HASP Student Payload Application for 2015

Payload Title: Measurements of ozone profile in the stratosphere and pollutant gases in atmosphere and troposphere using improved nanocrystalline sensors payload on a high altitude balloon platform.

Payload Class: (circle one) Small Large	Institution: University of North Dakota (UND) and University of North Florida (UNF)	Submit Date: 12-18-2014

Project Abstract:
UND and UNF 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 2015 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. 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 WO_3+ITO thin film gas sensors will detect the reducing pollutant gases such as CO, CO_2, 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. GaP 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 and new GPS will measure the altitude throughout the flight without any blockage of transmission will be mounted on the payload. Ozone and reducing gas sensors will be fabricated and calibrated by the students' team at UNF and also tested at UND. The developed payload can also use to fly on the long duration of balloon flight at Antarctica, which is our dream and long term goal.

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HASP2015 Proposal

Measurements of ozone profile in the stratosphere and pollutant gases in atmosphere and troposphere using improved nanocrystalline sensors payload on a high altitude balloon platform.

Submitted by

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

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Proposal Index

1. Project Summary

The UND and UNF 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 UND-UNF team proposes the HASP 2015 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.

Improved 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 WO_3+ITO thin film gas sensors will be used for detection of reducing pollutant gases such as CO, CO_2, 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. An ultra violet light sensor 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 and new GPS which can measure the altitude throughout the flight without any blockage of transmission will be mounted on the payload. 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 North Dakota and Florida 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 2014 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, and University of Central Florida 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 nanocrystalline ITO, ZnO+ITO and alpha phase of silver tungstate thin film gas sensors have better sensitivity and selectivity for detection of ozone gas at low pressure, while nanocomposite WO_3+ITO thin film gas sensors have better selectivity for detection of reducing gases such as CO, CO_2, SO_2 and VOCs. 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 2014 flight is given in fig.1. The flight picture and ozone profile are also shown in fig. 1.
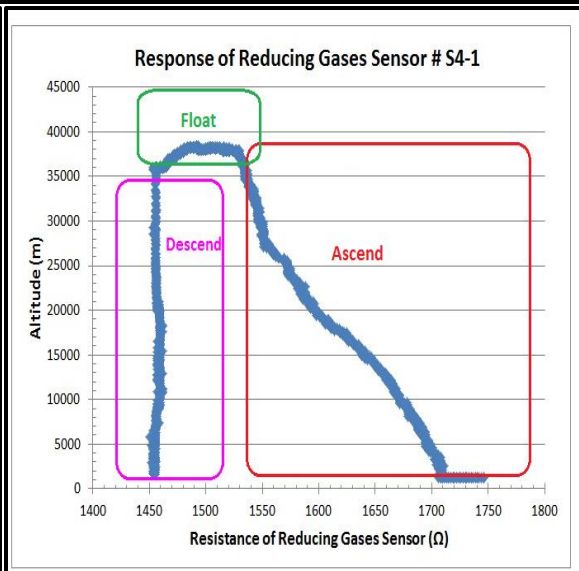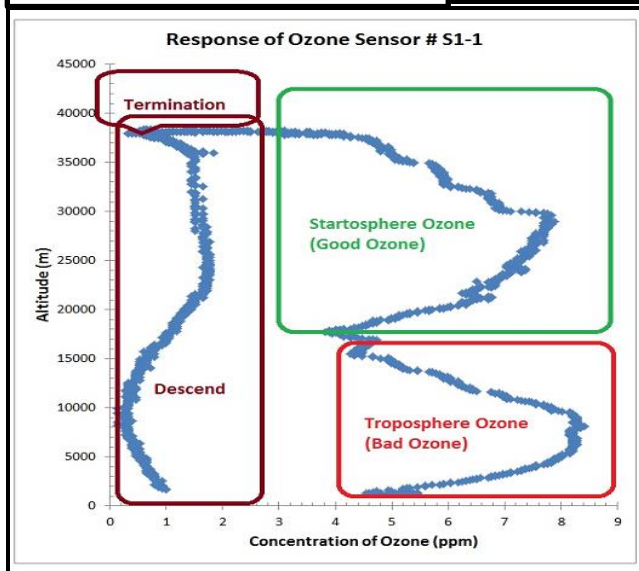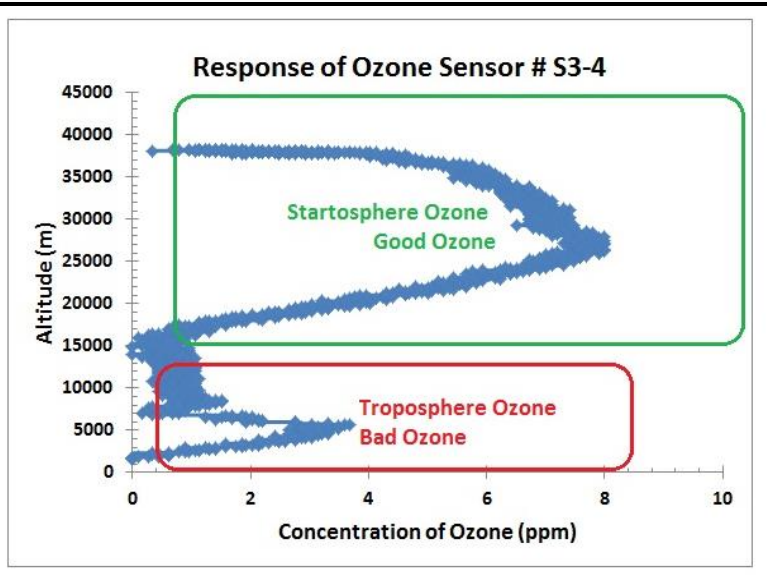
Fig.1 HASP 2014 payload, two ozone profiles measured by sensor # S1-1 and S3-4, 1 reducing gases profile measured by S4-1 and balloon flight in stratosphere

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 2015 flight with following new objectives for the measurement of ozone profile in the stratosphere using improved version of the gas sensors payload.

(i) High sensitive and selective 8 nanocrystalline ITO thin film gas sensors (Box#1) will be used for detection of ozone gas. Newly developed 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 improved version of 8 nanocomposite WO_3-ITO thin film gas sensors (Box#3) will be used for the measurement of reducing pollutant gases such as CO and CO_2 in the atmosphere and troposphere. Nanocrystalline gas sensors will have better stability and faster response and recovery time. 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.

(ii)   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.

(iii)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 $302\pm5\ ^oK$ 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.

(iv) We will replace light sensors (photodiodes) by new ultra violet (UV) light photodiodes in order to improve the spectral response. New GaP (FGA71) UV photodiode will be 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. 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.

(v) It was observed that the pressure sensor used in the last two flights 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 will be purchased from http://www.meas-spec.com/product/Pressure/MS5540C.aspx.

(vi) The current UBLOX gps will be replaced new GPS. New GPS from either Trimble or Byonics will used. The payload GPS data will be cross verified and compared with the HASP GPS data.
> http://www.trimble.com/embeddedsystems/copernicus2.aspx?dtID=overview&
> http://www.byonics.com/tinytrak/gps.php

(vii)   **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.

(viii)   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. There will no outgassing at the low pressure.

(ix) 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 high reflective surface of the material is capable of withstanding radiant temperatures in excess of $2000^{o}F$.

(x) The improved version of 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.

(xi) The surface topography of the sensors before and after the flight will be studied using a scanning electron microscope (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. The developed payload may work as **a free flying payload** for rapid detection of ozone or any other gas in the real time mode and will be useful for the weather balloon and rocket payload for the space and environmental applications. It will be also used to fly on the long duration of balloon flight at Antarctica, which is our dream and long term goal.

