SP. ACE 2009-2011: SECONDARY SCHOOL STUDENTS STUDYING
SOUND SPECTRA, MASTERING MAGNETISM
AND FOSTERING FUTURE FLIGHTS

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ABSTRACT

Giving secondary school students the opportunity to gain hands-on experience in space or near-space projects is the ambitious goal of Sint-Pieterscollege's Sp.Ace–project. Ongoing work covers the development of dataloggers using an ever increasing variety of sensors while improving techniques for testing flight hardware. Flight opportunities are now secured through cooperation with Belgium's Royal Meteorological Institute, as one balloon per year will be flown solely for educational purposes.

1. SOUND SPECTRUM

A sound spectrum experiment was built by students of Sint-Pieterscollege Brussels and Stedelijke Humaniora Dilsen as the cornerstone of their 'Kiruna expedition' in 2010\cite{1}. The goal of the experiment was to measure sound extinction in an increasingly rarefied atmosphere, and to identify any possible frequency dependencies in that extinction. To address these questions, a buzzer produced sounds of different frequencies and those were recorded by a microphone circuit.

Piëzo-speaker and microphone were being operated by a different microcontroller, both subsystems being developed by a different student team.

During the flight, sound spectra with frequencies from 100 to 10000Hz (with 100Hz increments) were produced and recorded every 30 seconds. Data were stored in external EEPROM. Peak intensities were consistently measured at 8100Hz, with smaller peaks occurring at various frequencies. Of these smaller peaks, only 4600Hz could be linked to a specific cause, being the resonance frequency of the speaker, as listed by the manufacturer.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{Figure1.png}
\caption{The sound-spectrum experiment, developed by students from Stedelijke Humaniora Dilsen and Sint-Pieterscollege Jette}
\end{figure}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{Figure2.png}
\caption{Sound spectra being recorded on the ground prior to flight. System response is nonlinear but repeatability is satisfactory.}
\end{figure}
2. EARTH'S MAGNETIC FIELD AT ALTITUDE

The balloon flight from Kiruna that carried the sound spectrum experiment also flew a 3D magnetometer developed at Sint-Pieterscollege. Based on off-the-shelf 2D analog modules, it carried 3 12-bit ADC’s and external EEPROM for data storage.

3. GAS SENSORS

As a new type of datalogger, gas sensors were introduced. These sensors, MQ-4 and MQ-7 are used to detect methane and carbon monoxide.

Figure 4. The 3D magnetometer developed at Sint-Pieterscollege. (Photo courtesy Tom Leleu)

Figure 6. The gondola as found by the recovery team.

Figure 7. MQ-4 Methane and MQ-7 Carbon Monoxide sensors: cheap and small, but poorly documented as far as behaviour under space-relevant conditions is concerned.
Unfortunately, the manufacturer was unable to specify whether these sensors would operate normally in a rarefied atmosphere, while being kept very cool. It was decided to develop the circuitry (dataline, heating circuit and 12-bit analog-to-digital conversion (ADC) and find out. The purpose of this ongoing project is to develop an operational breadboard circuit equipped with a radio transmitter and test it under a vacuum bell to see if the sensors can cope with the low overall pressure, and still yield accurate measurements. If so, a candle may be burned under the bell to artificially increase carbon monoxide levels prior to evacuation to confirm previous findings. Similarly small quantities of natural gas may be injected under the bell for the methane sensor, should it cope well with rarefied air.

4. ASGARD MAIDEN FLIGHT

April 28th, 2011 was the date for the maiden flight in the Asgard programme, a cooperation between ESERO (European Space Education Resource Office), the KMI (Koninklijk Meteorologisch Instituut) and Sint-Pieterscollege [2]. Once per year, a weather balloon is set to carry student experiments to the edge of space. Unlike ESA's Bexus Programme, Asgard is intended for secondary and even primary schools.

For this first flight four schools gathered in Ukkel near Brussels. These were Sint-Pieterscollege from Jette - acting as Principal Investigator - Sint-Jozefsschool from Wemmel, Colegio Retamar from Madrid, Spain and Saint Paul’s School from London, UK.

The 1.5kg gondola carried a set of Phasmid eggs, a reflight of the sound spectrum experiment, several camera's and an array of sensors intended to measure air pressure, temperature, air humidity and much more, totalling over 25 experiments in all.

Figure 8. Asgard-1 gondola, carrying, among many other experiments, solar cells (front), camera's (right) and an array of sensors (top).

Figure 9. The whole bunch: left-to-right the UK-team from Saint-Paul's School London, the Spanish team from Colegio Retamar Madrid, the team from Sint-Pieterscollege Jette and the pupils of Sint-Jozefsschool Wemmel.

