of generation of ozone in the presence of UV light. The amount of photo voltage generated and measured by the photodiodes will indicate how much of UV light available to interact with oxygen to convert into ozone gas near to ozone gas sensors. Our gas sensors arrays will detect and measure the concentration of that generated ozone gas. This **science concept** will also help us to understand the effect of any shadow or darkness on the sensors surface, particularly at the time of sunset and decrease of ozone concentration at the night time.

(iii) New Low Pressure Sensor

It was observed that the pressure sensor used in the previous flight was worked from atmosphere to 100 mbar and then saturate. We propose to replace it by new pressure sensor, which can measure the pressure up to 10 mbar or below.

The new sensors may be purchased from

(i) http://www.meas-spec.com/product/Pressure/MS5540C.aspx or

(ii) (ii) http://www.omega.com/pptst/PX170.html

(iv) **GPS**:
The current UBLOX GPS worked well during last flight. The antenna of GPS was installed away from the payload body and worked well. We will use the same GPS again. The payload GPS data will be cross verified and compared with the HASP GPS data.

(v) **Improved and thermally stable payload body:**
A single hollow aluminum tube structure will be used to make the payload body. The body work will be almost same as the last flight. This design will reduce the numbers of screws and nuts and hence weight of the payload. This will also allow us to open and close the payload easily for access of the hardware. We will try to reduce the mass of the body. The inner surface of body may have very low outgassing at the low pressure.

Thermal blanket made of aluminized heat barrier having adhesive backed (Part No. 1828- or equivalent) (Make: www.PegasusAutoRacing.com) will be applied on the payload for the improvement of thermal stability. The silver surface of the thermal blanket has high reflection with wide range of wavelength of light and hence capable of withstanding radiant temperatures in excess of 1000^{o}C.

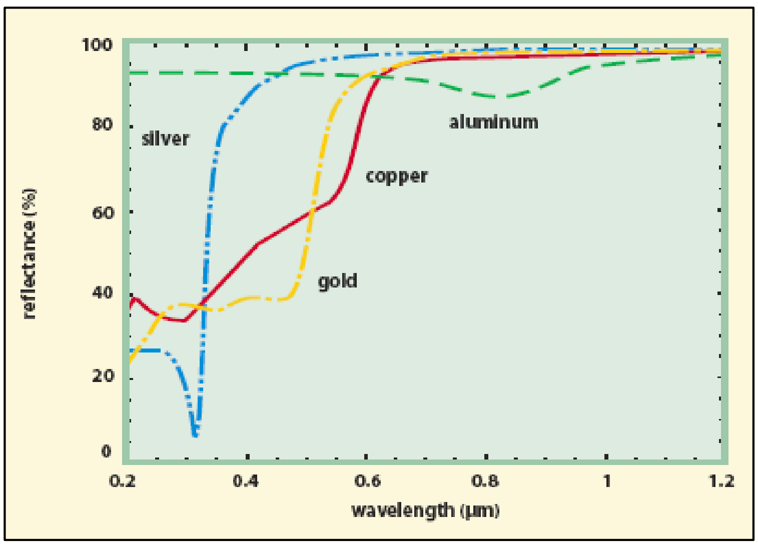


Fig.1(c) Variation of reflectance with wavelength of light from different color of surfaces
Courtesy: http://www.photonics.com/EDU/Handbook.aspx?AID=25501

(vi) **Improved version of software**
New software will allow us to convert all RAW files directly into one EXCEL file. Then, calibration trend line equations will be applied to convert the change in resistance values of sensors into the concentration of ozone gas in ppm. In addition, new LabVIEW program will allow us the quick monitoring of data and viewing of the plots during the thermal vacuum test and also during the flight.

(vii) Use of SEM+EDAX
The surface topography of the sensors before and after the flight will be studied using a scanning electron microscope (SEM) (FEI, Quanta 200D), and the chemical composition of the surface of the sensors will be analyzed by energy dispersive analysis of x-rays (EDAX) at UNF under supervision of Dr. Patel.

(viii) **Radio - Optional objective**: We are interested to add the 900 MHz or higher frequency radio for the data communication of data. This will depend upon the financial support and clearance of all the paper work and permission. If it will be possible, then, we will inform to Dr. Guzik and Michael Stewart about all required changes in the payload. We are interested to communicate our data using the HASP communication link as well as the payload radio. Government certified radio in the payload may be turned on or off by up linking of the command from the ground. Radio circuit will have an antenna and may operate by battery backup or HASP power. We want to test our technological concept for the communication. This will help us to build a free flying payload for our future venture.

3.3. Fabrication of Gas Sensors Arrays

Nanocrystalline ITO thin film gas sensors array (UNF patent pending) will be fabricated over the ultrasonically and chemically cleaned glass substrates. Fig. 2(a) shows the top view of 8 sensor arrays and the interface printed circuit board. Fig. 2(b) shows a scanning electron micrograph of one ITO thin film gas sensor having two gold electrodes for the external electrical contacts. Fig.2(c) shows a scanning electron micrograph of nanocrystalline gains of the ITO thin film, while the sensor boxes are shown in fig. 2(d).

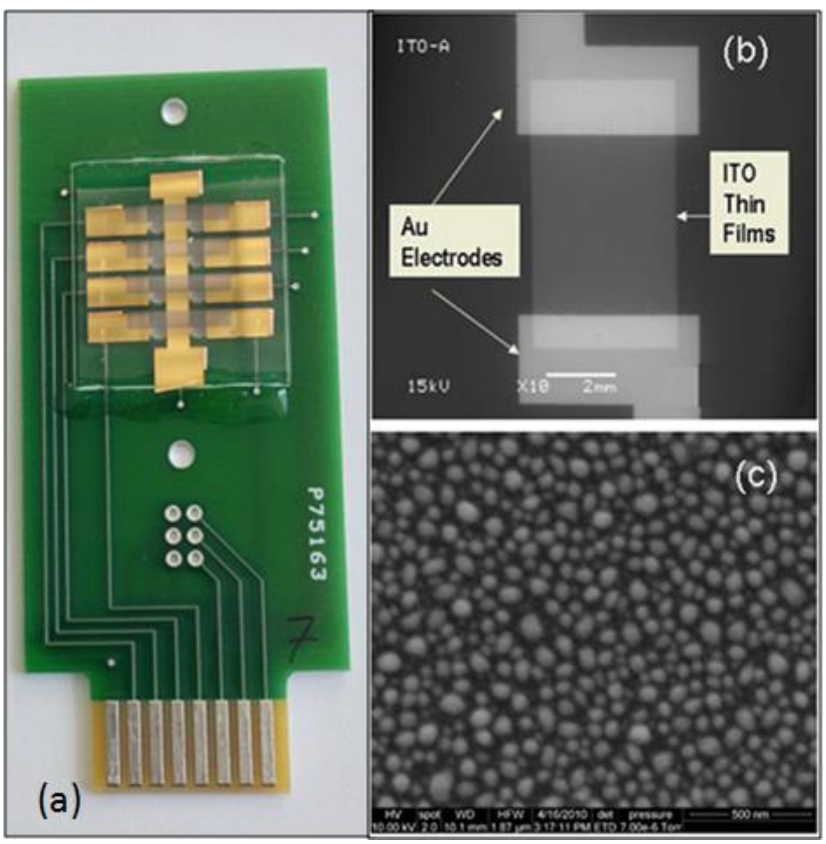


Fig.2 (a) 8 sensor array and interface mini PCB, scanning electron micrograph of (b) top view of one ITO gas sensor, and (c) nanocrystalline grains of ITO thin film

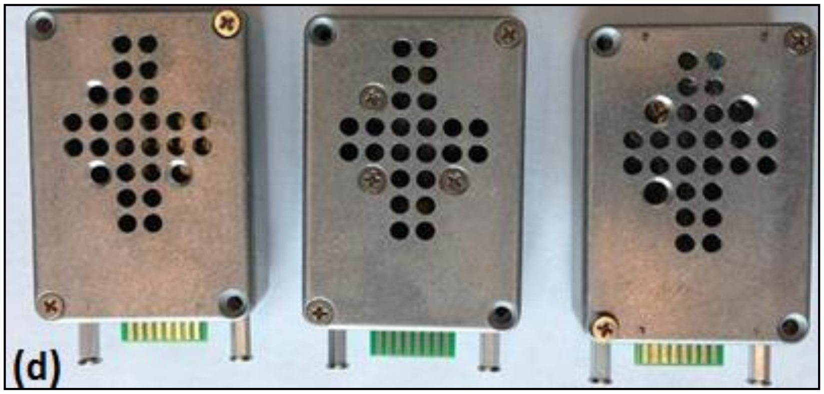


Fig.2 (d) sensors boxes

Three different types of gas sensor arrays boxes will be fabricated at UNF. Each box will have 8 gas sensors, one heater, one temperature sensor and one fan (Fig. 3).

Box#1: 8 nanocrystalline ITO (Indium Tin Oxide) thin film gas sensors for detection of ozone gas in the stratosphere.
Box#2: 8 nanocrystalline α-Ag_2WO_4 (silver tungstate) gas sensors for detection of ozone gas.in the stratosphere.
Box#3: 8 nanocomposite SnO_2-ITO thin film gas sensors for detection of pollutant gases in atmosphere and troposphere.

Each type of sensor array box will have different sensor characteristic parameters for the detection of gases.

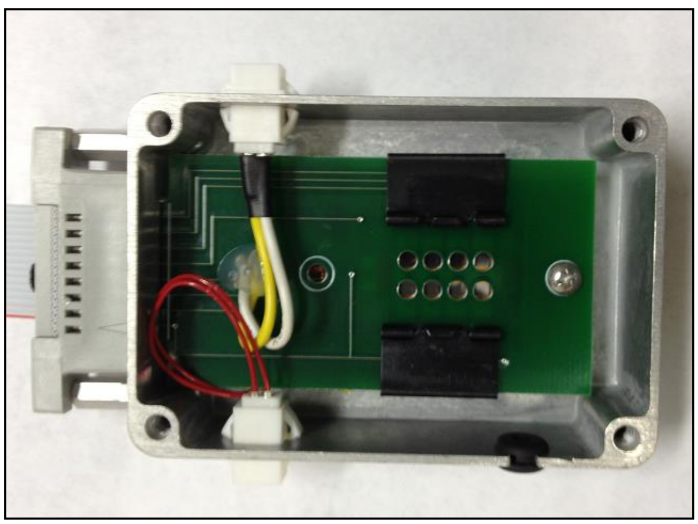


Fig. 3 Schematic diagram of sensor array box

The sensor array will be interfaced with the printed circuit board and its 16-pin female card edge connector and flat cable. Sensors will be tested and calibrated with ozone under low pressure at UNF. An ozone generator (Ozone Solutions, Model# OMZ-3400) will be used as the source of ozone, which generates 0 to 12 ppm ozone gas. A digital ozone detector (Eco Sensors, Inc., Model:A-21ZX) will be used to measure the concentration of ozone. Keithley electrometer and multimeter with LabVIEW software will be used to measure ressirance of all sensors simulataneously in the test chamber. The parameters of trendline equations of calibration plots will be used for the determination of concentration of ozone.

3.4 Working Principle of Gas Sensors

Interaction of oxidizing gas on surface of n-type ITO thin film sensor

Upon adsorption of charge accepting molecules at the vacancy sites, namely from oxidizing gases such as ozone (O_3), these electrons are effectively depleted from the conduction band of ITO. This leads to an increase in the electrical resistance of n-type ITO.

For example: ozone gas:

Oxygen vacancy (V) + Ozone (O_3) →Lattice Oxygen site (O_o) + O_2

Vacancies can be filled by the reaction with ozone. Filled vacancies are effectively electron traps and as a consequence the resistance of the sensor increases upon reaction with ozone.

Interaction of reducing gas on surface of n-type ITO thin film sensor

Oxygen vacancies on ITO surfaces are electrically and chemically active. These vacancies function as n-type donors decreasing the electrical resistivity of ITO. Reducing gases such as CO, H_2 and alcohol vapors result in detectable decreases in the electrical resistance of n-type ITO.

For example: methanol:

CH_3OH (methanol) + O^- (chemisorbed ion on surface of ITO)

→ HCOH (Formaldehyde) + H_2O (water) + e^- (electron)

Vapors come in contact with the surface and react with chemisorbed oxygen ions O- or O^{2-} and re-inject electrons into the conduction band.

In summary, the electrical resistance of ITO increases in the presence of oxidizing gases such as ozone. Upon adsorption of the charge accepting molecules at the vacancy sites, namely oxidizing gases such as ozone, electrons are effectively depleted from the conduction band, leading to an increase in the electrical resistance of n-type ITO. Note that our three different types of sensors boxes have n-type semiconductor gas sensors.

3.5 Mechanical Specifications of Payload:

The proposed 2016 payload body will be similar to the last year payload body. The important features of our newly designed payload body are easy to open and close the payload, easy access of PCB and sensor boxes, low rate of outgassing under low pressure, better stability with thermal and impact, and also reusable. The payload metal parts were procured payload from the supplier www.onlinemetals.com.

We are trying to replace an aluminum square tube by a fiber glass or carbon composite square tube in order to reduce the weight of payload and improve the thermal stability. We may order the fiber glass tube from http://www.eplastics.com/Fiberglass-FRP-Round-Square-Tubing. Currently, this company is not offering 6 inch square tube. This company informed us few months back that they may introduce 6 inch square tube in the market in near future.

The weight budget of various parts of the payload is given in the table-1.