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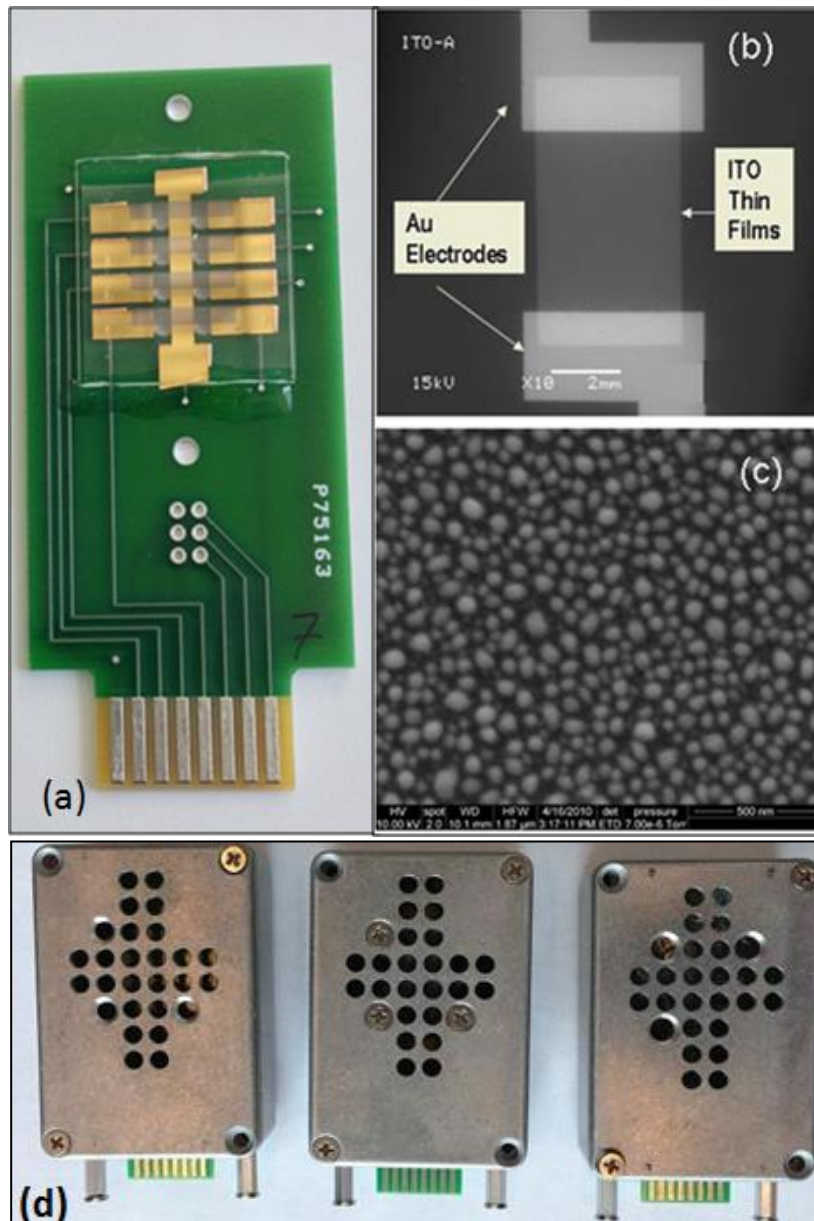
Fig.2 (a) 8 sensor array and interface mini PCB, scanning electron micrograph of (b) top view of one ITO gas sensor, (c) nanocrystalline grains of ITO thin film and (d) sensors boxes.

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 WO_3-ITO thin film gas sensors for detection of reducing pollutant gases in atmosphere and troposphere.

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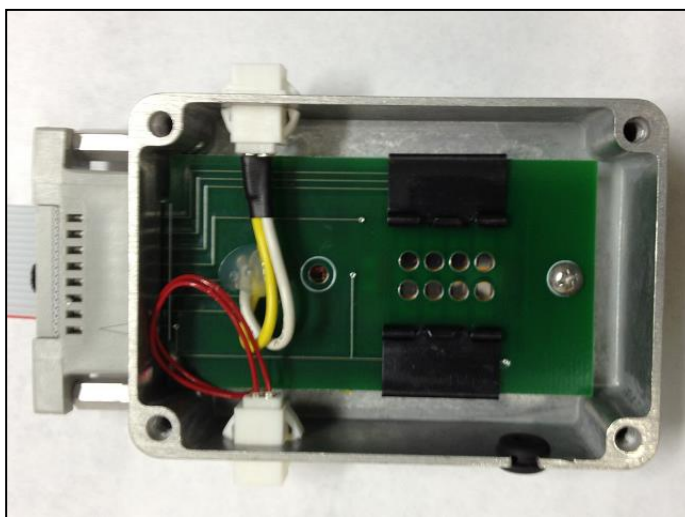

Fig. 3 Schematic diagram of sensor array box

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:
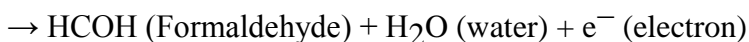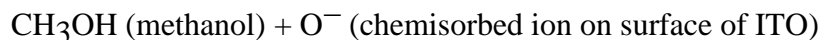**Oxygen vacancy (V) + Ozone (O_3) →Lattice Oxygen site (O_O) + O_2**
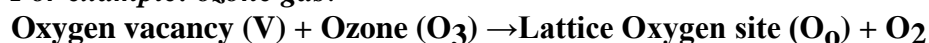
Vacancies can be filled by the reaction with ozone. Filled vacancies are effectively electron traps and as a consequence the resistance of the sensor increases upon reaction with ozone.

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)

$\rightarrow$ 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 2015 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 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. We are also exploring the carbon composite payload body. 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)	3 x 2 x 1 inch	200.00 g
8 Ozone sensors box #2 (including fan, heater, box)	3 x 2 x 1 inch	200.00 g
8 Pollutant sensors box#3 (including fan, heater, box)	3 x 2 x 1 inch	200.00 g
Microcontroller PCB with mounted components	4 x 6 inch	300.00 g
Payload body, top plate and thermal blanket	11 x 6 x 6 inch	1295.00 g
Few Cables, 1 GPS, 2 LEDs, 3 Photodiodes, nuts and bolts		380.00 g
HASP mounting plate	7.9 x 7.9 inch	550.00 g
Total		**3125.00 g**

Ken Emanuel (UNF) made the payload body design drawing. Design diagrams of payload are shown in Fig. 4 (a) to (k). The dimensions of payload of HASA 2015 will be about 279.4 mm x 149 mm x 149 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.
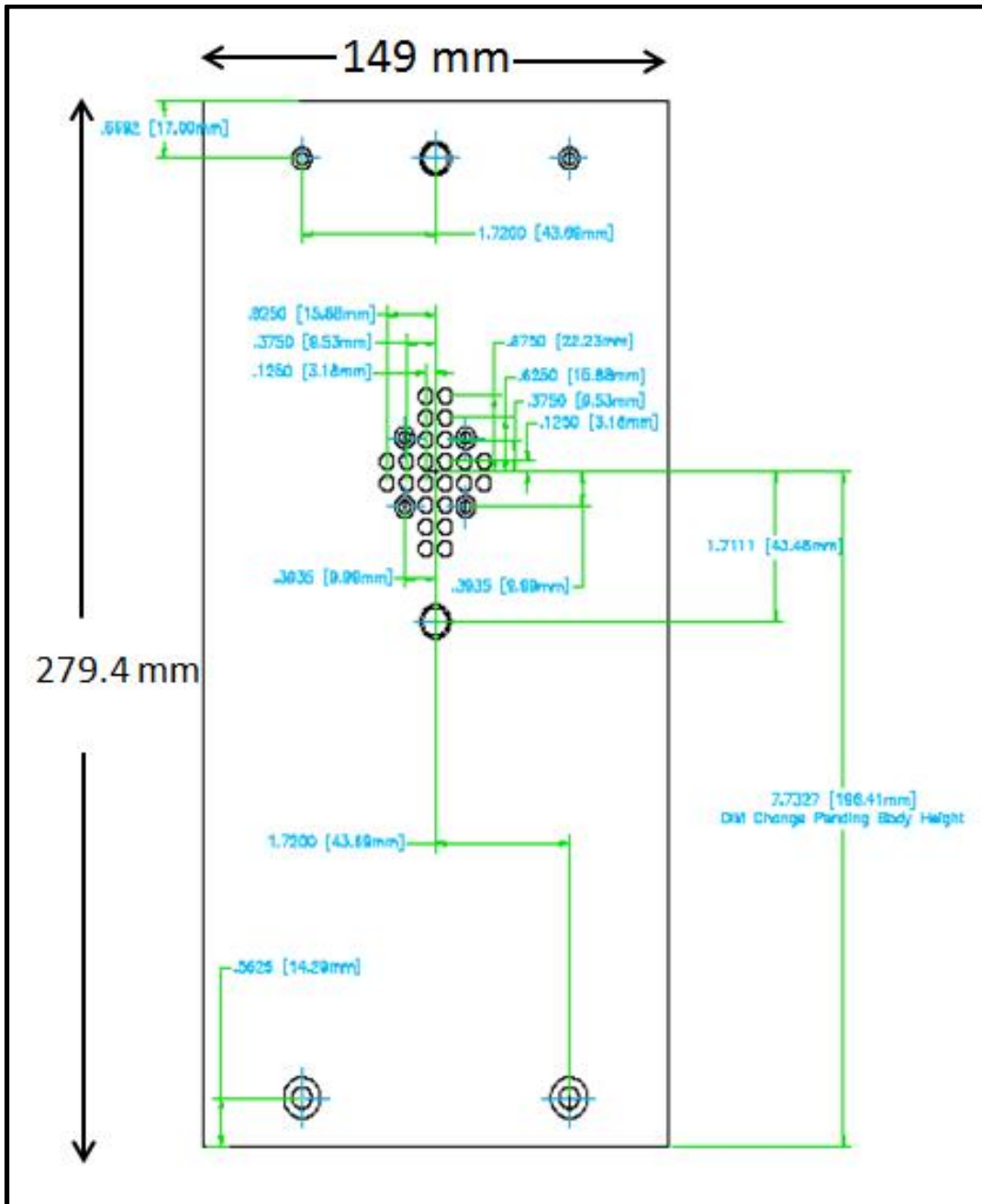
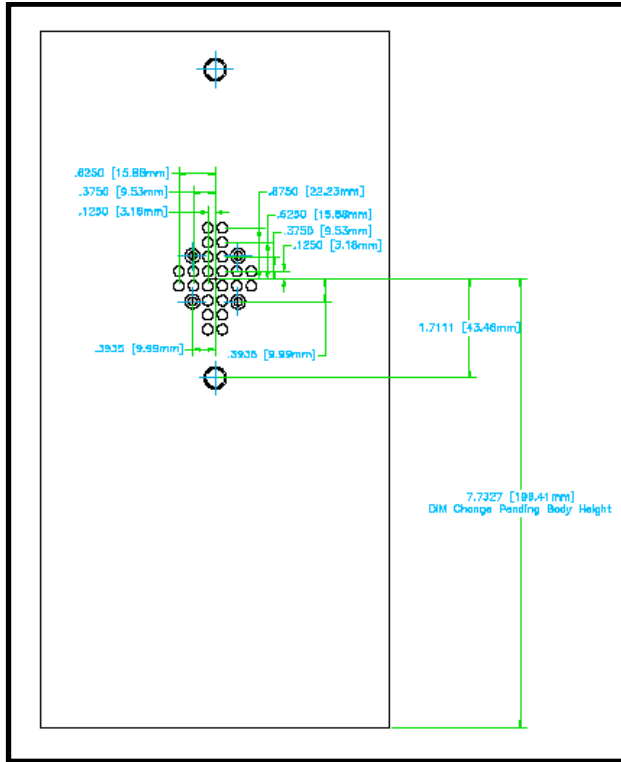Fig.4 (a) Design for holes on two opposite sides (Side #1 and 3) of payload body

