# HASP Student Payload Application for 2014

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|---|---|---|
| **Payload Title:** Development of free flying payload to measure ozone profile in the stratosphere and pollutant gases in atmosphere and troposphere using nanocrystalline sensors on a high altitude balloon platform. | | |
| Payload Class: (circle one)<br>Small Large | **Institution:** University of North Dakota (UND) and University of North Florida (UNF) | **Submit Date:**<br>12-08-2013 |


**Project Abstract:** 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 ozone profiles measured by sensors payload were matched very well with the expected profile. Based on the success and experience, particularly last two best flights and the few known scientific and technical issues of these payloads, the UND-UNF team proposes the HASP 2014 flight for the development of free flying payload to measure ozone profile using improved version of the gas sensor arrays and 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. Further improved 8 Nanocrystalline ITO thin film gas sensors and 8 Nanocomposite ZnO+ITO thin film gas sensors will measure oxidizing ozone gas, 8 Nano-composite $WO_3$+ITO thin film gas sensors will be used for detection of reducing pollutant gases such as CO, $CO_2$, in the atmosphere and troposphere. Temperature controller will be used to control operating temperature of all gas sensors. 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 photo voltage 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 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 outside ambient temperature, improved low pressure sensors which can measure about 1 mBar low pressure range and an Government approved GPS which can measure 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 as well as the Government certified radio, antenna and battery pack. Ozone and pollutant gas sensors will be fabricated and calibrated at UNF and also tested at UND.



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|---|---|---|---|
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# HASP2014 Proposal

**Development of free flying payload to measure ozone profile in the stratosphere and pollutant gases in atmosphere and troposphere using nanocrystalline sensors on a high altitude balloon platform**

**Submitted by**


**University of North Dakota (UND)**

**and**

**University of North Florida (UNF)**

**Students Team:**
Marissa Saad (Leader), Jonathan Snarr (consultant), and two more students (UND),
Kenneth Emanuel, Samuel Rhodes and Ryan Campiz (UNF)

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

## 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 matched very well with the theoretical expected profile. Based on the success, particularly last 2012 and 2013 flights and the few known scientific and technical problems of these payloads, the UND-UNF team proposes the HASP 2014 flight for the development of free flying payload to verify generation of ozone and measure ozone profile and pollutant gases in the atmosphere and troposphere using improved version of the gas sensor arrays payload. 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.

Further improved 8 Nanocrystalline ITO thin film gas sensors and 8 Nanocomposite ZnO+ITO thin film gas sensors will measure oxidizing ozone gas, 8 Nano-composite $WO_3$+ITO thin film gas sensors will be used for detection of reducing pollutant gases such as CO, $CO_2$, in the atmosphere and troposphere. Temperature controller will be used to control operating temperature of all gas sensors. 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 photo voltage 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 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 outside ambient temperature, improved pressure sensors which can measure high and low pressure ranges and an improved GPS which can measure 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 as well as the Government agency certified radio, antenna and battery pack. Radio will turn on or off by uploading commend from ground.

Gas sensors will be fabricated and calibrated with ozone gas in 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. The software will allow us to convert RAW files directly into one EXCEL file.

Furthermore, the surface topography of the sensors before and after the flight will be studied using a scanning electron microscope, and the chemical composition of the surface of the sensors will be analyzed by energy dispersive analysis of x-rays at UNF. This student project may be supported by both North Dakota and Florida Space Grant Consortia.

## (2) Significance of Project

ITO-QCM (Quartz Crystal Microbalance) sensor platform technology (Patented) and nanocrystalline oxide semiconductor thin films gas sensor arrays technology (U. S. Patent Pending) 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 lab, 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 University of North Dakota (UND) during 2008-2009. UNF team is continuously improving the performance of ozone sensors by changing its fabrication conditions and modifying its surface structure. These sensors were successfully tested on HASP 2008 to 2013 flights. These sensors 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 ambient temperatures 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 thin film sensors and nanocomposite ZnO+ITO gas sensors have better 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 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 is low cost and low weight for the rapid detection of gases in the troposphere and stratosphere.

## (3) Work Plan for the Proposed Science Experiment

The proposed work is a continuation of UND-UNF joint efforts made during the last six years. Brief information about the output of last six HASP flights is summarized in fig.1. The flight picture and ozone profile are shown in fig. 2.

| HASP Flight Year | Ozone profile measured | Technical Issues | Conversion of RAW data files | No of students involved | |
|---|---|---|---|---|---|
| | | | | UND | UNF |
| 2008 | Yes | Payload body was not user friendly | Mostly by manually | 4 | 2 |
| 2009 | Yes | Voltage regulator and capacitor | Mostly by manually | 3 | 3 |
| 2010 | Yes | Temperature of sensors raised during evening time | By software | 3 | 3 |
| 2011 | Yes | GPS failed after 60,000 ft. and saturation of pressure sensor below 100 mbar | By software | 2 | 4 |
| 2012 | Yes | GPS failed after 60,000 ft. and saturation of pressure sensor below 100 mbar | By software | 2 | 2 |
| 2013 | Yes | GPS failed after 60,000 ft. and saturation of pressure sensor below 100 mbar | By software | 2 | 2 |