Table-1 Payload weight and dimension budget

Item:	**Dimension**	**Mass (g)**
8 Ozone sensors box #1 (including fan, heater, box)	**Each box**	**200.0±2.0**
8 Ozone sensors box #2 (including fan, heater, box)	**3 x 2 x 1 inch**	**200.0±2.0**
8 Pollutant sensors box#3 (including fan, heater, box)	=76.2x50.8x25.4 mm	**200.0±2.0**
Microcontroller PCB with mounted components	**4x 6 inch** =101.6 x152.4 mm	**300.0±1.0**
Payload body, top plate and thermal blanket	**9 x 6 x 6 inch** =228.6x152.4x152.4 mm	**1100±10.0 g**
Few Cables, 1 GPS, 2 LEDs, 3 Photodiodes, nuts and bolts		**150±5.0 g**
HASP mounting plate	**7.9 x 7.9 inch** =200.6x200.6 mm	**550±3.0 g**
Total estimated mass of the payload and HASP plate		**2700±25.0 g**

Joe (UNF) did the design drawing and Matthew did fabrication work of the payload body of HASP2015. They will do it again this time. Design diagrams of payload are shown in Fig. 4 (a) to (k). The estimated dimensions of payload of HASA 2016 will be about 228.6 mm x 150 mm x 150 mm, which will be within the requirement of being less than 300 mm x 150 mm x 150 mm. There may be possibility to reduce proposed dimension as well as design.

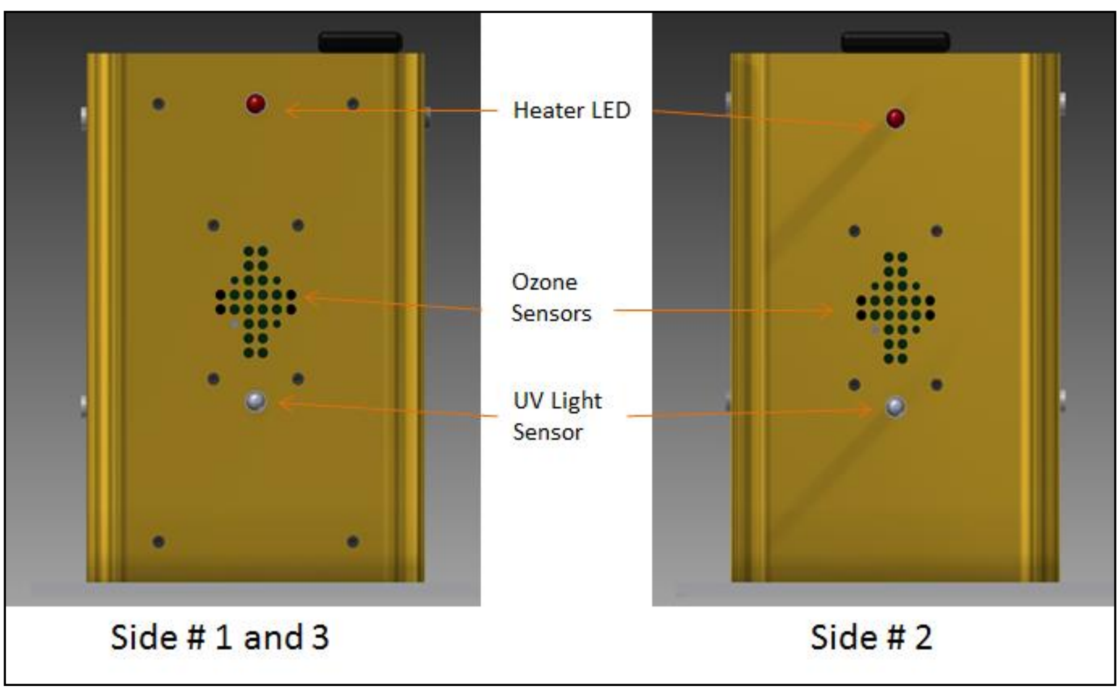


Fig. 4 (a) Side view design of the payload

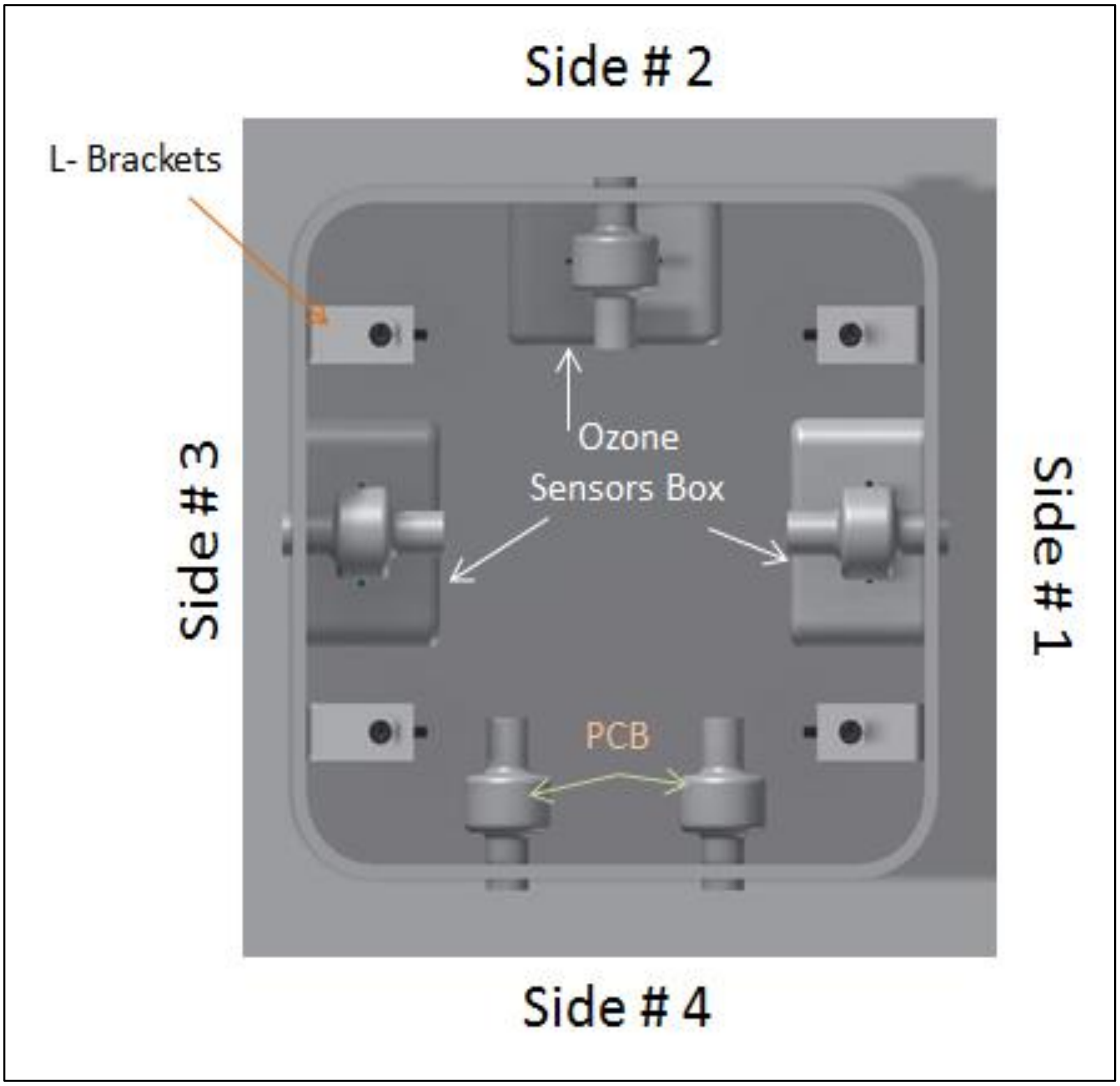


Fig. 4 (b) Top view design of the payload

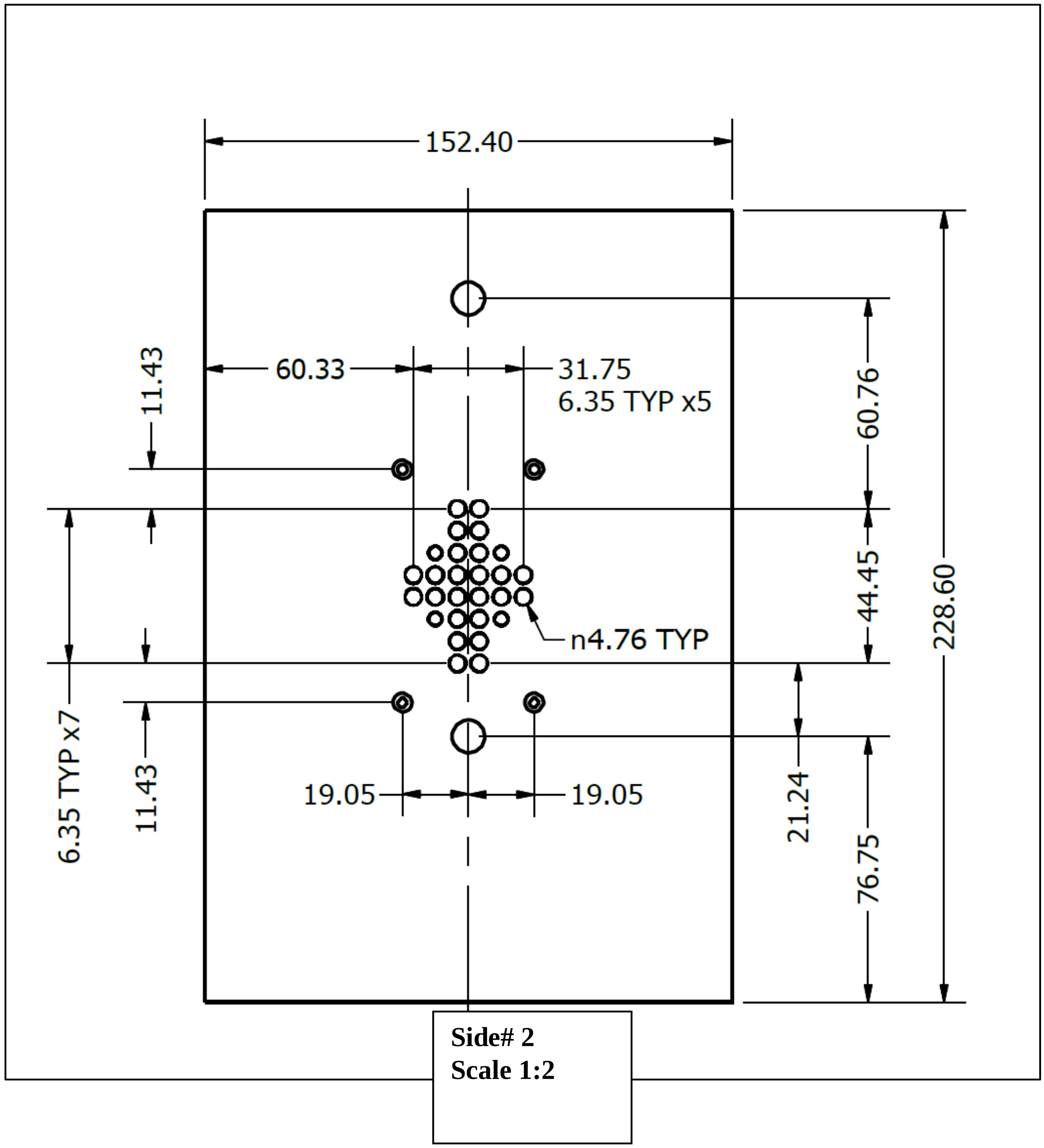


Fig. 4 (c) Design of side # 2 of the payload
All dimensions are in mm.

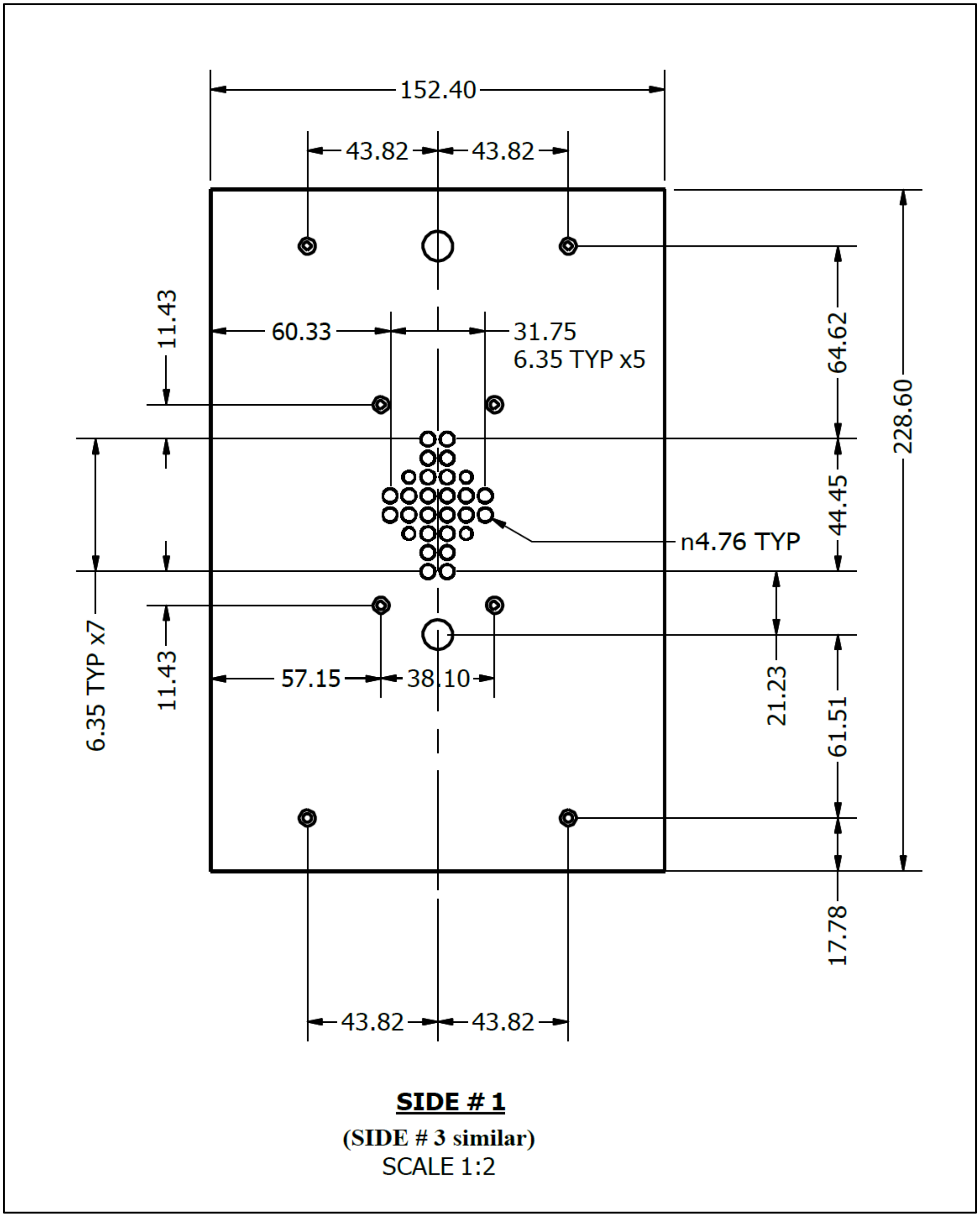


Fig. 4(d) Design of sides # 1 and 3 of the payload.
All dimensions are in mm.

