



# HASP 2018 Final Flight / Science Report

**Submitted by:** Vincent van den Moortel/Erik de Schrijver  
**Submit Date:** 12 / 14 / 2018  
**Institution:** Sint-Pieterscollege Jette/Belgium  
**Payload Number:** 2018-08  
**Payload Name:** STRAINS - Stratospheric Radiation Instruments

## I) Outreach

- **Local TV and Radio network Bruzz**  
[https://www.bruzz.be/wetenschap/sint-pieterscollege-jette-naar-nasa-met-eigen-stralingsexperiment-2018-08-29?fbclid=IwAR3Vi0GhPJlxO7o4jtnwp\\_ymjmxIIYFABb5XG8R0KdksowE8GbdYTladP\\_4](https://www.bruzz.be/wetenschap/sint-pieterscollege-jette-naar-nasa-met-eigen-stralingsexperiment-2018-08-29?fbclid=IwAR3Vi0GhPJlxO7o4jtnwp_ymjmxIIYFABb5XG8R0KdksowE8GbdYTladP_4)
- **Local news Magazine Bruzz**  
<https://www.bruzz.be/wetenschap/sint-pieterscollege-jette-naar-nasa-met-eigen-stralingsexperiment-2018-08-29?fbclid=IwAR22eSPC556s6qJKUqfU44HoZfJCbkQ-ZnSJpmCAXK4gwwXSbg24GD8HFck>
- **School Newspaper 'Schakel' (to be published just before Xmas holidays)**
- **Presentation at the annual gathering of the 'Euro Space Society' (ESS)** – in June 2018 – with former astronaut Dirk Frimout (STS-25) as chairman, most 'Space Teachers' of the ESS attending.
- **Scientific paper in preparation** for the '24<sup>th</sup> ESA Symposium on European Rocket and Balloon Programmes and Related Research', June 2019, Essen, Germany. Despite its name, this is a symposium for all such programmes and research worldwide. NASA always has a strong delegation (in the past Dr. Phil Eberspacher and Dr. Elliott Young – among others – have attended on numerous occasions). Deadline for the submission of abstracts is January 25<sup>th</sup>, 2019. Symposium website: <https://atpi.eventsair.com/QuickEventWebsitePortal/pac-symposium-2018/home>

## II) Team member information

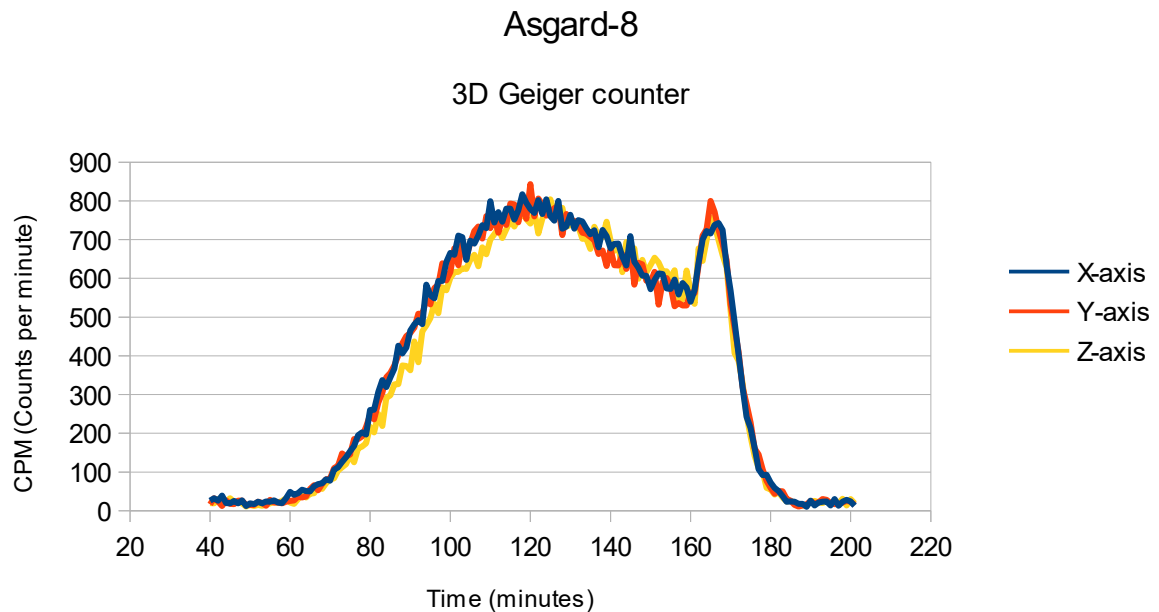
First name /Family name	Gender	Ethnicity	Race	Student Status	Disabled
Vincent Van den Moortel	M	non-hispanic	Caucasian	Undergraduate <sup>(1)</sup>	No
Jennifer Pham Van	F	non-hispanic	Asian	Undergraduate <sup>(1)</sup>	No
Ellen Van den Bossche	F	non-hispanic	Caucasian	Undergraduate <sup>(1)</sup>	Yes
Elie Kochuyt	M	non-hispanic	Caucasian	Undergraduate <sup>(1)</sup>	No
Jerome Sleewaegen	M	non-hispanic	Caucasian	12 <sup>th</sup> grade high schooler	No
Emilie Sanvito	F	non-hispanic	Caucasian	12 <sup>th</sup> grade high schooler	No
Elise Van den Bossche	F	non-hispanic	Caucasian	12 <sup>th</sup> grade high schooler	No
Ebe Coomans	M	non-hispanic	Caucasian	12 <sup>th</sup> grade high schooler	No
Jeff Van den Bossche	M	non-hispanic	Caucasian	12 <sup>th</sup> grade high schooler	No
Clara Vermoere	F	non-hispanic	Caucasian	12 <sup>th</sup> grade high schooler	No
Johan De Smet	M	non-hispanic	Caucasian	12 <sup>th</sup> grade high schooler	No