Figure 10. Asgard-1 shortly after take-off. Maximum altitude would be 32200m.
The upper atmosphere looks remarkably spacialike: a powerful motivator for students to engage in hands-on projects.

The entire British team and some Belgian students went chasing the balloon, that was equipped with a precision tracking device donated by TraxGo, a tracking services company. The students remaining at the KMI during the chase were offered a lecture on space research by Belgium's first astronaut, Mr. Dirk Frimout.

The hunt was adventurous, long and exhausting, but the gondola was recovered in France, having been found by an intrigued radio-amateur.

A profound sense of satisfaction and eagerness to look at the recorded data was taken home by all concerned. And the organizers - as tired as anyone else - vowed it had been worthwhile, and that Asgard held great promise for the future of SP.Ace at Sint-Pieterscollege.

4.1 GPS-data

The Asgard-1 gondola carried a GPS module, of which the manufacturer did not specify whether it operated at altitudes over 60000 feet (some don't). The phenomenon has been observed by US balloonists and is due to some manufacturers misinterpreting a US DOD guideline. Under these regulations, gps should not operate when altitude is greater than 60000 feet or velocity is in excess of 999mph. Instead these manufacturer's modules go dead when altitude is greater than 60000 feet or velocity is too high. Obviously, such modules are no good for high altitude ballooning.

The experiment failed however because the gps module lost satellite connection after a few minutes in the air. Since hardware and software functioned properly, this is considered a partial technical success, and will be flown again on Asgard-2, somewhere in the spring of 2012. As a safeguard against loss of signal, the gps module (insulated without metal coated foil) will be on the very top of the gondola, not inside as was the case on this flight.

4.2 Pressure measurements

An experiment has been developed to measure atmospheric pressure during balloon ascent to an altitude of 30 kilometers, where the air pressure is lower than 10 hPa. The pressure sensor's output is analog, so an external AD-convertor was required and the 12-bit ADC was chosen because of its good resolution without requiring signal amplification. Of course, it was necessary to determine the transfer function of the pressure sensor in order to allow conversion of measurement data into proper units. The data logger was therefore equipped with a transmitter and placed under a vacuum bell from where it can send data while a vacuum pump gradually diminishes the air pressure. A classical manometer is used as calibration reference.

On the Asgard maiden flight two pressure sensors were aboard, one in the gondola and one on top. The latter failed due to a sensor platform power shutdown, the former for unknown reasons. Investigating the cause of that failure, it turned out the sensor is unable to sustain a pressure difference between both sides of its active membrane. It would seem the sealant on the bottom side of the sensor is inadequate for low-pressure applications. Improvements are considered and will be tested shortly.

![Atmospheric pressure graph](image)
This malfunction demonstrates the need for more extensive testing, as our tests on the pressure sensor showed it to react properly to pressure changes. Those changes were always pulsed in nature though, unlike flight conditions, where pressure remains low for extended periods of time.

However, as the gondola had several openings to let cables through, it seems safe to assume pressure inside the gondola equaled outside pressure at all times. Hence, the pressure data from the Meteorological Institute's radiosonde can be used.

4.3 Temperature measurements

From the data taken outside the gondola it is clear that while the lapse rate drops to zero at about 10000m, it remains very low up to about 25000m.

With outside temperatures dropping to lows of about -55°C, the temperature in the gondola showed a slow decline, levelling off at about -7°C at balloon burst. Hence, commercial grade components (intended for operating temperatures between -10°C and +70°C) will do for work inside the gondola, while components exposed to the outside will have to be at least industrial grade (-40°C to +85°C) or preferably even military grade (-55°C to 152°C).

4.4 Air humidity measurements

Weather on launch day was very humid, low clouds and soft rain. Not surprisingly, air humidity outside the gondola was very high at ground level. Somewhat lower levels in the gondola were to be expected too, as the payload was integrated inside a building.

The crossing of both humidity levels at 10000m altitude is thought to be due to air trapped in the gondola and not or only partially being replaced with dryer outside air.

4.5 Flight path analysis

Due to a data storage malfunction, only ascent data were saved, from which an ascent profile could be deduced. As can be seen from fig.16, the ascent velocity is pretty constant throughout the troposphere (8m/s) and then decreases to about 5m/s.
From fig. 17, it is clear that major changes in wind speed can be deduced from the flight data, and associated with different layers in the atmosphere. A sharp drop in wind speed in the tropopause was observed here, with wind speeds increasing again in the lower stratosphere.

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REFERENCES