Fig.1 Overview of previous flights

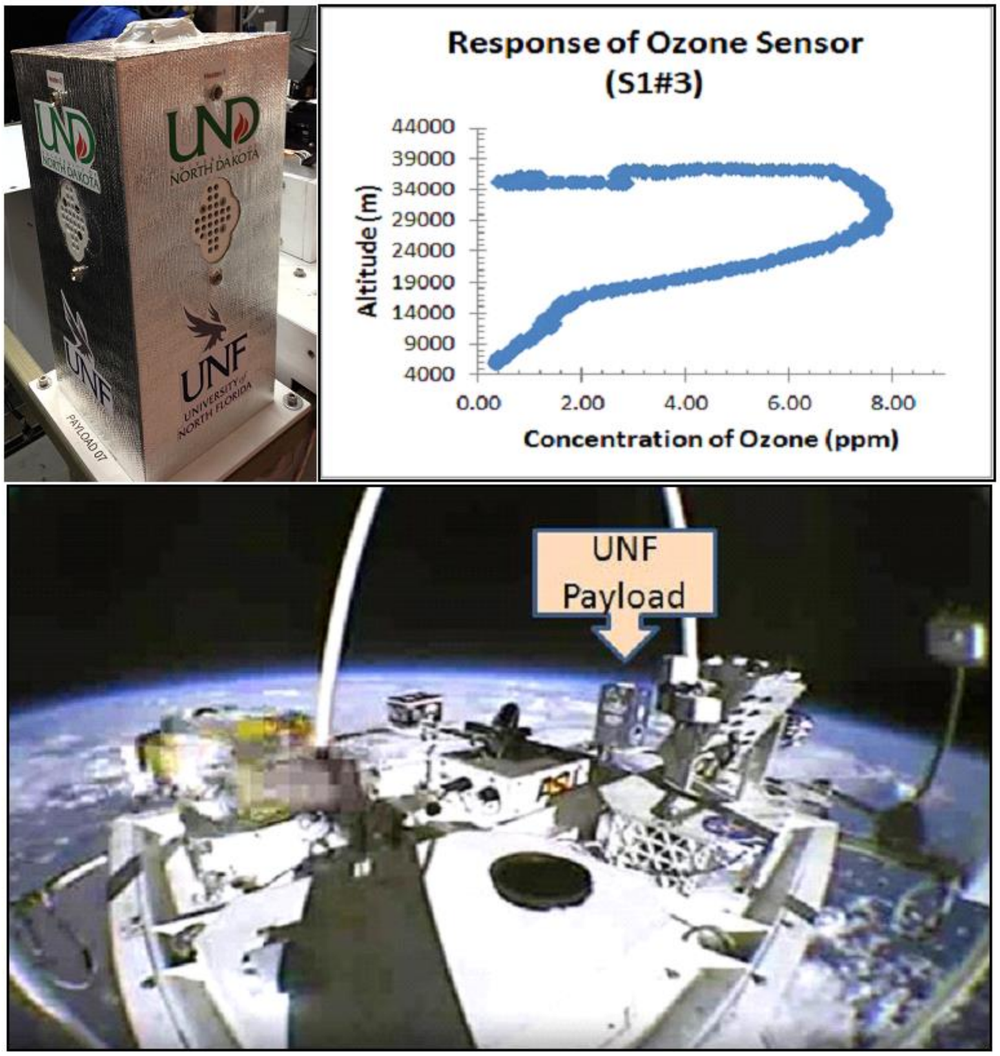


Fig. 2 UND-UNF payload on HASP 2013 payload, measured ozone profile by one of sensors and balloon flight in stratosphere

Based on the success and few known scientific and technical problems with the HASP balloon flights made during 2008 to 2013, the UND-UNF team proposes a HASP 2013 flight with following new objectives for the measurement of ozone profile in the stratosphere using improved version of the gas sensor arrays and radio payload.

(i) To develop low weight and thermally stable payload which can work as a free flying payload and easily integrate with meteorological weather balloon, rocket and sub orbital space vehicle for measurement of gas profile in the upper atmosphere layers.

(ii) 8 Nanocrystalline ITO thin film gas sensors (Box#1) and 8 Nanocomposite ZnO-ITO thin film gas sensors (Box#2) will be used for measurement of ozone gas profile in the stratosphere, while 8 Nanocomposite $WO_3$-ITO thin film gas sensors (Box#3) will be used for measurement of reducing pollutant gases such as CO and $CO_2$ in the atmosphere and troposphere. Nanocrystalline gas sensors will have better sensitivity, selectivity, stability and faster response and recovery time. Students of UNF will fabricate ITO thin film gas sensors using electron beam deposition method. Three sensors boxes (#1, 2 and 3) will be mounted on the three sides of rectangular payload body.

(iii) 4 new fabricated ITO sensors and 4 previously used ITO sensors in HASP2013 flight will be mounted in the Box#1 for comparison of stability of sensors.

(iv) All ozone gas sensors will be tested and calibrated simultaneously in the low pressure chamber in order to minimize the experimental error for the trendline equations of the plots for converting resistance values into concentration of ozone in part per million (ppm). The pressure and temperature inside the test chamber will be maintained same as in the stratosphere. Ozone sensors will be again tested at UND for the cross verification.

(v) Each sensors box having 8 gas sensors, 1 flexible heater, 1 temperature sensor and 1 mini fan will be mounted on side of payload body. Total 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 in the range of 25 to 30 $^{o}$C using 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.

(vi) An ultra violet (UV) light sensor will be mounted just below the gas sensors box on each side of the payload body. The light sensor will support the science concept of generation of ozone in the presence of UV light. The amount of photo voltage generated and measured by the UV light sensor will indicate how much of UV light available to interact with oxygen to convert into ozone gas near to ozone gas sensors. Nanocrystalline ITO thin film gas sensors will detect and measure the concentration of that generated ozone gas. This 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 how much concentration of ozone decrease at night time.

(vii) A temperature sensor (TMP 36) will be mounted on the outer surface of payload to monitor any change in the outside ambient temperature with altitude and time.

(viii) It was observed that the pressure sensor used in the last two flights was worked well from atmosphere to 100 mbar and then saturate. We propose to use two pressure sensors: one will measure from atmosphere to 100 mbar and second will measure below 100 mbar to monitor the pressure in the stratosphere.

(ix) It was found that GPS used in the last two flights was not functioning after 60000 feet altitude. The transmission was blocked or jammed under the Government regulation. We proposed to use improved and Government certified GPS to measure the altitude of balloon flight. The measure altitude using GPS will be cross verified and compared with the HASP GPS data.

