LUFTBLICK
EARTH OBSERVATION TECHNOLOGIES

LuftBlick Report 2019002

Fiducial Reference Measurements for Air Quality

TN on change/upgrade of instrument

Version 8, 31th Dec 2022

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Document Change Record

Issue	Date	Section	Observations
1	30th Jun 2019	All	First version
2	31st Dec 2019	4	Added new hardware parts
3	28th Jun 2020	4	Incorporated HW section of CIDL
4	31st Dec 2020	5.2	Updated CIDL
5	30th Jun 2020	5.2	Updated CIDL
6	31st Dec 2021	5.2	Updated CIDL, Added new operating computer
6-1	12th Jan 2022	5.2	Updated CIDL
7	22nd Jun 2022	5.2	Updated CIDL, Added dehumidifier
8	21st Dec 2022	All	Added section 2.3 (EVO spectrometers), section 2.7 (spectrometer box humidity sensor), and 3.2 (TR1 vertical shaft modification). Updated sections 4.3, 4.8 and 4.9 (spring screws), section 4.5 (microprocessor), and CIDL.

Acronyms and Abbreviations

HCHO	Formaldehyde
NO_2	Nitrogen Dioxide
O_3	Ozone
AOD	Aerosol Optical Depth
CCN	Contract Change Note

CIDL	Configuration Items Data List
ESA	European Space Agency
FRM4AQ	Fiducial Reference Measurements for Air Quality
IOF	Instrument Operation File
Pandonia	ESA Ground-Based Air-Quality Spectrometer Validation Network
Pandora	Pandora spectrometer system
RMS	Root mean square deviation
TN	Technical note
USS	Unwanted Spectral Signal
wrms	Weighted RMS

1 Introduction

This report is deliverable 1 (D1) of the ESA project "Fiducial Reference Measurements for Air Quality" (FRM4AQ) [5, 6]. It is a technical note (TN) describing changes and updates of hardware and construction of the Pandora spectrometer system (Pandora). It mainly covers the modifications applied since May 2018, for which the status of the instrument is described in the final report *Cede* [7] of CCN#1 [4, 3] to ESA's Pandonia project [2, 1].

The document has main sections for different parts of Pandora: section 2 for the Pandora box, section 3 for the tracker and section 4 for the sensor head unit including the fiber. Inside each section, the specific hardware modifications are summarized in chronological order. Each hardware modification has a corresponding entry in the Configuration Items Data List (CIDL). The HW section of the CIDL is given in in section 5 and the online version of the CIDL can be accessed here.

1.1 Applicable Documents

[1] Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study [Proposal], LuftBlick Proposal 201309A, Issue 2, 2013.

[2] ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study [Statement of Work], ENVI-SPPA-EOPG-SW-13-0003, Issue 1, Revision 3, 2013.

[3] CCN1 to ESA Ground-based Air-Quality Spectrometer Validation Network Uncertainties Study [Proposal, Proposal 201705A, Issue 2, 2017.

[4] CCN1 to ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study [Statement of Work], ESA-EOPG- MOM-SOW-1, Issue 1, Revision 1, 2017.

[5] Fiducial Reference Measurements for Air Quality [Proposal], LuftBlick Proposal 201805DEV, Issue 1, 2018.

[6] Fiducial Reference Measurements for Air Quality [Contract and Statement of Work], ESA Contract No. 4000125841/18/I-NS, 2018.

[7] A. Cede. ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, LuftBlick Report 2018005: Final Pandonia report, 2018.

[8] A. Cede and N. Abuhassen. OMI validation support, LuftBlick Report 2016006: Tracker Design Document, 2016.

[9] A. Cede and N. Abuhassen. OMI validation support, LuftBlick Report 2016012: Tracker prototype report, 2016.

[10] A. Cede and M. Tiefengraber. ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, LuftBlick Report 2014004: Pandora-2S Design and Evolution Document, 2014.

[11] M. Müller and M. Tiefengraber. ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, LuftBlick Report 2017005: Tracker prototype performance evaluation report, 2017.

[12] M. Müller, M. Tiefengraber, and A. Cede. ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, LuftBlick Report 2018001: Final tracker design and performance document, 2018.

[13] D. Santana, A. Cede, M. Tiefengraber, M. Müller, and M. Gebetsberger. Fiducial Reference Measurements for Air Quality, LuftBlick Report 2019004: Configuration Items Data List, 2019.

[14] M. Tiefengraber and A. Cede. ESA Ground-Based Air-Quality Spectrometer Validation Network and Uncertainties Study, LuftBlick Report 2016001: Report on Feasibility to Retrieve Trace Gases other than O3 and NO2 with Pandora, 2016.

[15] M. Tiefengraber, A. Cede, Kreuter A., B. Wimmer, D. Santana, M. Gebetsberger, M. Müller, and C. Posch. Pandonia Operations, LuftBlick Report 2018008: Network status report, 2019.

