HASP Student Payload Application for 2008

Payload Title: O_3 Sensor Technology Development and Atmospheric Experimentation

Payload Class: (circle one)	Institution:	Submit Date:
[✓ Small] Large	Dakota Space Society Research Consortium, University of North Dakota	17-Dec-2007

Project Abstract

There are several significant and unanswered questions regarding ozone (O_3), and ozone depletion in the atmosphere. These issues demand the development of new reliable and cost effective sensors to monitor ozone over the Earth. One such unique, easily produced in mass, and newly developed (patent pending) sensor array, by the University of North Florida (UNF), is the solid-state nanocrystalline Indium Tin Oxide (ITO) thin film gas sensor. These sensors do not need to operate at very high operating temperature and follow as an improvement compared to the earlier reported tungsten oxide sensors by Hansford *et al.* (2005). In recent months, ITO gas sensors were tested and calibrated with different concentration of ozone (0.5 ppm to 14 ppm) under different pressures using the Low-pressure Test Bed at the Space Life Science Lab (SLSL), Kennedy Space Center (KSC-XA) as a student project through Space Florida with the support of NASA. Our next goal in this process is to launch the sensors with their interface circuitry into the upper atmosphere using a long duration high altitude balloon. This flight compares and validates ITO sensors with the currently used electro-chemical ozone sensors. This project continues through the Dakota Space Society student led consortium.

Team Name:	Team or Project Website:
Dakota Space Society	http://groups.google.com/group/UND-HASP

	Student Team Leader Contact Information:	Faculty Advisor Contact Information:
Name:	Mr. Nathaniel P. Ambler	Dr. Ronald Fevig
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O_3 Sensor Technology Development and Atmospheric Experimentation

Nathaniel P. Ambler, University of North Dakota
Dr. Ronald A. Fevig, University of North Dakota
Dr. Vadim Rygalov, University of North Dakota
Dr. Nirmal Patel, University of North Florida

Abstract & Background Information

Climate change involves complex issues pertaining to ozone, other greenhouse gases, and additional measurable parameters. There are numerous significant and unanswered questions surrounding ozone (O_3), and ozone depletion in the atmosphere, which demand the development of new reliable and more cost effective sensors. Such sensors can monitor the Earth's atmosphere and can easily undergo validation with remotely sensed data (*e.g.* satellite data). One such unique and newly developed (patent pending) sensors array by the University of North Florida (UNF), easily produced in mass, is the solid state nanocrystalline Indium Tin Oxide (ITO) thin film gas sensors. These sensors arrays follow as an improvement compared to the earlier reported tungsten oxide sensors (Hansford *et al.*, 2005). Here arrays of 24 sensors were fabricated on glass and alumina. These arrays of sensors were developed and fabricated at University of North Florida with support of the Department of Defense (DoD), Office of Naval Research and US Army, ECBC. Each sensor on the array is capable of working individually, in-concert with other sensors, or simultaneously with all sensors. During last summer, ITO gas sensor arrays fabricated over alumina and glass substrates were successfully tested and calibrated with different concentrations of ozone (0.5 ppm to 14 ppm) under varying pressures using the Low-pressure Test Bed at the Space Life Science Lab (SLSL), Kennedy Space Center (KSC-XA), as a student project through Space Florida with the support of NASA. It was found that ITO gas sensors have good sensitivity and response time with low concentrations of ozone, reasonable selectivity for ozone gas, good reversibility, and stability. This endeavor was aided by Dynamac Corporation scientists, Dr. Phillip A. Fowler and Joseph Benjamin; University of Florida and University of North Dakota research scientist, Dr. Vadim Rygalov; University of North Florida materials research scientist, Dr. Nirmal Patel; and the support of Dr. Sager and associated NASA personnel. The next step in this process is to successfully fly the sensor aboard a long duration high altitude balloon to gain atmospheric calibration data, as well as compare this data with current data (i.e., satellite data from the Total Ozone Mapping Spectrometer (TOMS).) Eventually this technique can validate current solid-state ozone sensors. This project continues through the Dakota Space Society Consortium student group with the additional support of the North Dakota Space Grant Consortium and the University of North Dakota's High Altitude Balloon Group.

PREVIOUS WORK AND ACKNOWLEDGEMENT

As mentioned briefly in the abstract, this work is a continuation of work started at the SLSL, KSC-XA, under the support of Space Florida and its 2007 summer students. This project, although successfully calibrated in the low pressure test bed, failed to provide any flight data due to a telemetry problem shortly after launch. These images are reproduced here, courtesy of Space Florida. Shown in Figure 1 are pictures of the 2007 KSC Intern Balloon Launch at Kelly Park, Florida. These images show the student directed research project mentored by NASA personnel, academic researchers, and Space Florida representatives.