<sup>(1)</sup> These students were 12<sup>th</sup> grade high schoolers when they worked on HASP. They have graduated from Sint-Pieterscollege Jette on June 29<sup>th</sup>, 2018. Vincent Van den Moortel graduated cum laude and is now enlisted at the KUL – Catholic University of Leuven, in Civil Engineering. Jennifer Pham Van graduated cum laude and is now enlisted at the VUB – Free University of Brussels, in BioEngineering. Ellen Van den Bossche is now enlisted at the VUB – Free University of Brussels in biology. Elie Kochuyt is now enlisted at the KUL – Catholic University of Leuven – Saint Louis (Francophone University Brussels) in a bilingual (Dutch-French) Bachelor of Law program. He hopes to specialise in Space Law.

## III) Primary mission science/failure analysis

- Concerns about the possibility of the Geiger Counter modules failing in flight proved unwarranted, and all 3 modules were fully functional after flight. This confirms the assessment made after the Asgard-8 weather balloon flight in April 2018 where these modules performed nominally throughout the flight (peak altitude 31km).
- While testing prior to integration revealed no problems, data recording during the passive vacuum test in Palestine, Texas, broke off after a few seconds. The different Geiger Counter data recording circuits all 3 stopped functioning after a few seconds/minutes, hinting at a common design or manufacturing fault, but not a single point failure, as the different circuits failed at different times.
- Software testing on the benchtop hardware revealed no issues.
- Testing on the flight hardware revealed erratic registration of data on two of the Geiger Counter circuits, but data were never recorded for longer than a few seconds. The third circuit did not register data at all. Inspection of circuit soldering revealed cracked and/or damaged solder joints in each circuit. These damages are presumably due to small air bubbles enclosed between the PCB and the component pads, leading to cracks as the gas expanded during vacuum tests. Thermal cycling could have aggravated these problems. Resoldering the contacts on one of the data recording circuits solved the issue, confirming the validity of the analysis.

The goal of the experiment was to build on data obtained from the Asgard-8 weather balloon flight. The next figure shows the radiation levels in cpm, on 3 mutually perpendicular axes, as obtained during this flight over Belgium in April 2018.