2 Pandora box

2.1 July 2017 - Rugged Pandora operating computer Cincoze DC-1100

Originally, standard commercial laptops were used in the Pandora spectrometer system. With the much higher data rate for Pandora-2S, we have noticed more and more connection interruptions, which required frequent actions from the local or network operator to solve it. Therefore, the laptops have been replaced with rugged single board computers for all Pandoras starting in July 2017 (figure 1). Since those computers have more reliable interface ports, this has significantly reduced the connection issues.

Figure 1: Rugged Pandora operating computer Cincoze DC-1100. Image taken from `http://www.cincoze.com/goods_info.php?id=32`.

2.2 Oct 2018 - SciGlob Relay Board RB2

The relay board is part of the interface box inside the Pandora box. It is the communications interface for all hardware pieces, which do not go directly into the operating computer, i.e. the head sensor and tracker. It also contains the relays that are used to control the power of the different hardware parts, such as the spectrometers, and the tracker. Compared to its predecessor SciGlob Relay Board RB1 (figure 2), which only could connect the old tracker, RB2 (figure 3) can act as interface to the new tracker LuftBlick TR1 too. Hence for each instrument, where the tracker is upgraded to LuftBlick TR1, the relay board must be upgraded too. This new version of the relay board has also some LED's that are useful to diagnose the eventual communication problems that could happen, with the different connected hardware parts.

Figure 2: SciGlob Relay Board RB1

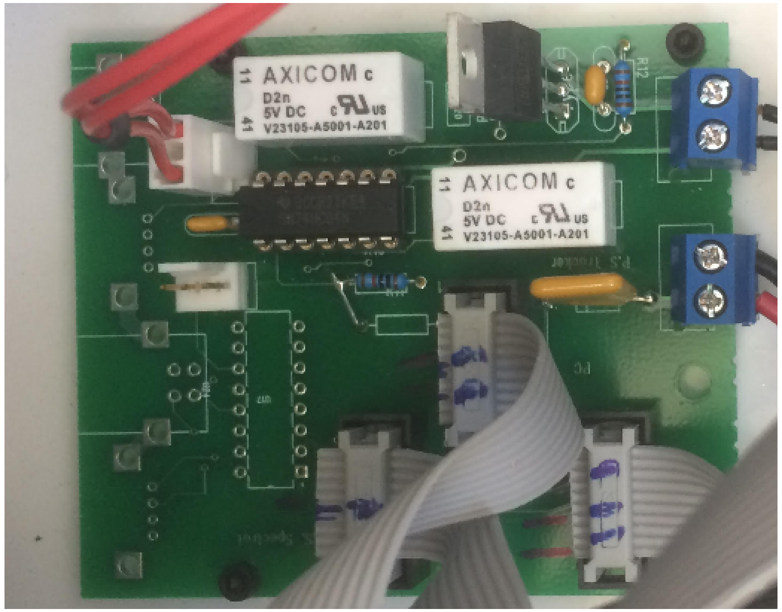
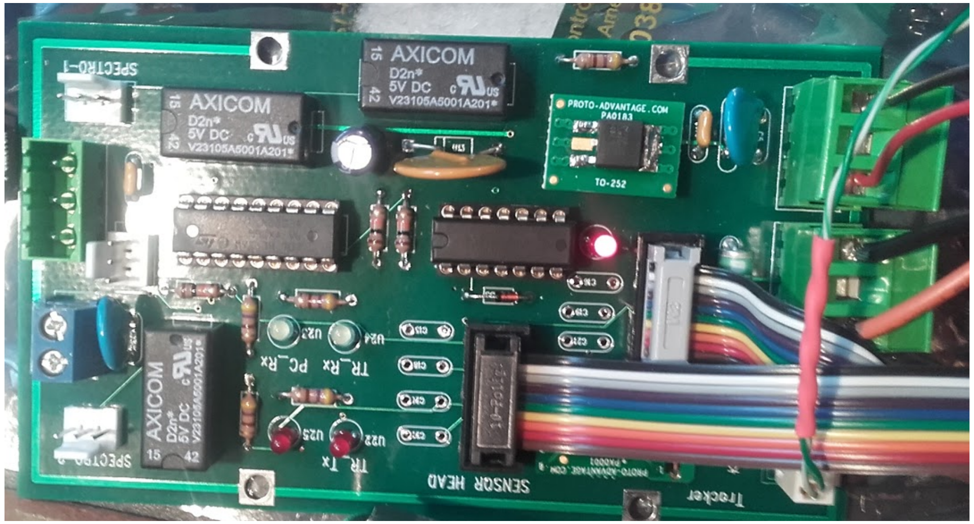


Figure 3: SciGlob Relay Board RB2



2.3 Feb 2021 - Avantes EVO spectrometers

The CMOS detectors have evolved significantly in the last years, and are now displacing the dominant position of the CCD detectors. The Avantes spectrometers manufacturer released a new line of products named "EVO" (`https://www.avantes.com/products/spectrometers/starline/`), which uses this latest technology of CMOS detectors.