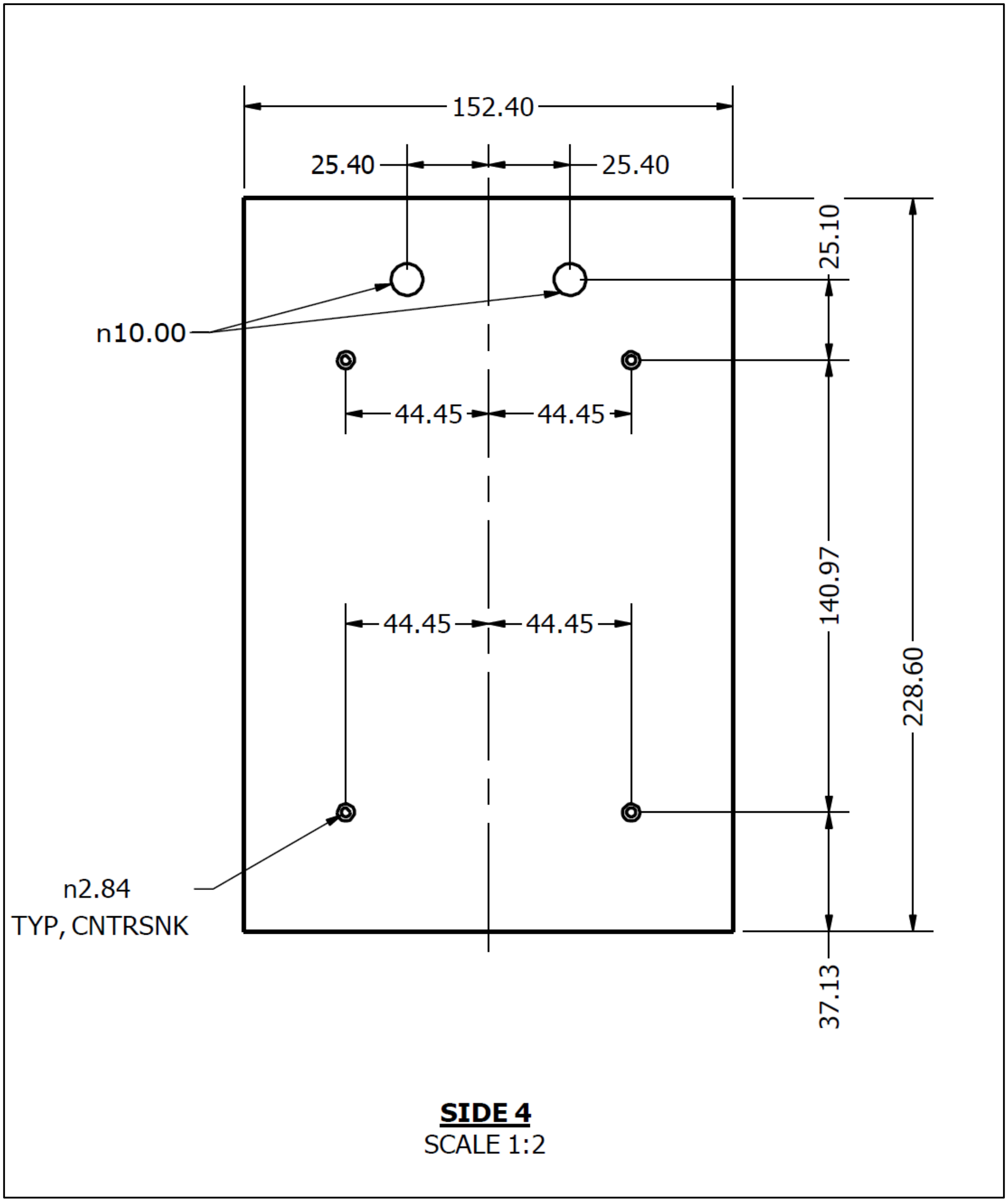


Fig. 4(e) Design of side # 4 of the payload
All dimensions are in mm.

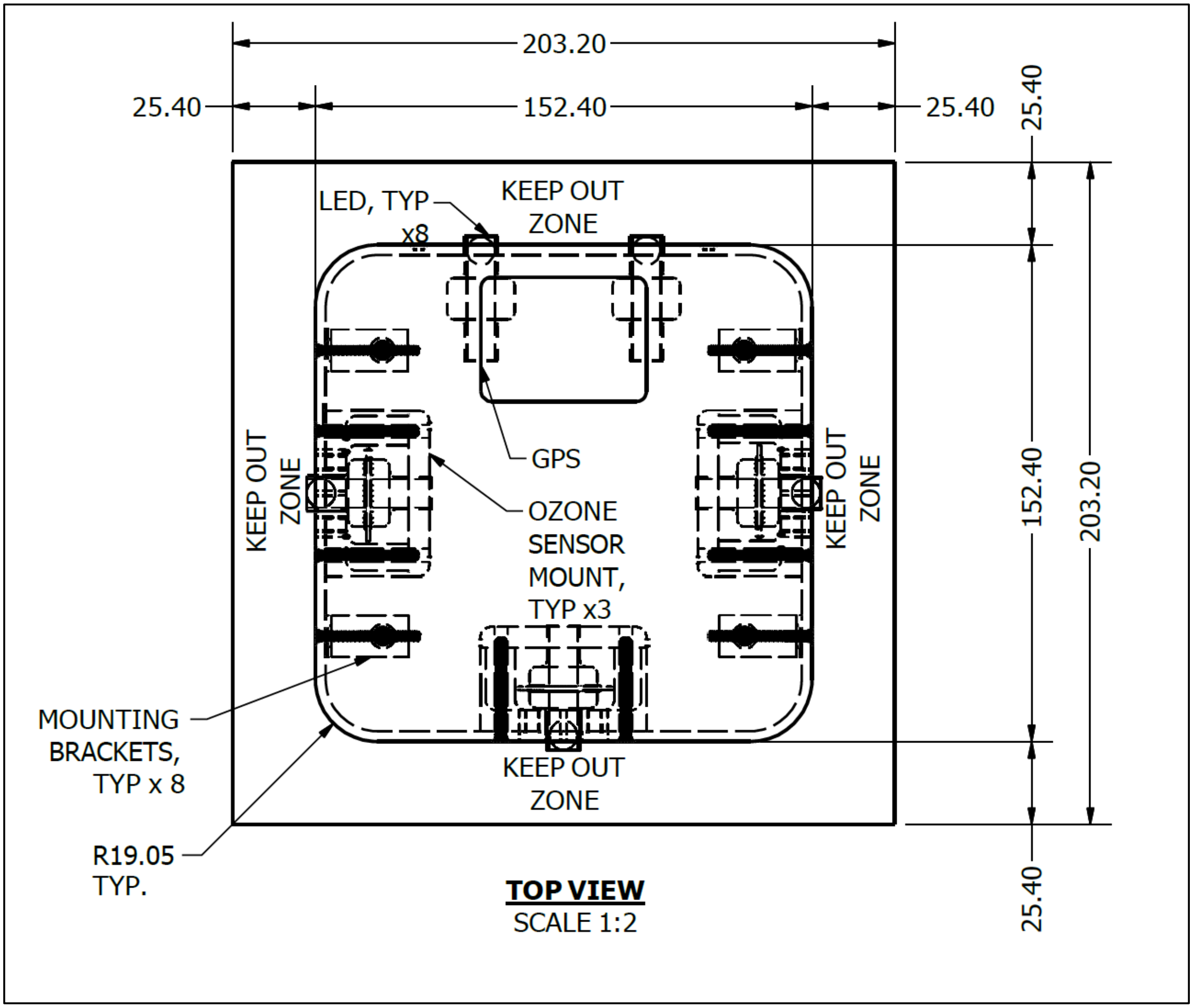


Fig. 4 (f) Design of top view of the payload
All dimensions are in mm.

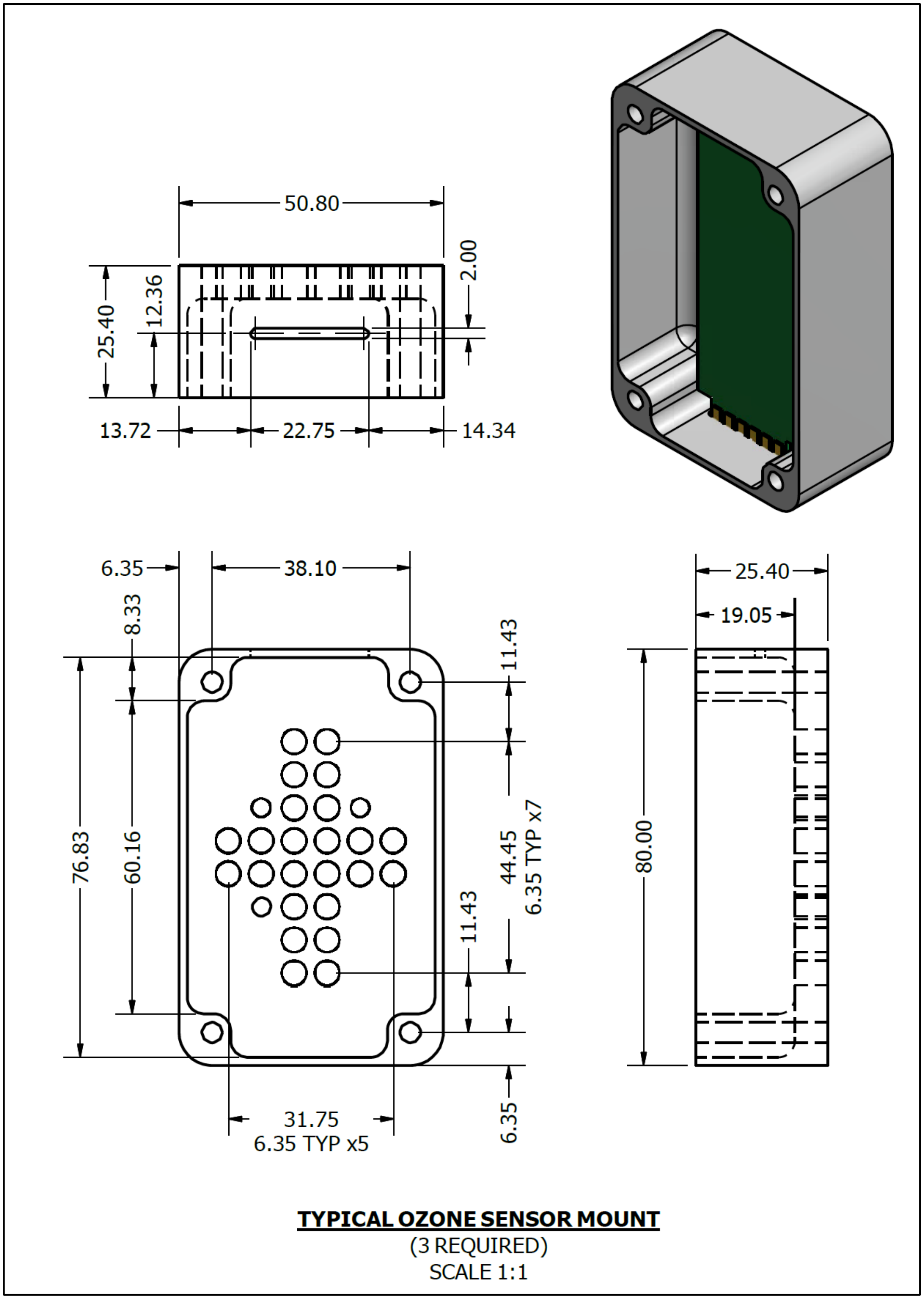


Fig. 4 (g) Design of top view of the payload
All dimensions are in mm.