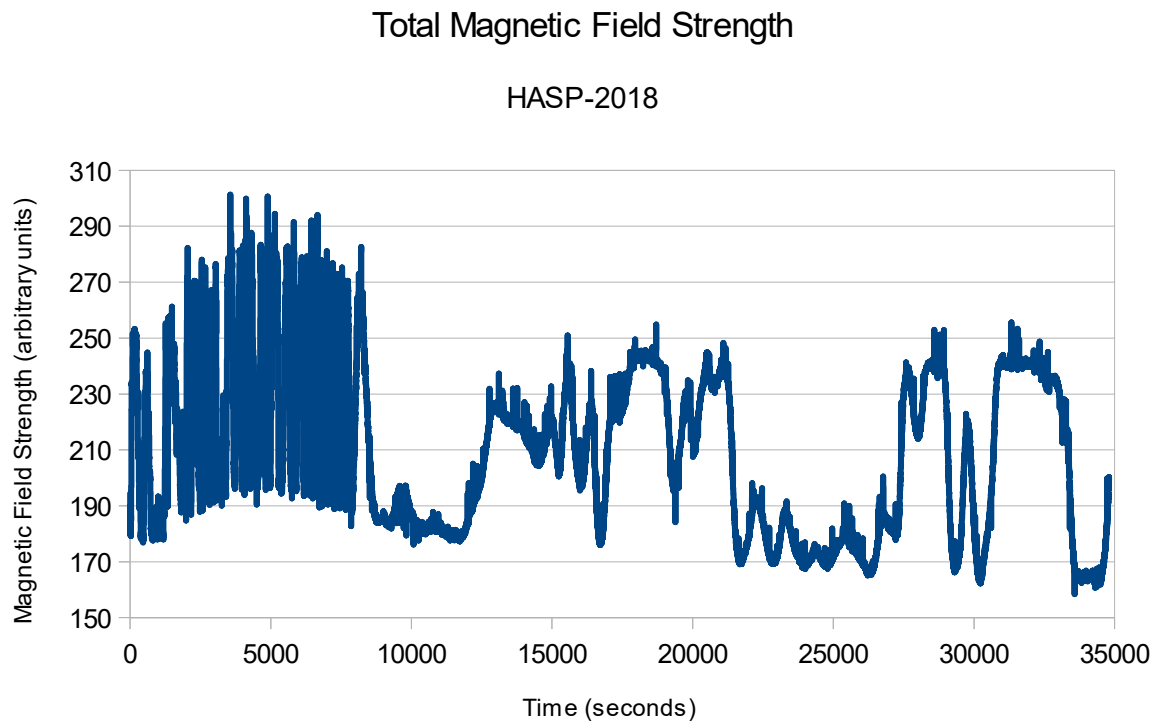


The reason for the second, more narrow peak is that the horizontal axis is time, not altitude, and the balloon's descent occurs at a far greater velocity than its ascent. The lowest point between both peaks can therefore be inferred to be the time of peak altitude (which is corroborated by GPS and pressure data).

Vertically incident radiation (yellow curve) can be seen to lag the horizontal curves (blue and red) below the so-called Pfozter maximum. Above the Pfozter maximum, the yellow curve seems to top the other curves, especially as the data approach maximum altitude. It is unclear from these data however if this is a real or a stochastic effect. The primary goal of the STRAINS experiment was to verify – using the far greater measuring time available on HASP (as compared to a weather balloon's flight) – the validity of these preliminary conclusions, and to investigate whether the difference continued to increase at even greater altitudes. Other objectives included the search for a correlation between radiation level and azimuth, dependence of the radiation on time-of-day, and stability of the radiation level during the float phase.

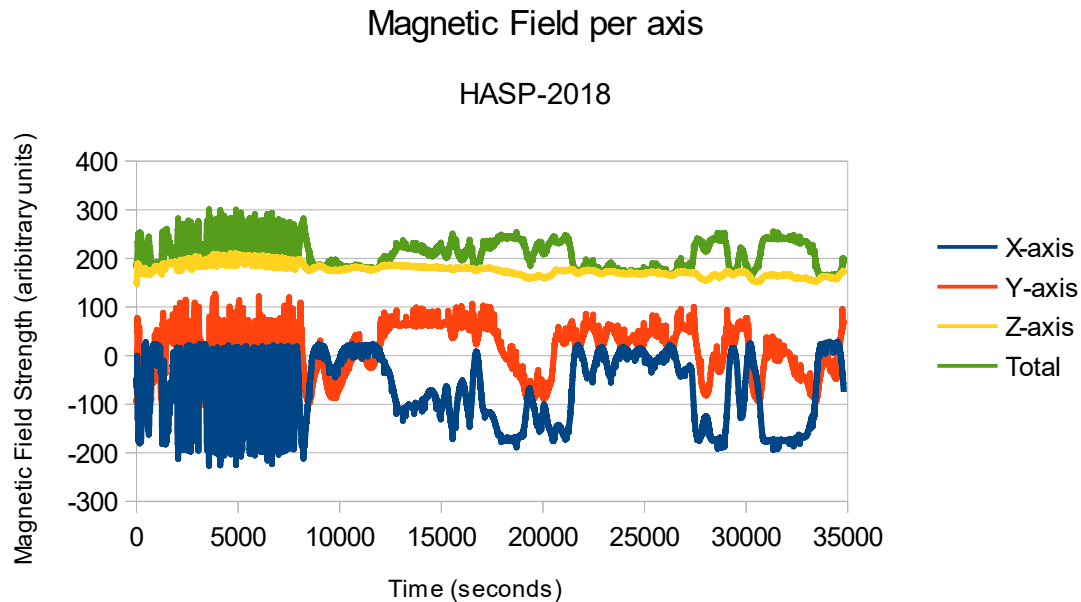
#### IV) Secondary mission science analysis

- The STRAINS experiment carried an on-board magnetometer (HMC5883L) that was intended to permit the correlation of horizontal radiation to azimuth. The rotation of the gondola would rule out any conclusions as to the source or genesis of radiation by use of an on-board reference system, so an external reference system was needed. GPS data would allow to determine the position of the gondola at any time, as well as its heading, but not its orientation going into that particular direction. Hence the use of a magnetometer to provide a fixed reference independent of the gondola's proper motion. (The assumption being of course, that Earth's magnetic field would not change direction significantly over the course of the flight).
- It was hoped that the Geiger Counter data obtained on the Asgard-8 weather balloon flight in April 2018 could be confirmed, and that the horizontal radiation levels correlated with azimuth. For this reason, the magnetometer was never calibrated, as only relative field intensities were needed.
- Unfortunately the Geiger Counter experiment failed. The magnetometer that was included as a supporting sensor therefore turned out to be the one yielding the most interesting data. The total magnetic field strength, expected to be constant throughout the flight, proved anything but constant, as shown in the next figure.

