HASP Student Payload Application for 2011

Payload Title: **Measurement of the ozone profile in the stratosphere using nanocomposite sensor arrays and chemical sensitive thin film transistors 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: 12-17-2010

Project Abstract: The UND and UNF team have successfully flown payloads on both the HASP 2008 and 2009 balloon flights for the purpose of measuring the ozone gas profile in the stratosphere. The nanocrystalline ITO thin film gas sensor array developed by UNF was used for the detection of the ozone gas profile, while the signal conditioning and microcontroller circuits developed by the UND team were used in the ozone sensor payload. HASP 2010 payload successfully cleared all the required thermal vacuum tests and is waiting for the flight. Based on the success and the few known problems of these payloads, the UND-UNF team proposes a HASP 2011 flight for the verification of earlier data using improved versions of the sensors and payload. Two different groups of ozone sensor arrays: (i) nanocrystalline nanocomposite ITO and (ii) chemical sensitive thin film transistor gas sensors on glass substrates will be used for the comparison of sensitivity, speed of response, and stability of the sensors. In addition, GaSb or Sb_2Te_3 thin film pressure sensors will be fabricated and calibrated and included in the payload to measure the change in pressure with change in altitude. The UNF team invented nanocomposite gas sensor arrays and chemical sensitive thin film transistors, which show better sensitivity than that of ITO sensors on glass. Both groups of ITO sensors for ozone will operate at temperature about 30 ^oC and need no high temperature heater, unlike other metal oxide sensors, which may conserve electrical power. First, UNF sensors will be calibrated with ozone gas at UNF, and then at UND labs for cross verification. Then, UNF sensors will be integrated into the UND electronics package to complete the payload. Both teams will jointly analyze the data after the flight. 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.

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HASP2011 Proposal

Measurement of the ozone profile in the stratosphere using nanocomposite sensor arrays and chemical sensitive thin film transistors on a high altitude balloon platform

Submitted by

University of North Dakota (UND)

and

University of North Florida (UNF)

Students Team:
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Nathan Walker, Bernadette Quijano, and Jason Saredy (UNF)

Faculty Advisors:
Dr. Ronald A. Fevig (UND) and
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(1) Project Summary

The UNF team, in collaboration with UND has successfully flown payloads on both the High Altitude Student Platform (HASP) 2008 and 2009 balloon flights for the purpose of measuring the ozone gas profile in the stratosphere. The nanocrystalline ITO thin film gas sensor array developed by UNF was used for the detection of the ozone gas profile, while the signal conditioning and microcontroller circuits used in the ozone sensor payload were developed by the UND team. Based on the success and the few known problems with these payloads, the UND-UNF team developed the HASP 2010 payload to verify earlier data using improved versions of the sensors and payload. This HASP 2010 payload successfully cleared the thermal vacuum tests and was certified for the flight, which will occur in May 2011. In addition to continuing development and further testing of the of the ozone sensor payload, and validation of previous measurements of the ozone profile in the stratosphere, the UND-UNF team is interested in (i) testing recently modified version of nanocomposite sensor arrays and newly developed chemically sensitive thin film transistor (CSTFT) gas sensors for the measurement of the ozone profile in the stratosphere and (ii) developing and fabrication of the low power consumption and light weight payload for the HASP 2011 flight. In addition, a newly developed thin film pressure sensor will be included in the payload to measure the change in pressure with altitude during the flight. The output of this work would not only confirm the measurement of the ozone profile by different types of sensor arrays, but also develop prototype sensor products for commercialization.

(2) Significance of Project

Nanocrystalline gas sensor array technology is being developed 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, and the U.S. Department of Defense. These sensors have also been used for the detection of ozone gas in the stratosphere. Nanocrystalline indium tin oxide (ITO) gas sensors were successfully calibrated with ozone gas at the Kennedy Space Center (KSC) and at the University of North Dakota (UND) during 2007, and successfully tested at the Columbia Scientific Balloon Facility (CSBF) during 2008 and 2009. These sensors have also been used by the students of Louisiana State University and University of Central Florida for their balloon project.

The proposed development and fabrication of different types of gas sensors and payloads 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 nanocomposite WO_3+ITO and TiO_2+ITO gas sensors have high stability under harsh upper atmospheric conditions. CSTFT sensors have the additional advantage of amplification of weak signals by the field effect transistor action. UNF developed gas sensors and CSTFT sensors are very small in size, have low weight and low power consumption, which meets the payload requirements for space applications. The UNF developed gas and CSTFT sensors can easily be integrated into microcontroller electronic circuits. Compared to the typically expensive 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 stratosphere. The developed sensor payload will meet all the requirement of the HASP for the balloon flight.

(3) Work Plan

The proposed work is a continuation of our HASP efforts over the last three years. A brief discussion of our productivity is given here as a background.