Figure 1- 2007 KSC Intern Balloon Launch at Kelly Park

SENSOR FABRICATION PLAN

Not only is this a validation of design and fabrication, and research into ozone monitoring, it is in fact a general investigation of the affect of pressure on sensor technologies. At 36 km, pressure is roughly less than one percent compared to that at sea level, as seen below in Figure 8. The effect this has on certain sensors limits the accuracy of their absolute molecular measurements. This investigation serves both as the foundation for graduate thesis work and on-going sensor research.

<u>Student Work plan for the fabrication of ozone sensors at the UNF</u>

1. Indium tin oxide (ITO) thin film gas sensors array will be fabricated over glass and alumina substrates (patent pending). Several arrays are fabricated for this project.

2. The surface morphology of sensors are examined using a Scanning Electron Microscope (SEM), and the chemical composition of sensors will be determined using an Energy Dispersive Analysis of X-rays (EDAX) in order to check and verify some of the fabrication parameters of the sensors.

3. Necessary testing of the ITO sensors with test gas will be performed at UNF. Electrical resistance data will be recorded and disseminated. These sensors change their resistance values as a result of ozone concentration.

4. The sensors' array will interface with the printed circuit board (patent pending) via its connection to the 25-pin connector.

5. A miniature, flexible, and low power heater (Minco make) will be integrated on the backside of the sensor arrays. The purpose of the heater is to combat the low temperatures at high altitude and to keep the sensors at a temperature around 25^{o}C. A miniature thermocouple will also be mounted to monitor and control the temperature using an electronic circuit.

6. The sensors' array with heater and printed circuit board mount in the low weight container box.

7. A miniature low power fan will be mounted on the container box so that fan can push the gas molecules over the surface of the sensors at the prescribed rate. This will not affect the balloon's state. A wire mesh will be fixed over the fan in order to filter out dust particles as well as protect the surface of the sensors.

8. The entire box may look similar to the following picture of the sensors' system box, which was fabricated during the summer of 2007. This is shown in Figure 2, along with a PC board containing sensors.

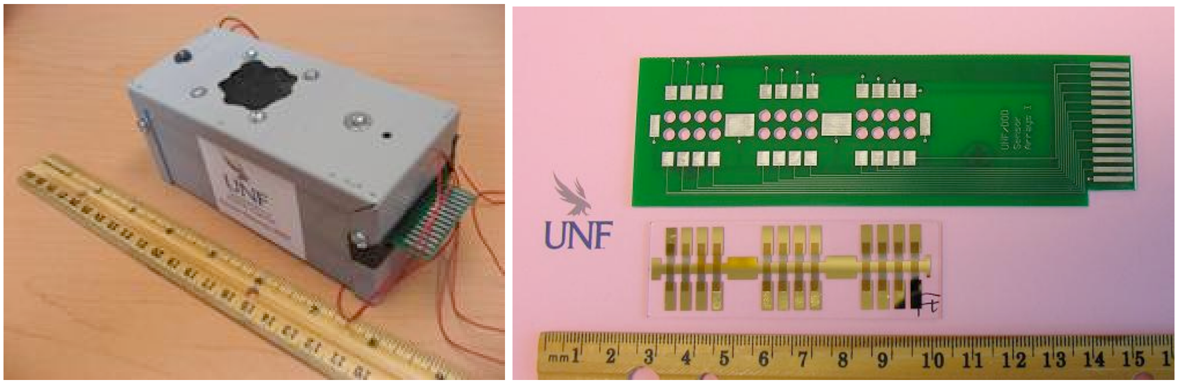


Figure 2 – 2007 Summer Sensor Payload and PC Board with Sensors

9. The box containing the sensors, the heater, and the fan system will be delivered to the Dakota Space Society care of Mr. Nathaniel Ambler and his team at UND for further interfacing with the data communication circuit, the temperature control circuit for the heater, and the data storage. All the

electronic circuit parts will be developed at the University of North Dakota by the local Dakota Space Society and will be tested with the sensors' system on the ground before launch.

10. If required, the necessary modification of sensors and/or circuitry will be performed after testing the electronic communication circuits at UND on a test flight.