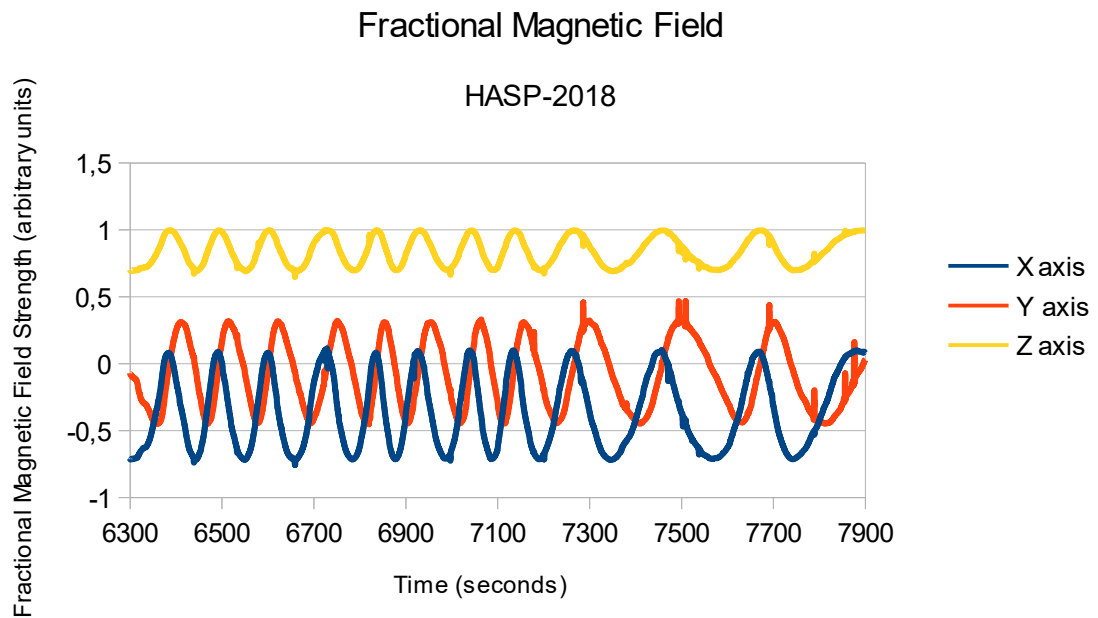


Wildly oscillating in the first phase of the flight, the variation in field strength seems to abate at about 8000s into the flight, which corresponds to the beginning of the float phase. This seems to indicate that the movement of the gondola is somehow related to the measured field strength variations.

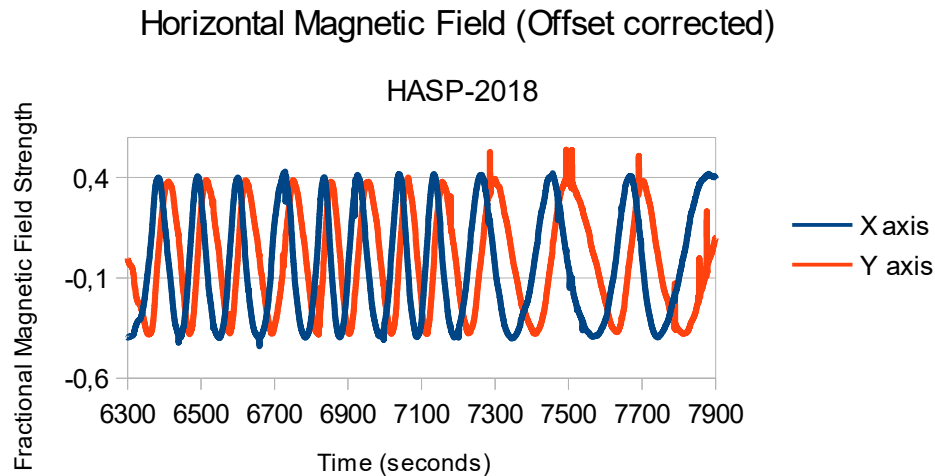
Looking at how the magnetic field along each of the different axes contributes to the total field strength yields the following figure.