HASP 2008

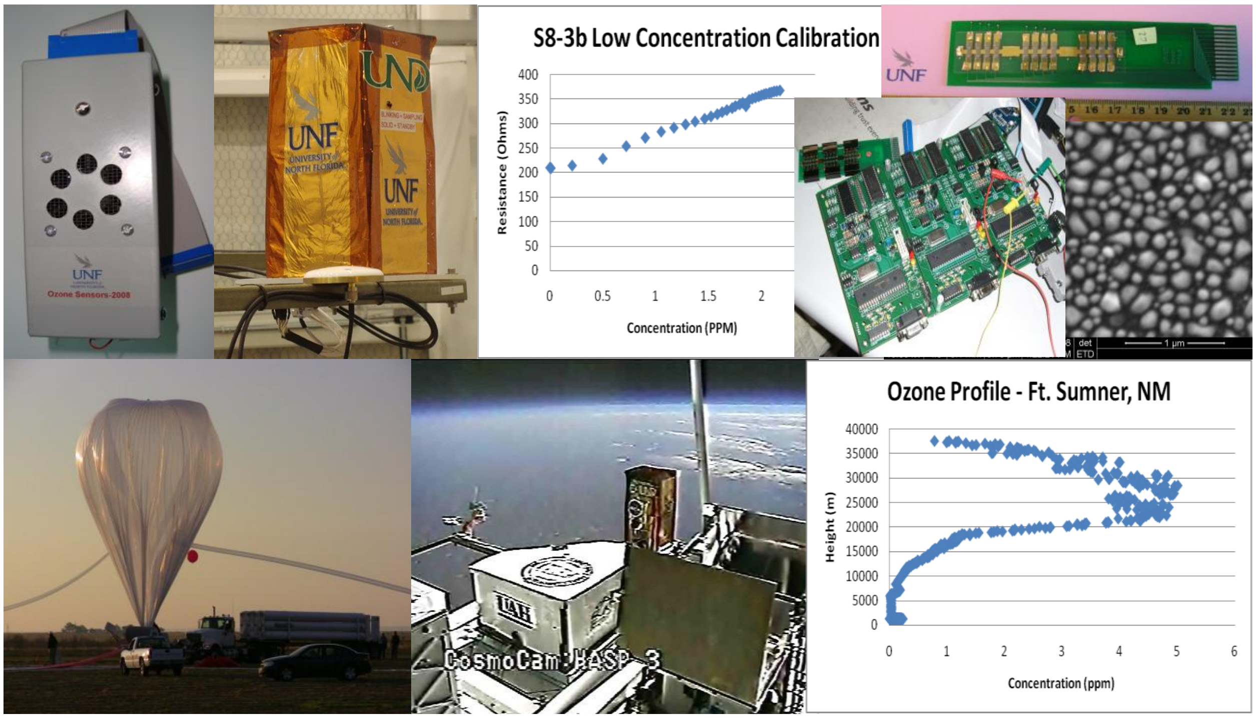

Fig. 1 Pictures of ozone sensors, UND-UNF payload and HASP 2008 flight data

The UND and UNF team made a joint effort to measure the ozone gas profile in the stratosphere through the HASP 2008 flight. Sensor arrays (patent pending) were developed and fabricated at UNF. The payload was launched on a HASP balloon flight and remained airborne for about 32 hours. The payload and data were recovered. The UND-UNF sensors and payload successfully measured the profile of ozone at different altitudes. The measured ozone profile nearly matched with the expected theoretical profile, but the maximum magnitude of the measured value of ozone was smaller by a few ppm than that of the expected value because of the effects of hurricane Ike during the flight period. Some of the pictures and figures of the HASP 2008 project are highlighted in Fig. 1. One thesis for a master’s degree and one research paper presented and published at an international conference (Ambler *et al* 2008) were major outputs of the HASP 2008 project.

HASP 2009

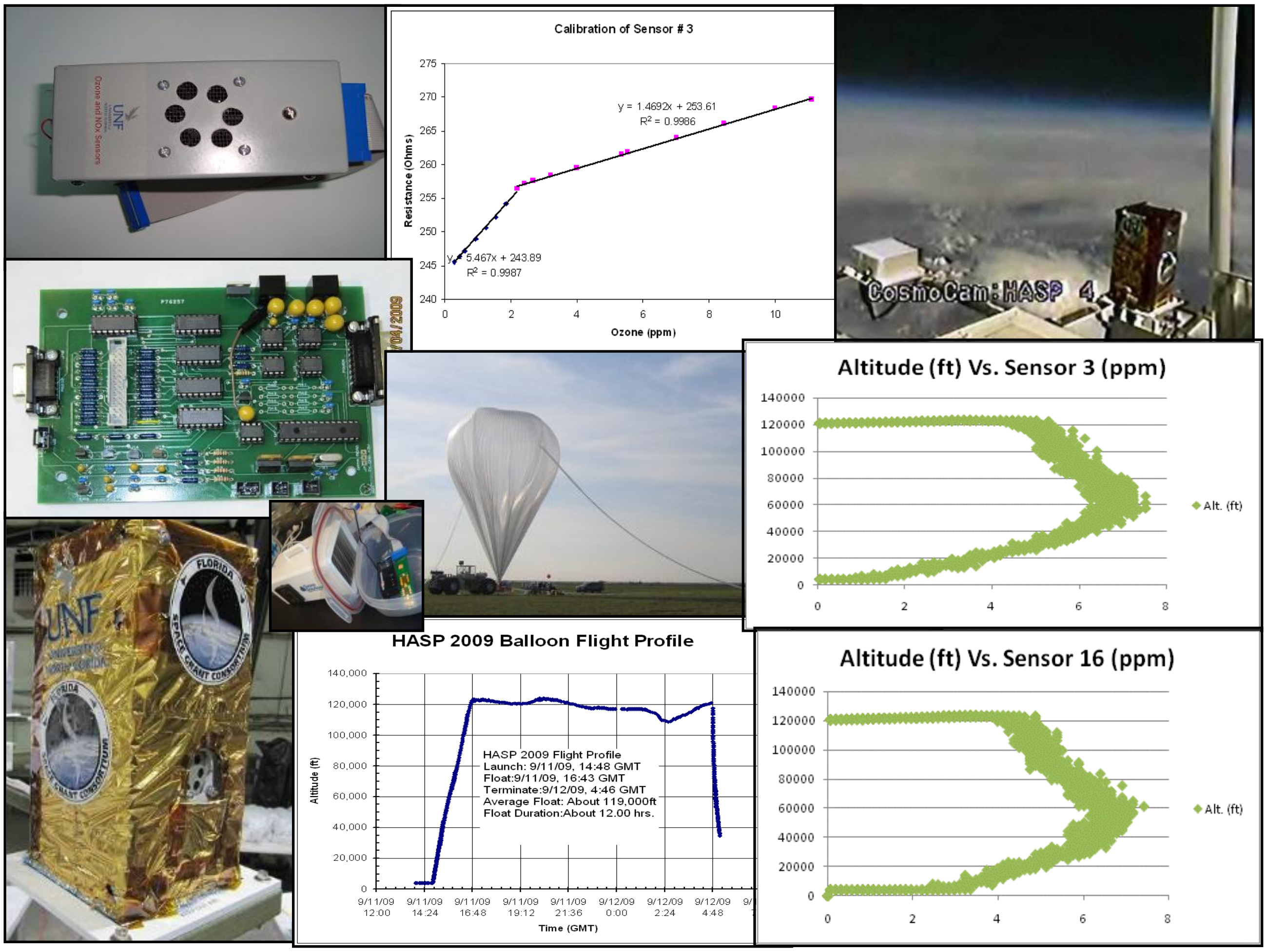

Fig. 2 Pictures of ozone sensors, UND-UNF payload and HASP 2009 flight data

Based on this fruitful experimental work from HASP 2008, the UND-UNF team participated in the HASP 2009 flight using three different groups of sensor arrays with the support of FSGC. During the first thermal vacuum test, a few electronic components failed and were replaced. One voltage regulator for one of the three sensor array groups failed after the second thermal vacuum test and was not replaced. The payload was certified to fly with two groups of sensor arrays. All 15 sensors measured the ozone profile during the balloon flight during the ascent. The measured ozone profile at different altitudes matched the expected theoretical profile. Some of the pictures and figures of the HASP 2009 project are highlighted in Fig. 2. One thesis for an honor's degree and one research paper are being prepared based on the HASP 2009 project.

RockOn RockSat 2009

Dr. Ron Fevig and his team (UND) and Dr. Nirmal Patel and his team jointly developed and fabricated a payload for the detection of background gases in the mesosphere under NASA's "RockOn RockSat" program, as shown in Fig. 3.