SciGlob was interested to test this new type of spectrometers because they have an ultra fast electronic shutter that allows to measure at very low integration times, up to 9μs. This feature permits to prescind from any attenuation filter in the filterwheels, leaving free space for other filters, like polarizers (Only an ND4 is still needed, but is just to speed up the sun searches).

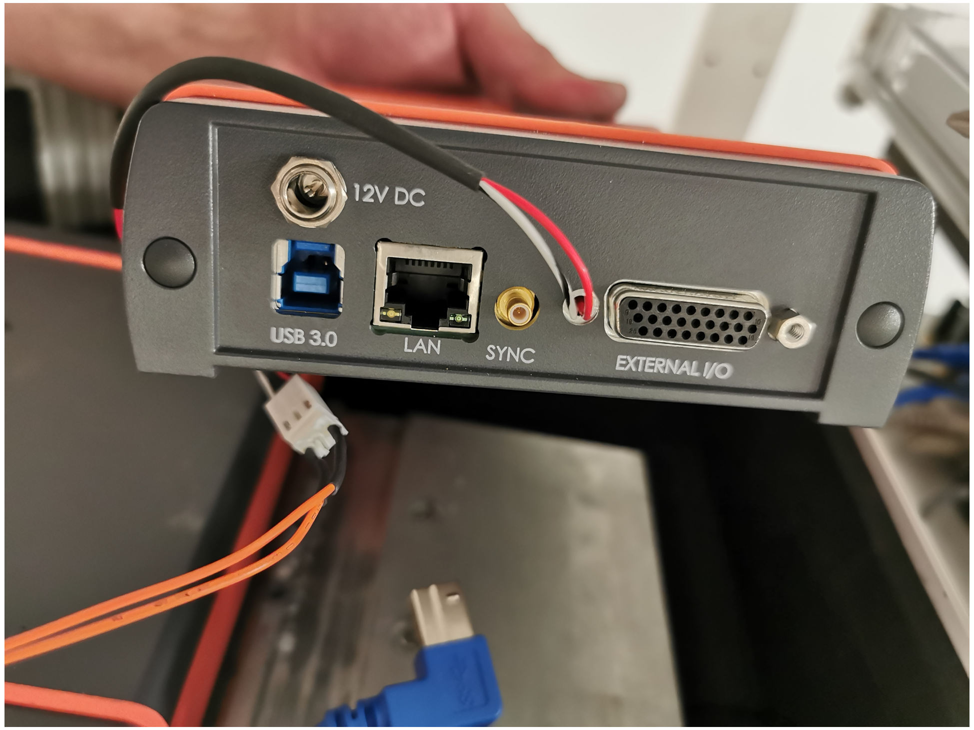
Two testing Pandoras were updated with AvaSpec-ULS2048CL-EVO spectrometers, Pandora 71 (1S) since February 2021, and Pandora 209 (2S) since August 2021. After confirming its successful behavior the EVO spectrometers became the default option for new instruments from November 2022.

The main characteristics of this new spectrometer are:

- Detector: CMOS linear image sensor, 14×200 μm
- Wavelength range: 280-530nm (uv) / 400-900nm (vis)
- Slit: 50μm
- Grating: UC, 1200lines/mm (uv) / VB, 600lines/mm (vis)
- Resolution: 0.6nm (uv) / 1.2 (vis)
- A/D converter: 16bits, 6MHz
- Integration time: 9μs-59s
- Fiber connector: SMA
- Readout electronics: New AS-7010 USB 3.0 board, with faster microprocessor, 50 times more memory capacity than the previous version (AS-5216) which allows to store more spectra onboard and realize more functionality.
- Signal to Noise: 300:1
- Options: Data collector lens (DCL) to enhance sensitivity, order sorting filters (OSC) to reduce the second order effects.

Figure 4: Front view of the Avantes ULS2048CL-EVO spectrometer.

Figure 5: Rear view of the Avantes ULS2048CL-EVO spectrometer.



2.4 July 2021 - Rugged Pandora operating computer Kingdel NC4000

Starting in 2021 the Cincoze computers shown in section 2.1 were less and less available and therefore a replacement was needed. The model Kingel NC4000 (figure 6) was first tested in March 2021 and is used in the Pandoras since July 2021. It shows equal or even better performance than the Cincoze DC1100.

Figure 6: Rugged Pandora operating computer Kingdel NC4000. Image taken from `http://www.kingdel.com.cn/prodel.aspx?id=76`.

2.5 Aug 2021 - Rugged Pandora operating computer HUNSN i5-8GB

Soon after switching to model Kingel NC4000 (section 2.4), another option for the operating computer was tested. The HUNSN i5-8GB (figure 7) shows equal performance than the Kingdel.