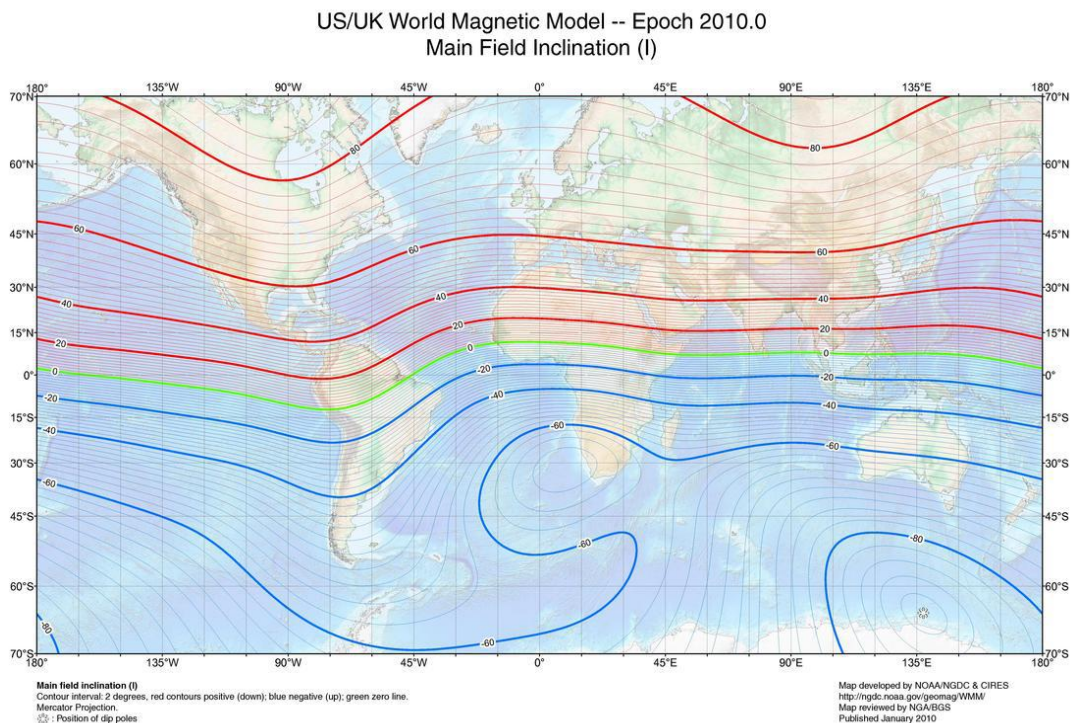
Clearly, the X- and Y-axes are the ones showing the greatest variations, but that was to be expected, as the movement of the gondola is basically an irregular rotation around the vertical Z-axis, accompanied possibly by some small amplitude pendulum movement or a precession causing slight variations in the vertical component of the field. Under that assumption, the 3 signals should vary with identical periodicity, which is indeed verified. The figure below illustrates this, for an excerpt of the data early in the float phase. Note that the data show the fractional field, that is the field component divided by the total field strength at that moment.



If the magnetic field is constant (in both magnitude and orientation), and neglecting the pendulum movement, the X and Y components of the field should interrelate as sine and cosine of azimuth. On the figure above it can be seen however, that the X and Y components of the field do not oscillate around zero as expected, due to an initial offset (as per datasheet of the sensor) that needs to be removed from the signal. Doing so yields the following.



It is immediately clear that both signals have the same amplitude, which stands to reason in its own right, but the amplitude itself is indicative of the Magnetic Field's inclination. At 0,4, it means the inclination of the field (relative to the horizontal, as commonly defined) should be approximately  $66^\circ$ , quite consistent with the  $62^\circ$  that can be read from the map below.



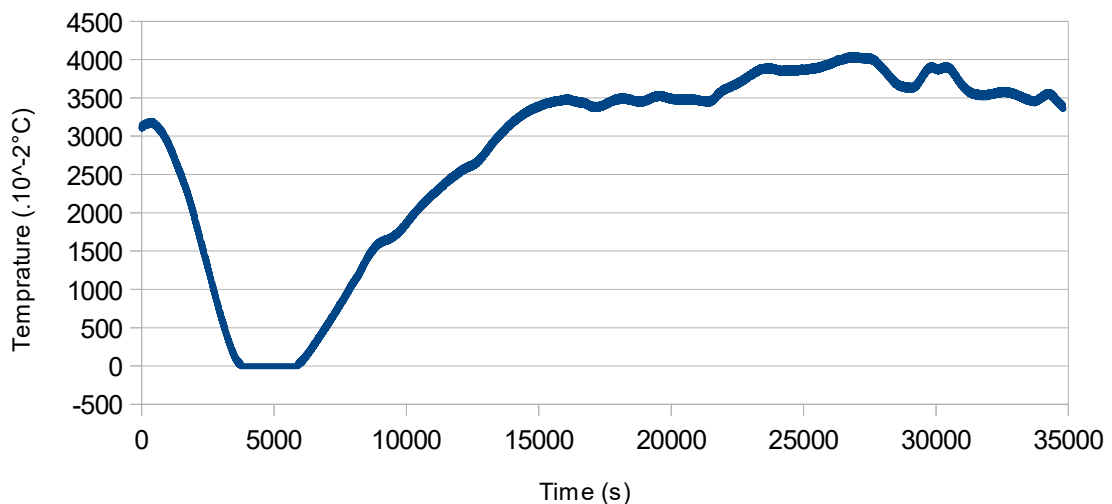
(Source: [https://commons.wikimedia.org/wiki/File:World\\_Magnetic\\_Inclination\\_2010.pdf](https://commons.wikimedia.org/wiki/File:World_Magnetic_Inclination_2010.pdf))