TEAM STRUCTURE

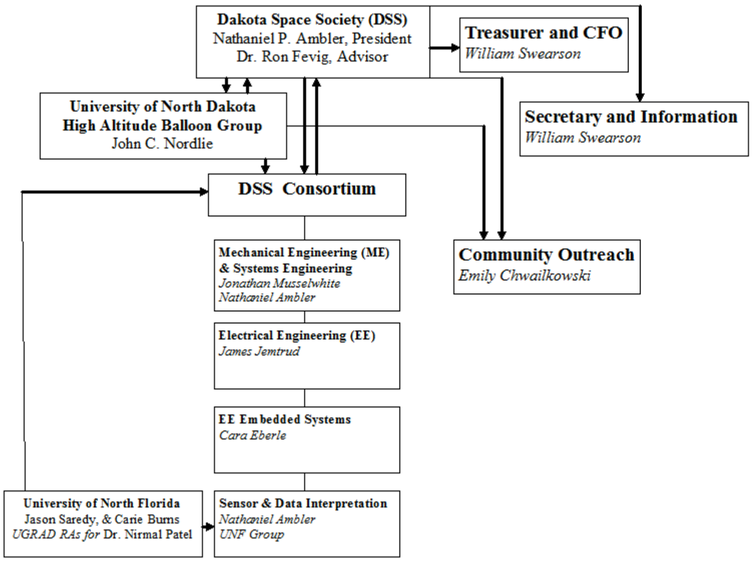


Figure 3 – UND Dakota Space Society Team Structure

Project Engineering Management Competencies:

President of the DSS Consortium and President of the DSS: Nathaniel P. Ambler*

The presiding officer of DSS and his office will execute the overall project. These specific duties include, but are not limited to, the following:

- *Delegating unassigned tasks*
- *Maintaining Project Schedule on Critical Path*
- *Ensuring proper financial and institutional support*
- *Meeting appropriate deadlines and reviews*
- *Fostering continued good-will among prior participants*
- *Approve and submit all financial requests*
- *Utilize prior research experience in this field from KSC, and B.S. in Mechanical Engineering to fill any technical needs*

Treasurer and CFO: William Swearson

The Treasurer and CFO will maintain accurate financial records, and communicate to the individual group leaders the available resources.

Secretary and Information: William Swearson

The Secretary and information officer will maintain appropriate minutes of all consortium meetings, dates, and records. This includes keeping an updated portal of information through the Google group for the UND Hasp Program (http://groups.google.com/group/UND-HASP).

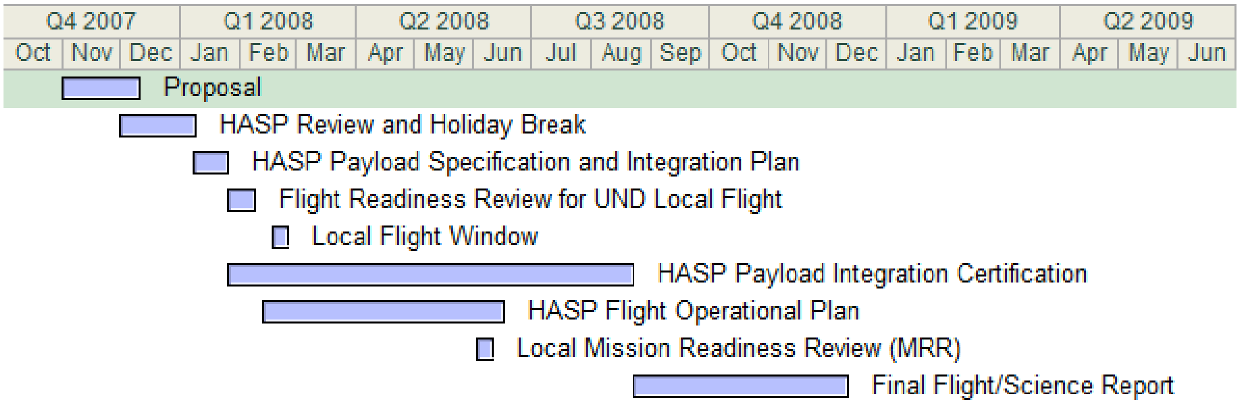
Community Outreach: Emily Chwailkowski*

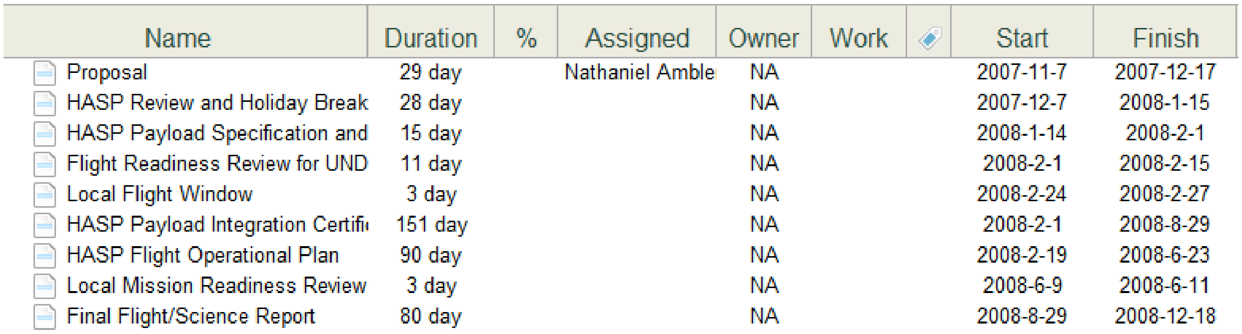
The community outreach officer will help in organizing local outreach efforts through the Dakota Space Society in conjunction with the Dakota Space Grant Consortium and the UND High Altitude Balloon Group. This involves participating and planning activities for K-12 schools and various local colleges, making presentations to local science and engineering groups, publicizing the project, and creating long-term data about group participants to create an appropriate future impact survey of the project.