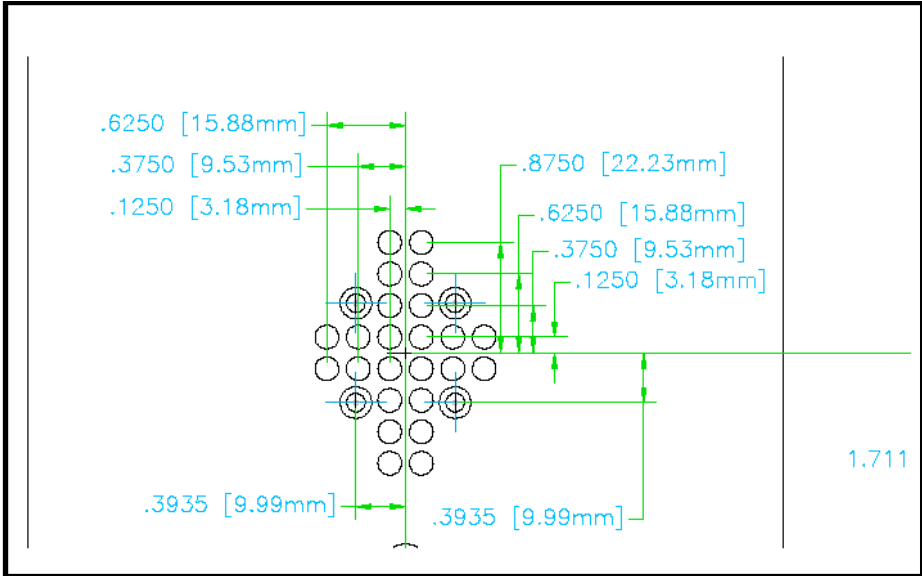Fig.4 (b) Design for holes on Side # 2 of payload body

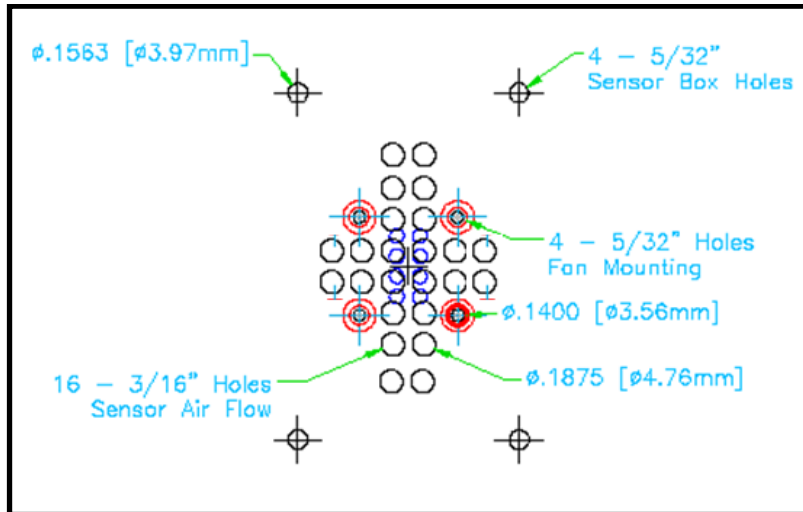Fig.4 (c) Details of design for holes on three sides of payload body for fan and air inlet

Fig.4 (d) Details of design for holes on three sides of payload body and sensor box
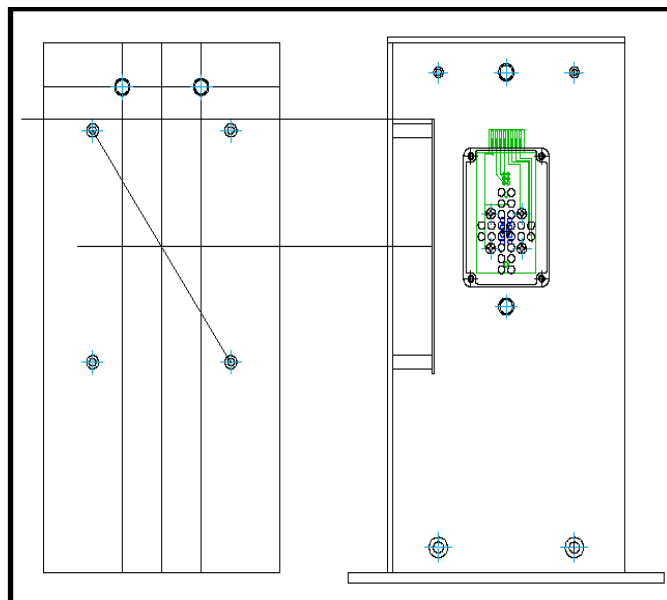

Fig.4 (e) Design for holes on payload body for mounting microcontroller PCB and sensor box
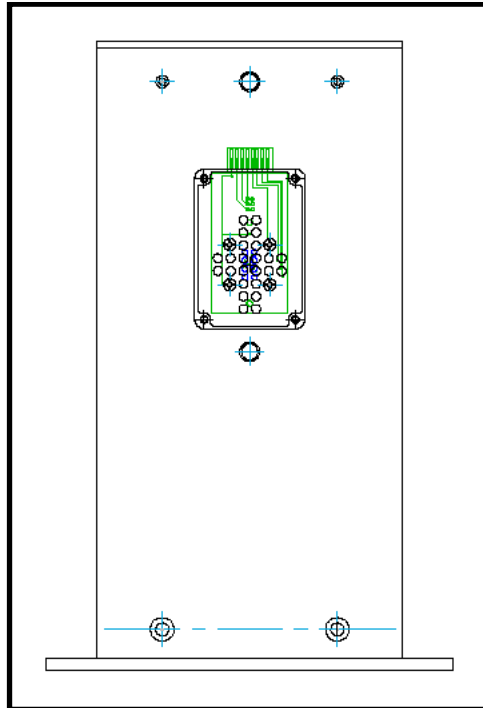
Fig.4 (f) Design for holes on payload body for mounting of sensor box, LED, Light sensor and HASP mounting plate
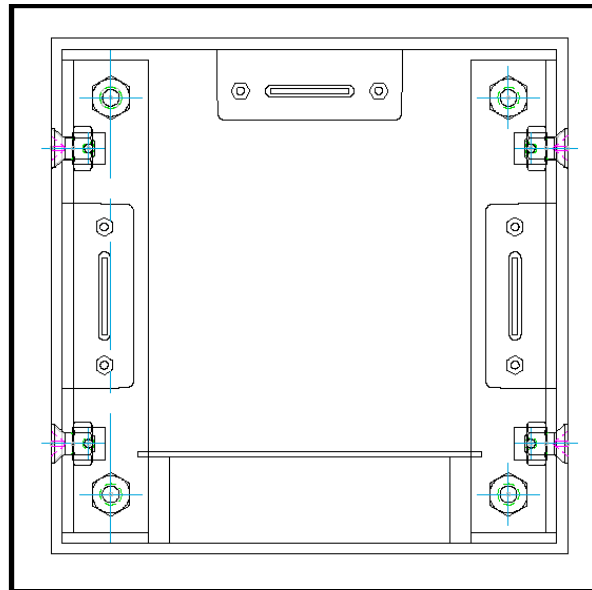