The variation of the vertical component of the field could be explained by assuming that the gondola is balancing at the lower end of the flight train. As the fractional field on the z axis varies with an amplitude of 0,152 an angle of  $\arcsin(0,152) = 8,7^\circ$  can be inferred. As  $\cosine()$  is approximately 1 for small angles, the effect of such balancing would be hard to extract from the X and Y data.

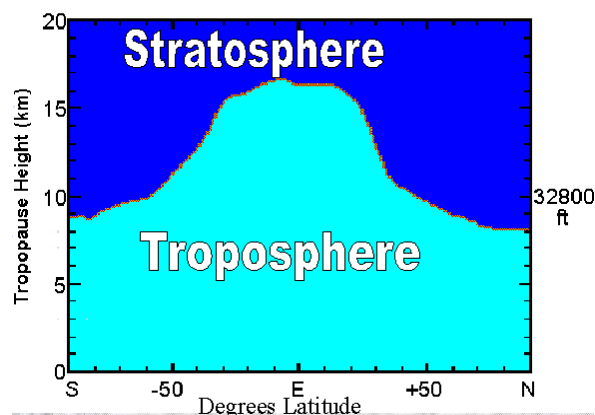
## V) Other aspects

- Lacking experience in long duration flight, it was decided to beef up insulation as was used on the team's previous weather balloon missions. This involves a styrofoam layer covered with thermal blanket foil. As payload dimensions on HASP are more restricted than on the Asgard weather balloon missions, the styrofoam layer would be significantly thinner: 3mm foamboard was selected, as opposed to the 3cm styrofoam layer of an Asgard gondola. To compensate, not a single but multiple layers of thermal blanket were secured to the side panels of the setup.
- The active thermal control system consisted of a 12V, 4W heater pad and a Peltier cooler element. The heating system was to start heating as soon as temperatures dropped below freezing. Recordings of the housekeeping data show the heater pad did indeed turn on as expected when temperatures dropped below 0°C. As a result, payload temperatures never dropped significantly below freezing, as can be seen in the following figure.

HASP2018 Temperature vs time



It should be noted that the temperatures go negative at an ambient pressure of 6617Pa, which corresponds to an altitude of approximately 18800m (in the 1976 Standard Atmosphere), well above the tropopause\*. This indicates that the passive thermal system actually performed quite well on its own.



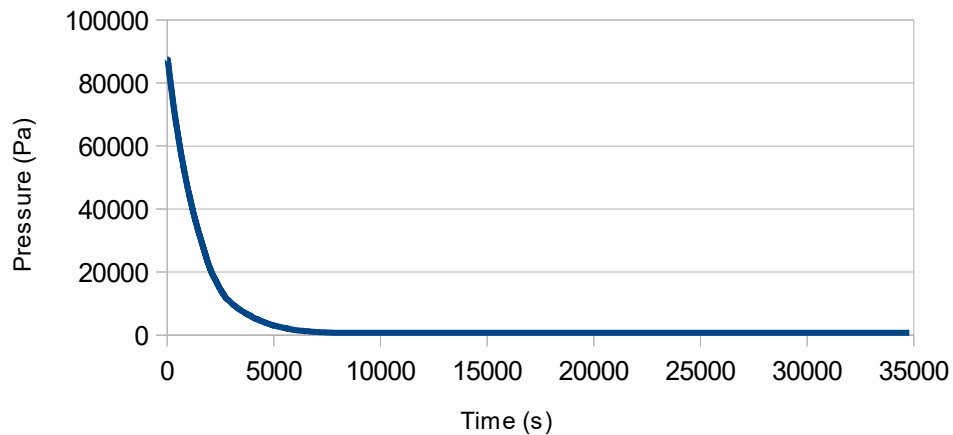


\* Tropopause altitude is a function of latitude and season, as can be seen on the previous figure.  
(Source: <http://www-das.uwyo.edu/~geerts/cwx/notes/chap01/tropo.html>)

Based on this information, the tropopause above Fort Sumner early September should be at approximately 13km.

- Pressure recording throughout the flight permit to derive altitude as function of time during both ascend and float phases.