Technical Engineering Management Point of Contacts:
Mechanical Engineering (ME) and Systems Engineering: Jonathan Musselwhite (UND) *et al.*
Electrical Engineering (EE): James Jemtrud (UND) *et al.*
EE Embedded Systems: Carla Eberle (UND) *et al.*
Sensor and Data Interpretation: Jason Saredy (UNF), Carie Burns (UNF), and Nathaniel P. Ambler* (UND)

TASKS AND CRITICAL 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.





Name	Duration	%	Assigned	Owner	Work		Start	Finish
Proposal	29 day		Nathaniel Amble	NA			2007-11-7	2007-12-17
HASP Review and Holiday Break	28 day			NA			2007-12-7	2008-1-15
HASP Payload Specification and	15 day			NA			2008-1-14	2008-2-1
Flight Readiness Review for UND	11 day			NA			2008-2-1	2008-2-15
Local Flight Window	3 day			NA			2008-2-24	2008-2-27
HASP Payload Integration Certifi	151 day			NA			2008-2-1	2008-8-29
HASP Flight Operational Plan	90 day			NA			2008-2-19	2008-6-23
Local Mission Readiness Review	3 day			NA			2008-6-9	2008-6-11
Final Flight/Science Report	80 day			NA			2008-8-29	2008-12-18

Figure 4 –Preliminary Task Timeline & Critical Path

HASP INTEGRATION

It is expected that as many as three students (two undergraduates and one graduate) and one faculty member will travel to LSU in late July of 2008 for the integration of the sensor payload onto HASP. It is expected that as many as six students (four undergraduate, and two graduates) and two faculty members will travel to Ft. Sumner for launch of the HASP payload.

PAYLOAD SPECIFICATION

The sensor operates and ozone measurements are processed according to the electronics block diagram shown in Figure 5. Resistance values from the ozone sensor are converted to voltages by the conditioning circuitry, which are then read by an LTC1298-based A/D converter. These values are processed by a BS2-IC microcontroller which interfaces with the HASP data handling system. Temperature 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 LM78LXX voltage regulators and is provided to each payload electrical subsystem in Figure 5.

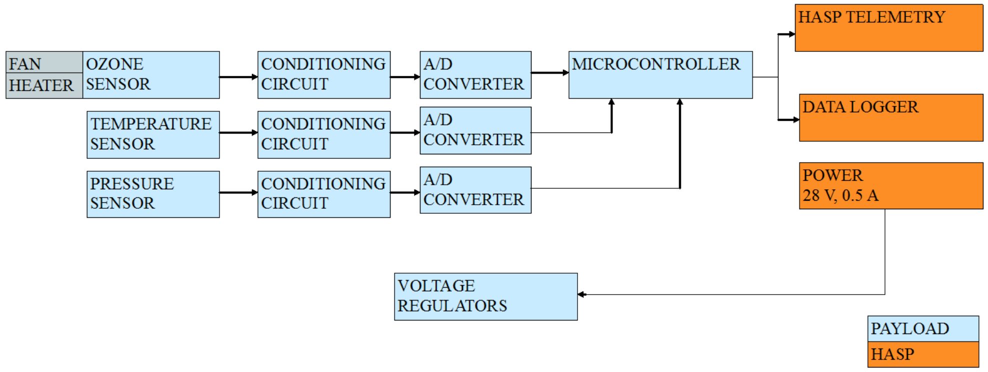


Figure 5 – Electronics Block Diagram

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 (v. 09.09.2007) and is shown below in Figure 6 (Besse, 2007). This mounting plate design will not require modification.