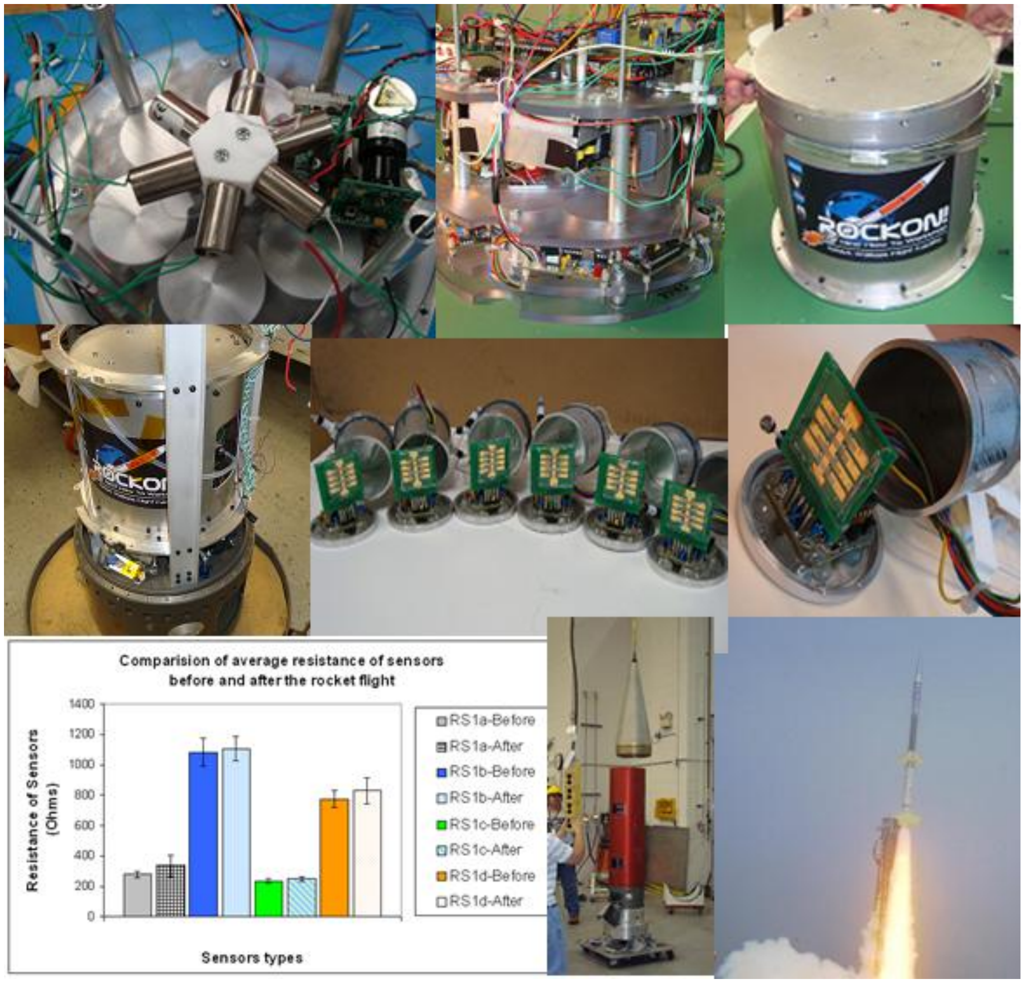

Fig. 3 Pictures of sensors, UND-UNF payload and RockOn RochSat sensor data

Six vessels were used to detect gases at the different altitude ranges. Each vessel had 8 gas sensors for the detection of 4 gases such as hydrogen, oxygen, methane and nitrous oxide. The sensors and payload cleared all required series of tests such as the three axis 30G vibration, spin, rotation, center of gravity, electrical, and output signal tests performed by NASA safety engineers. The UND-UNF sensors and payload was then integrated with the rocket. The two stage Terrier-Orion rocket that carried the experiments payloads was successfully launched into the mesosphere to an altitude of about 110 km on June 26, 2009 from NASA's Wallops Flight Facility, VA on the Eastern shore. After recovering the rocket payload from Atlantic Ocean, it was found that the atmospheric port of the rocket was accidentally reactivated to an open position instead of a closed position after landing in the sea water. As a result, water entered into our payload and short circuited the memory cards, corrupting the data. However, the sensors vessels were not affected by the intrusion of water. All sensors were found to be in good working condition after the flight.

Work Plan for the Proposed Project

Based on the success and a few known problems with the HASP 2008 and 2009 payloads, the UND-UNF team proposes development of payloads for HASP 2011 flights for the verification of earlier data using improved versions of the sensors and payload. Four different groups of ozone sensor arrays: (i) nanocomposite inorganic-ITO sensors and (ii) Chemical Sensitive Thin Film Transistor (CSTFT) sensors on glass substrates will be used for the comparison of sensitivity, speed of response and stability. Each group will have 8 sensors. Different combinations of nanocomposite materials will be tested to improve sensing properties. An improved version of the payload would be integrated and tested by both team. In addition, GaSb or Sb_2Te_3 thin film pressure sensors will be fabricated on mica / Mylar substrate and will be mounted in a small vessel having several holes. The change in electrical resistance of thin film pressure sensors with change in the ambient pressure will be measured and calibrated with the standard gauges. Thin film pressure gauge will be incorporated in the payload to measure the pressure during the flight. The data will be compared with the data provided by the HASP.

Working Principle of Gas Sensors

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>

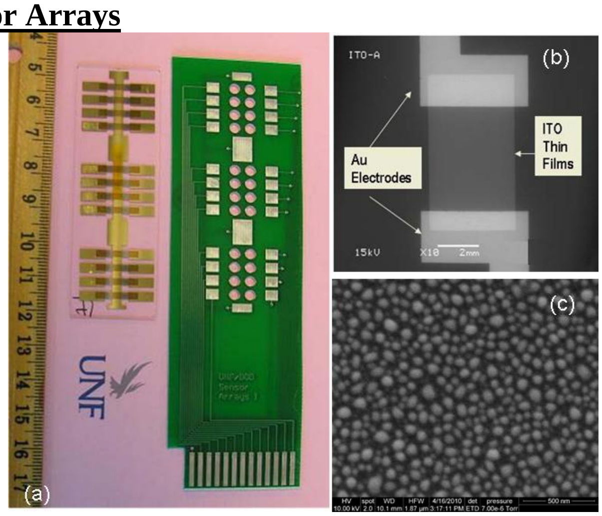

Fig.4 (a) 24 sensor array and interface PCB, scanning electron micrograph of (b) top view of one ITO gas sensor and (c) nanocrystalline grains of ITO thin film