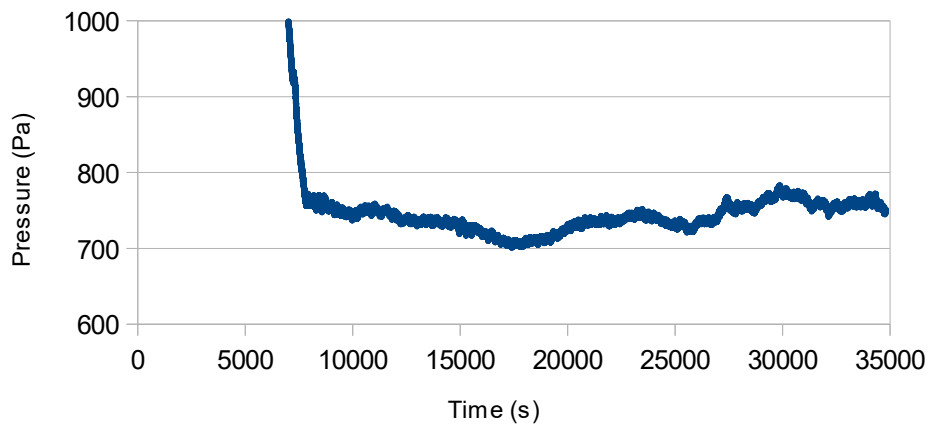
Pressure vs time



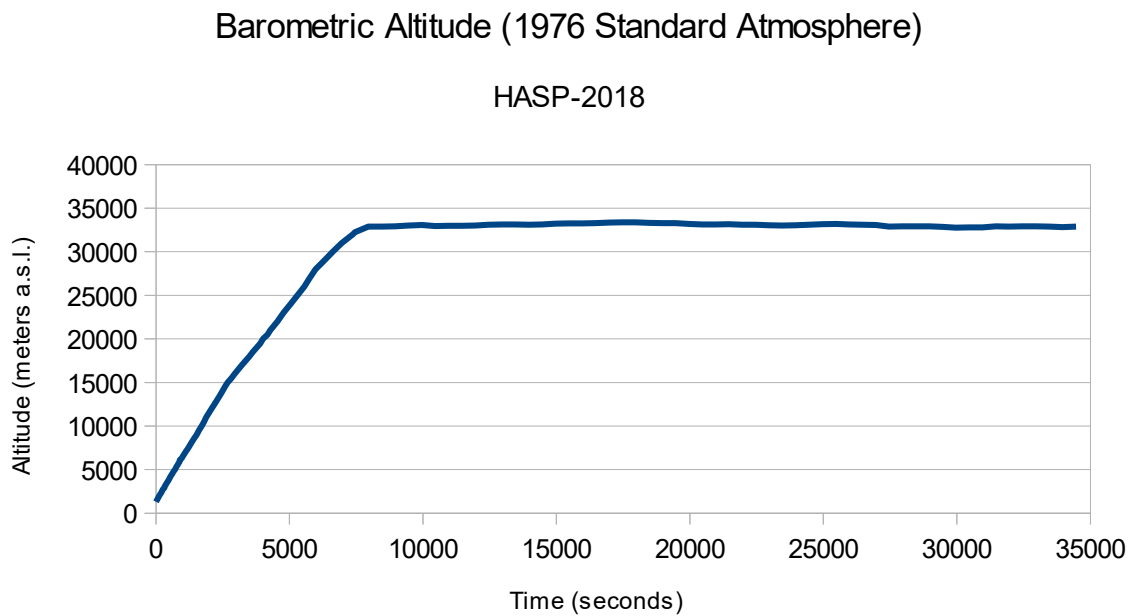
Prior to launch, the pressure at ground level was 87460Pa, which, according to the 1976 Standard Atmosphere, would put the launch site at an altitude of 1224m above sea level. The actual value is 1262m, according to Google Earth.

The pressure stability during the float phase can be made clear by omitting the first – low altitude, high pressure – segment of the previous graph.