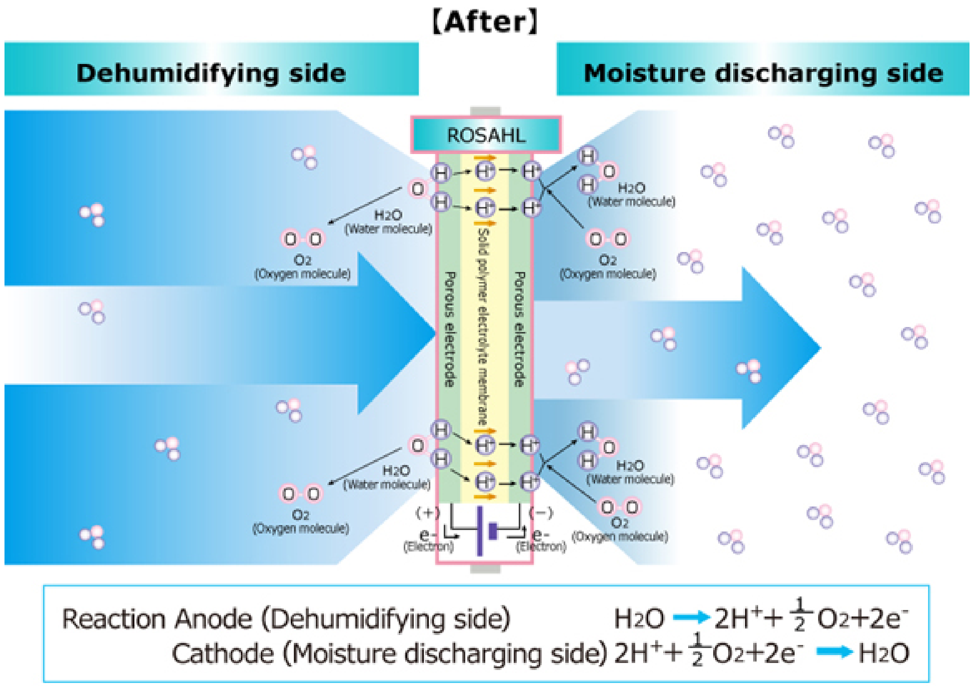
Figure 7: Rugged Pandora operating computer HUNSN i5-8GB. Image taken from `https://www.amazon.com/gp/product/B07WK379VJ/ref=ppx_od_dt_b_asin_title_s00?ie=UTF8&th=1`.

2.6 May 2022 - Rosahl Dehumidifier for Spectrometer Box

Humidity entering the Pandora spectrometer box has always been a problem for Pandora, especially in humid places and when the Pandora box is placed outside and not inside a building. When the humidity gets too high, condensations might appear in the optical components of the spectrometer, which significantly changes the instrument's sensitivity and also damages the affected parts in the long term. To avoid that big silica-gel packages are included in the spectrometers box in order to keep the humidity low. However this method has its limits, and the silica gel bags are not always regularly checked by the local operators. So to avoid these moisture problems at these humid and warm locations, it is needed to operate these instruments at a setting temperature of 20°C instead of 15°C, which would be our preferred temperature.

A very innovative dehumidification concept has been developed recently by the Japanese company Rosahl, see
`http://www.ryosai.co.jp/products/index_en.html`,
The concept of this method is explained in figure 8.

Figure 8: Concept of dehumidifier: The dehumidifier electrolytically decomposes and removes moisture in a container using a solid polymer electrolyte membrane. When a direct current is applied to the porous electrode attached to the special solid polymer electrolyte membrane, moisture at the anode side ("Dehumidifying side") is separated into hydrogen ions and oxygen. The hydrogen ions pass through the solid polymer electrolyte membrane to the cathode side ("Moisture discharging side"). The hydrogen ions react with oxygen in the air on the cathode side to form water molecules(gas) and are then discharged.



In spring 2022, SciGlob tested this new dehumidifier on Pandora 234 (figure 9), and the results have confirmed the specs from the manufacturer, so that SciGlob is planning to include such a device in each Pandora from now on. In a next step a smaller version from the same company will be tested for use in the head sensor.

Figure 9: Inside of Pandora 234 spectrometer box with the dehumidifier installed.

2.7 May 2022 - Spectrometer Box Humidity Sensor

Also to prevent condensation problems, a new humidity sensor has been installed in the spectrometers box, model TI HDC2080EVM (`https://www.ti.com/tool/HDC2080EVM`). The operational software (BlickO) was adapted to monitor this sensor, so that the local operators can see value of the relative humidity inside the spectrometers box at near real time. In this way the value of the relative humidity will indicate the operators when it is necessary to replace the silica gel bags. It also contains a temperature sensor, which is useful to measure the temperature gradient inside the spectrometers box. Initial tests in P234 worked fine, but unfortunately this specific sensor has been discontinued. SciGlob is currently looking for an alternative model, with proper support and a good dealer network.

Figure 10: Spectrometer Box Humidity Sensor installed at the lid of the Pandora 234 spectrometer box.