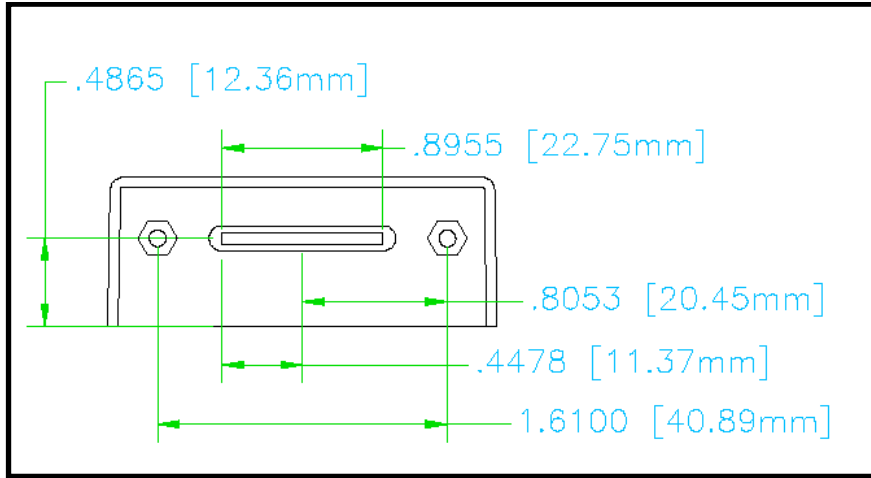
Fig.4 (g) Top view of payload

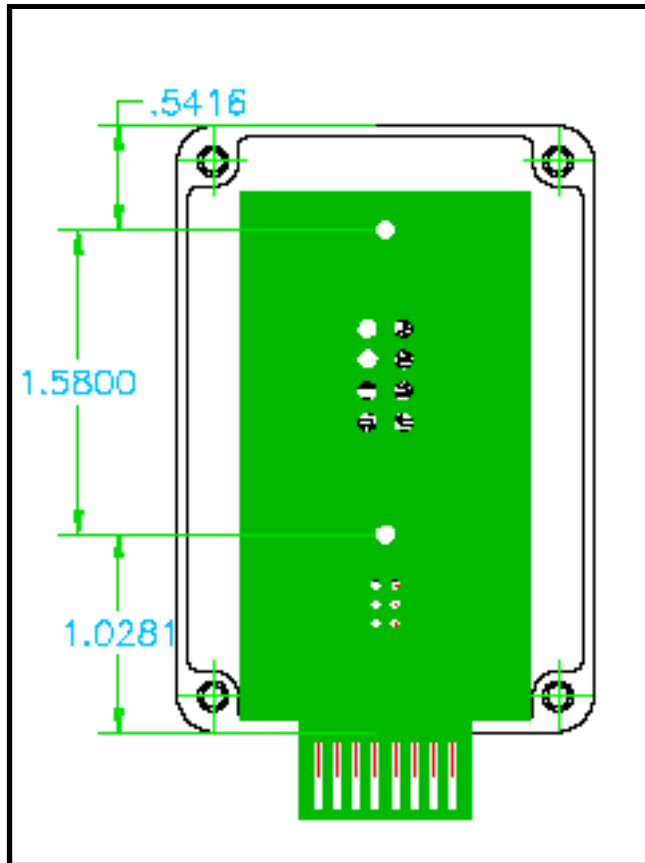Fig.4 (h) Design for standoff and PCB slot in the sensor box

Fig.4 (j) Design for standoff to mount sensor SPCB in the box
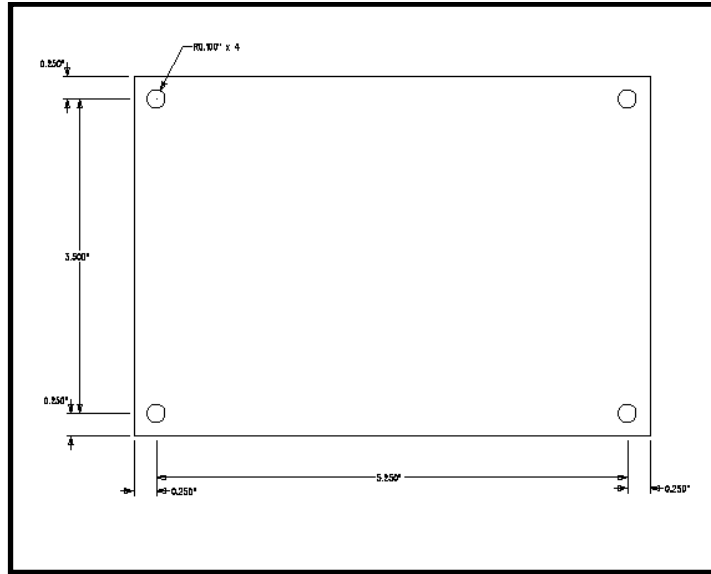
Fig.4 (j) Design for hole of the microcontroller PCB
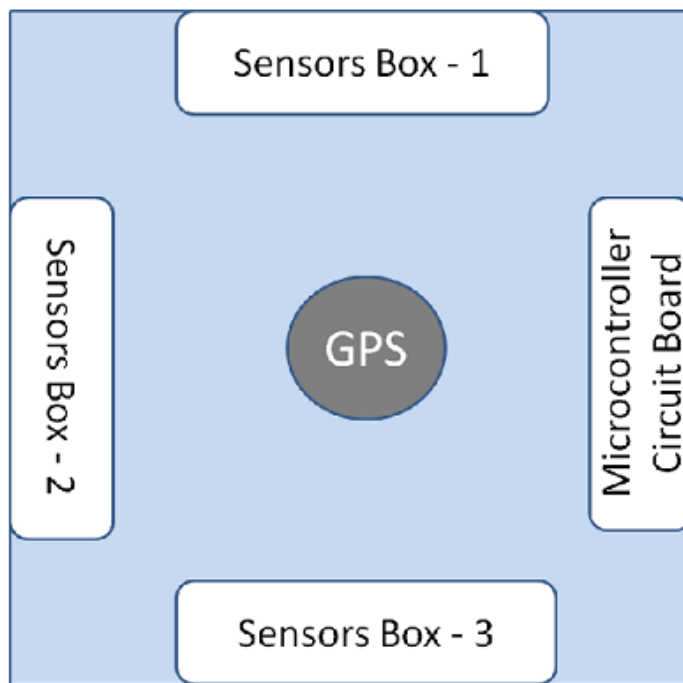
Fig. 4 (k) Top view of payload shows mounting of three sensors boxes and microcontroller circuit board.

The payload will be mounted on the HASP mounting plate using aluminum rectangles, bolts, washers and nuts.

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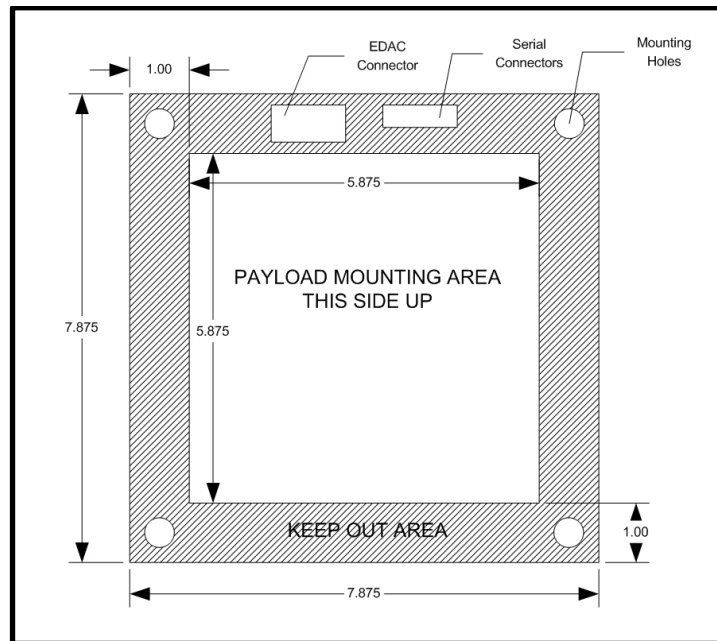
Fig. 5 Mounting Plate for small payload (Courtesy: HASP Version 02.17.09)
http://laspace.lsu.edu/hasp/documents/public/HASP_Interface_Manual_v21709.pdf

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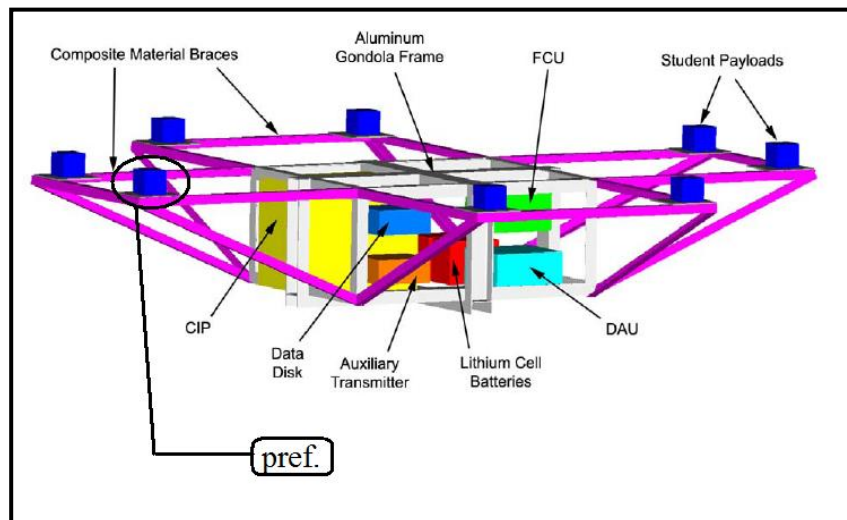
Fig. 6 Proposed HASP Configuration (Dr. Guzik and Wefel, 2004)