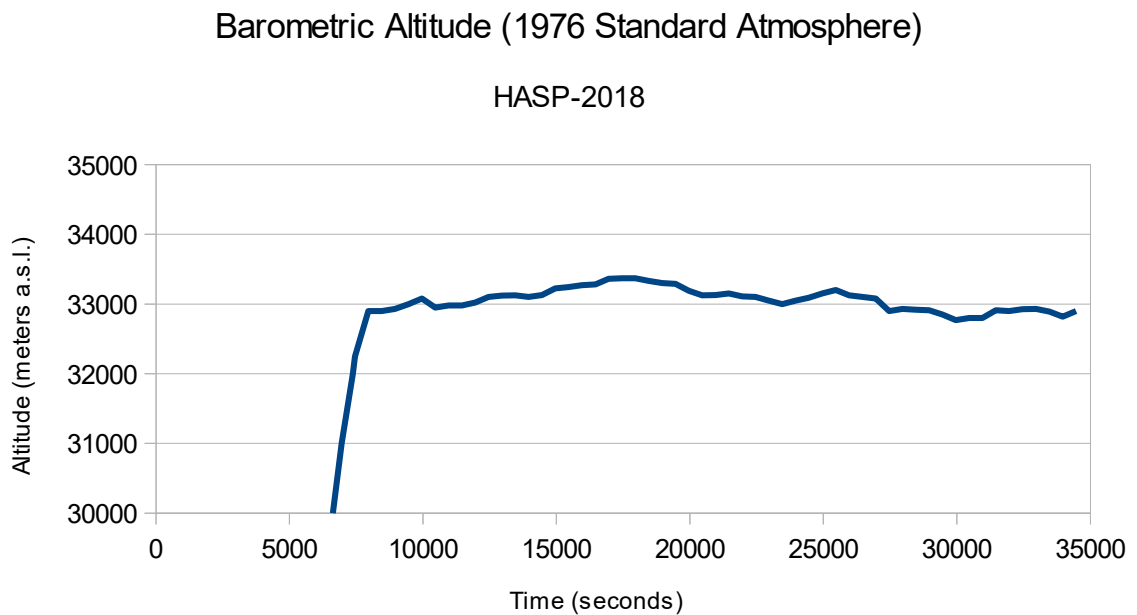
Pressure stability during float



Using the 1976 Standard Atmosphere as a model, these data were converted to an altitude vs time graph.



Bringing focus back to the float phase by omitting the first low altitude segment of the graph:



This indicates the HASP platform undergoes altitude changes of less than 500m, or about 1,5%.

## VI) Lessons learned

- Troubleshooting capabilities were severely hindered by the absence of the data downlink and by not having a team on the spot at integration in Texas. Either of these would probably have permitted to identify the cracked contacts as the root cause of the failure, or at the very least would have given much more time for investigating and fixing.
- High quality soldering needs to be looked into, and quality control of soldered joints needs to be stepped up. Testing under vacuum and thermal conditions similar to those encountered in flight are necessary prior to shipping to the US. The former issue will be tackled using ECSS-Q-ST-70-08C on 'The manual soldering of high-reliability electrical connections'. Testing will be performed in cooperation with industry, in such manner as to replicate what is being done at Palestine Texas, i.e. the payload should be active during the vacuum test and the thermal vacuum cycling. Given the limited speed at which high school students progress in such a project, a project should be well advanced (benchtop model operational) before a HASP proposal should be considered.
- In order to allow fast and easy access to the payload the thermal protection should be either integrated in the side panels or easy to remove.
- The payload's mechanical design should be so that boards and components are easily accessible and can be replaced without much ado. A system akin to a graphics card slot could be taken as a model.
- On-board memory devices ( $\mu$ SD cards) should be easily accessible, not only for physical replacement, but also for readouts and formatting. The same holds for microcontrollers: they should be easily accessible for physical replacement, but also for software upgrades and/or modifications. Ideally, one of the side panels should carry a dedicated connector for these purposes.

### Summary:

A lot was learned in this project:

- cooperation, personnel management
- time management and keeping track of deadlines and progress milestones
- financial management: keeping experiment and travel costs within budget
- technical issues: power management, insulation, mechanical design
- coping with failure: failure analysis, identifying measures and procedures to avoid reoccurrence

Many things will serve us in the future:

- Downlink telemetry and testing thereof
- Improved mechanical design and specifics on endured failures
- Frequent progress evaluations

## VII) Conclusions

The failure of the main mission goal was a severe setback and will mark all involved. It is to be expected that the students pursuing engineering (i.e. Vincent and Jennifer) will carry the care for quality control and testing with them throughout their professional life. If for no other reason, HASP has been a character-forming experience.

Rising to the challenge of figuring out what happened and trying to extract the maximum amount of information from what data where gathered was a rewarding experience in its own right.

For the school, the advantages of having to report frequently on progress has improved management and driven home the point that a roadmap with lots of small steps, entrusted to the students is the way to go as it improves oversight and allows for earlier detection of bottlenecks, holdups and even showstoppers.

With your permission, Sint-Pieterscollege will certainly apply again, though not on a yearly basis. The reasons for this are twofold. First, the school needs to absorb the lessons learned and verify that they have been absorbed properly and that the student teams of the future are stronger and better organised than they have ever been in the past. Second, travel to the US is barely affordable, and doing so on a yearly basis is beyond our means. But we hope to be with you again in 2020.

In the mean time, it is with deep gratitude that we thank all involved for giving us this truly amazing experience, and we do so in our own name, on behalf of the team, the school, and the parents.

Vincent Van den Moortel, STRAINS Team leader

Erik de Schrijver, STRAINS Team coach