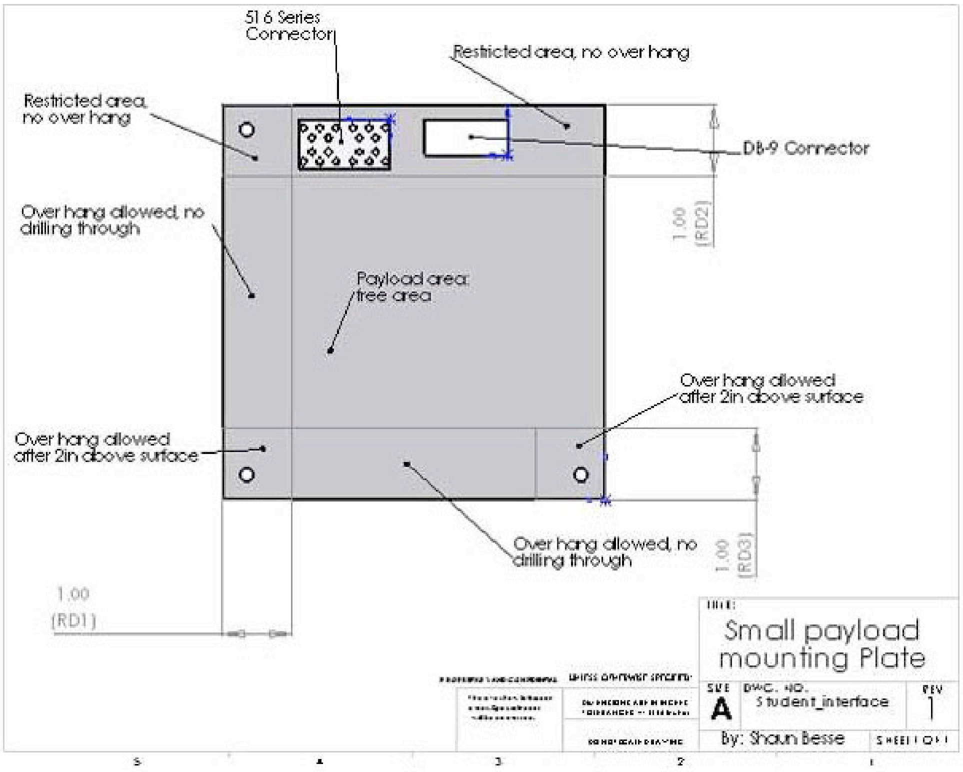


Figure 6 – Mounting Plate (Besse, 2007).

DESIRED LOCATION AND ORIENTATION

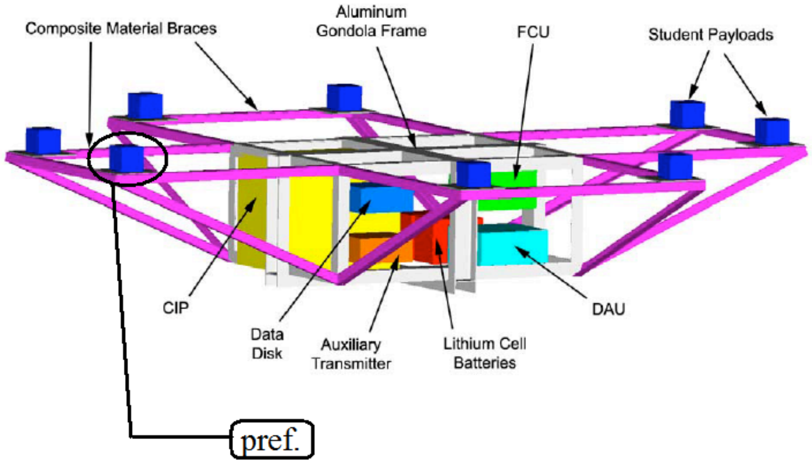


Figure 7 – Proposed HASP Configuration (Guzik and Wefel, 2004)

The requested smaller payload should be oriented on the side away from any solar cells to avoid disparate solar thermal radiation.

PAYLOAD HEIGHT

This payload requested is the small payload; its height will be 30 cm, and the sides will be 15 cm x 15 cm.

MASS BUDGET

The mass budget is itemized below in Table 1.

Table 1 – Itemized Mass Budget

Item:	Mass:
Sensors (including thermistor, and pressure transducer)	450g
SS Data Recorder	250g
Temperature Regulator	300g
Connections	400g
Structure	350g
Total	**1750g**

This is less than the 3 kg limit for the smaller payloads.

POWER BUDGET

The 0.5 Amps at 28 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	8 W (max.)
Sensor Fan	2 W
Total	**11 W**

This is less than the 14 W limit for the smaller payloads.

THERMAL MODELING

Preliminary heat transfer calculations 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, based on the prior work performed at KSC-XA, utilized the proposed materials for the walls, and a minimum temperature of -60^{o}C and a general operating temperature of 15^{o}C (found from altitude variation from 0 km to 36 km shown in Figure 8).

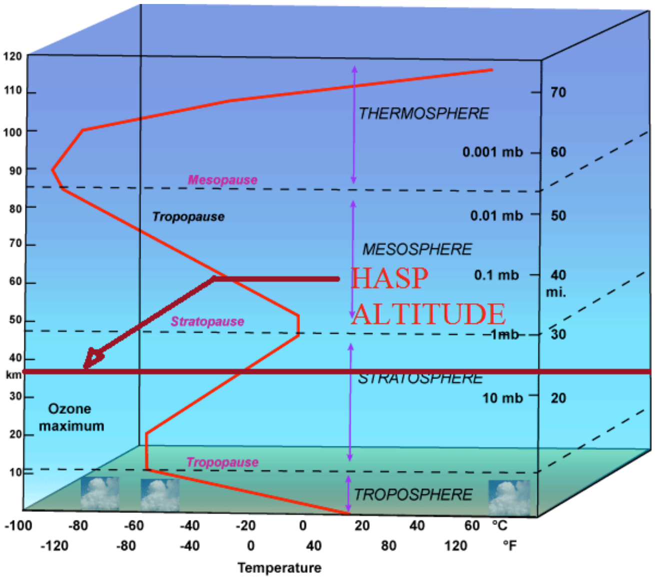


Figure 8 – Modified Altitude Profile (Atkins, 2007)

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 microcontroller 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 1200 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.