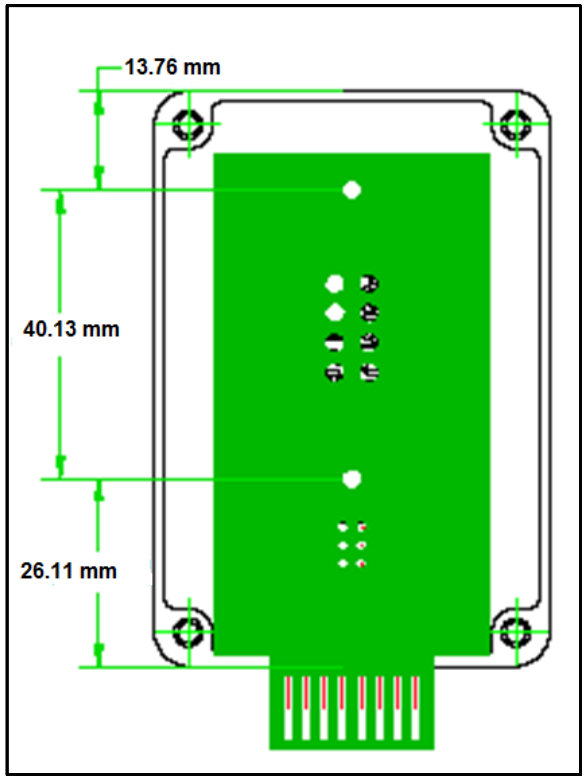


Fig.4 (h) Design for standoff to mount sensor PCB in the box

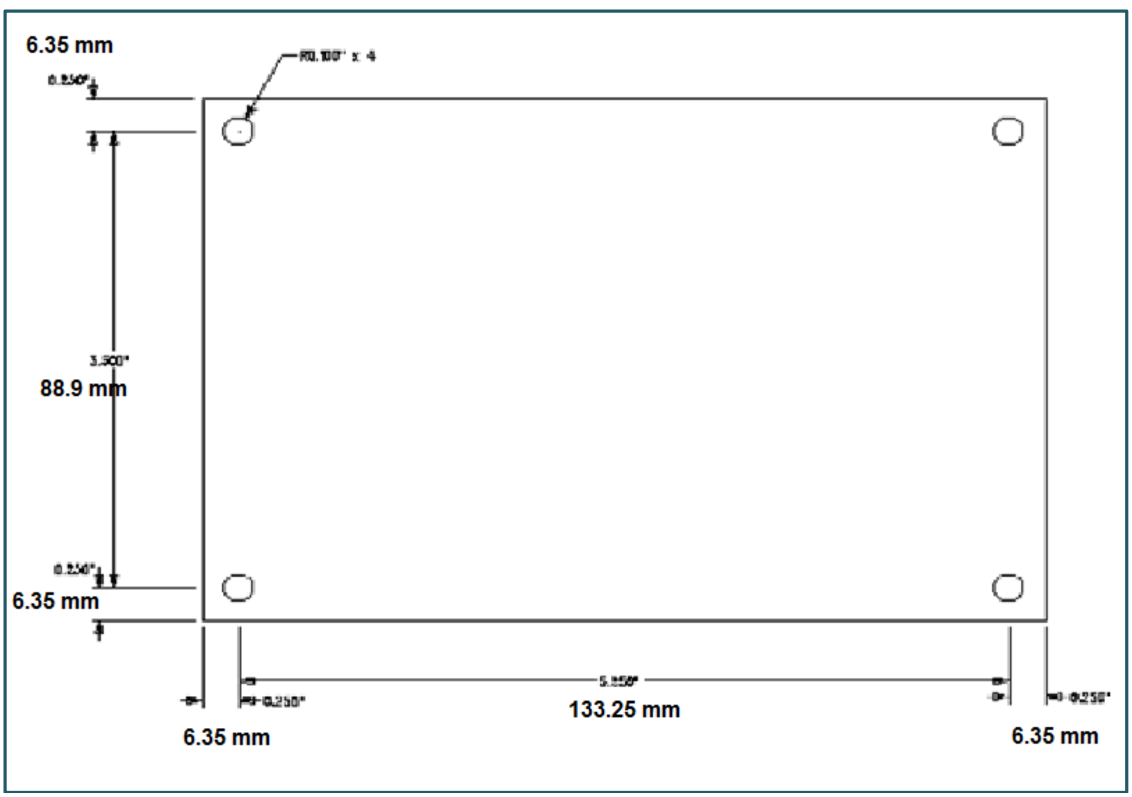


Fig. 4 (i) Design for hole of the microcontroller PCB

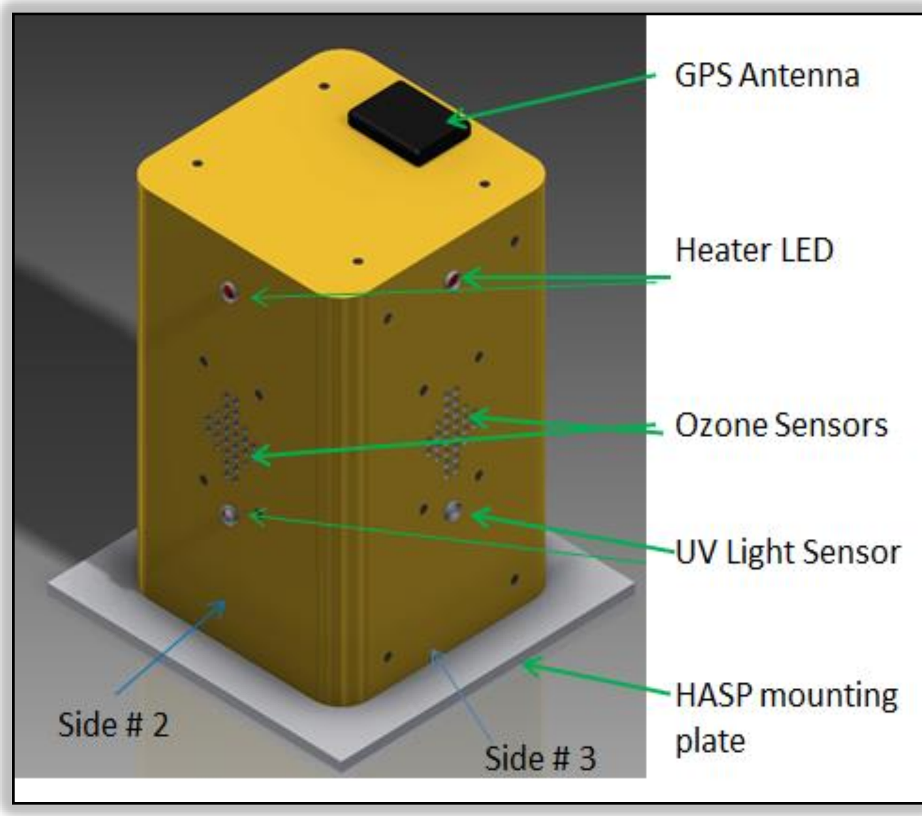


Fig.4 (j) Design of payload body

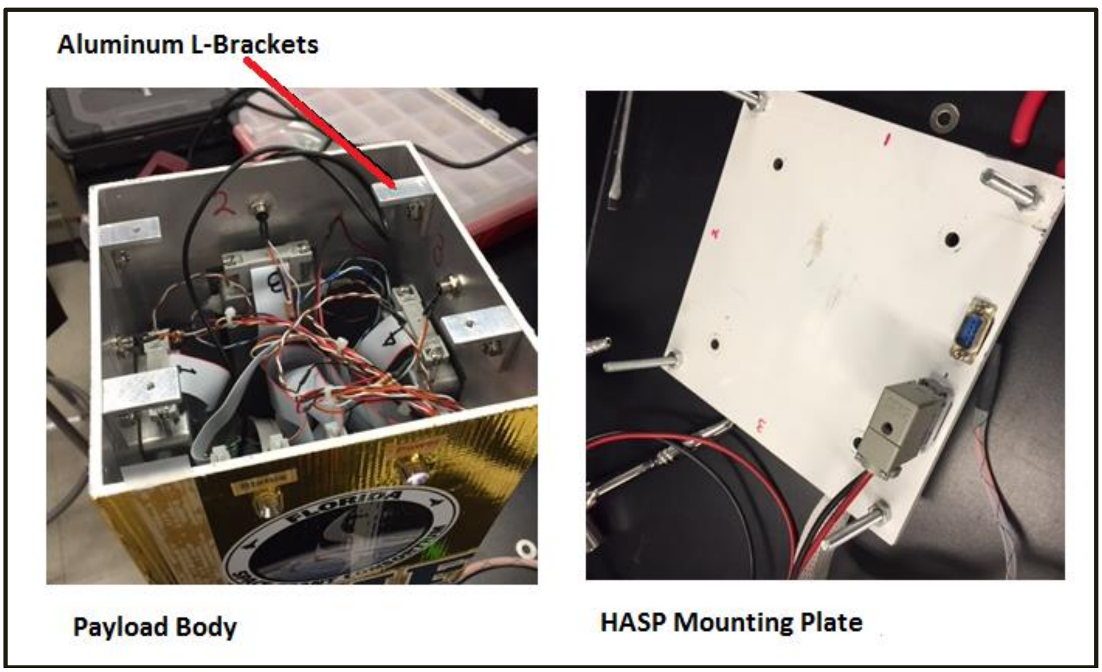


Fig. 4 (k) Mounting of payload body with HASP plate by L-brackets

The payload will be mounted on the HASP mounting plate using aluminum L-brackets, bolts, washers and nuts as shown in fig. 4(k).

3.6 Payload Mounting Footprint

Selection of the small payload dictates the mounting plate that interfaces with the payload. This mounting plate design is provided in the HASP Student Payload Interface Manual (Version 02.17.09) and is shown below in Fig.5. This mounting plate design will not require any modification.

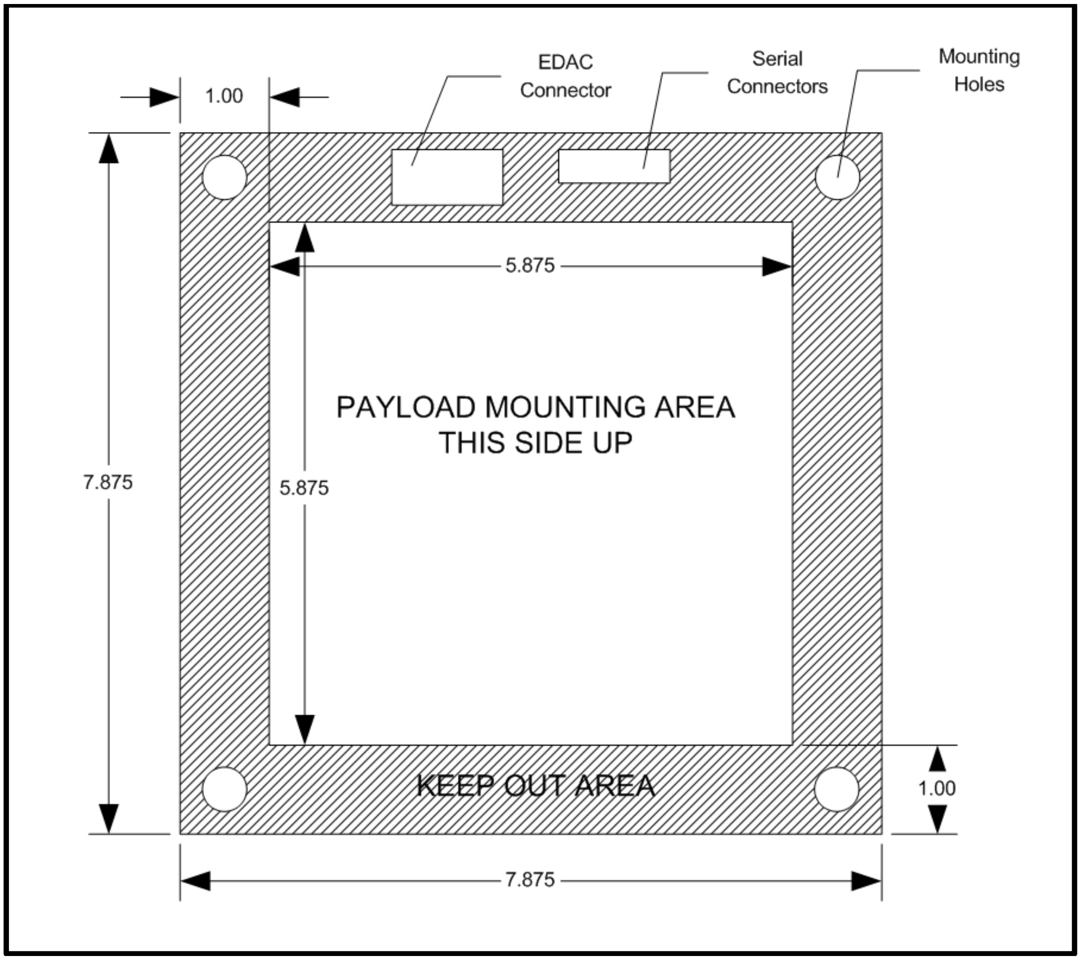


Fig. 5 Mounting Plate for small payload (Courtesy: HASP Version 02.17.09)
http://laspace.lsu.edu/hasp/documents/public/HASP_Interface_Manual_v21709.pdf

3.7 Desired location and orientation of payload on HASP

The requested smaller payload should be oriented on the side away from any solar cells to avoid disparate solar thermal radiation. There should not be any obstacle for air circulation into payload and also any shadow of other payload. We would like the position of the payload (#7) on HASP to be the same as in the previous flights. We hope that the power supply of position #7 should not have any issue with power supply Fig. 6 shows our desired location of payload on HASP.

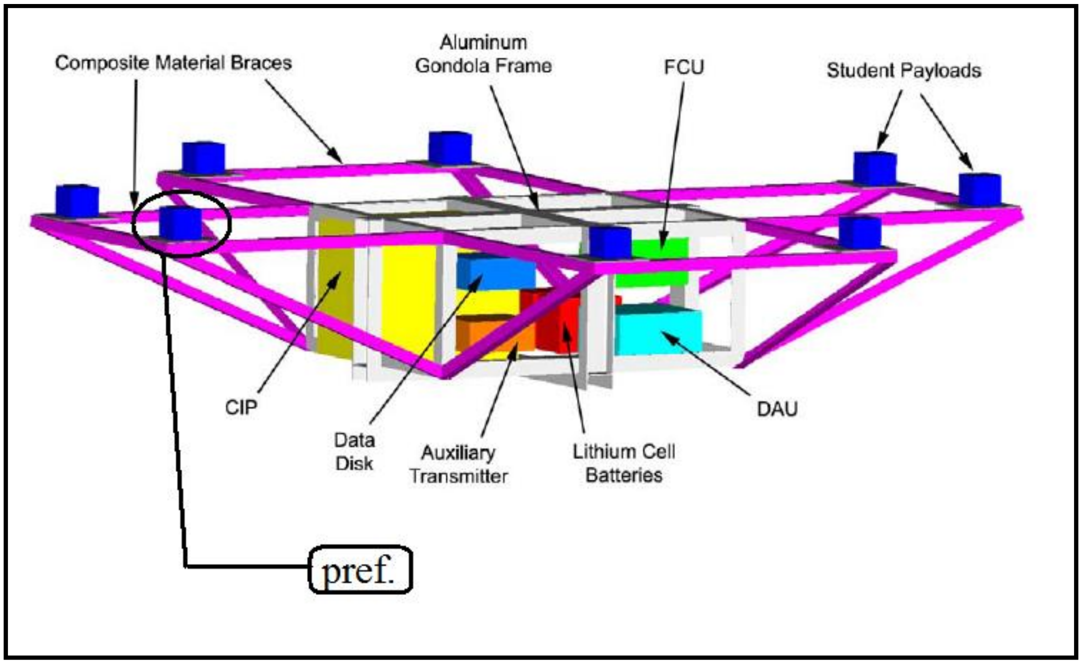


Fig. 6 Proposed HASP Configuration (Dr. Guzik and Wefel, 2004)

4. Electronic Circuits

The block diagram of circuit is shown in fig. 7 (a), while several sections of circuits are shown in fig. 7 (b) to (h). Two identical microcontroller PCBs will be fabricated. One PCB will be used for the payload, while for other PCB will be used to stimulate software and backup. The microcontroller circuit was designed by Mr. Jonathan earlier and then refabricated by Ken.