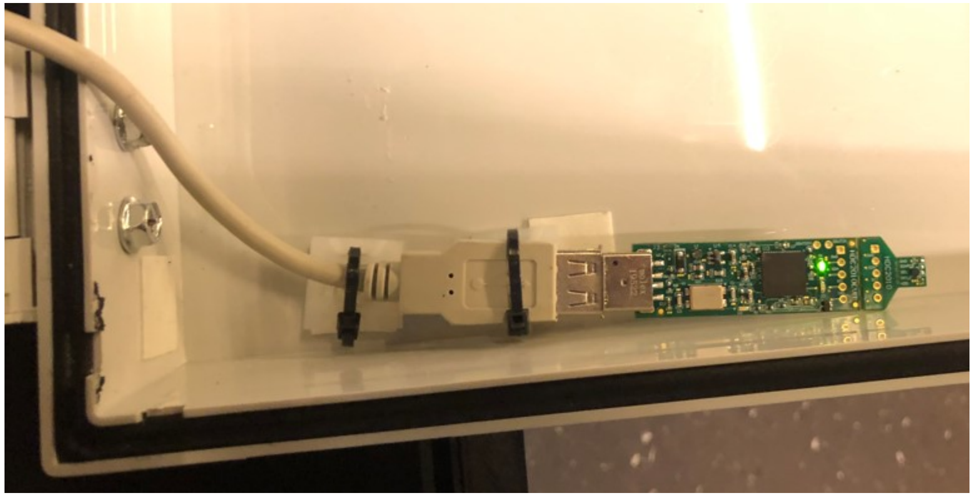
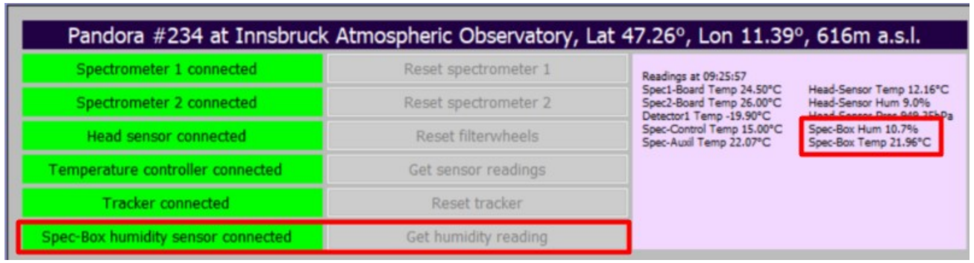


Figure 11: Spectrometer Box Humidity Sensor reading in BlickO.



3 Tracker

3.1 Oct 2018 - LuftBlick Tracker TR1

The tracker used in all Pandoras until Oct 2018 is the Pan-Tilt Unit-D46-70 from FLIR Motion Control Systems, Inc. (`http://www.flir.com/mcs/view/?id=53712`) [10]. In 2016 it was decided that using a different tracker system will be an essential step to improve the overall performance of the instrument [8]. A new tracker prototype was built and evaluated [9] [11]. While the test results were very good in most aspects, this first prototype still had one major issue: the hardware costs already exceeded 5000 Euro, which brings the total costs of the tracker up to about 10000 Euro per piece. For this reason, in a meeting with ESA in October 2017, LuftBlick offered to ESA, that it will work together with SciGlob on a modified new tracker version, of which the hardware costs will be below 3000 Euro. This new prototype is described in *Müller et al.* [12] and became the operational model LuftBlick Tracker TR1, which is used for Pandoras from now on (figure 12).

Figure 12: LuftBlick tracker TR1

3.2 Jan 2020 - LuftBlick TR1 vertical shaft modification

A small improvement was done in the main vertical shaft of the LuftBlick Tracker TR1. The new main vertical shaft has now a flange with four screws, that allows to easily dismount the upper body of the tracker with respect to the base plates. This reduces the mounting or dismounting time, and also allows to tighten the internal screws that keeps the azimuth motor connected to the vertical shaft in a more easy way. Once dismounted, the split of the tracker in two pieces also allows to use a more compact packing for shipping.