UPLINK SERIAL COMMAND RATE

No uplink commands are anticipated.

ANTICIPATED USE OF ANALOG DOWNLIKS

No additional analog downlinks are anticipated.

ANTICIPATED ADDITIONAL DISCRETE COMMANDS

No additional active discrete commands are anticipated.

ANTICIPATED PROCEDURES

Prior to Integration:

- Set initial values for data recorder
- Place sensors in appropriate payload slots
- Insert batteries
- Check all batteries

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:

- Set initial values for data recorder
- Place sensors in appropriate payload slots
- Insert all new batteries
- Check all batteries
- Connect HASP Power Connector
- Connect HASP Serial Connection

Flight Operations:

- Record values for resistance across the sensors

Post-Flight Operations:

- Remove batteries
- Remove data recorder
- Remove payload and sensors for further inspection

REFERENCES

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.

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.

HASP – Student Payload Interface Manual, Version 09.07.07, 25 November 2007
< http://laspace.lsu.edu/hasp/documents/public/HASP_Interface_Manual_v90707.pdf>

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

BUDGET

The anticipated budget for the project is laid out in Table 2. Support for this project has been generously offered by the North Dakota Space Grant Consortium pending selection of our payload.

Table 2 – Anticipated Budget

Item	*Information*	*Expense*
University of North Florida		
Student Research Assistantship	10 hr/week * 4 months	$ 1,600.00
Materials	Chemicals, heater, PCB, box, fan, etc.	$ 1,490.00
Travel & Accommodation	Professor and Student	$ 1,750.00
Incidentals	Shipping, Mailing, etc.	$ 150.00
	Sub-Total	$ 4,990.00
University of North Dakota		
Student Research Assistantship	Summer GRA	$ 3,000.00
Materials	Circuits, Memory, Heater	$ 3,000.00
Travel and Accommodations	Faculty, and Students	$ 9,000.00
Incidentals	Shipping, Mailing, etc.	$ 610.00
	Sub-Total	$ 15,610.00
	Approximate Total	$ 20,600.00

Biography of PIs

Student Leader:

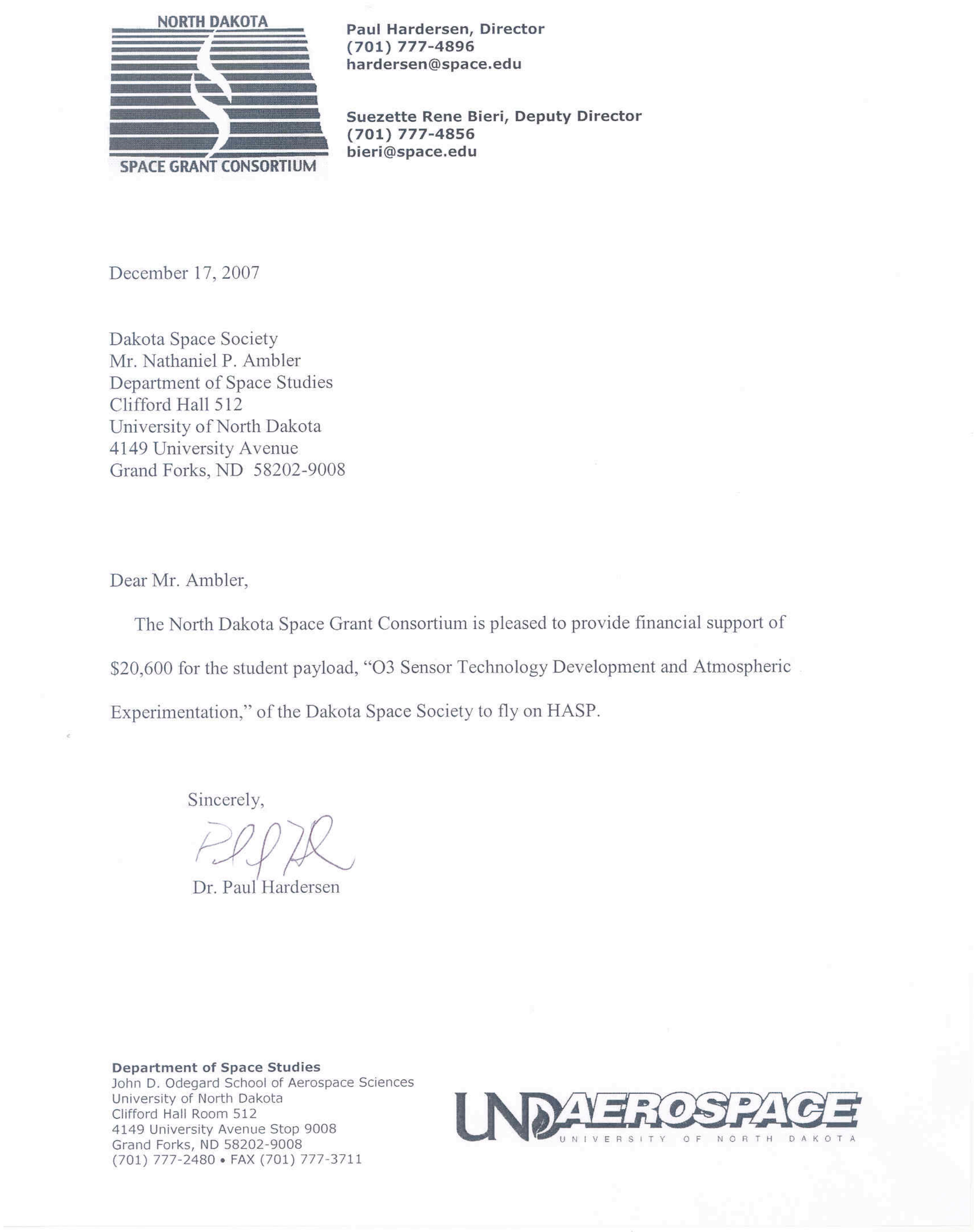
Nathaniel P. Ambler is a U.S. Citizen, graduate student at the University of North Dakota, Grand Forks, North Dakota. He was awarded a B.S. in Mechanical Engineering in 2005 from the University of Florida where he served as the primary-investigator on an engineering related economic study of aseptic packaging, and as a co-investigator on an effort to automate controls for unmanned vehicles (UAVs, UGVs, and USVs). He worked previously as a teacher of physics and mathematics in secondary education in Seminole County, Florida, and as a researcher in a summer research program at the Kennedy Space Center with NASA. He is currently involved in an on-going research project with NASA mentor Janira A. Ramos, and serves as a graduate teaching assistant (GTA). He currently serves as the President of the Dakota Space Society, which is organizing the local High Altitude Student Platform (HASP) student effort.

Faculty Leaders:

Nirmalkumar G. Patel, Ph.D. is U.S. Citizen, Physics Lecturer and Sensor Scientist at University of North Florida, Jacksonville, Florida. He was awarded his B.S (Physics) in 1976, M.S (Physics-Solid State Electronics) in 1978 and Ph.D. degree (Physics- Semiconductor Thin films Devices) in 1984 from Sardar Patel University, India. He was Professor at Sardar Patel University, during which time he was awarded a DAAD fellowship to work at University of Dortmund, Germany (1986-87), as Visiting Scientist / Professor at the Institute of Chemical and Biological Sensors, Munster, Germany (1996, 1998, 1999 and 2000). He was a PI of Indo-German joint research project on Biosensors for Food and Clinical Analysis. He has 23 years experience in academic work in India and 6 years in USA, and is an established investigator in solid-state gas sensors, with 35 research papers, one patent on biosensors, and one patent pending on nanocrystalline gas sensors arrays. He has been co-investigator on four major sensor research grants funded by the US DOD.

Ronald A. Fevig, Ph.D. is a U.S. Citizen and has a B.A. and M.S. in Mathematics, a M.S. in Space Studies, and a Ph.D. in Planetary Sciences from the University of Arizona. While pursuing his Ph.D. he was heavily involved in a student satellite program that built two CubeSats. He also helped mentor two senior engineering design teams that designed high-altitude balloon payloads. He is currently a post-doctoral researcher and adjunct instructor at the University of North Dakota. In addition to his other responsibilities, he is the faculty advisor for the Dakota Space Society and is a key faculty member involved with the high-altitude ballooning project.

Letter of Support



NORTH DAKOTA
SPACE GRANT CONSORTIUM

Paul Hardersen, Director
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Suezette Rene Bieri, Deputy Director
(701) 777-4856
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December 17, 2007

Dakota Space Society
Mr. Nathaniel P. Ambler
Department of Space Studies
Clifford Hall 512
University of North Dakota
4149 University Avenue
Grand Forks, ND 58202-9008

Dear Mr. Ambler,

The North Dakota Space Grant Consortium is pleased to provide financial support of $20,600 for the student payload, "O3 Sensor Technology Development and Atmospheric Experimentation," of the Dakota Space Society to fly on HASP.