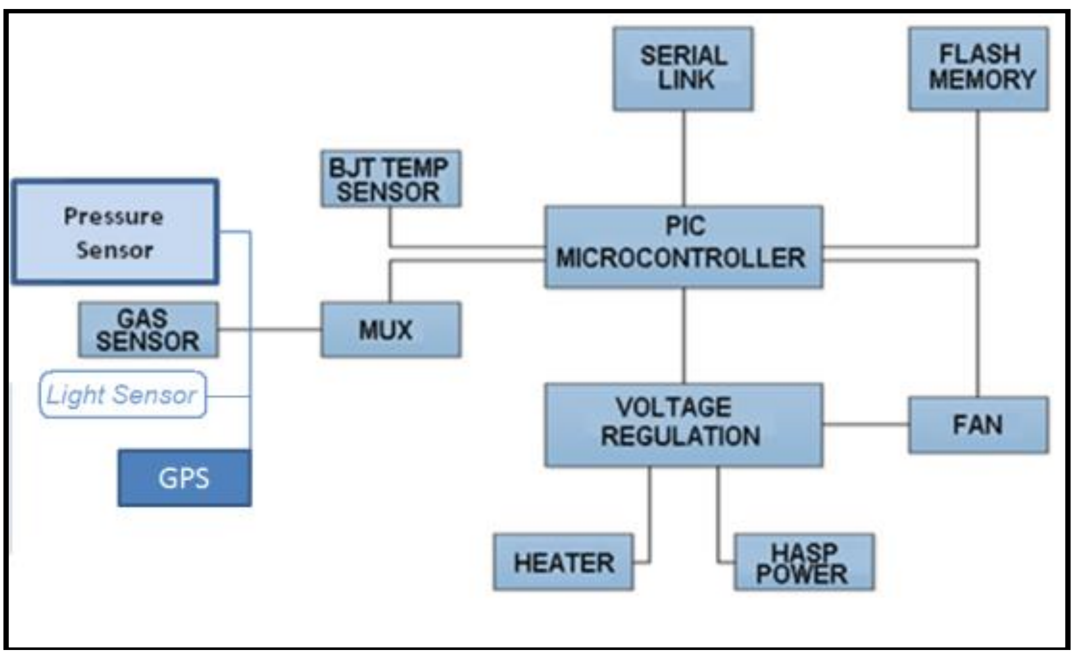


Fig. 7(a) Block diagram of payload ciruct

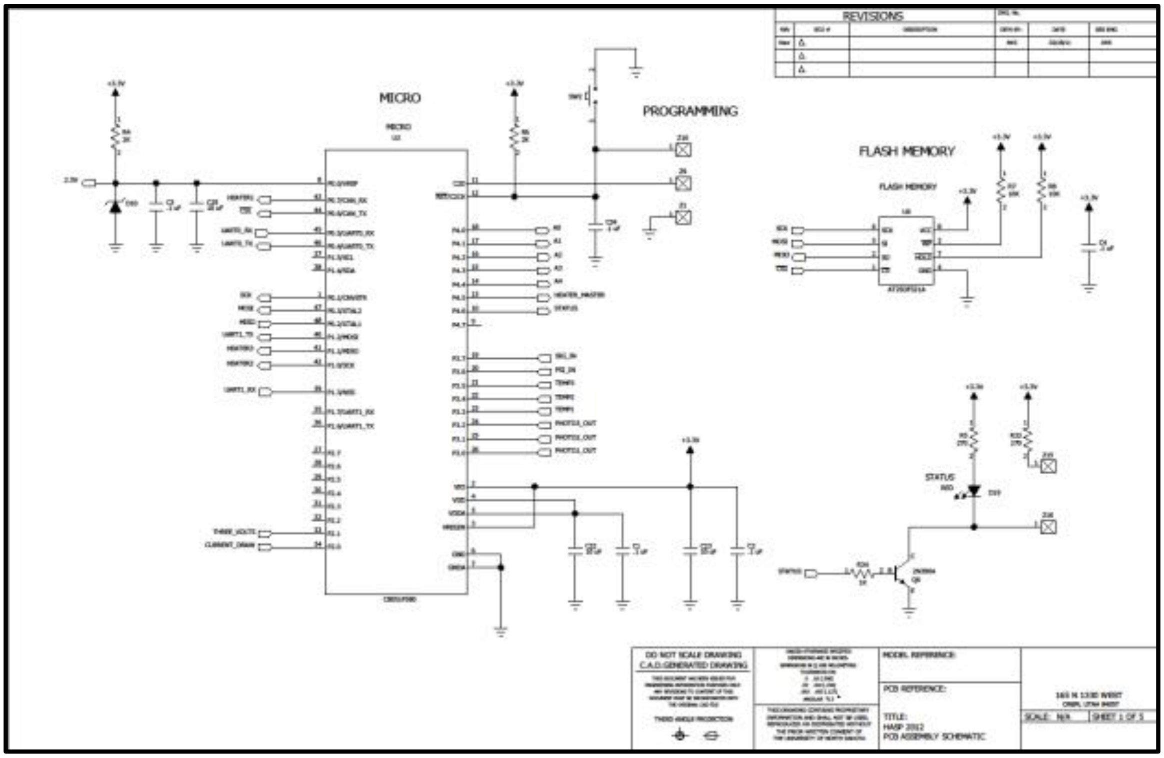


Fig. 7 (b) Circuit for microcontroller and flash memory

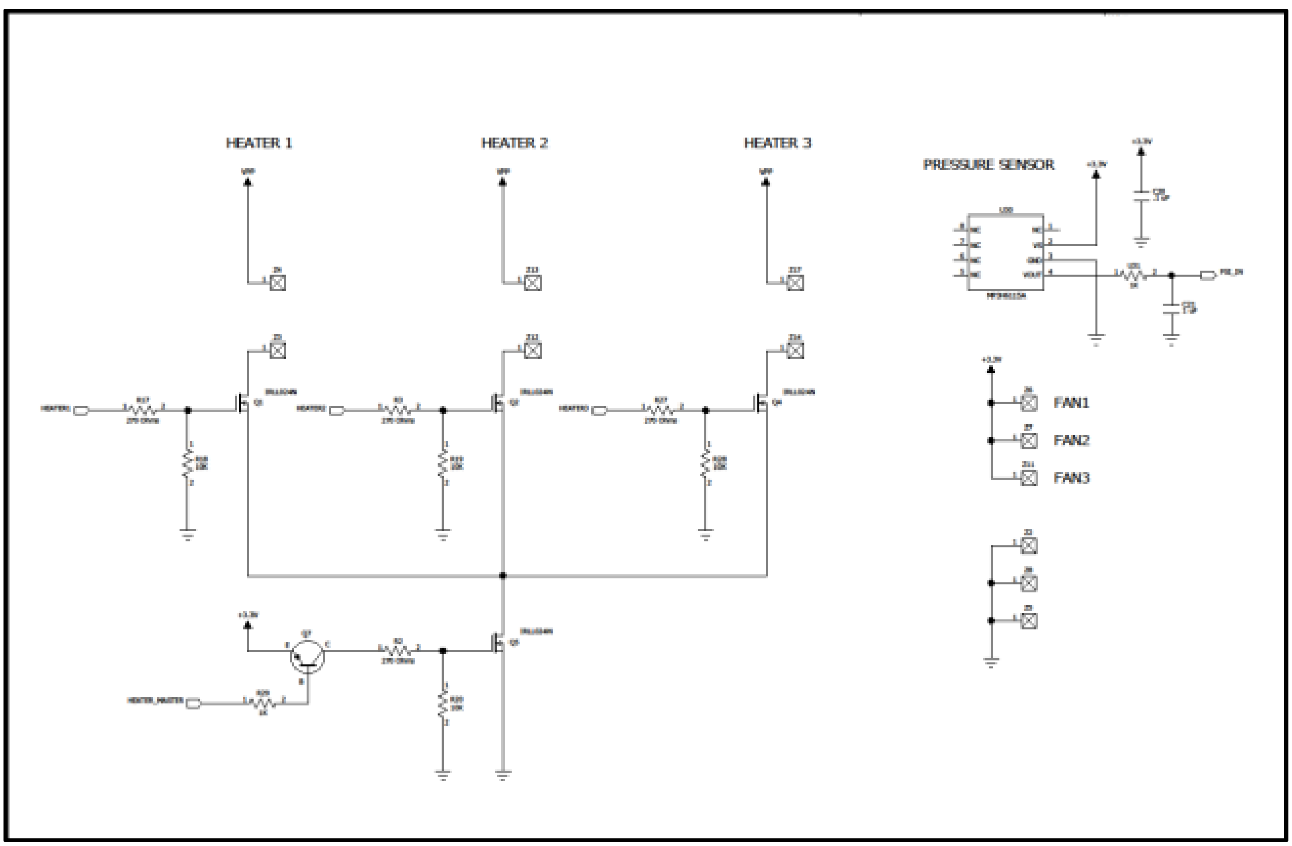


Fig. 7(c) Circuit for three heaters, three fans and pressure sensor

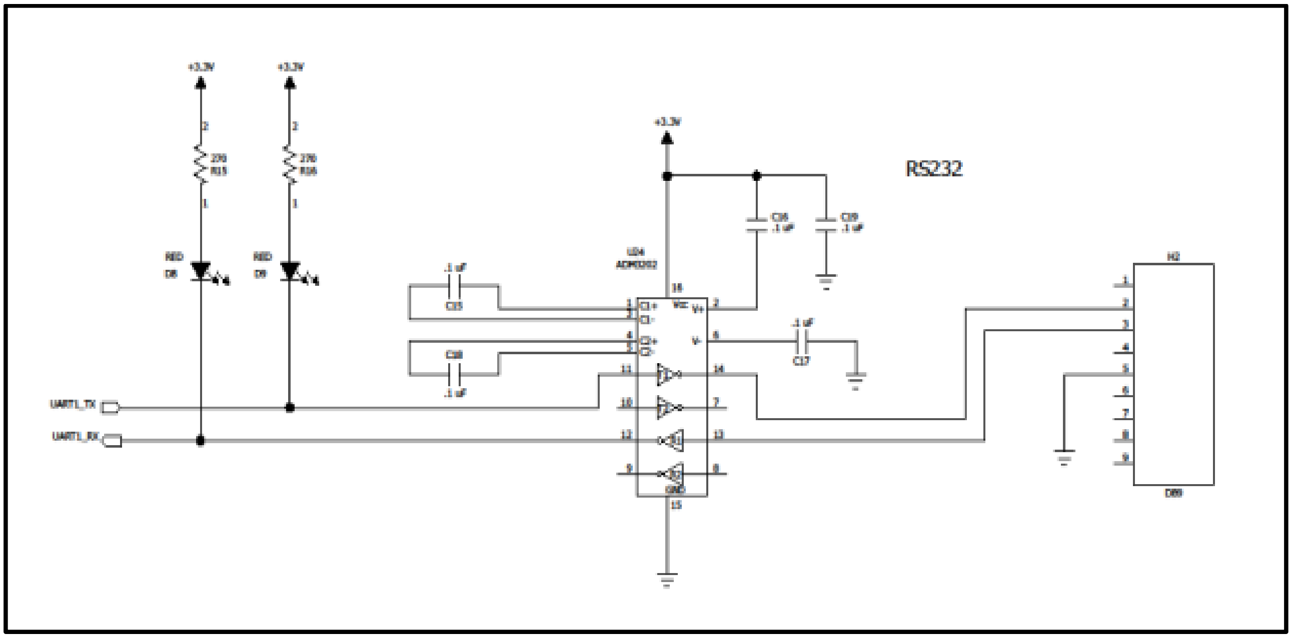


Fig.7 (d) Circuit for RS232

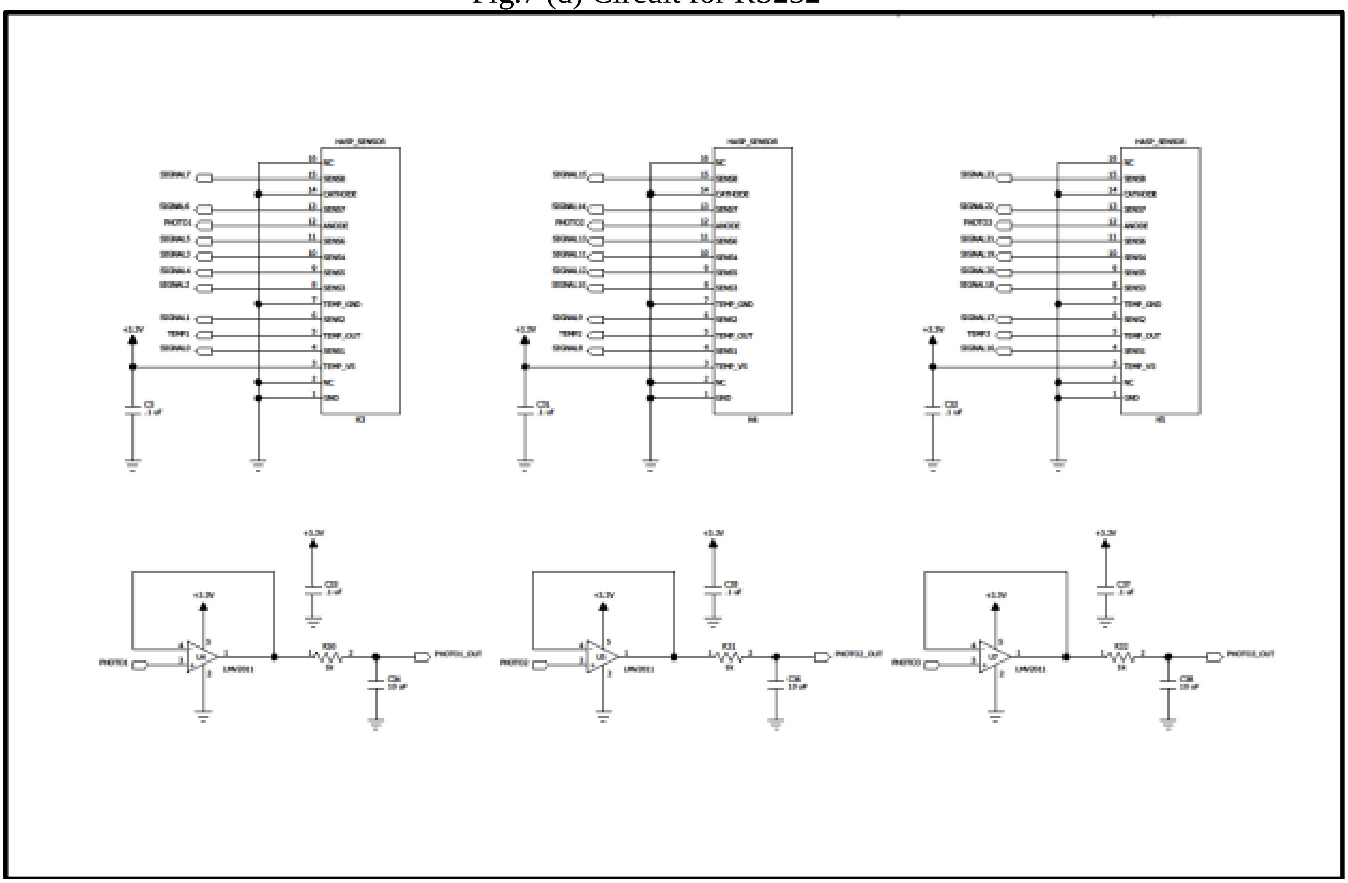


Fig.7 (e) Circuit for three ozone sensors boxes and three photo (light) sensors

5. Payload Power Budget

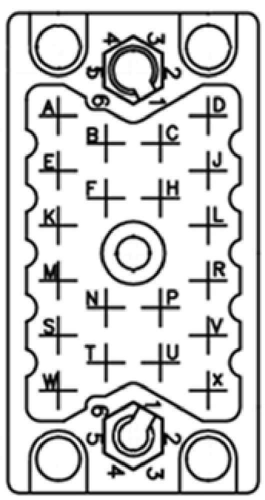
The 0.5Amps at 30VDC power supplied by HASP adequately accommodates the power requirements for the payload electronics, as well as the heater and fan for the sensor. Table 2 details the preliminary estimate for our power budget.

Table 2 – Itemized Power Budget

Item	**Power requirement**
Payload Electronics	1 W
Sensor Heater	7 W (max.)
Sensor Fan	2 W
Total	**10 W**

This is less than the 15 W limits for the smaller payloads.

As per the instructions, on the EDAC 516 power connector only pins A,B,C,D are wired to the payload as +30 VDC power supply and pins W,T,U,X are wired to payload as power ground to avoid failure to the power circuit or loss of payload. A voltage regulator is not necessary according to initial tests despite the slightly higher +33 VDC at launch for the sensor; however, a voltage regulator and divider will be used for peripherals. Fig. 8 shows the EDAC516 receptacle pin layout.



Function	**EDAC Pins**	**Wire Color**
+30 VDC	A,B,C,D	White with red stripe
Power Ground	W,T,U,X	White with black stripe
Analog 1	K	Blue
Analog 2	M	Red
Signal Return	L, R	Black
Discrete 1	F	Brown
Discrete 2	N	Green
Discrete 3	H	Red with white stripe
Discrete 4	P	Black with white stripe

Fig. 8 EDAC516 receptacle pin layout (Courtesy: HASP manual).