(x) The new addition to the payload will be use of 900 MHz or higher frequency radio for communication of data. We propose 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 commend from the ground. Radio circuit will have antenna and may operated 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.

(xi) 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 low pressure.

(xii) Thermal blanket made of aluminized heat barrier having adhesive backed (Part No. 1828-12x24) (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.

(xiii) UNF sensors will be integrated with the UND electronics circuit and software to complete the payload. The software will allow us to convert all RAW files directly into one EXCEL file. Then, calibration trendline equations will be applied to convert the change in resistance values of sensors into the concentration of ozone gas in ppm. Both teams will jointly analyze the data as well as any issue after the flight.

(xiv) 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. Nirmal Patel.

(xv) The developed payload will 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, rocket payload for space and environmental applications.

## (4) Working Principle, Fabrication of of Gas Sensors and Payload

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

Upon adsorption of charge accepting molecules at the vacancy sites from oxidizing ozone ($O_3$) gas, electrons are effectively depleted from the conduction band of ITO. Vacancies can be filled by reacting with ozone. Filled vacancies are effectively electron traps and as a consequence, the resistance of the sensor increases upon reacting with ozone.

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

**<u>Fabrication of Gas Sensor Arrays</u>**

Nanocrystalline ITO thin film gas sensors array (UNF patent pending) will be fabricated over the ultrasonically and chemically cleaned glass substrates. Fig. 3(a) shows the top view of 8 sensor arrays and the interface printed circuit board. Fig. 3(b) shows a scanning electron micrograph of one ITO thin film gas sensor having two gold electrodes for external electrical contacts. Fig.3(c) shows a scanning electron micrograph of nanocrystalline gains of the ITO thin film, while sensor boxes are shown in fig. 3(d).

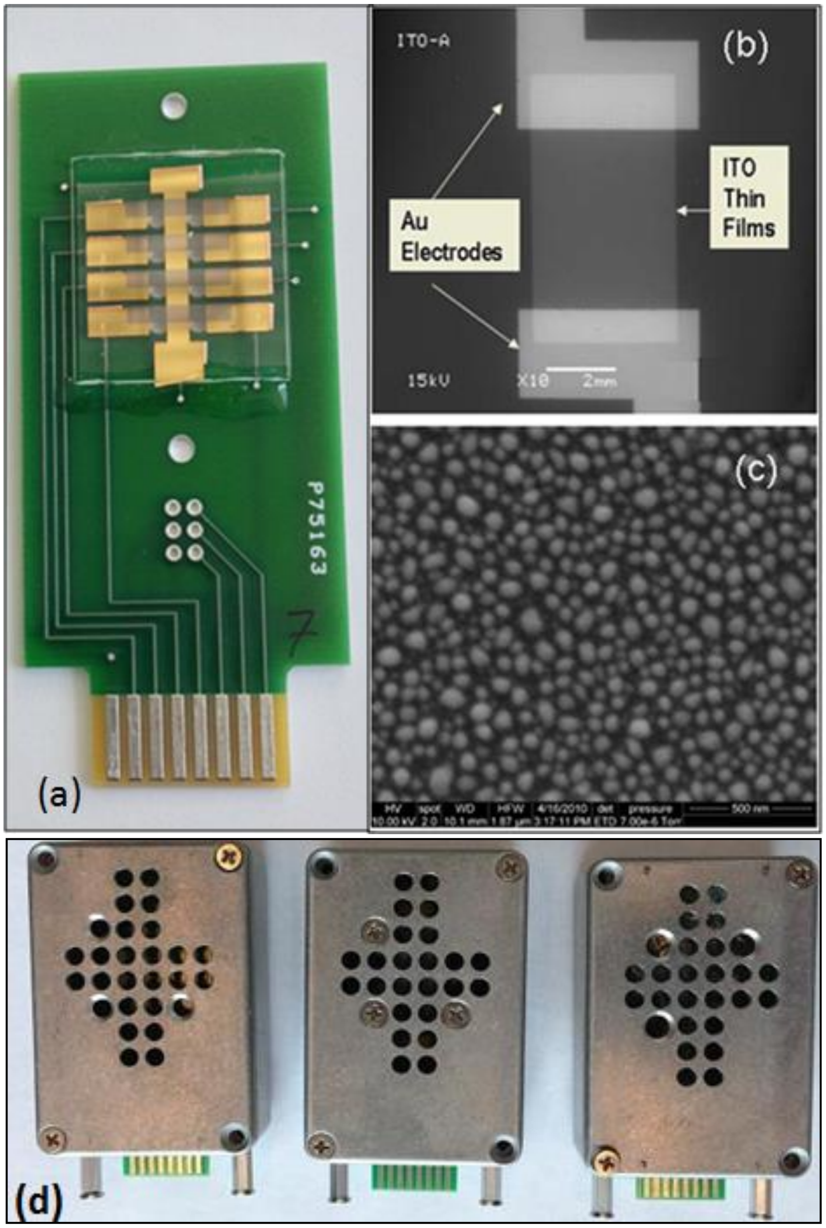

Fig.3 (a) 8 sensor array and interface mini PCB, scanning electron micrograph of (b) top view of one ITO gas sensor,(c) nanocrystalline grains of ITO thin film and (d) sensors boxes.

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. 4).

**Box#1:** 8 nanocrystalline ITO thin film gas sensors for detection of ozone gas in the stratosphere.
**Box#2:** 8 nanocomposite ZnO-ITO thin film 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.