Nanocrystalline ITO thin film gas sensors array will be fabricated over glass substrates. Fig. 4(a) shows the top view of 24 sensor arrays and the interface printed circuit board (patent pending). Fig. 4(b) shows a scanning electron micrograph of one ITO thin film gas sensor having two gold electrodes for external electrical contacts. Fig.4(c) shows a scanning electron micrograph of nanocrystalline gains of the ITO thin film. Two different groups of gas sensor arrays will be fabricated at UNF. Each group will consist of 8 nearly identical sensors. Both groups of sensor arrays will be fabricated on a 1 inch x 3inch ultra cleaned glass substrate and mounted on to the interface circuit board as shown in Fig. 5. Group-1 will consist of nanocrystalline nanaocomposite WO_3+ ITO thin film gas sensors array fabricated on a glass substrate. Group-2 will consist of a nanocomposite TiO_2+ITO thin film gas sensors array fabricated on a glass substrate. Group-3 will consist of nanocomposite inorganic-ITO thin film gas sensors array and will serve as back up sensors. Each group of sensor arrays will have different characteristic parameters for the detection of ozone gas. Recently, the UNF team found that a thin organic layer such as Nafion, and inorganic ultra thin films such as TiO_2 and WO_3 over nanocrystalline ITO thin films form nanocomposites, which show higher sensitivity to ozone gas.

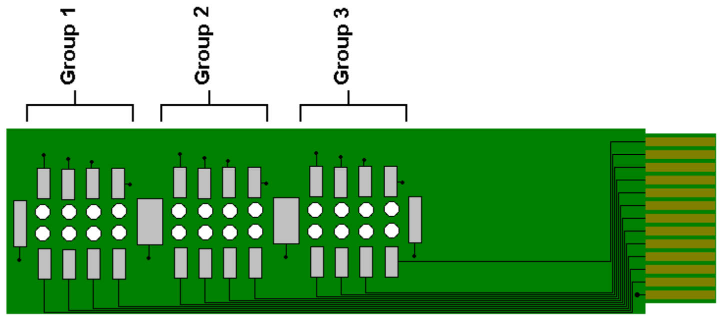

Fig. 5 Schematic diagram of 3 groups of sensor arrays mounted on printed circuit board (PCB)

In addition to gas sensor arrays, CSTFT sensors will be fabricated on glass substrates and interfaced with another PCB for the comparison of measurements of the ozone profile.

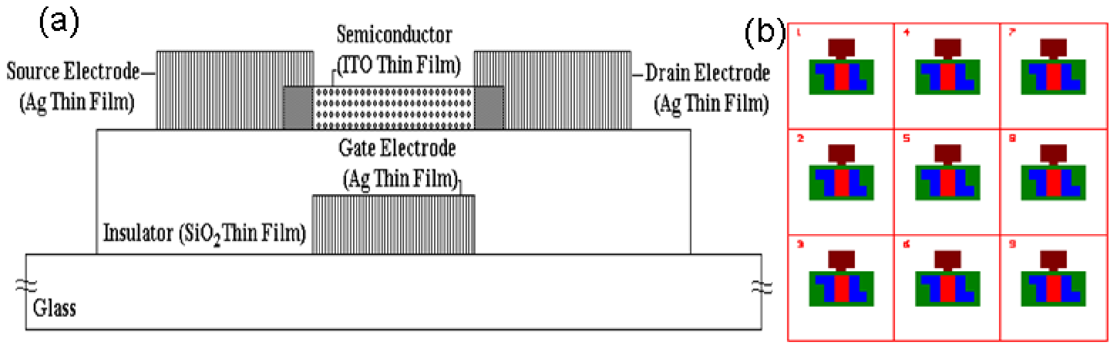

Fig. 6 (a) Cross sectional schematic view of TFT and (b) top view of nine CSTFTs

CSTFT sensors are recently developed and fabricated at UNF using a high vacuum system having a 4 crucible, 3 KW electron beam evaporation system. The new vacuum system features the ability to change four different mask designs for fabrication of thin film transistor sensors without breaking the vacuum. Fig.6 (a) shows a cross sectional view of the CSTFT, which shows all of the deposited layers. Note that the layers are not drawn to the scale. The advantage of this CSTFT design is that the source and drain are interchangeable. Fig.6 (b) shows a schematic diagram of the top view of nine CSTFTs. The brown color is a layer #1 for the gate, the green color is layer # 2 for the insulator, the red color is layer #3 for the chemical sensitive oxide semiconductor, and the blue color is layer #4 for the source and drain electrodes.

The sensor array will be interfaced with the printed circuit board and its 26-pin connector and 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. The slope of the calibration plots will be used for the algorithms and the design of microcontroller electronic circuits and software for the payload.

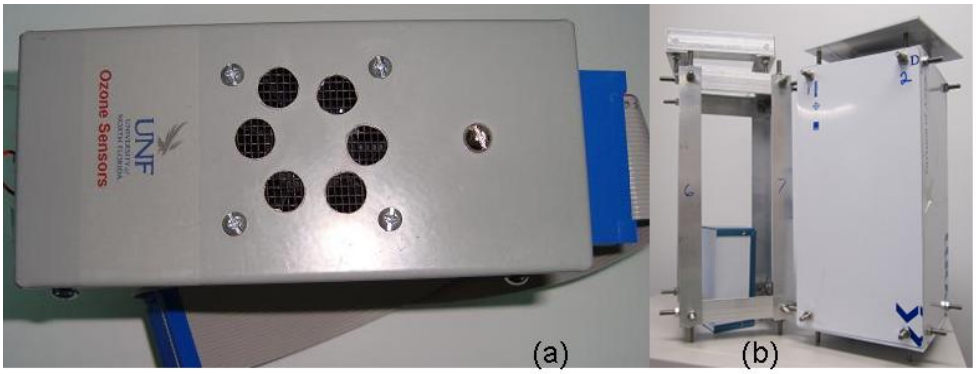

Fig. 7 (a) Ozone sensor container and (b) payload structure frame

Fabrication of payload

A miniature, flexible, and low power heater (Omega Inc.) 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 around 25°C. A miniature temperature sensor 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 case as shown in Fig. 7(a). This case will be mounted on low weight payload body (Fig. 7b). The wall of the payload will be covered by a thermal blanket. A miniature low power fan will be mounted on the front case to push gas molecules over the surface of the sensors. The fan will not be connected with any electrical power, but will operate as a windmill during the upward and downward flight of the balloon. A wire mesh will be fixed over the fan in order to filter out dust particles and protect the surface of the sensors. The fan may stop rotating in the stratosphere because of low pressure. The case containing the sensors, heater, and temperature sensor will be interfaced with the microcontroller circuit and payload. 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.