HASP will provide power to our payload through EDAC 516 connector. The following fig. 9 shows the circuit diagram for interfacing of HASP mounting plate EDAC 516 connector with voltage regulation of payload subsystems. Below is the switching power supply circuit, which is used in previous payloads. It has performed flawlessly. It is based around a National Semiconductor LM2905-3.3 switcher with ramp up voltage capability provided by C11, R13, and R14. 30 volts from the EDAC connector is provided via its 4 connections to a reverse protection diode, D11. A current limiting resistor, R1, is in series with D11. The 30 volt supply is then reduced to 3.3 volts via the switching power supply U21 and supporting components.

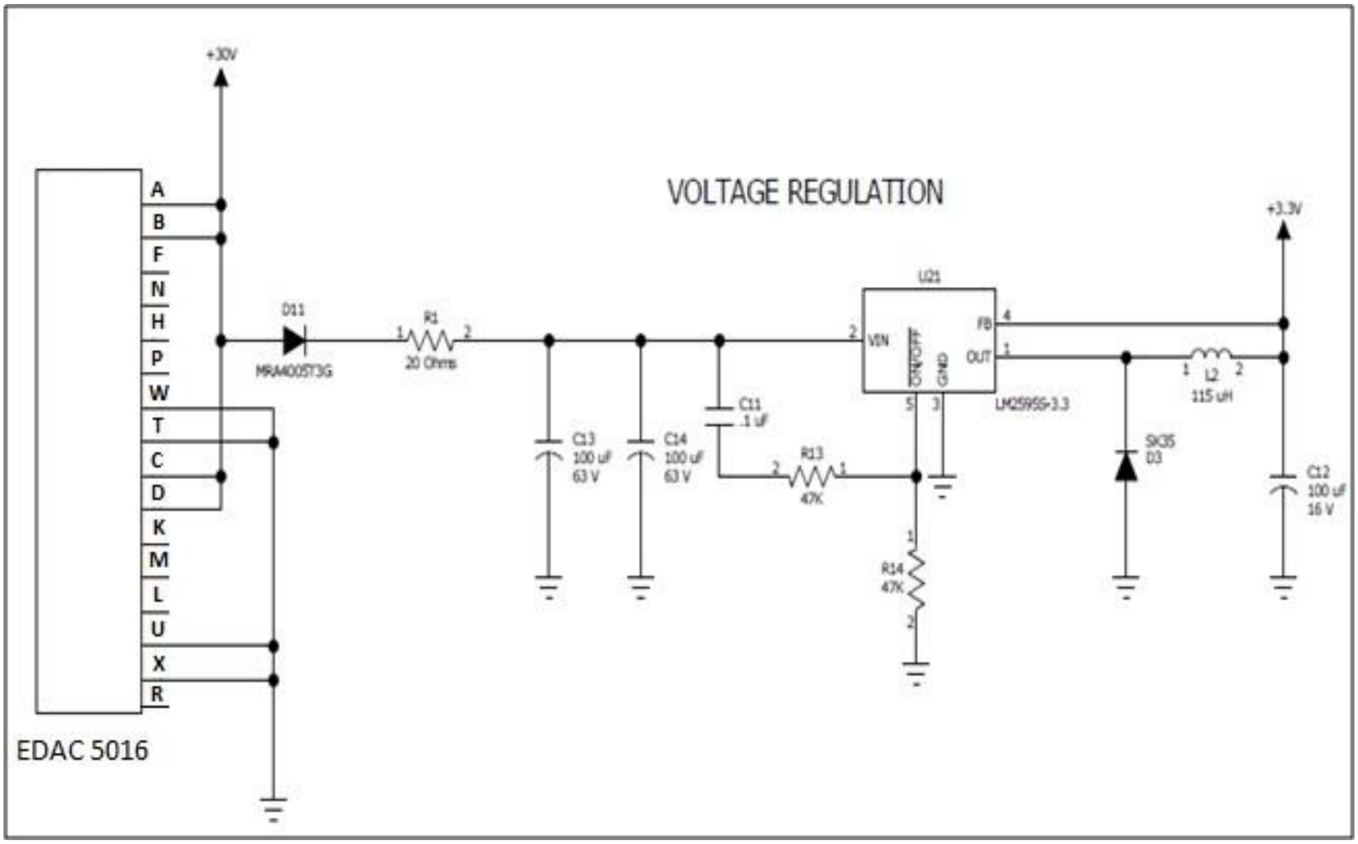


Fig.9 interfacing of EDAC 5016 of mounting plate with the payload voltage regulation circuit

Measured current draw at 3.3 VDC for different function of circuit operation is listed in the table-3.

Table-3 Current Draw by the payload

Circuit Function	**Current draw (mA)**
Payload Power ON, but all heaters OFF	35±5
Payload Power ON and Heater #1 ON	140±5
Payload Power ON, Heater #1 and 2 ON	250±5
Payload Power ON, Heater #1, 2 and 3 ON	360±5

The voltage applied to the payload during the HASP 2015 flight is shown in fig.10 (a) for information. It was found that applied voltage remain nearly constant about 3300 mV. The current drawn by the payload during the flight is shown in fig. 10(b). Payload draw minimum 34 to 35 mA when all three heaters were off, while maximum about 360 mA when all three heaters were on. The power budget was maintained under the upper limit of HASP requirement during the flight.

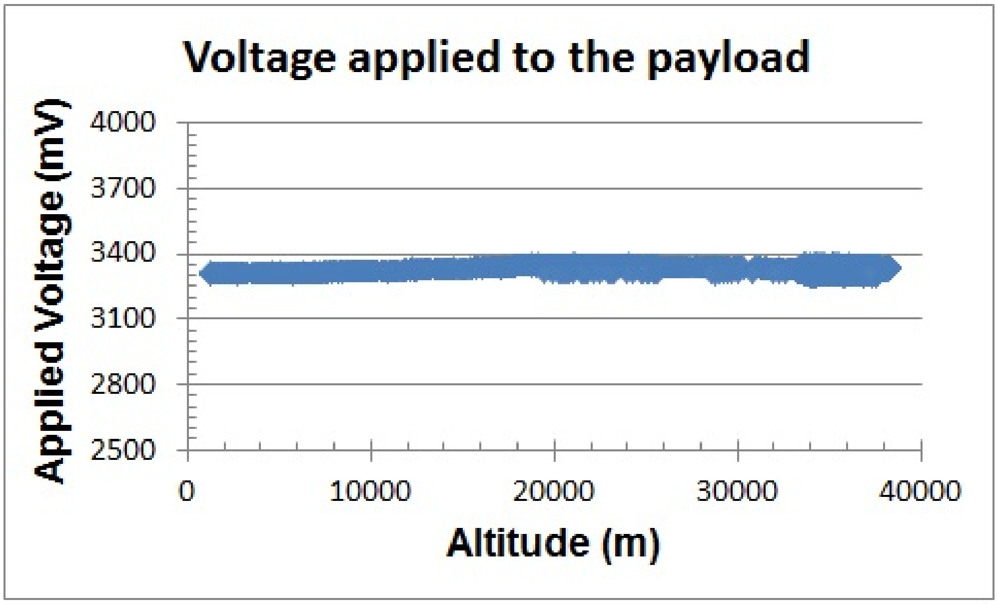


Fig.10 (a) Voltage applied to the payload during the HASP 2015 flight.