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 and developed by Mr. Jonathan Wade (UND) earlier.
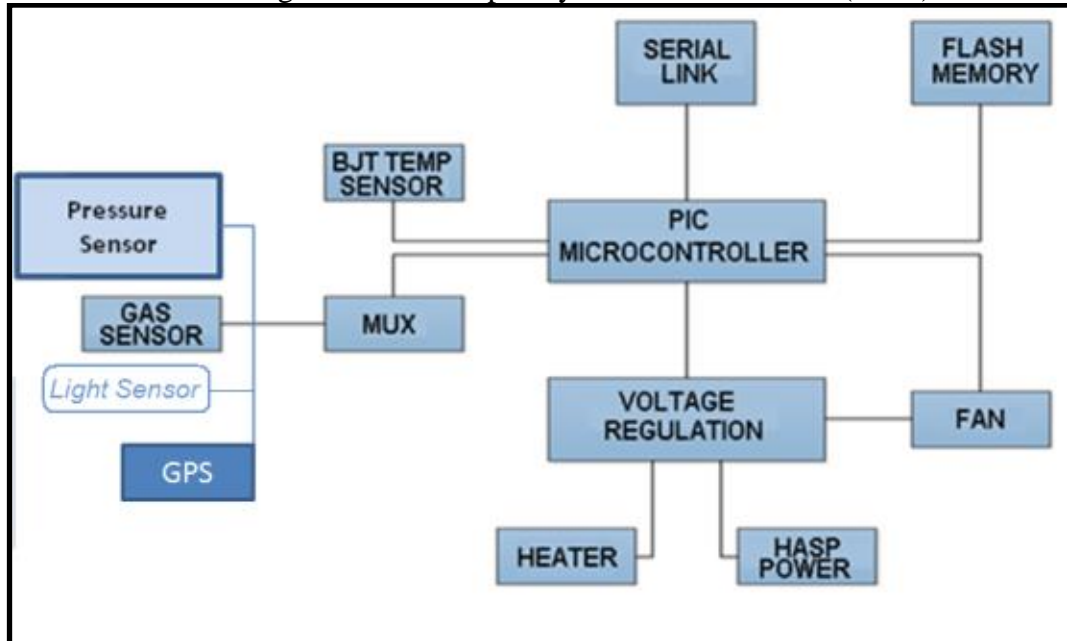
Fig. 7(a) Block diagram of payload ciruct
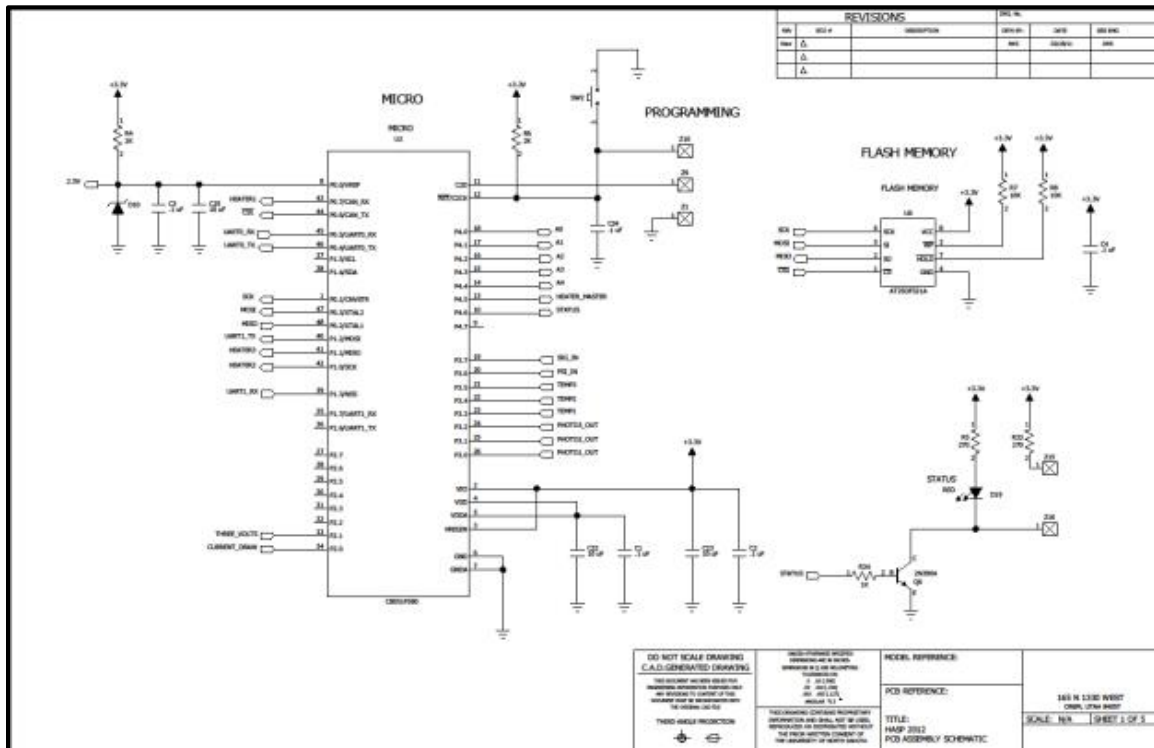
Fig. 7 (b) Circuit for microcontroller and flash memory
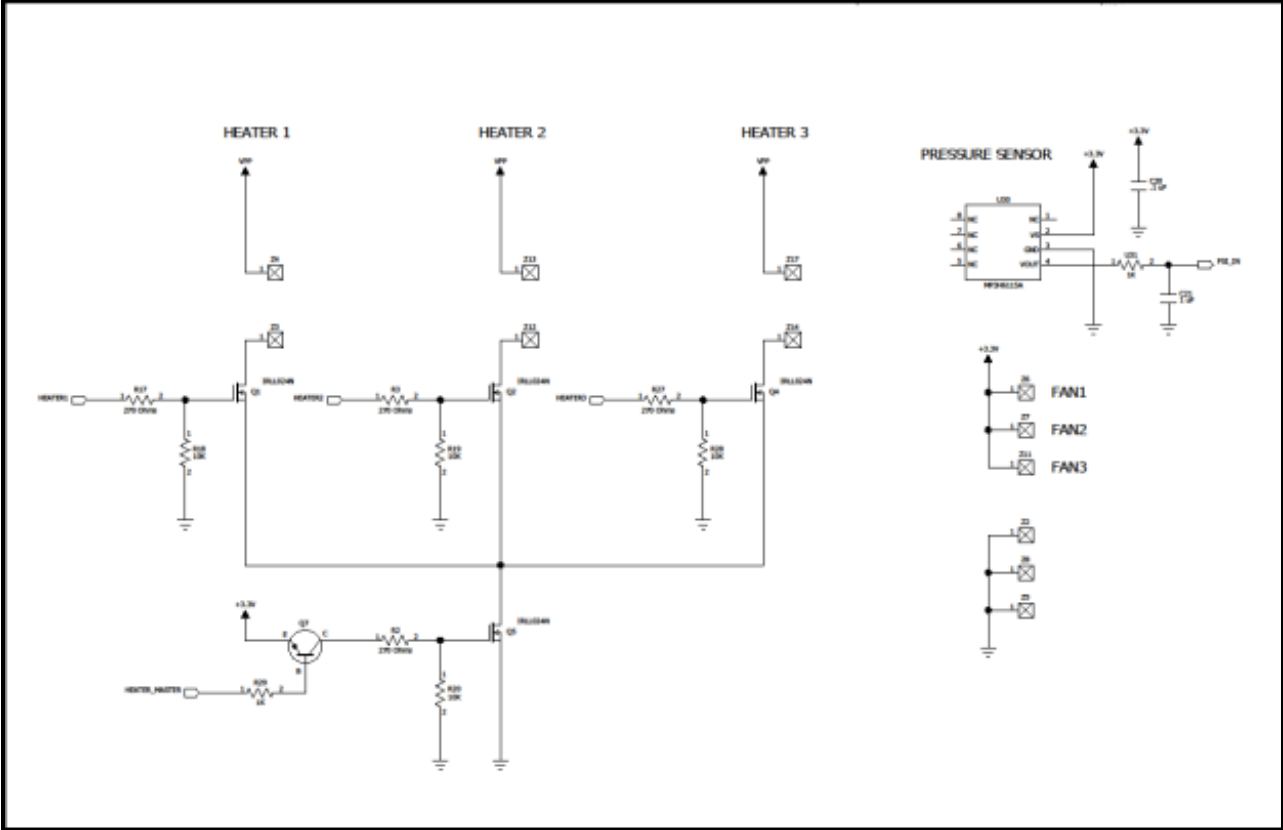
Fig. 7(c) Circuit for three heaters, three fans and pressure sensor
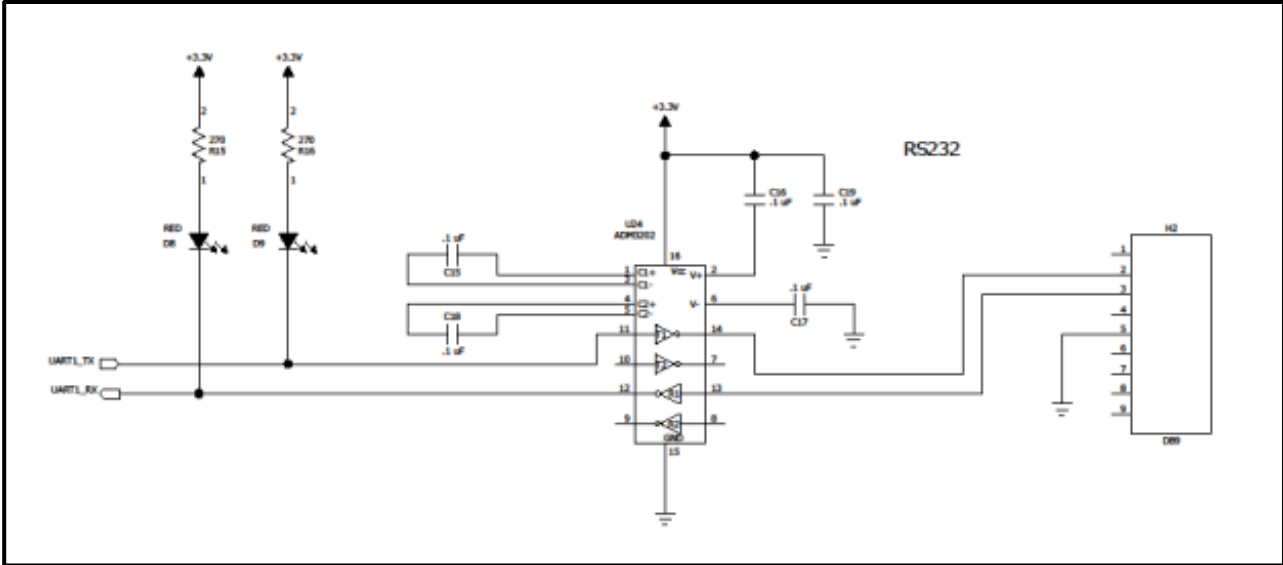
Fig.7 (d) Circuit for RS232
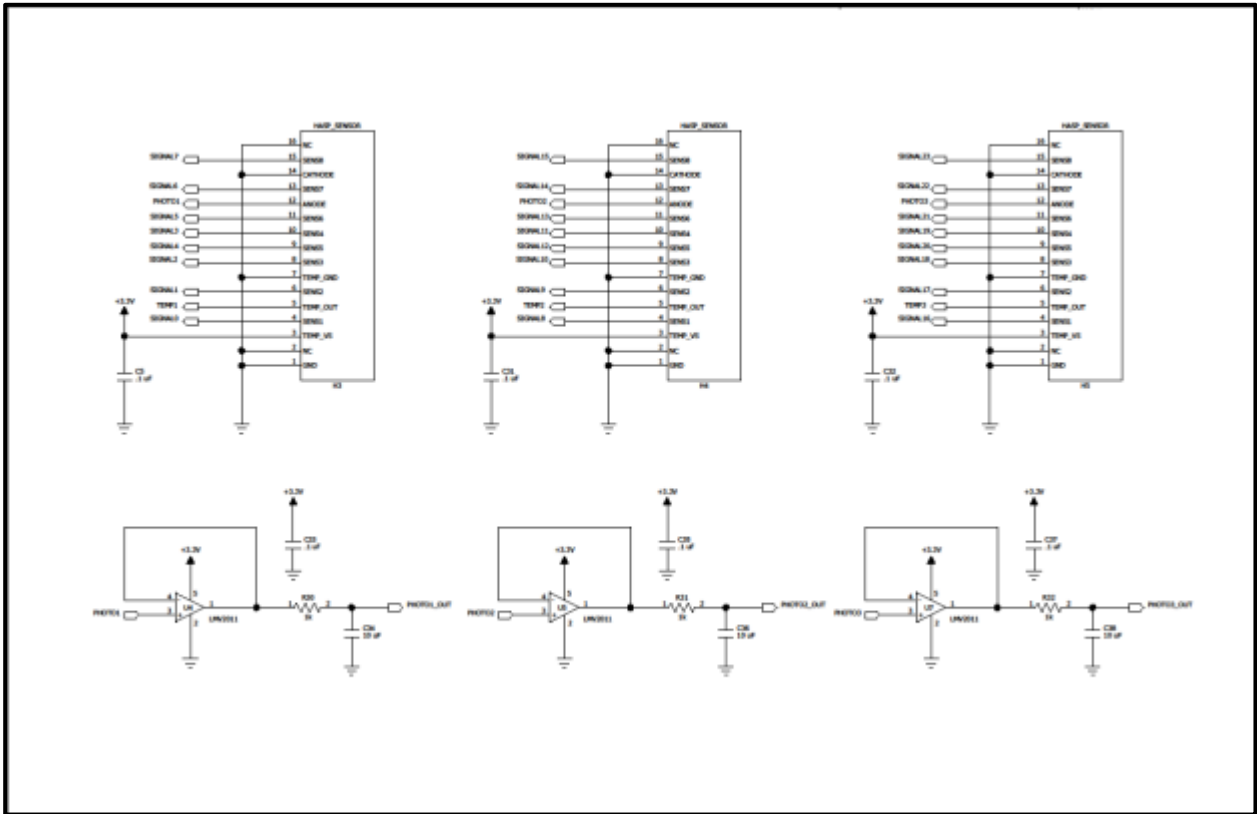
Fig.7 (e) Circuit for three ozone sensors boxes and three photo (light) sensors