Figure 13: LuftBlick tracker TR1 - new vertical shaft

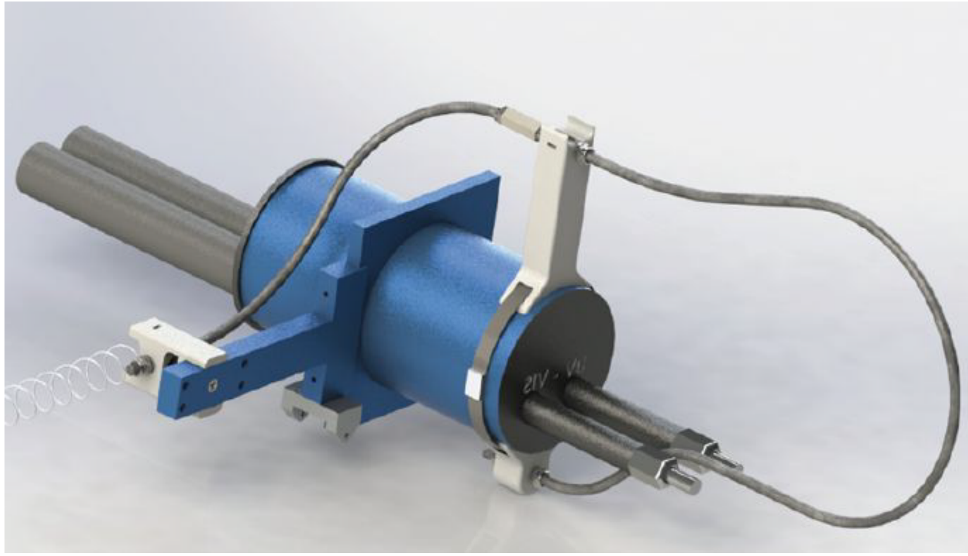
4 Sensor head unit

4.1 Jun 2017 - LuftBlick Fiber Guide FG1

Pandora-1S uses a 400 μm core and 440 μm clad diameter single strand high OH-content fused silica fiber with a silicone jacket and SMA connectors on both ends. The numerical aperture of the fiber is 0.22 and the fiber length can vary from 3 m to 20 m, typically 10 m (it depends on the distance between inside and outside Pandora parts).

We know that in order to derive Aerosol Optical Depth (AOD) from direct sun observations, the fundamental requirement for the instrument is to be radiometrically stable. However we have noticed sensitivity variations of the Pandoras during the day and also “jumps” in the sensitivity of a few percent from time to time. Analyzing these variation we suspected the fiber to have an influence, since it is differently bent over the course of the day. Therefore we have developed LuftBlick Fiber Guide FG1 (figure 14). Its main functional parts is a hand-made metallic guide, along which the fiber optics are fixed.

Figure 14: Pandora-2S head sensor with LuftBlick Fiber Guide FG1.

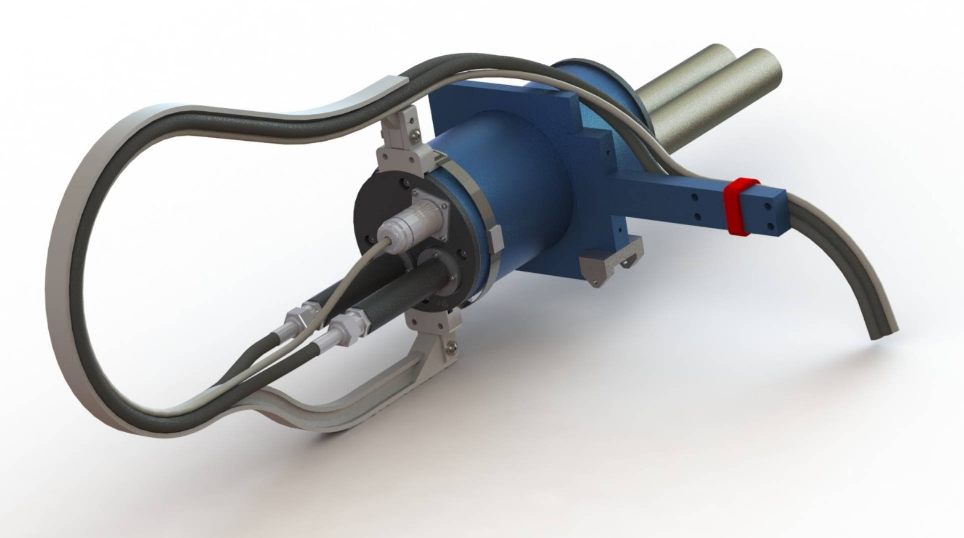


We have noticed a significant improvement of the instrument's stability, when the fiber guide is used and believe that AOD measurements are only possible in that way. In addition to better radiometric stability, the fiber guide also makes the instrument installation much simpler, since it leaves the local operator with only one clear defined fiber layout options.

4.2 Feb 2018 - LuftBlick Fiber Guide FG2

LuftBlick Fiber Guide FG2 is an evolution of Fiber Guide FG1 (figure 15). It has the same advantages as FG1, but can be easier produced and added to any Pandora. It fixes the fiber layout in the first meter after the head sensor, which we consider the most critical segment.

Figure 15: Pandora-2S head sensor with LuftBlick Fiber Guide FG2.



4.3 Jul 2018 - SciGlob Spring Screws SS1

As shown in the quarterly network status reports [15], problems with the filterwheel movements have been the most frequent hardware issues in 2018. This issue is mostly caused by too much friction between the gear of the filterwheel 1 stepper motor and the teeth on the filterwheel itself. We noticed that this problem could be fixed by replacing the screws holding the stepper motor (figure 16) with "spring screws", which reduce this fraction substantially and still produce the necessary force to move the filterwheels (figure 17). This type of spring screws is called SciGlob SS1 and was used for the first time on some instruments in July 2018. This fix was only tested in a few instruments, but the idea was finally discarded later, because it was not needed anymore with the new nylon made filterwheels (see 4.10) and the more powerful filterwheel motor drivers of the new head electronic board (see 4.6).

Figure 16: Pandora filterwheel housing (black part on bottom) with the stepper motor turning the filterwheels mounted on it using screws without springs.