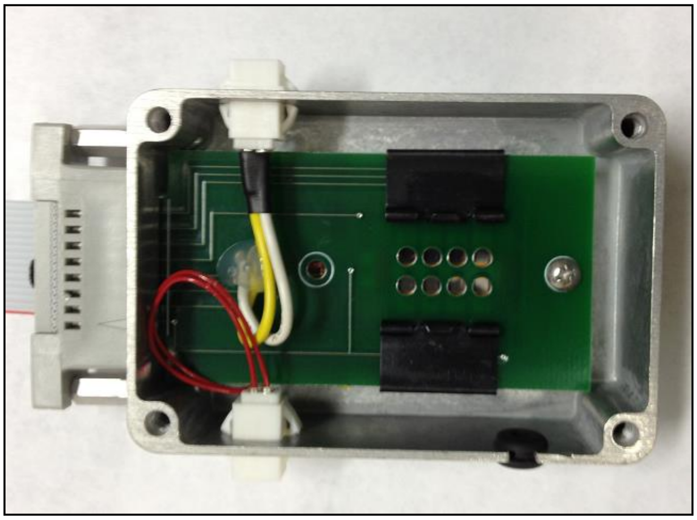

Fig. 4 Schematic diagram of sensor array box

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. The surface morphology of the gas sensors and CSTFTs before and after recovery of the payload will be examined using a scanning electron microscope (SEM) at UNF. The chemical composition of the sensors will be determined using Energy Dispersive Analysis of X-rays (EDAX) at UNF in order to check for any possible damage and contamination on the surface of the sensors occurred during the flight.

**Fabrication of payload**

A miniature, flexible, and low power heater (MINCO or OMEGA make) will be integrated on to the backside of the sensor arrays. The purpose of the heater is to combat the low temperatures of the troposphere and keep the sensors at a nearly constant temperature in the range of 25 to 30°C. A miniature temperature sensor (TMP 36) will also be mounted to monitor and control the temperature of the sensors using a closed loop control electronics circuit. The sensors array with a printed circuit board will be mounted in a low weight aluminum box. Three boxes will be mounted on the three sides of the low weight payload body. Outer temperature sensor and GPS antenna will be mounted on the top plate of the payload. The wall of the payload will be covered by a thermal blanket. A miniature low power fan will be mounted on the front of the sensor box to push gas molecules over the surface of the sensors. The fan will mainly work during the upward and downward journey of the flight. The fan may stop rotating during float in the stratosphere because of the low pressure. A wire mesh will be fixed over the fan in order to filter out dust particles and protect the surface of the sensors. The sensor box containing the sensors, fan, heater, and temperature sensor will be interfaced with the microcontroller circuit and payload.

## (5) UND and UNF Team Structure

The team structures, distribution of work and management methods will remain largely the same as last year with inclusion few new students. Fig.5 shows the chart for the team management

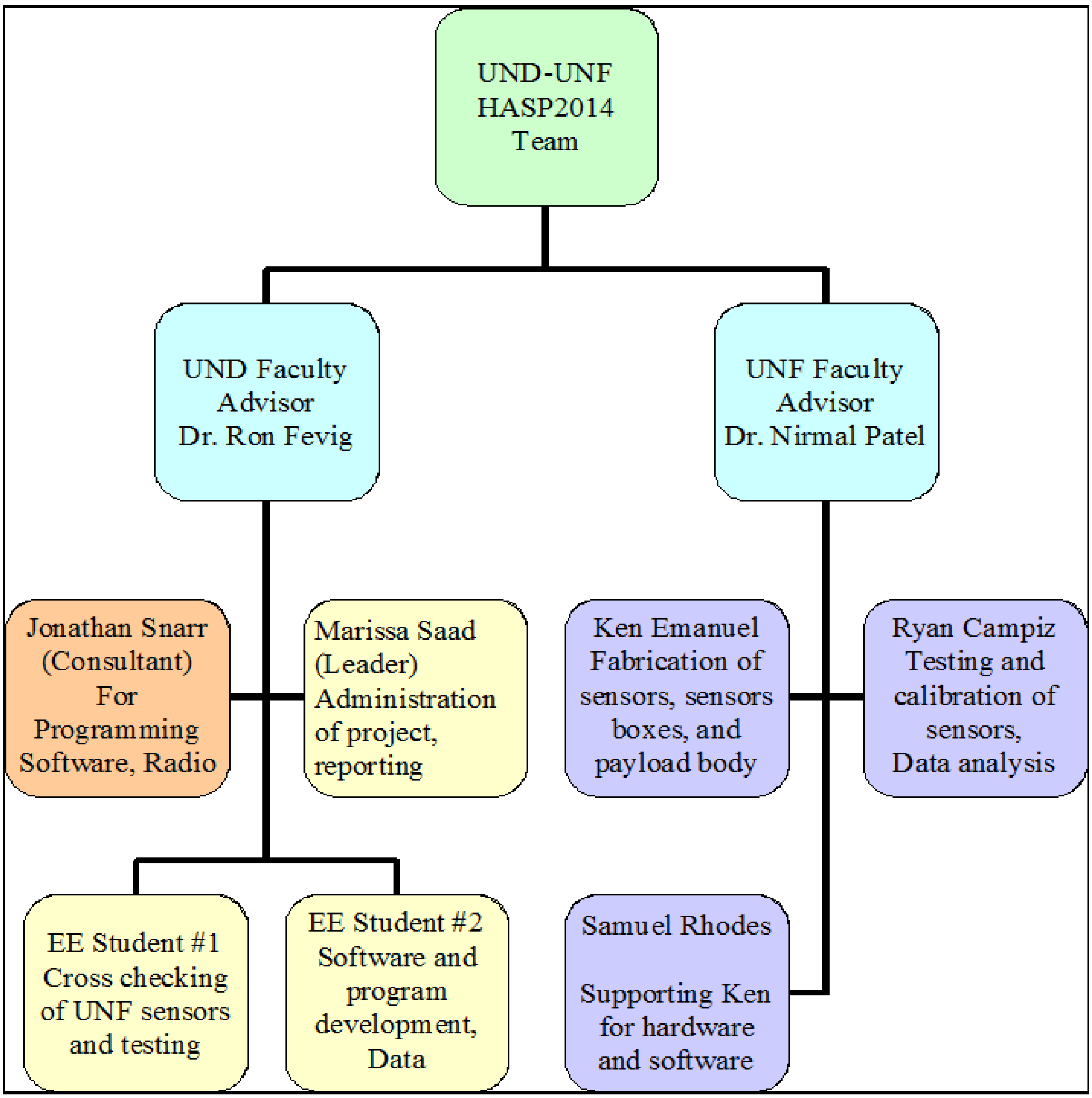


Fig.5 Team Management

**UND Team**

(1) Marissa Saad (Student Leader) is an astronomy graduate research student. She 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. She will pass on the leadership to other UND student after completion of her graduation.