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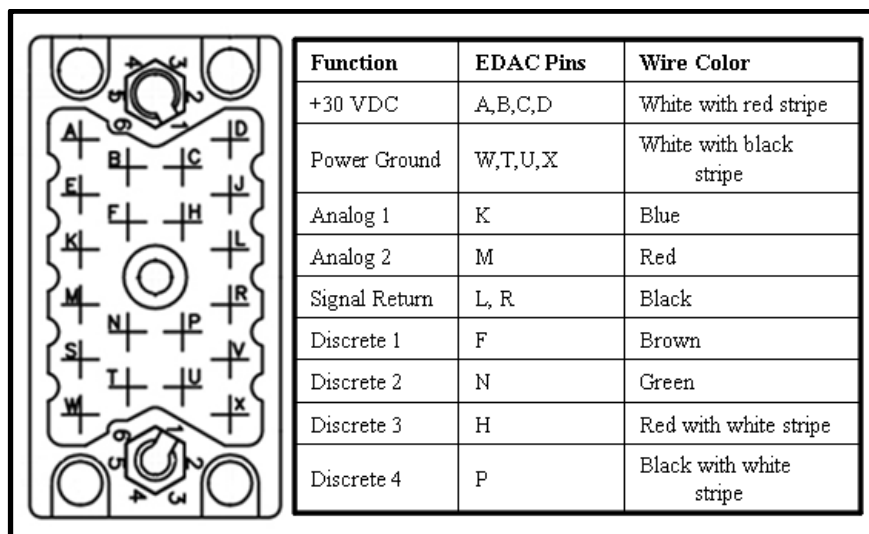
Fig. 8 EDAC516 receptacle pin layout (Courtesy: HASP manual).

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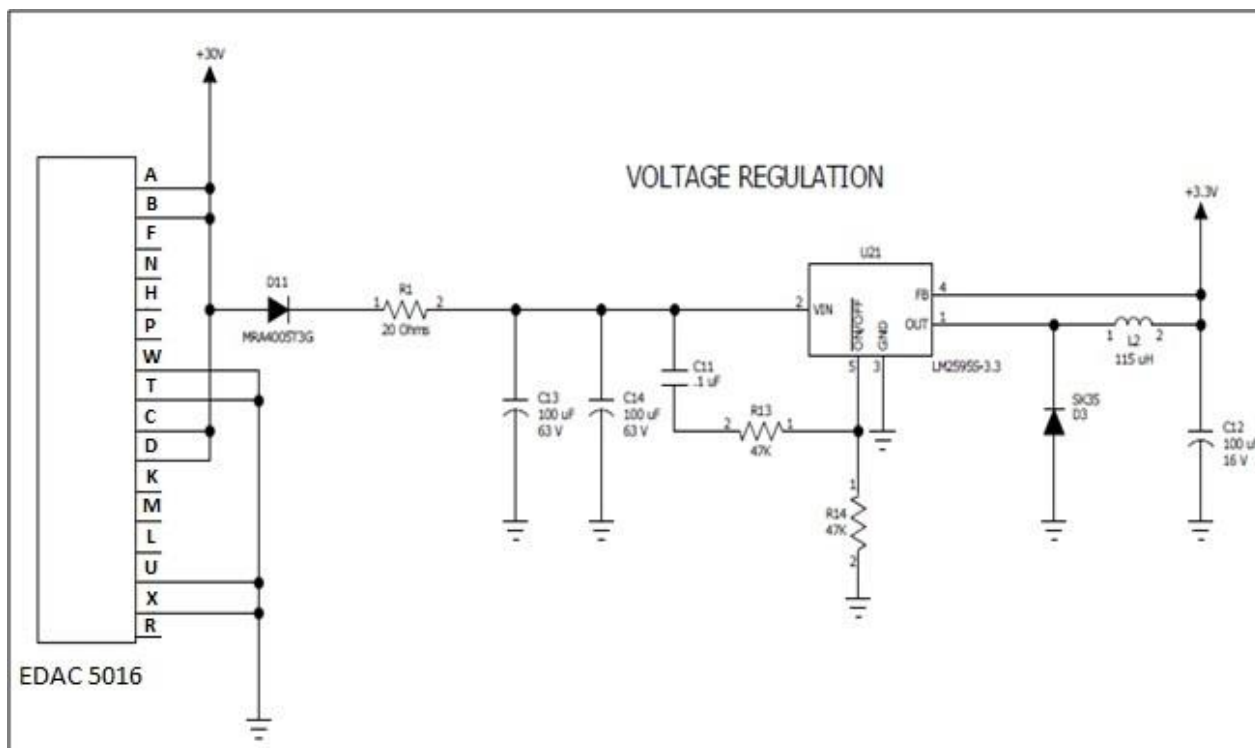
Fig.9 interfacing of EDAC 5016 of mounting plate with the payload voltage regulation circuit