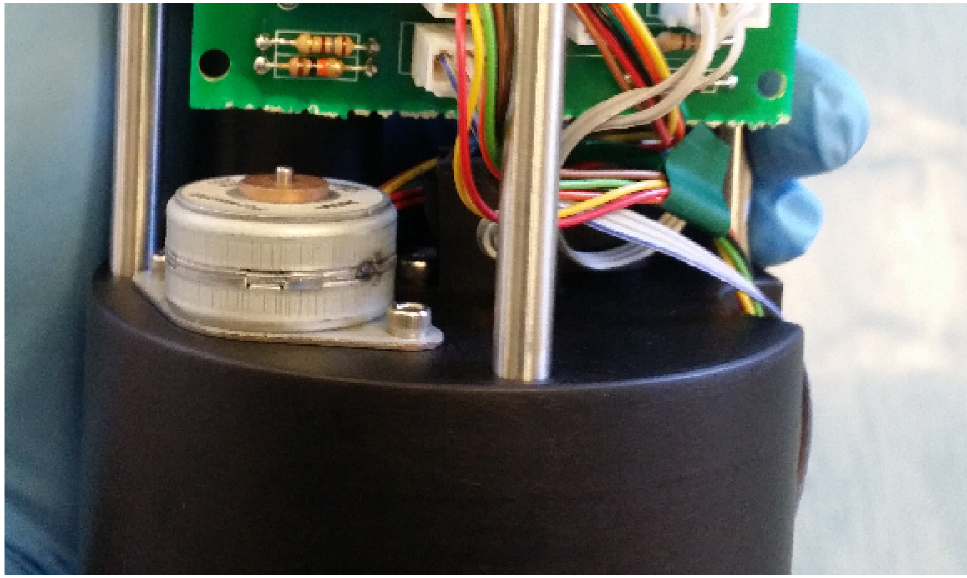
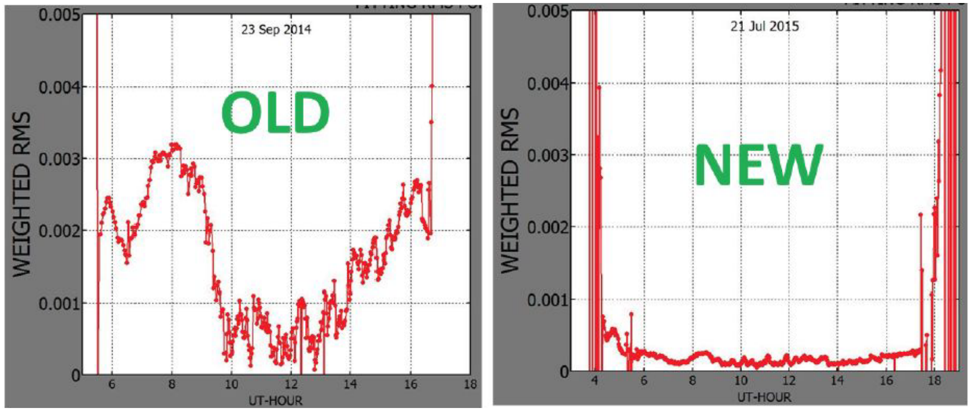


Figure 17: Filterwheel housing cover plate with the stepper motor turning the filterwheels mounted on it using screws with springs.

4.4 Aug 2018 - Wedged entrance window Edmunds Optics #34-242

Before 2015, Pandora used uncoated, flat, fused silica entrance windows of 25 mm diameter and 3 mm thickness. In that time we always had noticed a non-atmospheric spectral signal in the direct sun observations, which we called “unwanted spectral signal” (USS) and which significantly increased the RMS in the spectral fitting [14]. This caused slightly reduced accuracy in the direct sun retrieval of O_3 vertical columns, moderately reduced accuracy for NO_2, and virtually unusable data for HCHO. Then we replaced the uncoated entrance window with a properly hard-coated windows. After this change, this USS decreased by a factor of about 10 (figure 18). As a result, the USS had insignificant effect on O3, very little effect on NO2 and reduced effect on HCHO [7].