(2) Jonathan Snarr (Consultant) was a student leader of HASP2010 and 2011 flights and also consultant for 2012 and 2013 flights. He developed of the new version microcontroller circuits, GPS and software for the payload. He will continue to help the UND-UNF team for electronic circuits; hardware and software work and also provide all previous versions of software and hardware to the team. He will responsible for assisting all the members of the team.

(3) One EE student #1 will develop the electronic circuit board, software, interfacing of sensors and integration of payload with HASP platform.

(4) One EE student #2 will help with the software work as well as the HASP communication line with payload.

(5) Additional, yet unidentified members will be added to the effort as the needs arise.

**UNF Team**

(1) Ken Emanuel is an undergraduate mechanical engineering student and was an active participant for HASP2012 and 2013 efforts. He will useful for the fabrication of the gas sensor arrays. He will also design and fabricate sensor array boxes and payload body and integrating sensors with flexible heater, temperature sensor and fan in the metal box. He will also integrate the payload body and mount the sensors box in the payload.

(2) Ryan Campiz is an undergraduate EE student. He will be responsible for testing and calibration of sensors. He will also perform the post flight data analysis work and report work.

(3) Samuel Rhodes is an undergraduate EE-ME student. He will work with UND team for software work and also support to Ken for hardware work.

## (6) 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. However, this schedule also includes the strong intent to fly an identical payload locally through the High Altitude Ballooning group at the University of North Dakota (UND), this task includes creating an identical bus to that of HASP so that all anomalies can be detected in a true flight mode. Work plan path is given in Fig.6.

| 2014 | UND | UNF |
|---|---|---|
| January | Conceptual Design Review (CoDR) for sensors, electronic circuits, software and payload. Reviewing issues of HASP2008 to 2013 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.<br>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 report writing | |
| December | Submission of the science report and then enjoying holidays. | |

Fig. 6 Work plan path

## (7) HASP Integration and Launch

It is expected that a minimum of two students from UND and UNF and one faculty member from UNF will travel to CSBF, Palestine, Texas in first week of August of 2014 (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 for launch of the HASP2014 payload during September 2014 (as per the date given by HASP and CSBF ).

## (8) Payload

The 2014 payload body will be similar to the 2013 payload body. The main features of our newly designed payload body are easy to open and close payload, easy access of PCB and sensor boxes, low rate of outgassing under low pressure, better stability with thermal and impact, and reusable. The parts of payload body will be procured from supplier www.onlinemetals.com.

The sensors' operations and gas measurements are processed according to the improved version of payload block diagram shown in Fig. 7. Resistance values from the gas sensors and pressure sensor are converted to voltages by the conditioning circuitry. These analog values are converted to digital values by a microcontroller which interfaces with the HASP data handling system. Temperature sensor, light sensor and pressure sensor readings are processed in a similar manner and are folded into the data stream by the microcontroller. Power from HASP is conditioned by circuitry based on voltage regulators and is provided to each payload electrical subsystem.