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	30±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	350±5

The voltage applied to the payload during the HASP 2014 flight is shown in fig.10 (a) for information. It was found that applied voltage remain nearly constant about 3300mV. The current drawn by the payload during the flight is shown in fig. 10(b). Payload draw minimum 30 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.
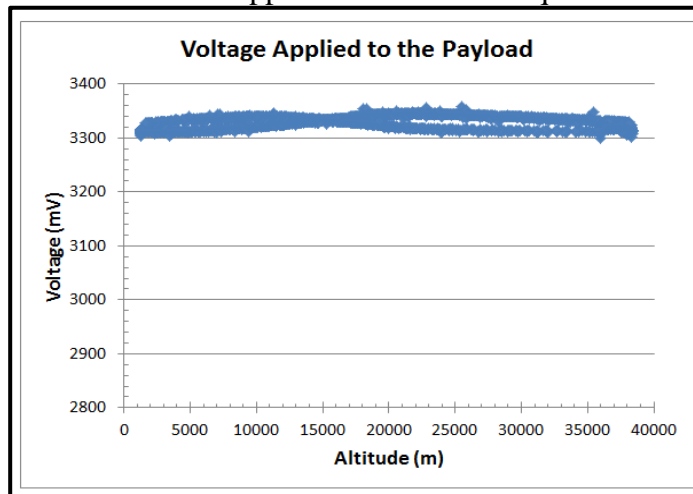
Fig.10 (a) Voltage applied to the payload during the HASP 2014 flight.
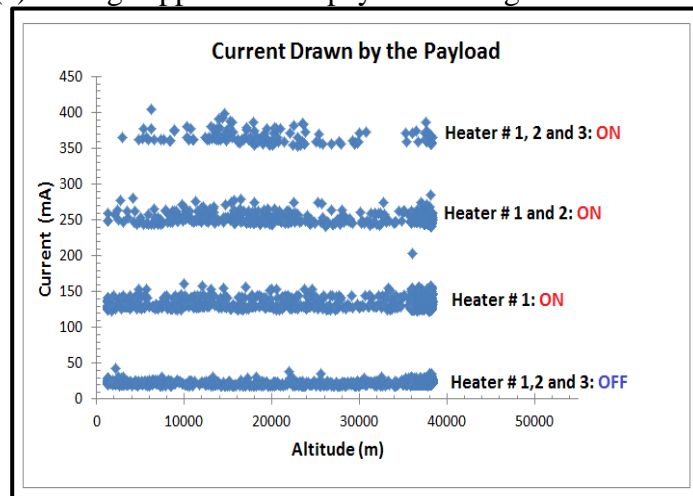
Fig.10 (b) Current drawn by the payload during the HASP 2014 flight

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 and a general operating temperature of 15°C (found from altitude variation from 0 km to 36 km shown in the modified altitude profile (Fig. 11 (a).

$$\text{Heat Transfer} = q = m(\Delta T)C_p \qquad (1)$$
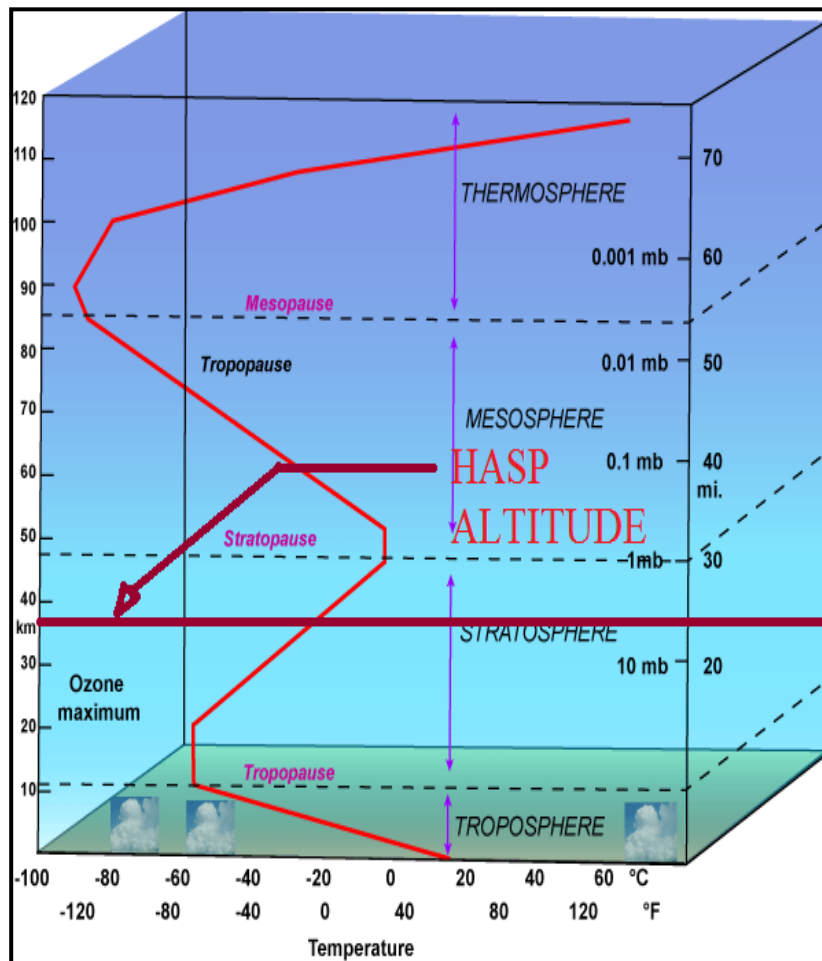
Fig. 11(a) Modified Altitude Profile (Atkins, 2007)

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 2000°F. This thermal blanket will minimize the variation of internal electronics temperature conditions. The temperature of ozone sensors will be controlled in the range of 302 ± 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 2014 flight is shown in fig.11 (b) for information. The temperature of sensors was remaining constant 302±5 ^{o}K.
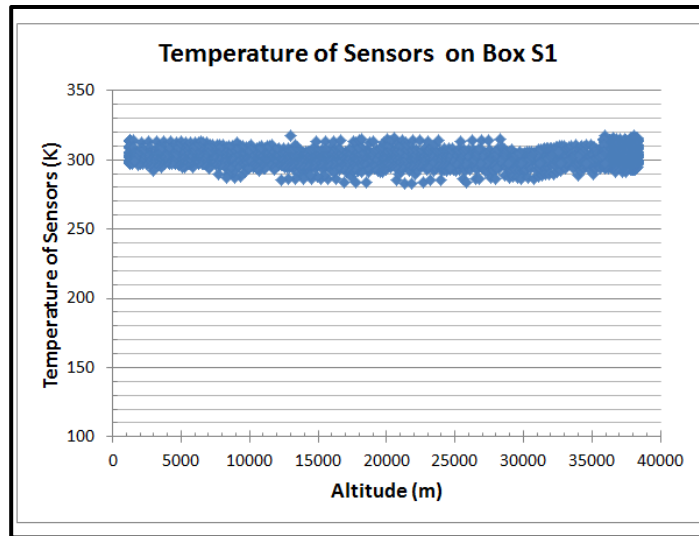
Fig. 11 (b) Temperature of ozone sensors box#1

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

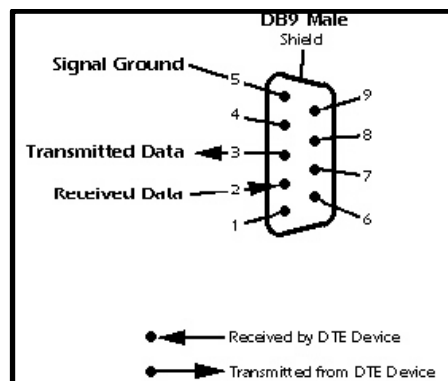| Byte #			Description	Example	Units
1	-	4	Packet Sync	HASP	n/a
5	-	8	GPS Source	XGPS	n/a
9	-	23	Time stamp	,1407604205.265	sec
24	-	29	Altitude	,38044	m
30	-	35	Sensor 1-1	,01067	ohms
36	-	41	Sensor 1-2	,01390	ohms
42	-	47	Sensor 1-3	,01438	ohms
48	-	53	Sensor 1-4	,01248	ohms
54	-	59	Sensor 1-5	,01282	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