Sincerely,

Dr. Paul Hardersen

Department of Space Studies
John D. Odegard School of Aerospace Sciences
University of North Dakota
Clifford Hall Room 512
4149 University Avenue Stop 9008
Grand Forks, ND 58202-9008
(701) 777-2480 • FAX (701) 777-3711

UND AEROSPACE
UNIVERSITY OF NORTH DAKOTA

Supplemental Document Provided by the University of North Florida

HASP Student Payload Application for 2008

Payload Title: O_3 Sensor Technology Development and Atmospheric Experimentation

Name of University Professor / Scientist

Dr. Nirmalkumar G. Patel
Department of Chemistry and Physics
University of North Florida
1 UNF Drive
Jacksonville, Florida 32224

Telephone (Office) 904-620-1670
Cell Phone: 904-200-2855
Email: npatel@unf.edu

Name of UNF Student(s)

(i) Mr. Jason Saredy (Under-Graduate Student, Physics Major and working as a research assistant since last three years with Dr. Patel)
And / or
(ii) Ms. Carie Burns (Under-Graduate Student, Physics Major and voluntary working with Dr. Patel)

Work plan for the fabrication of ozone sensors

11. Indium tin oxide (ITO) thin film gas sensors array will be fabricated over glass and alumina substrates (patent pending). Several arrays will be fabricated for the project.

12. The surface morphology of sensors will be examined using Scanning Electron Microscope (SEM) and chemical composition of sensors will be determined using Energy Dispersive Analysis of X-rays (EDAX) in order to check and verify some of the fabrication parameters of sensors.

13. Necessary testing of ITO sensors with test gas will be performed at University of North Florida. Electrical resistance data will be provided to Nathan, UND.

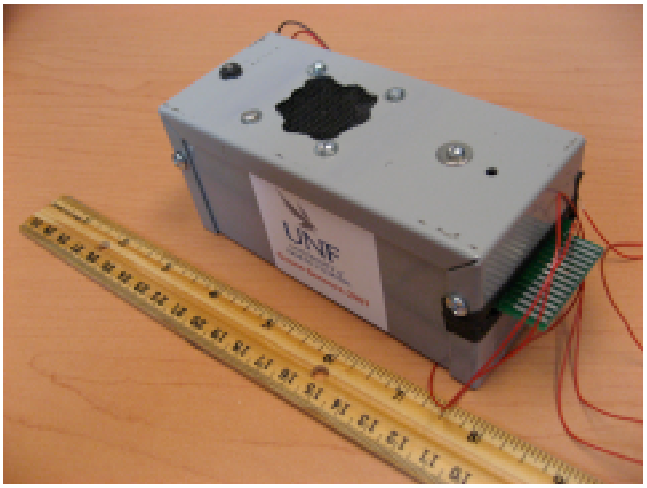
14. The sensors array will be interfaced with printed circuit board (Patent pending) and connected with 25-pin connector.

15. A miniature, flexible and low power heater (Minco make) will be integrated on back side of sensors arrays. The purpose of heater is to combat the low temperature at high altitude and to keep sensors at temperature about 25°C. A miniature thermocouple will also be mounted to monitor and control the temperature using electronics circuit.

16. Sensors array with heater and printed circuit board will be mounted in the low weight container box.

17. A miniature and low power fan with battery will be mounted on the container box so that fan can push the gas molecules over the surface of the sensors. A wire mesh will be fixed over the fan in order to filter out the dust particles as well as protection of surface of the sensors.

18. The entire box may look similar to or better than the following picture of sensors system box, which was fabricated during last summer project.



19. The boxes having sensors, heater and fan system will be delivered to Nathan and his team at UND for further interfacing with the data communication circuit, the temperature control circuit for the heater and the storage of data circuit. All the electronic circuit parts will be developed by the other groups of project and will be tested with the sensors system on the ground before launching of a balloon.

20. If required, the necessary modification of sensors or / and circuit parameters will be performed after testing with the electronic communication circuits at UND.

HASP Student Payload Application for 2008

Payload Title: Sensor Technology Development and Atmospheric Experimentation

Name of University Professor / Scientist

Dr. Nirmalkumar G. Patel
Department of Chemistry and Physics
University of North Florida
1 UNF Drive
Jacksonville, Florida 32224

Telephone (Office) 904-620-1670
Cell Phone: 904-200-2855
Email: npatel@unf.edu

Budget

(1)	Student's salary – 10 hr/week * 4 months (@ $10/hr)	= $ 1600.00
(2)	Materials charges for chemicals, heater, PCB, box, fan, etc	= $ 1490.00
(3)	Travel & accommodation for Professor & Student	= $ 1750.00
(4)	Incidentals (for Shipping / mailing, etc)	= $ 150.00

Total Amount = $ 4990.00

Note: The plus or minus of Budget head # 2, 3 and 4 will be adjusted from each other.