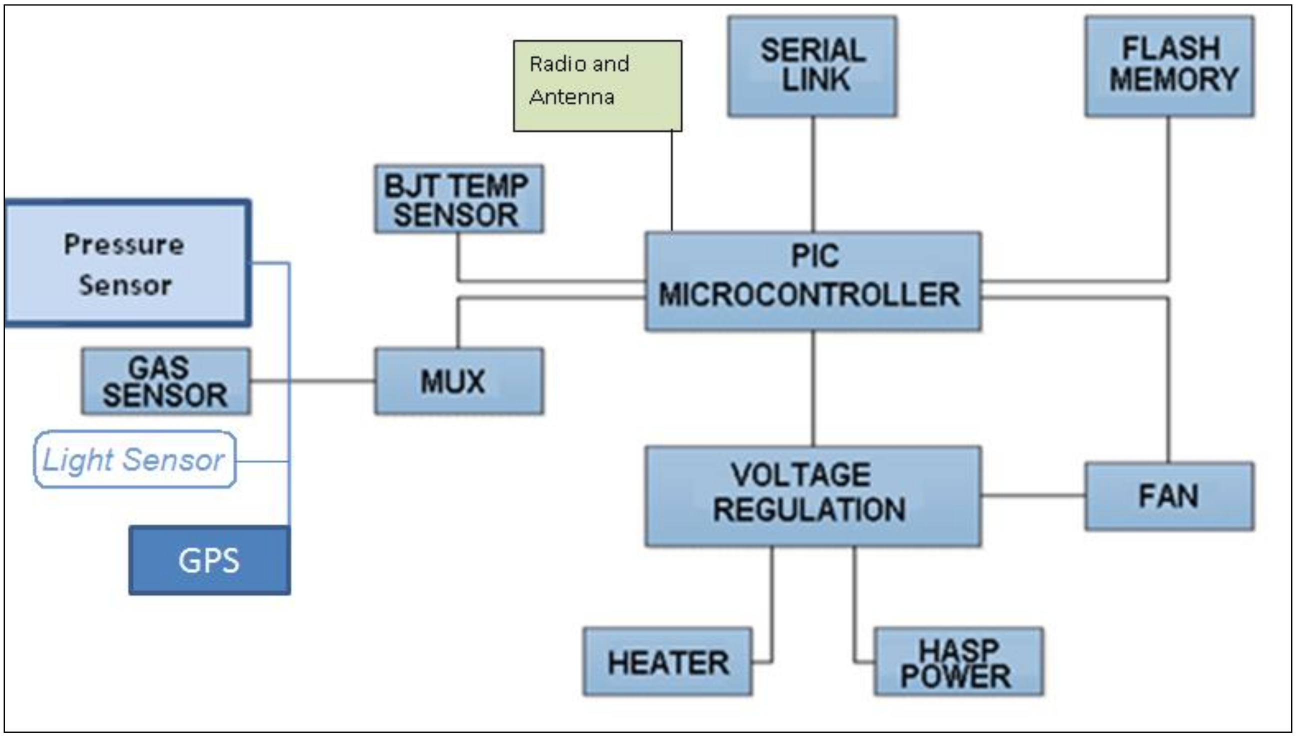


Fig.7 Block diagram of electronic circuit

## 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.8. This mounting plate design will not require modification.

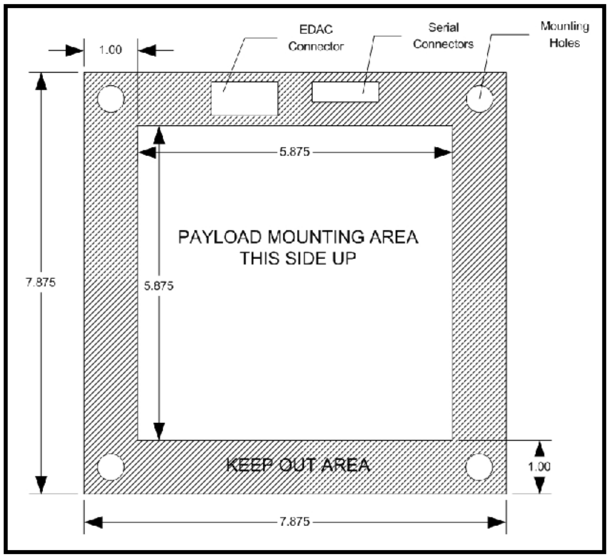


Fig. 8 Mounting Plate for small payload (Courtesy: HASP Version 02.17.09)
http://laspace.lsu.edu/hasp/documents/public/HASP_Interface_Manual_v21709.pdf

## Desired location and orientation

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 2008 to 2013 flights. We hope that the power supply of position #7 should not have any issue with power supply Fig. 9 shows our desired location of payload on HASP.

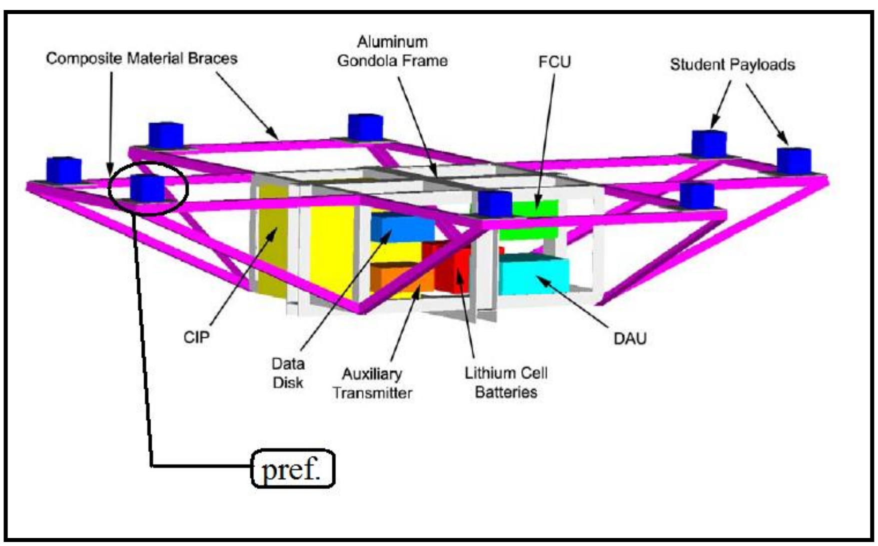


Fig. 9 Proposed HASP Configuration (Guzik and Wefel, 2004)

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## Payload Dimension

The proposed payload is under the category of small payload. The height of payload will be within 30 cm and sides will be within 15 cm x 15 cm.  Payload mass will be about 2.1 ± 0.1kg.

## Payload Mass Budget

The weight budget is itemized below in Table 1.

Table 1 – Itemized Mass Budget without mounting plate

| **Item:** | **Mass:** |
| --- | --- |
| Sensor arrays boxes  (including fan, heater, box) | 300g |
| Electronic circuits board | 300g |
| Payload body, top plate and thermal blanket | 1300g |
| Cables and any other items | 200g |
| **Total** | **2100g** |

The expected mass of payload will be about 2.10 kg without HASP mounting plate, which is quite less than the 3.0 kg limit for the smaller payloads. We will try to lower weight.

## Payload Power Budget

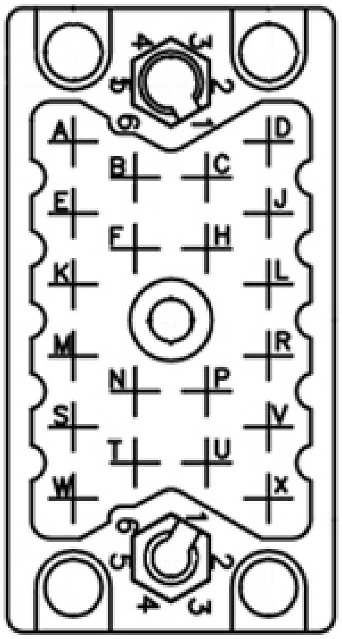
The 0.5 Amps at 30 VDC power supplied by HASP adequately accommodates the power requirements for the payload electronics, as well as the heater and fan for the sensor.  Table 2 details the preliminary estimate for our power budget

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.