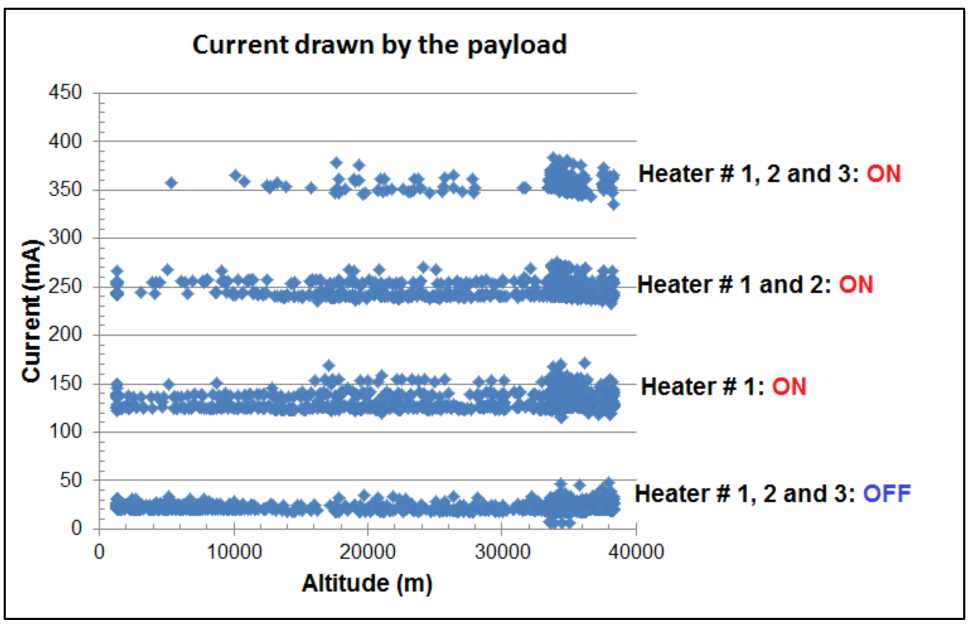


Fig.10 (b) Current drawn by the payload during the HASP 2015 flight

6. Thermal Stability of the Payload

Preliminary heat transfer calculations using equation (1), heat transfer, showed the onboard sensor heater is adequate to keep the sensor at the nominal conditions. An additional exploration of the effects of temperature on component integrity is ongoing, and part of the investigation. These initial estimations utilized the proposed materials for the walls, and a minimum temperature of -60°C (=333 K or 140 °F) and a general operating temperature of 15°C (=288 K or 59 °F) (found from altitude variation from 0 km to 36 km shown in the modified altitude profile (Fig. 11 (a)).

$$\text{Heat Transfer} = q = m(\Delta T)C_p \quad (1)$$

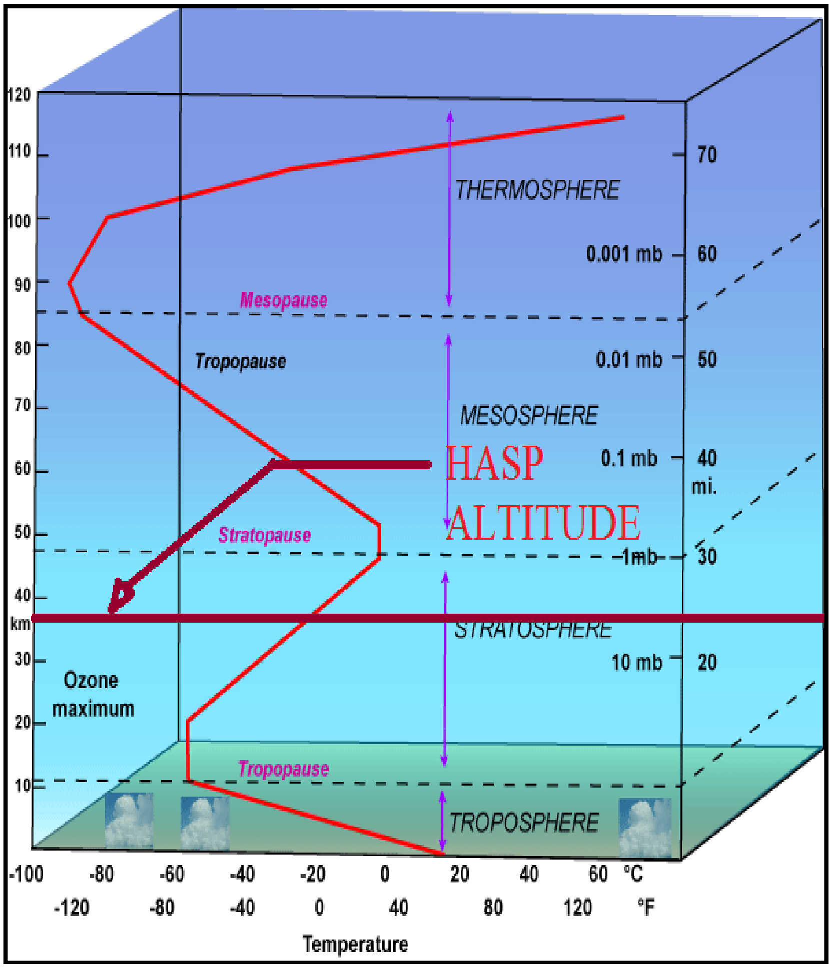


Fig. 11(a) Modified Altitude Profile (Atkins, 2007)

Our last payload had good thermal stability. We will try to further improve the thermal stability of the payload. As mentioned in our objectives, the outer surface of payload body will be covered by the thermal blanket made of aluminized heat barrier having adhesive backed (Part No. 1828) (Make: www.PegasusAutoRacing.com) for the improvement of thermal stability. The high reflective surface of the material is capable of withstanding radiant temperatures in excess of 1000°C. This thermal blanket will minimize the variation of internal electronics temperature conditions. The temperature of ozone sensors will be controlled in the range of 304 ± 5 K using an On-Off controller, a polyimide flexible heater (MINCO make) and a temperature sensor TMP 36). We may replace the aluminum body of payload by fiber glass or carbon composite body for reducing weight as well as improving thermal stability. The variation of temperature of one of ozone sensors box #1 with altitude during the HASP 2015 flight is shown in fig.11 (b) for information. The temperature of sensors was remaining constant 304±5 °K.

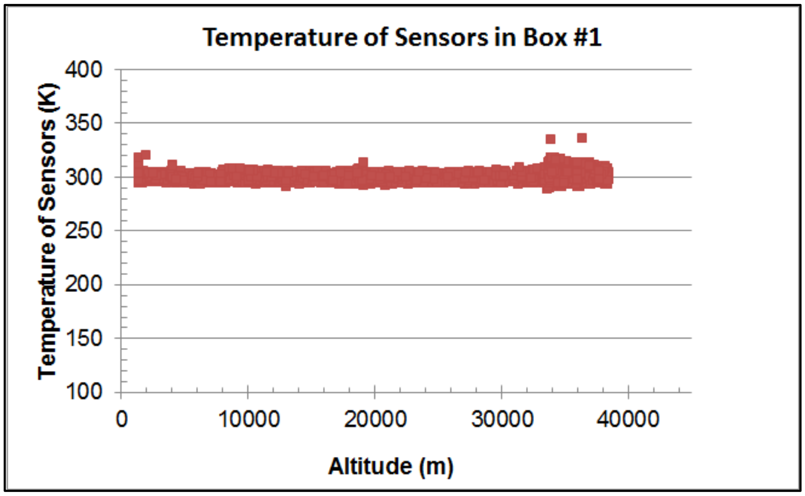


Fig. 11 (b) Temperature of ozone sensors box#1

7. Data Communications

The payload module requires the RS232 HASP telemetry to send the status of resistance vales to the ground. A data-recording unit will be included with master controller on PCB in the event that the telemetry link fails. The DB9 connecter (Fig.12) is required to the HASP system's telemetry system so that the data can be sent to the base station via the RS232 link. The RS232 link will operate at 2400 baud, with the standard RS232 protocol with eight data bits, no parity, one stop bit, and no flow control. A standard packet will contain the information-formatted vis-à-vis the Student Payload Serial Connection section of the HASP-Student Interface Document.

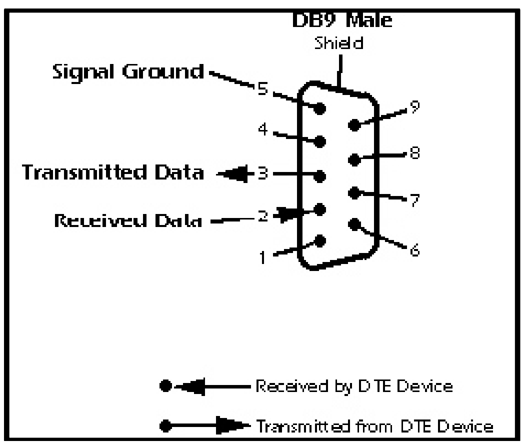


Fig. 12 DB9 pin diagram (Courtesy: HASP manual)

Downlink Telemetry Specifications

(a) Serial data downlink format:

Packetized- Record +/- 232 bytes transmitting in 5 second intervals

(b) Approximate serial downlink rate: 372 bps

(c) Table-4 shows the information about serial data record including record length and information contained in each record byte. Total record length : 238 bytes

Table-4 Data record length

Byte #			Description	Example	Units
1	-	4	Packet Sync	HASP	n/a
5	-	8	GPS Source	XGPS	n/a
9	-	23	Time stamp	,1407604205.265	sec
24	-	29	Altitude	,38044	m
30	-	35	Sensor 1-1	,01067	ohms
36	-	41	Sensor 1-2	,01390	ohms
42	-	47	Sensor 1-3	,01438	ohms
48	-	53	Sensor 1-4	,01248	ohms
54	-	59	Sensor 1-5	,01282	ohms
60	-	65	Sensor 1-6	,01450	ohms
66	-	71	Sensor 1-7	,01358	ohms
72	-	77	Sensor 1-8	,01060	ohms
78	-	83	Sensor 2-1	,01623	ohms
84	-	89	Sensor 2-2	,02874	ohms
90	-	95	Sensor 2-3	,02999	ohms
96	-	101	Sensor 2-4	,01820	ohms
102	-	107	Sensor 2-5	,01993	ohms
108	-	113	Sensor 2-6	,02956	ohms
114	-	119	Sensor 2-7	,02812	ohms
120	-	125	Sensor 2-8	,01371	ohms
126	-	131	Sensor 3-1	,01495	ohms
132	-	137	Sensor 3-2	,01652	ohms
138	-	143	Sensor 3-3	,01669	ohms
144	-	149	Sensor 3-4	,01748	ohms
150	-	155	Sensor 3-5	,01720	ohms
156	-	161	Sensor 3-6	,01619	ohms
162	-	167	Sensor 3-7	,01506	ohms
168	-	173	Sensor 3-8	,01441	ohms
174	-	179	Temp 1	,00298	K
180	-	185	Temp 2	,00309	K
186	-	191	Temp 3	,00297	K
192	-	197	Photovoltage 1	,00460	mV
198	-	203	Photovoltage 2	,00464	mV
204	-	209	Photovoltage 3	,00467	mV
210	-	215	CPU Temp	,00304	K
216	-	221	Power Rail Voltage	,03317	mV
222	-	227	Power Rail Current	,00148	mA
228	-	233	Pressure	,00117	mBar
234	-	238	Heater Status	,1101	n/a

The standard RS-232 connectivity rate for a small payload is 1200 baud. We will certainly try to remain within the limit this time by improving our software program and hardware.

(d) Number of analog channels being used: 0

(e) Number of discrete lines being used: 0

(f) Are there any on-board transmitters? If so, list the frequencies being used and the transmitted power. We will update this information to Dr. Guzik, if we able to add it.

(g) Other relevant downlink telemetry information. Not Applicable

Uplink Commanding Specifications

(h) Command uplink capability required: Yes

(i) If so, will commands be uplinked in regular intervals: No

(j) How many commands do you expect to uplink during the flight (can be an absolute number or a rate, i.e. *n commands per hour*): 1 command per hour maximum

(k) Provide a table of all of the commands that you will be up linking to your payload

The proposed commands are mentioned in the table-5. Any changes in the list will be updated at the time of PSIP and FLOP.

Table 5: Uplink Commands

#	Command Description	Cmd. Code	Checksum	Confirmation/Notes
1	Reset	0x71	0x31	"HELLO" upon reset
2	Erase data in flash	0x72	0x32	"ERASING FLASH"…"COMPLETE"
3	Upload data in flash	0x73	0x33	"NO DATA"
4	n/a	n/a	n/a	n/a
5	Master Heater Override Switch On	0x75	0x35	Heater Status (default)
6	Master Heater Override Switch Off	0x76	0x36	Heater Status
7	On Board Data Logging On	0x77	0x37	Data (default)
8	On Board Data Logging Paused	0x78	0x38	Data empty
9	Stream UNF GPS data	0x79	0x39	"UGPS"
10	Stream HASP GPS data	0x7A	0x3A	"HGPS"

(l) Are there any on-board receivers? If so, list the frequencies being used.

NO

(m) Other relevant uplink commanding information.

None

(n) UND-UNF Team is requesting the HASP to provide us the GPS strings from the HASP gondola every 1 second.

(o) Define a successful integration of your payload:

Payload successfully mounts to platform, both mechanically and electronically. Payload successfully performs a sensor/communication check, and systems health checks to ensure proper data/headers formatting. After an initial test sequences a steady 1 Hz flashing STATUS LED indicates a sound system. After initial system testing is complete the system will successfully packet and send data to HASP computer and ground station computer will decipher and provides data plots of ozone concentration in real-time during the final preflight testing (the thermal vacuum testing).

(p) List all expected integration steps:

1. Successfully interface the payload to platform.
   a. Mount the payload to the HASP platform
   b. Connect and interface the payload with the power system and the communication bus

(q) List all checks that will determine a successful integration:

a) Perform communication and data checks.
b) Successfully execute command set.
c) Monitor system to ensure proper operation via real time data stream of all sensors data readings, pressure, photo voltage of light sensors and ambient temperature.

8. Steps for Measurements of Ozone

Fig. 13(a) shows various steps for the detection of ozone by the sensors payload during the flight.The detection of reducing gases will also have similar steps.