UND and UNF Team Structure

The team structures and management methods will remain largely the same as the HASP 2009 and 2010 effort with inclusion few new students. Fig.8 shows the chart for the team management.

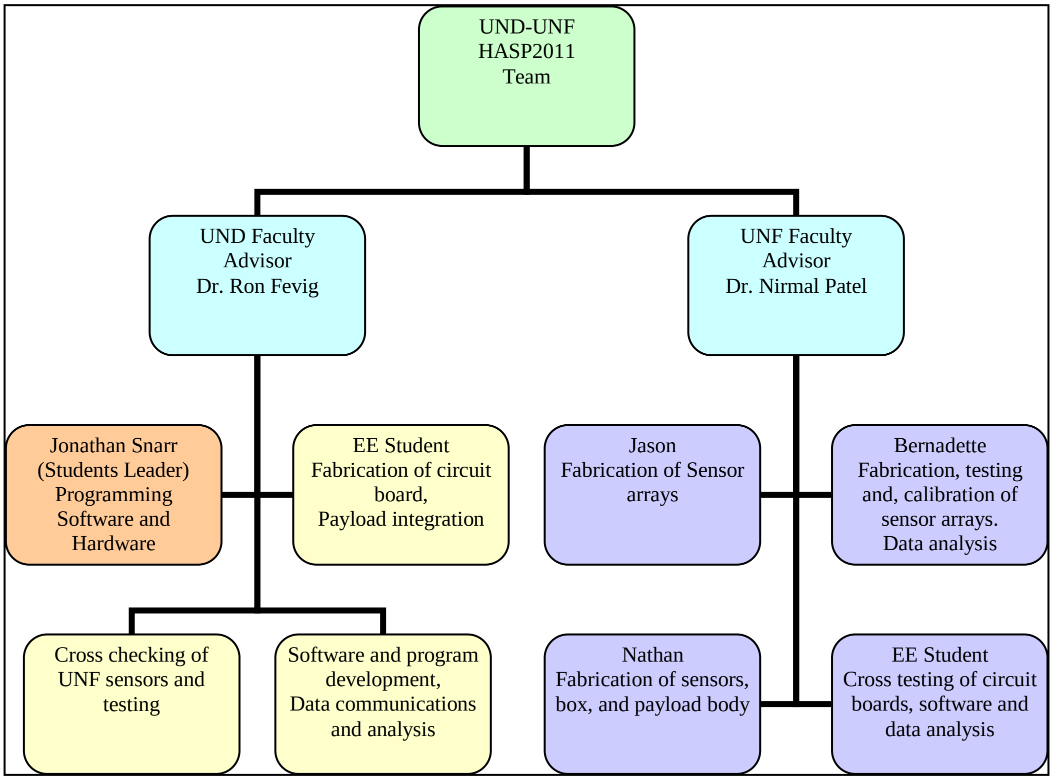

Fig.8 Team Management

UNF –

(1) Jason Saredy is a graduate Physics student and was an active participant in the last three HASP efforts. He will help Bernadette for fabrication of the gas sensor arrays and Chemical sensitive thin film transistors and thin film pressure sensors.

(2) Bernadette Quijano is an undergraduate mechanical engineering student and was an active participant in the last two HASP efforts. She will be responsible for fabrication, testing and calibration of sensors. She will also work on designing and fabrication of payload body. She will also perform the post flight data analysis work and report work.

(3) Nathan Walker is an undergraduate electrical engineering student and was an active participant in the last three HASP efforts. He and other students will fabricate sensor arrays and integrating sensors with flexible heater, RTD and fan in the metal box. He will also integrate the payload body and mount the sensors box in the payload and help in testing the printed circuit board.

UND-

(1) Jonathan Snarr (Interim Leader) was a student leader of HASP 2010 effort and will help establish the necessary framework garnered from the past flight to help support the 2011 HASP UND/UNF effort. This position however, will be filled by a senior student of UND later on. Leader will take care of the organization of meeting and teleconference meeting with all members and faculty advisors, and communicating with HASP. He will take lead for the integration and thermal vacuum testing of

payload at Palestine, TX and pre-flight testing at Fort Sumner, NM. He will also responsible for the data analysis work.

(2) One EE student will develop the electronic circuit board and integration of payload with HASP platform.

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

(4) One Space Studies student will test the UNF sensor arrays and box. He will also cross-check and verify the calibration of the sensors.

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

Task and Work Plan Path

2011	UND	UNF
January	Conceptual Design Review (CoDR) for sensors, electronic circuits, software and payload. Reviewing failure issues of HASP 2009.	
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, chemical sensitive thin film transistors and pressure sensor
May	Fabrication of circuit board and programming	Calibration of sensors and delivery of sensor arrays to UND for testing
June	Testing of circuit and sensor arrays. Integrating the circuits and the sensor arrays	Fabrication of sensors box and payload body. Reviewing HASP 2010 flight, 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	Testing of UND circuit and program, integration of sensor arrays in box. Delivery of sensor boxes and payload body to UND
August	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.	
November	Data analysis and report writing	
December	Submission of science report	

Fig. 9 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. The work plan is given in Fig.9.

HASP Integration

It is expected that a minimum of three students from UND and UNF and one faculty member from UND/UNF will travel to CSBF, Palestine, Texas in first week of August of 2011 (as per the date given by HASP) for the integration of the sensor payload onto HASP. It is also expected that approximately four students from UND and UNF and two faculty members (UND and UNF) will travel to Ft. Sumner for launch of the HASP 2011 payload during September 2011 (as per the date given by HASP and CSBF).

Payload Specification

The sensors' operations and ozone gas measurements are processed according to the improved version of electronic circuits given in Fig. 10 to 12. The actual circuit will be based on modified version of Figs. 11 and 12. Resistance values from the ozone gas sensors and pressure sensor are converted to voltages by the conditioning circuitry. The drain current of chemical sensitive thin film transistors will be converted in to appropriate conditioning circuitry. These analog values are converted to digital values by a microcontroller which interfaces with the HASP data handling system. Temperature sensor and pressure sensor (optional) 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.