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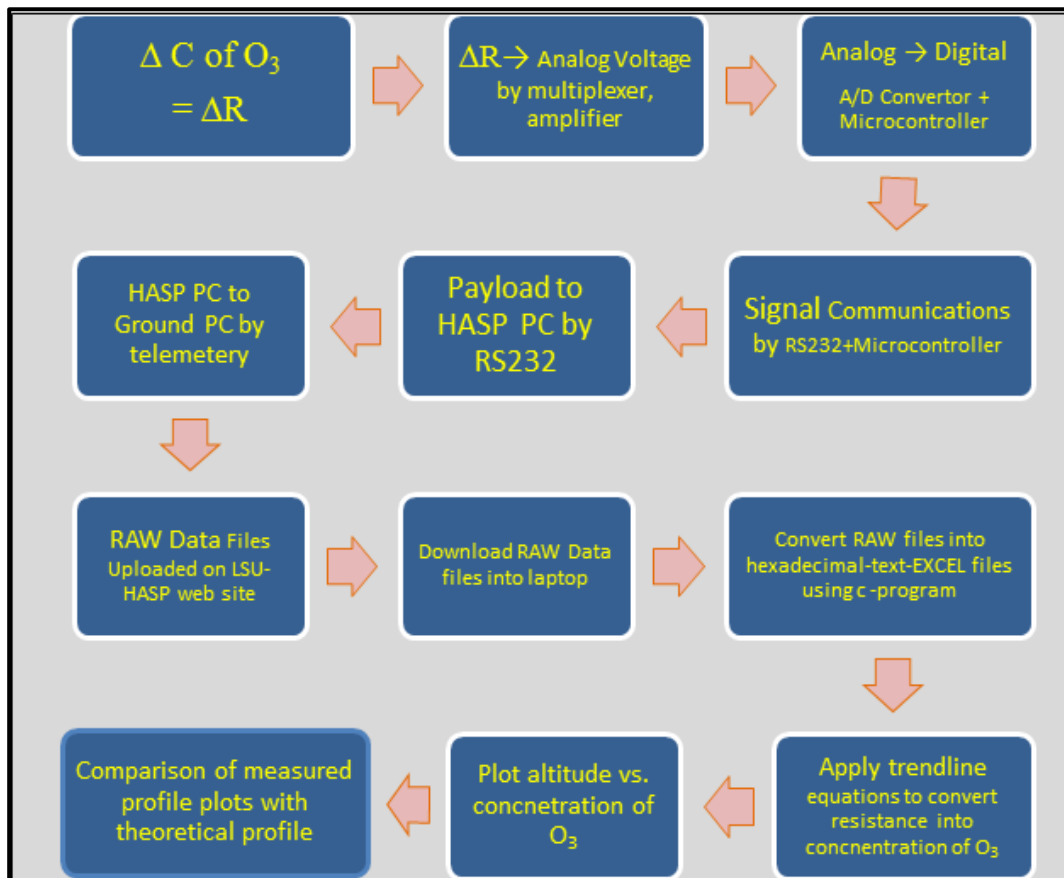
Fig.13(a) Steps for the detection of ozone by the payload

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. UND and UNF Team Structure

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 2015.

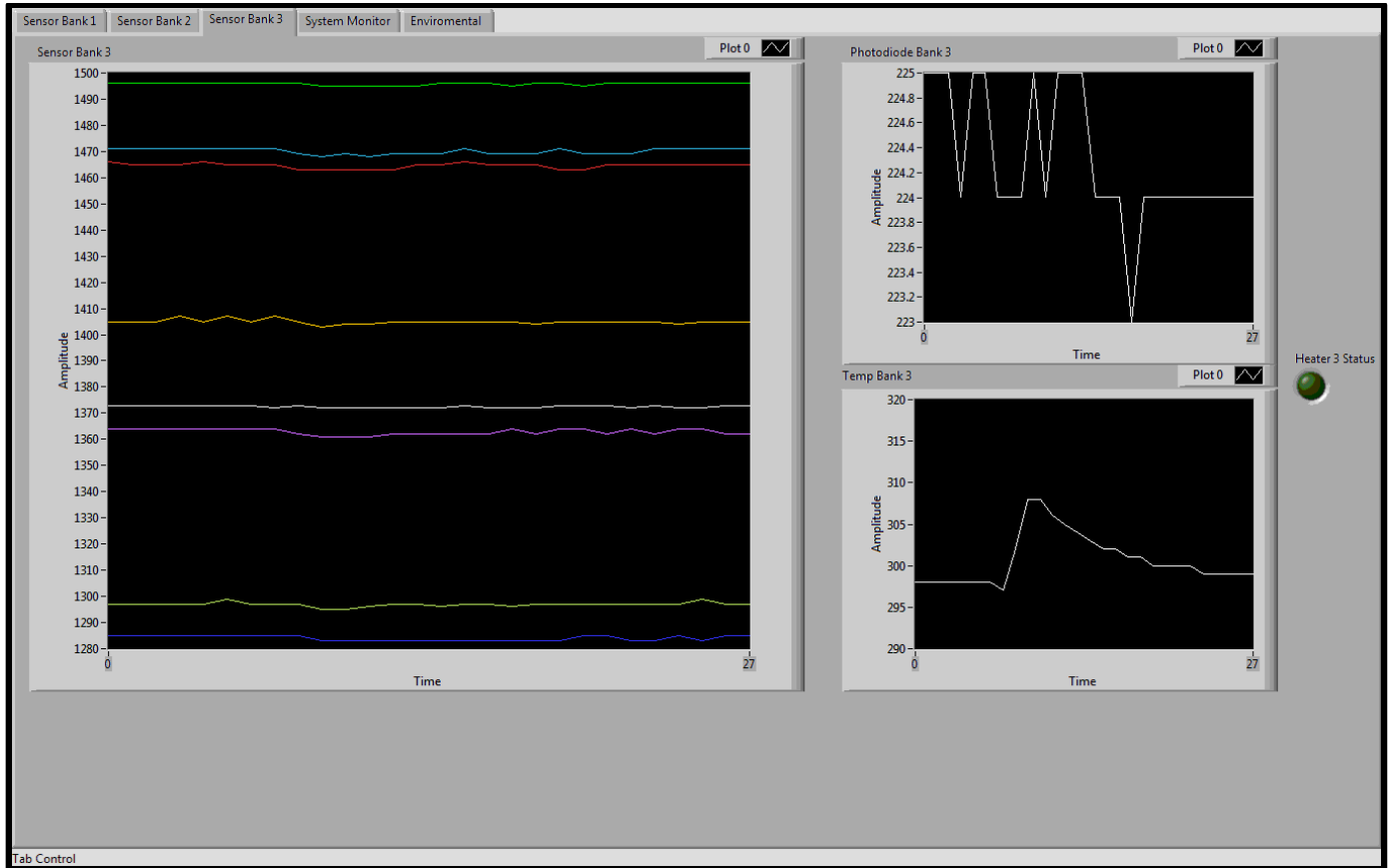| HASP 2015	
UNF	**UND**
Dr. Nirmal Patel UNF Faculty Advisor	Dr. Ron Fevig UND Faculty Advisor
Brittany Nassau (Team Leader) Sensors Fabrication, Hardware, Administration and Reporting	Sean McCloat (UND Leader) Space studies, Hardware Reporting
Ken Emanuel (Consultant) Hardware and Software	Jonathan Wade (Consultant) Hardware and Software
Joseph Silas Design and Payload Body	Students-1 may be added
Matthew Linekin Sensors Testing and Calibration	Student-2 may be added
Bernardo Craveiro Programming and Data analysis	

Fig.14 UND-UNF 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 2015. 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. She will work as a team leader and will 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.

(1) Brittany Nassau (UNF Team Leader)
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Email: Brittany.Nassau@gmail.com
Race: White

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    Cell#: 904-520-1605
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(5) Sean McCloat (UND Team Leader)
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    Cell#: 631-813-7819
    Email: spmccloat@gmail.com
    Race: White / Caucasian

Two more students from Grand Fork High School may join the team subject to the permission of their school, parents and UND.

10. Task and Work Plan Path

The initial work break down schedule (WBS) 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-4.

Table-4 Work plan path

2015	UND	UNF
January	Conceptual Design Review (CoDR) for sensors, electronic circuits, software and payload. Reviewing science reports and issues of HASP2008 to 2014 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 a minimum of two to three students from UND and UNF and Dr. Nirmal Patel, faculty advisor from UNF will travel to CSBF, Palestine, Texas in first week of August of 2015 (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 HASP2015 payload during September 2015 (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

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 O3 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 02.17.0
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

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