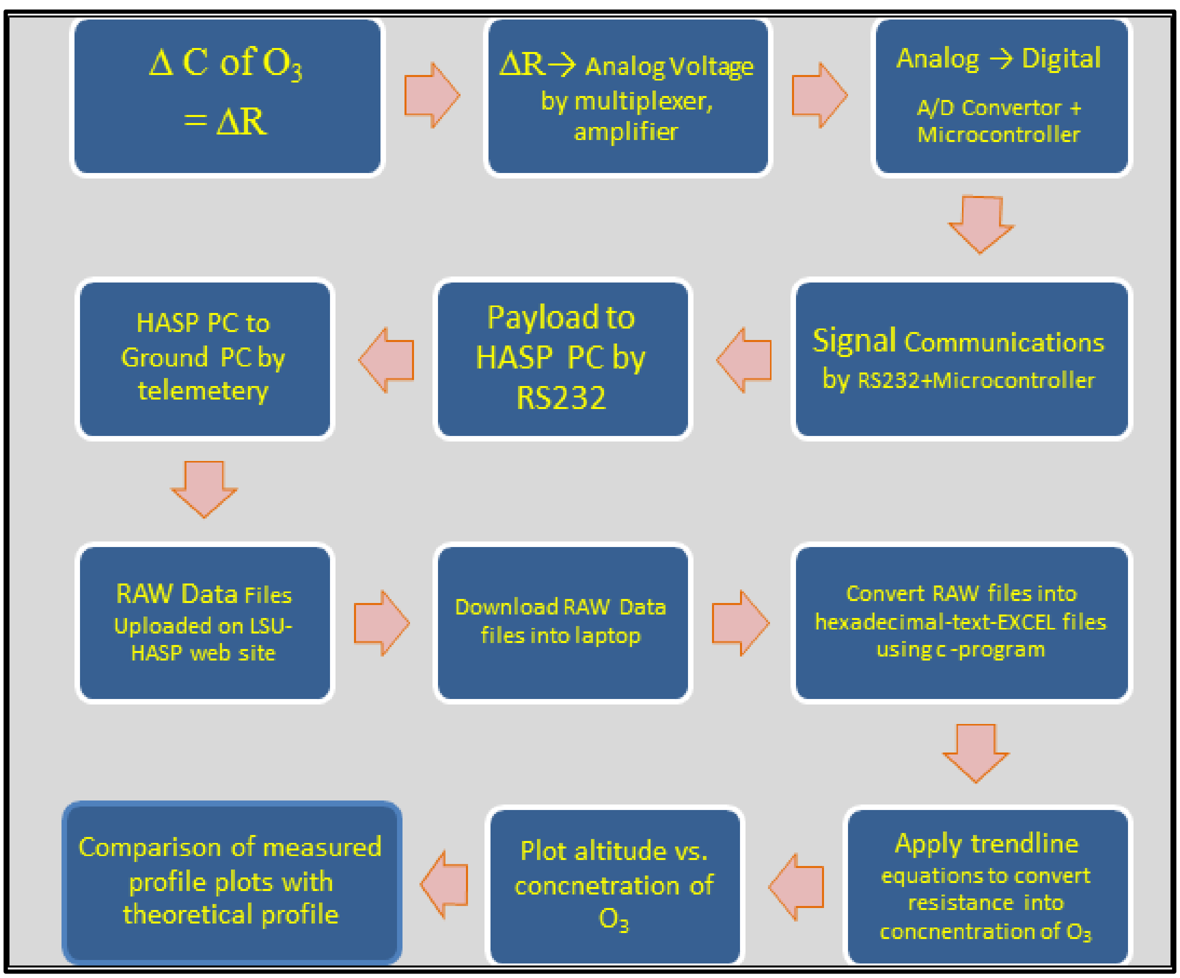


Fig.13(a) Steps for the detection of ozone by the payload

Team has also developed the program for testing the HASP payload. The different style of screens for quick monitoring data directly from the LSU website server can be possible. This LabVIEW based program will save time to download the files and then apply software program to put data in EXCEL and then make plots. This will help us monitoring data easily during the thermal vacuum test as well as during the flight. One of screen picture is shown in fig.13 (b).

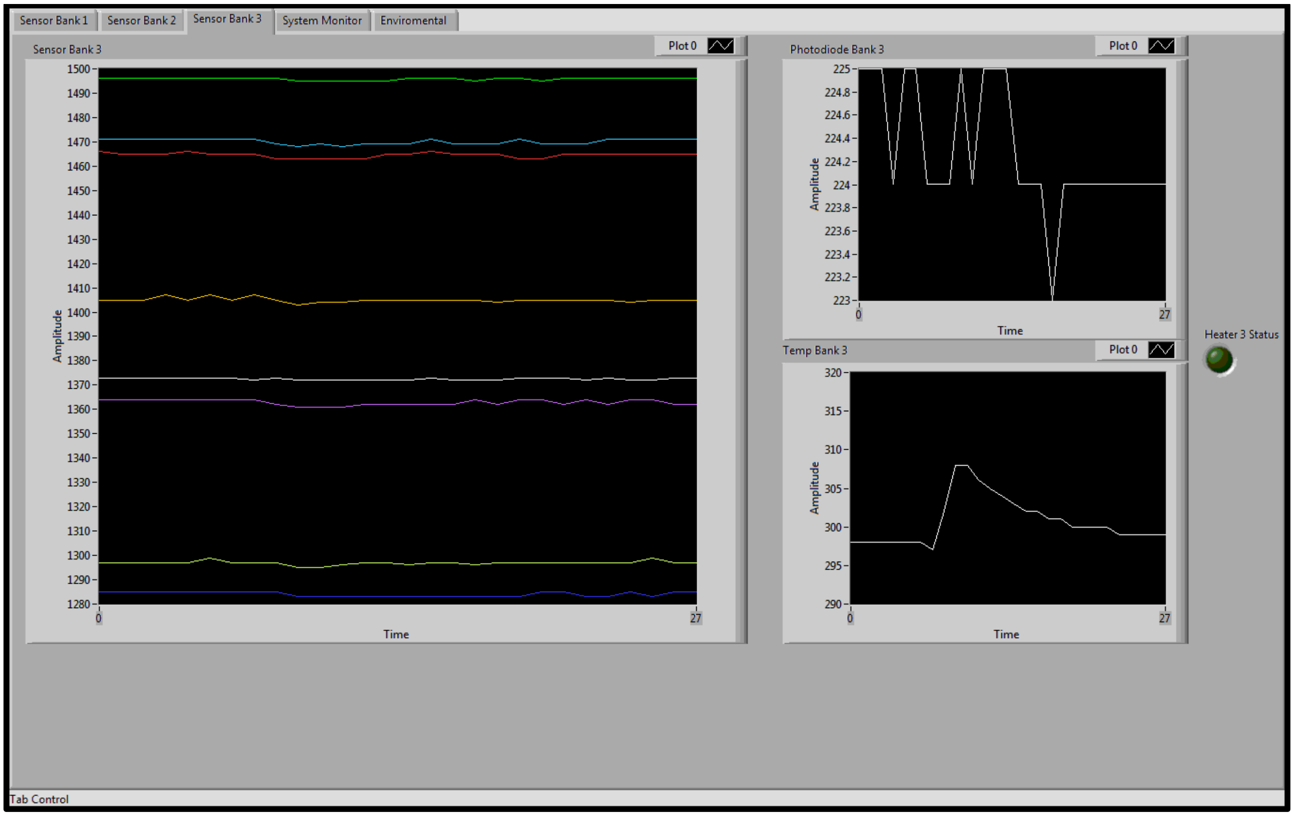


Fig.13 (b) Screen picture of data monitoring

9. UNF and UND Team and Demographic Information

Fig.14 shows the chart for the team management. The listed work distribution is tentative, which will be organized further after making joint tele or video conference in January 2016.

HASP 2016 UNF	HASP 2016 UND
Dr. Nirmal Patel UNF Faculty Advisor	Dr. Ron Fevig UND Faculty Advisor
Brittany Nassau (Team Leader) Sensors Fabrication, Hardware, Administration and Reporting	Chris Follette Space studies, Data analysis, Report
Ken Emanuel (Consultant) Overall supervision	Student-2 may be added
Joseph Silas Design and Payload Body	
Matthew Linekin Payload body fabrication	
Jesse Lard Sensors fabrication and testing, Calibration, Report	
Chris Farkas PCB fabrication and hardware testing. Data Analysis	
Caleb Grantham Payload body design and fabrication	

Fig.14 UNF-UND team

Faculty Advisors

Both Dr. Nirmal Patel (Faculty Advisor from UNF) and Dr. Ron Fevig (Faculty Advisor from UND) are involving in the development of sensors payload and participated HASP balloon flight since 2008. Both were jointly conducted teleconference, face time conference on cell phones, email communications with their team members regularly every month for the previous flights. This will be continuing for HASP 2016. Dr. Patel is mentoring students for the fabrication, testing and calibrations of nanocrystalline gas sensors, design and fabrication of payload, data analysis and improvement of software program, while Dr. Fevig is mentoring students for the improvement of microcontroller circuits, interfacing of sensors, atmospheric studies and space applications.

Demographic Information of Students

Brittany (UNF) worked as an active participant during HASP 2014 and 2015. She will work as a team leader. She will take help of Jesse to take care of the organization of meeting and teleconference meeting with all members and faculty advisors, and communicating with the HASP. She will take lead for the integration and thermal vacuum testing of payload at Palestine, TX and pre-flight testing at Fort Sumner, NM. She will also responsible for the flight operation plan, monthly reports, and updating of progress of work and any issue to both the advisors and also for the final science report. The demographic information of all students is given in table-6.

Table-6 Demographic information of students

#	Name	Gender	Ethnicity	Race	Student Status	Disability
University of North Florida Students Team						
1	Brittany Nassau Cell: 904-495-1765 Brittany.Nassau@gmail.com	Female	Non-Hispanic	Caucasian/White	UG-Electrical	No
2	Ken Emanuel Cell: 904-614-2117 kennecom@gmail.com	Male	Non-Hispanic	Caucasian/White	UG-Electrical	No
3	Joseph Thomas Silas Cell: 904-520-1605 Cruiser_9482@yahoo.com	Male	Non-Hispanic	Caucasian/White	UG-Mechanical	No
4	Matthew Linekin Cell: 904-631-8575 N00601480@ospreys.unf.edu	Male	Non-Hispanic	Caucasian/White	UG-Mechanical	No
5	Jesse Lard Cell: 850-348-3510 jesselard@gmail.com	Male	Non-Hispanic	Caucasian/White	UG-Mechanical	No
6	Chris Farkas Cell:904-413-6047 N00965140@ospreys.unf.edu	Male	Non-Hispanic	Caucasian/White	UG-Physics	No
7	Caleb Grantham Cell: 904-477-3163 N00902652@ospreys.unf.edu	Male	Non-Hispanic	Caucasian/White	UG-Mechanical	No
University of North Dakota Student						
1	Chris Follette christopher.follette@my.und.edu	Male	Non-Hispanic	Caucasian/White	G-Space Studies	No

One or two more students from UND may join the team.

10. Task and Work Plan Path

The initial work break down schedule includes the basic tasks required of the HASP project, which includes the Proposal, Integration Plan, Integration Certification, Operation Plan, and Science Report. The proposed work plan path is table-7.

Table-7 Work plan path

2016	UND	UNF
January	Conceptual Design Review (CoDR) for sensors, electronic circuits, software and payload. Reviewing science reports and issues of HASP2008 to 2015 flights.	
February	Preliminary Design Review (PDR) for sensors, electronic circuits, software, payload, integration of payload with HASP and data analysis.	
March	Critical Design Review (CDR) for sensors, electronic circuits, software, payload, integration of payload with HASP and data analysis.	
April	Designing of circuit board and programming. Fabrication and testing of sensor arrays, designing of payload body	
May	Fabrication of circuit board and programming, modifications, if any Calibration of sensors and delivery of sensor arrays to UND for testing	
June	Testing of Radio, circuit and sensor arrays (if available). Integrating the circuits and the sensor arrays	Fabrication of sensors box and payload body. Reviewing HASP flights, data and any issues.
July	Integration of circuit board and sensor box with the payload body. Development of protocols for communication of payload with HASP computer and RAW files to EXCEL file Integration of sensor arrays in box. Integration of sensor boxes with payload body. Integration of PCB to payload and sensors box	
August	Flight operation plan, Testing payload, thermal vacuum test of payload and integration of payload with HASP platform	
September	Pre-flight testing of payload, launching of payload and downloading data files, and data analysis work	
October	Payload recovery, testing of sensor arrays and other components, SEM+EDAX analysis of sensor arrays and shorting of issues and failure analysis. Data analysis.	
November	Data analysis and writing science report	
December	Submission of the science report and planning for the next flight.	

11. HASP Integration and Launch

It is expected that at least three students from UNF, one or two students from UND and Dr. Nirmal Patel, faculty advisor from UNF will travel to CSBF, Palestine, Texas in first week of August of 2016 (as per the date given by HASP) for the integration of the sensor payload onto HASP. It is also expected that approximately two students from UND and UNF and one faculty member (UND or UNF) will travel to Ft. Sumner, NM for launch of the HASP2016 payload during September 2016 (as per the date given by HASP and CSBF).

12. Anticipated Procedures

Prior to Integration:

- Testing and Calibration of sensor arrays
- Set initial values for data recorder
- Place sensor arrays in appropriate payload slots

- Check program and LED for status

Integration:

- Mount payload module to HASP
- Connect HASP Power Connector
- Connect HASP Serial Connection
- Test system by recording initial readings and making sure all data is nominal
- Troubleshoot

Pre-Flight Operations and testing:

- Set initial values for data recorder
- Place sensors in appropriate payload slots
- Connect HASP Power Connector
- Connect HASP Serial Connection
- Check mass and size pf payload
- Test thermal-low temperature and high temperature test and also all commands
- Test pressure and vacuum test
- Test 10g vertical and 3g horizontal vibration/impact test

Duration of Flight:

We are flexible for the duration of flight. Minimum 6 to 8 hours flight during day time will be fine for us.

Flight Operations:

- Record values for resistance across the sensors

Post-Flight Operations:

- Examine all parts of payload
- Remove PCB and sensors box from the payload. Test PCB with power and test sensor box
- Check sensors box for electrical testing, SEM+EDAX analysis, and failure analysis.

13. Financial Considerations

UND will seek funding through the North Dakota Space Grant Consortium. UNF will request the Florida Space Grant Consortium for the funding for the students support, travel and consumables.

14. References

(1) Solid-State Sensors Behavior in Reduced Pressure Environments Demonstration Using an Experimental Indium Tin Oxide Ozone Gas Sensors for Ozone Sounding; Nathan Ambler, Ronald Fevig and Nirmal Patel, Proceedings of 59th International Astronautical Congress , Glasgow, (Sept 29-Oct 3, 2008), C2.I.17

(2) Hansford, Graeme M., et al. "A low cost instrument based on a solid state sensor for balloon-borne atmospheric O_3 profile sounding." Journal Environmental Monitoring (2005): 158-162.

(3) Guzik, T. Gregory and John P. Wefel. "The High Altitude Student Platform (HASP) for Student-Built Payloads." 35th COSPAR Scientific Assembly. Houston, Texas, 2004. 1-8.

(4) HASP – Student Payload Interface Manual, Version 02.17.9 http://laspace.lsu.edu/hasp/documents/public/HASP_Interface_Manual_v21709.pdf

(5) Atkins, Noel. Survey of Meterology. 10 November 2007 http://apollo.lsc.vsc.edu/classes/met130/notes/chapter1/vert_temp_all.html