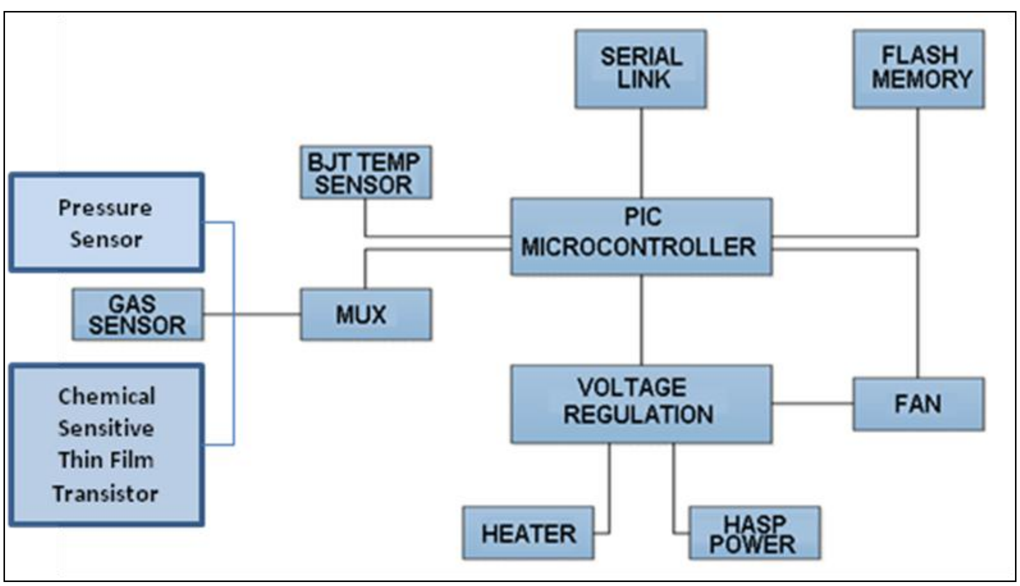

Fig.10 Block diagram of electronic circuit

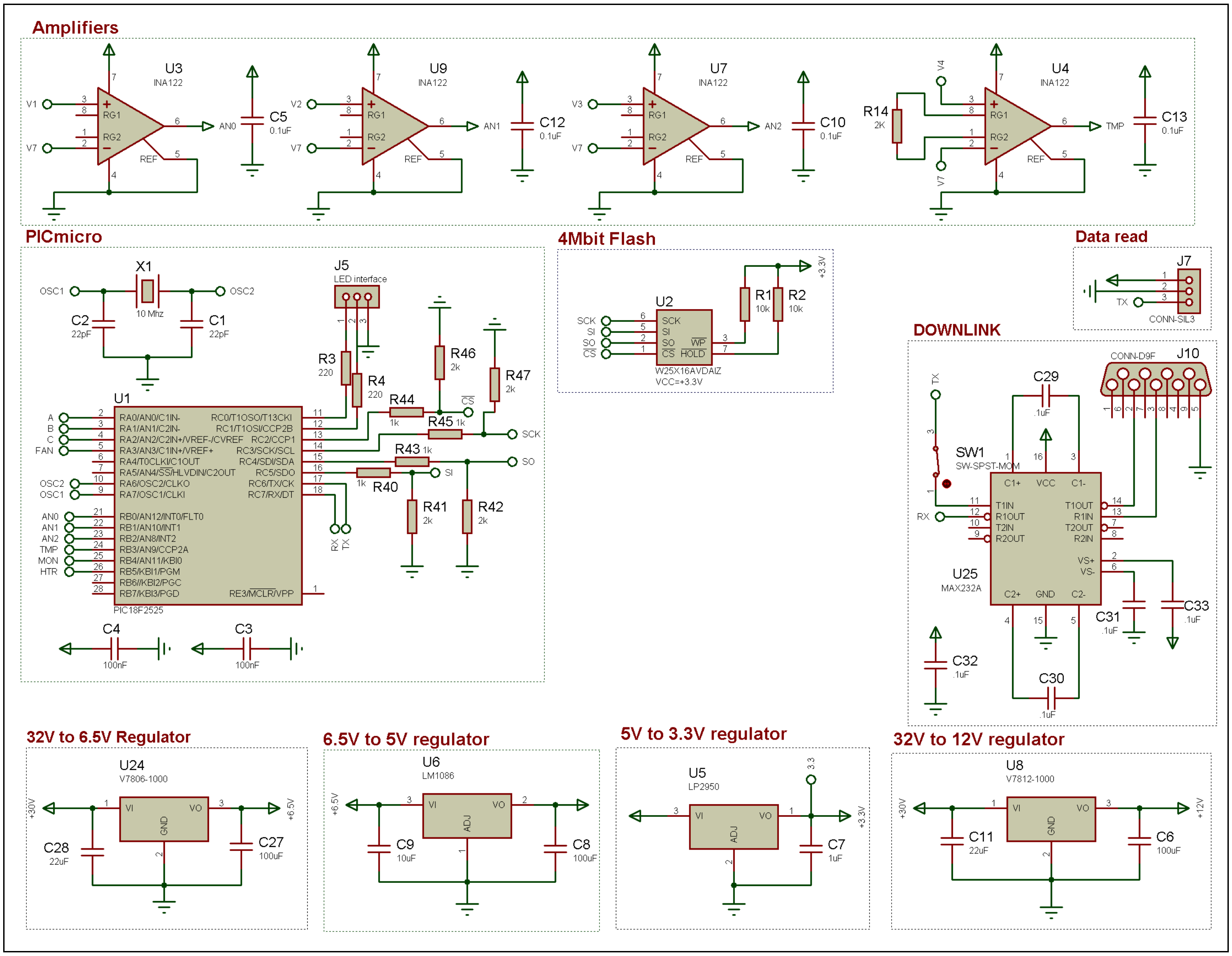

Fig.11 Electronic circuit for amplifier, microcontroller, voltage regulator and downlink