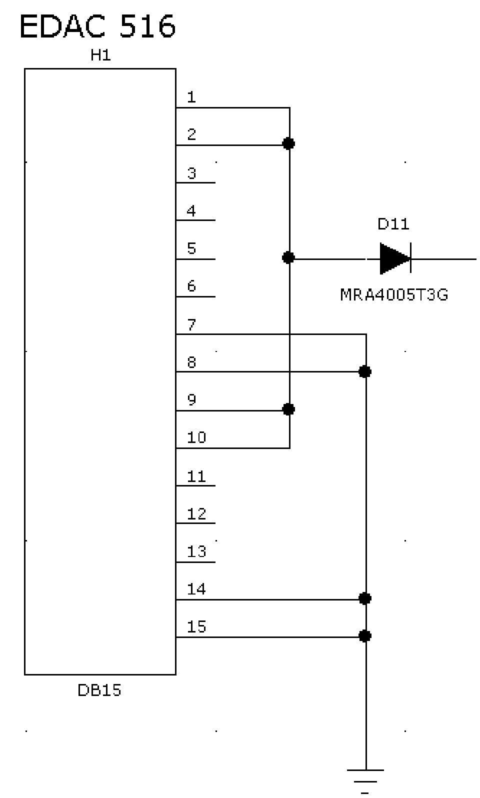
As per the instructions, on the EDAC 516 power connector only pins A,B,C,D are wired to the payload as +30 VDC power supply and pins W,T,U,X are wired to payload as power ground to avoid failure to the power circuit or loss of payload.  A voltage regulator is not necessary according to initial tests despite the slightly higher +33 VDC at launch for the sensor; however, a voltage regulator and divider will be used for peripherals. Fig. 11 shows the EDAC516 receptacle pin layout.

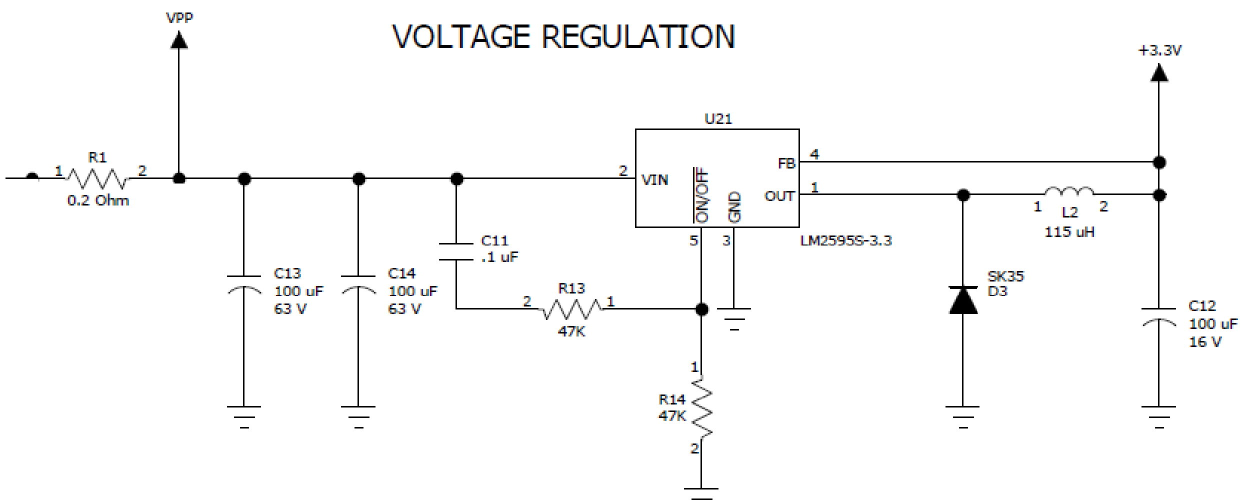



| Function | EDAC Pins | Wire Color |
|---|---|---|
| +30 VDC | A,B,C,D | White with red stripe |
| Power Ground | W,T,U,X | White with black stripe |
| Analog 1 | K | Blue |
| Analog 2 | M | Red |
| Signal Return | L, R | Black |
| Discrete 1 | F | Brown |
| Discrete 2 | N | Green |
| Discrete 3 | H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

Fig. 11 EDAC516 receptacle pin layout (Courtesy: HASP manual).

Below is the switching power supply circuit UND/UNF has embedded in the past 3 payloads. It has performed flawlessly. It will once again be embedded in the 2013 payload. 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 buck switching power supply U21 and supporting components.




Preliminary heat transfer calculations, utilizing such equations as shown in equation 1, heat transfer, showed the onboard sensor heater is adequate to keep the sensor at 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 Fig. 10, altitude profile).