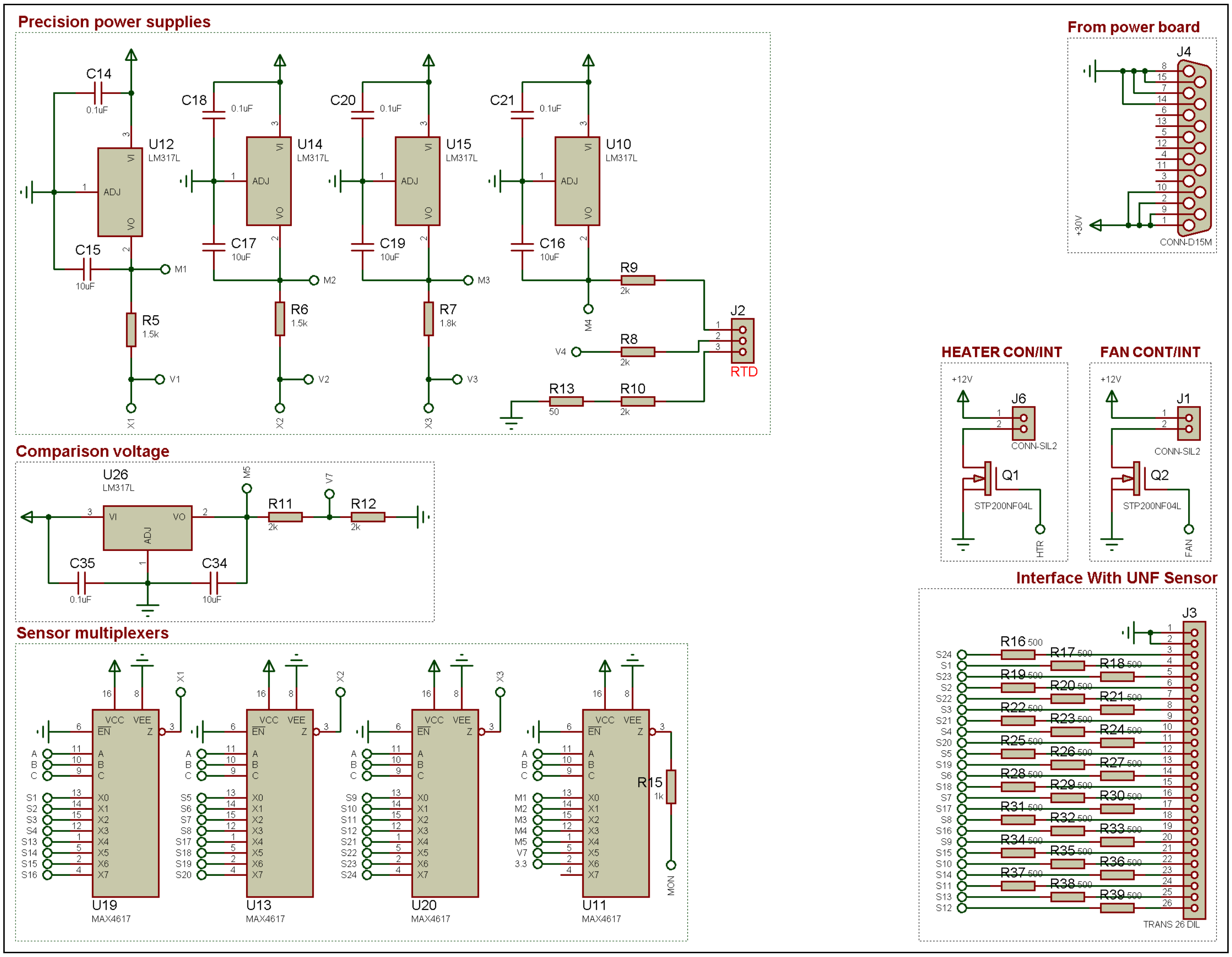

Fig.12 Electronic circuits for multiplexer and power supply

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.13. This mounting plate design will not require modification.

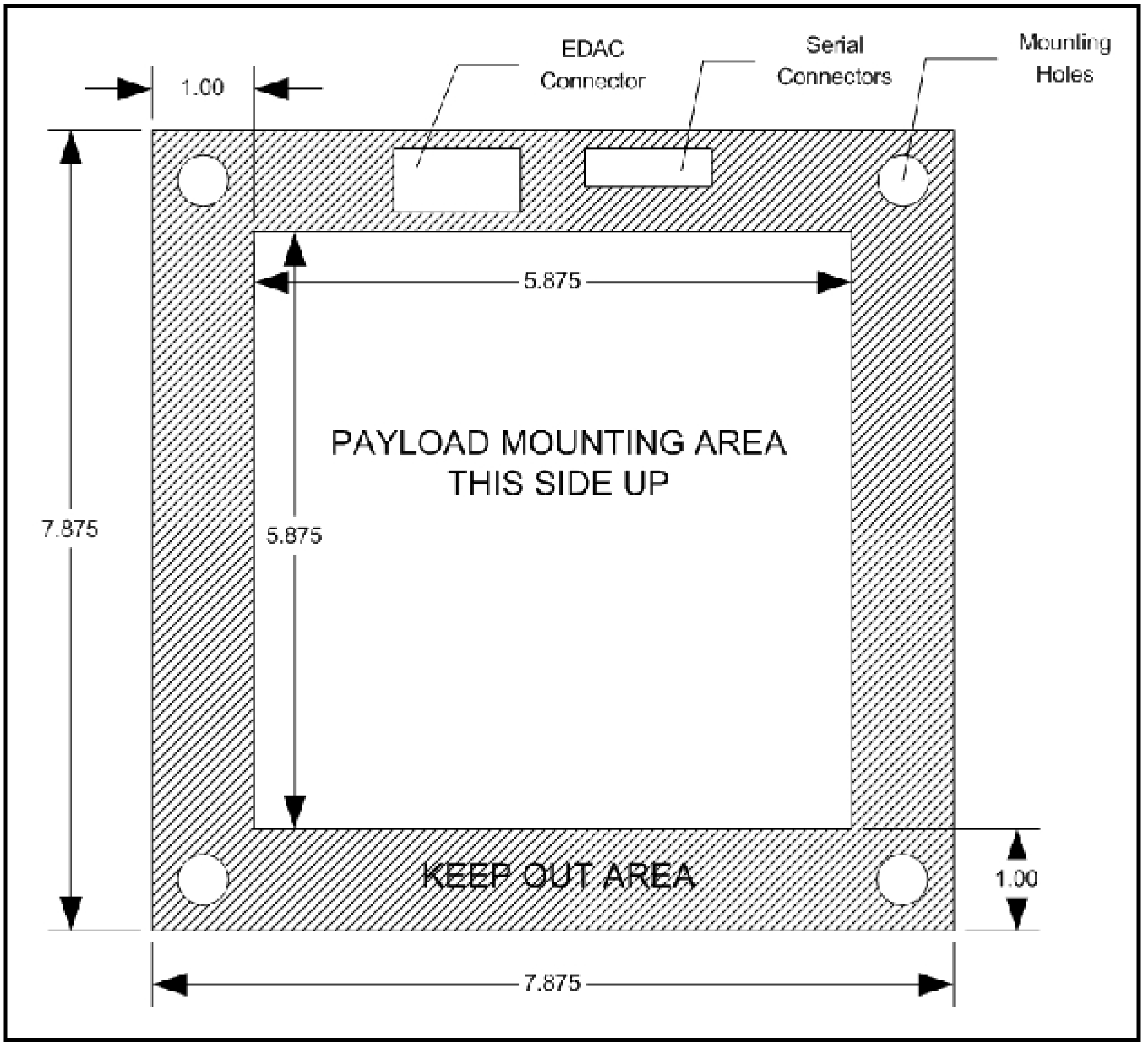

Fig. 13 Mounting Plate for small payload (courtesy: HASP Version 02.17.09)

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. We also prefer that CosmoCam camera should be able to view our payload, particularly at the night time to watch the blinking of LED for the data collection. We would like the position of the payload on HASP to be the same as in the previous two flights. Fig. 14 shows our desired location of payload on HASP.

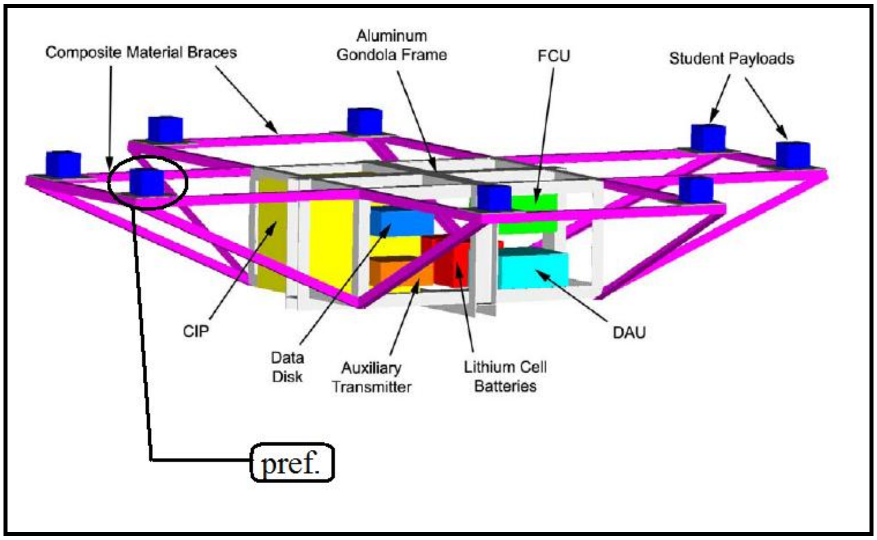

Fig. 14 Proposed HASP Configuration (Guzik and Wefel, 2004)

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Payload Dimensions

The proposed payload is under the category of small payload. The height of the payload will be within 30 cm and sides will be within 15 cm x 15 cm.

Payload Mass Budget

The mass budget is itemized below in Table 1.

Table 1 – Itemized Mass Budget

Item:	**Mass:**
Sensor arrays box (including RTD, fan, heater, box)	250g
Electronic circuits board	350g
Payload frame, screws and nuts	700g
Payload sides and thermal blanket	500g
Cables and any other items	200g
Total	**2000g**

The expected mass of the payload will be about 2.00 kg, which is quite less than the 3.0 kg limit for the smaller payloads.

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.

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. 15, altitude profile).

Equation 1 – Heat Transfer

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

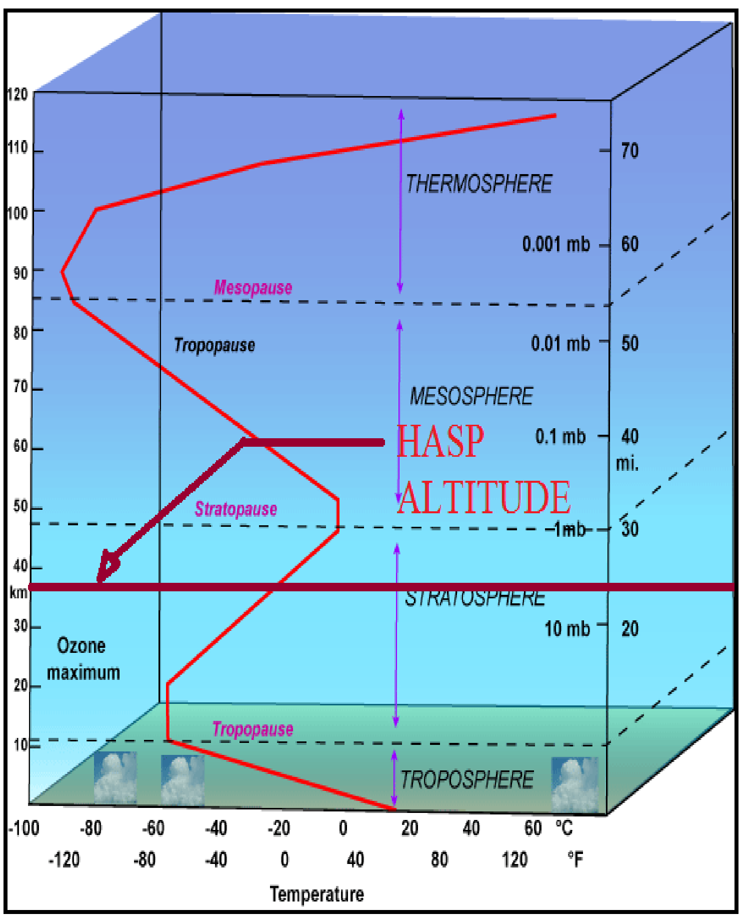
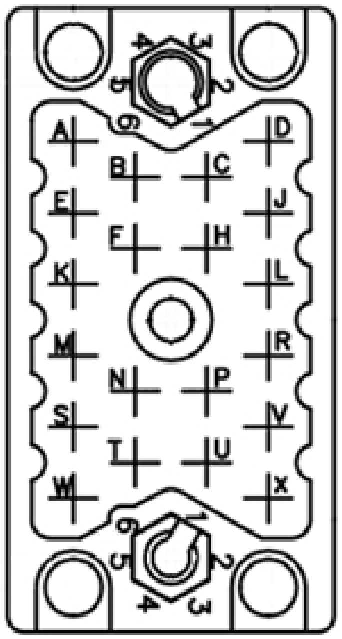


Fig. 15 – Modified Altitude Profile (Atkins, 2007)

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. 16 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. 16 EDAC516 receptacle pin layout (Courtesy: HASP manual).

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. 17 shows DB9 pin diagram.

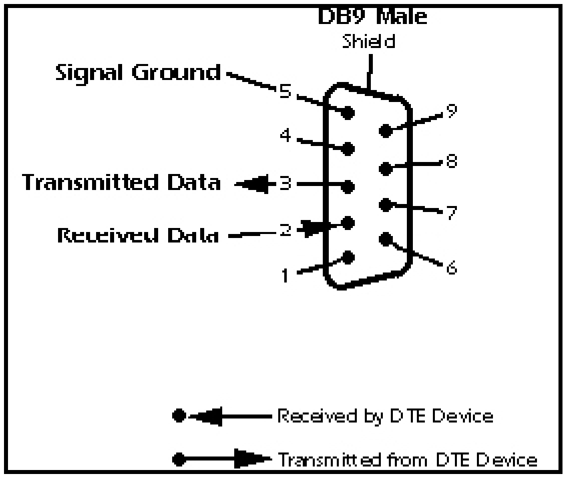


Fig. 17 DB9 pin diagram (courtesy: HASP manual)

Uplink Serial Command Rate

No uplink commands are anticipated.

Anticipated Use of analog downlinks

No additional analog downlinks are anticipated.

Payload

There will be no hazardous chemicals, 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
- Check all batteries

- 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 FSGC for the funding for the travel and consumables.

References

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