Equation 1 – Heat Transfer

$$q = m(\Delta T)C_p$$

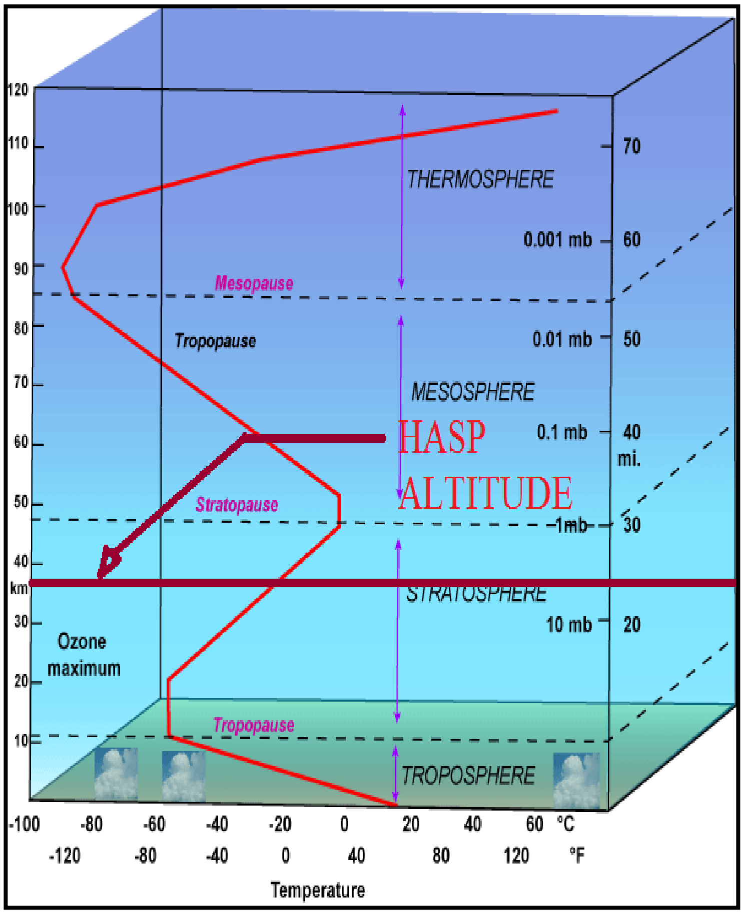



Fig. 10 – Modified Altitude Profile (Atkins, 2007)

## Downlink Serial Telemetry Rate

The payload module requires the RS232 HASP telemetry to send the state of resistance to the ground. A data-recording unit will be included with master controller in the event that the telemetry link fails. The DB9 connecter 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 shows DB9 pin diagram.

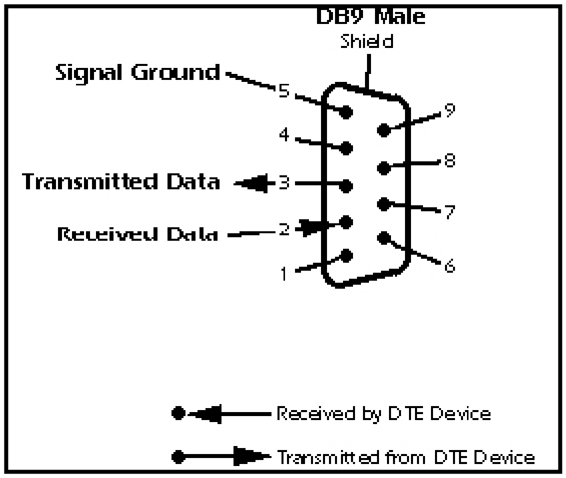


Fig. 12 DB9 pin diagram (courtesy: HASP manual)

**I. Downlink Telemetry Specifications:**

A. Serial data downlink format:

Packetized

B. Approximate serial downlink rate

193 bps

C. Specify your serial data record including record length and information contained in each record byte.

15 bytes for data packet synchronization (“HASP2013 UBLOX,”)
10 bytes for UTC time
7 bytes for MLS altitude
24x6 bytes for filtered ozone date
3x6 bytes for sensor module temperatures
3x6 bytes for photo diode voltages
6 bytes for CPU temperature
6 bytes for system voltage
6 bytes for system current draw
6 bytes for atmospheric pressure in milli-bar
5 bytes for heater on/off status

Total record length: 241 bytes

D. Number of analog channels being used:

0

E. If analog channels are being used, what are they being used for?

NA

F. Number of discrete lines being used:

0

G. If discrete lines are being used what are they being used for?

NA

H. Are there any on-board transmitters? If so, list the frequencies being used and the transmitted power.

ISM 902-928 FHSS – 915 MHz, 1W

I. Other relevant downlink telemetry information.

The onboard Transceiver will mimic the downlink data sent through the HASP gondola to the HASP ground station. It is UND/UNF's desire to determine the range capability and data transmission integrity of the chosen radio set for future free flying payloads.

## II. Uplink Commanding Specifications:

A. Command uplink capability required:

Yes

B. If so, will commands be uplinked in regular intervals:

No

C. 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*)

1-2 commands per hour maximum

D. Provide a table of all of the commands that you will be uplinking to your payload

| Byte | Hex Value | Description |
|---|---|---|
| 1 | 0x01 | SOH |
| 2 | 0x02 | STX |
| 3 | 0x71 | Checksum for 0x31 |
| | 0x72 | Checksum for 0x32 |
| | 0x73 | Checksum for 0x33 |
| | 0x74 | Checksum for 0x34 |
| | 0x75 | Checksum for 0x35 |
| | 0x76 | Checksum for 0x36 |
| | 0x77 | Checksum for 0x37 |
| 4 | 0x31 | System Reset |
| | 0x32 | Erase Flash |
| | 0x33 | Upload Data |
| | 0x34 | Stream Sensor Readings |
| | 0x35 | Heaters on |
| | 0x36 | Heaters off |
| | 0x37 | Logging on |
| | 0x38 | Logging off |

| | | |
|---|---|---|
| | 0x39 | Stream UBLOX |
| | 0x3A | Stream HASP GPS |
| | 0x3B | XTend Radio Enable |
| | 0x3C | XTend Radio Disable |
| 5 | 0x03 | ETX |
| 6 | 0x0D | CR |
| 7 | 0x0A | LF |

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

ISM 902-928 FHSS – 915 MHz, 1W

F. Other relevant uplink commanding information.

None

G. Request: Team is requesting the HASP to provide the GPS strings from the gondola every 10 seconds

## Anticipated Use of analog downlinks

No additional analog downlinks are anticipated.

## Payload

There will be no hazardous chemicals, radioactive material, gases and biological samples or parts in the payload.

## Anticipated Additional Discrete Commands

No additional active discrete commands are anticipated.

## 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
- 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
- Send sensors box to UNF for electrical testing, SEM+EDAX analysis, and failure analysis.

## Financial Considerations

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

## References


(1) Solid-State Sensors Behavior in Reduced Pressure Environments Demonstration Using an Experimental Indium Tim 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