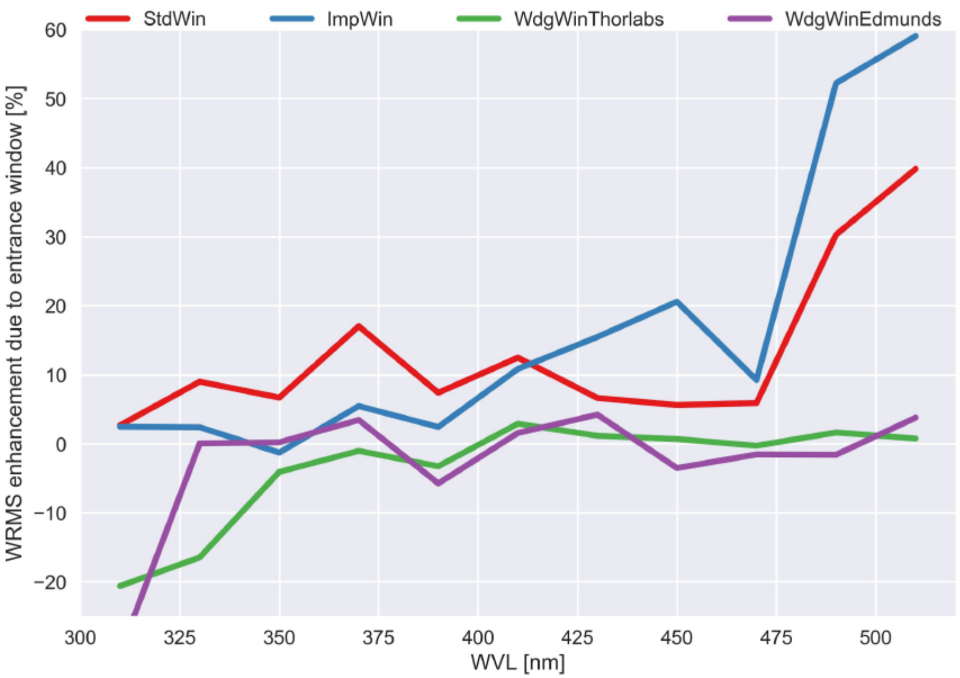
Figure 18: RMS of spectral fitting for total NO_2 for a Pandora with an uncoated entrance window (left) and a coated entrance window (right).



However over time we noticed two disadvantages of the coated window: first the USS was still present at this reduced amount and negatively influencing the data, especially for HCHO, and second, the coating, despite being advertised as weather proof, was fading over time and its positive effect was reduced.

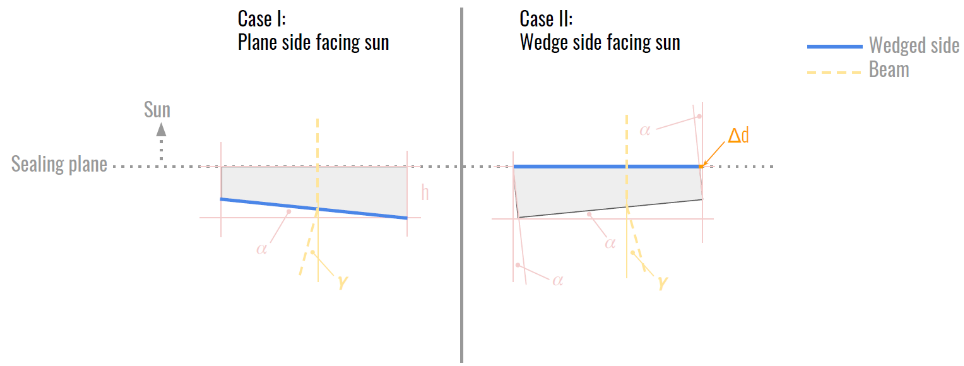
Since the USS comes from etaloning caused by interference between the (parallel) front and back surface of the window, we started testing wedged windows, which should not show such effect. Figure 19 shows measurements performed using Pandora 121 at Tenerife in Aug 2018. During sunny conditions the entrance of the instrument was alternated between no window at all, 2 types of coated flat windows and 2 types of wedged windows, both with a 0.5° angle between the two surfaces. The results showed that the wrms of the spectral fitting for the wedged windows was as good as for the case of no window. This convinced us that the wedged window is the right optical element to minimize the USS.

Figure 19: Increase of spectral fitting wrms with 20 nm wide windows compared to the situation without entrance window as a function of wavelength. StdWin is the "standard" coated entrance window, ImpWin is another flat window using a different coating with somewhat improved performance in the UV, and WdgWin Thorlabs and WdgWin Edmunds are wedged window from different provider.



The wedged window can be placed on the head sensor either with the flat surface or the wedged surface facing up (see figure 20). While from an optical perspective we do not expect a large difference for these two cases, we were worried about the sealing of the instrument when having the wedge. Originally the entrance window was fixed on top of the head sensor with a retainer ring and an silicon o-ring in between. After some testing we settled on the following new way to mount the wedged entrance window: underneath the flat surface of the wedge, which "looks" to the inside of the head sensor, is an additional o-ring with soft stiffness, which adjusts to the different thickness of the wedge, while between the wedged surface and the retainer ring is a high stiffness o-ring.

Figure 20: Different possible orientations for wedged window.



4.5 Oct 2018 - RabbitCore Microcontroller RCM4100

The new LuftBlick tracker TR1 uses a different communication protocol than the FLIR one (RS485 instead of RS232). Initially it was planned to control it directly from the head microcontroller, plus adding some other auxiliary sensors in the head (see 23). So a re-design of the head board was done to include the new sensors. Looking for future upgrades, a new head microcontroller was tested, updating the standard RabbitCore RCM 2020 to a more powerful RCM 4100, which had a few extra analog inputs that could be used for future upgrades. After some iterations in the desing, it was concluded that the previously used microcontroller (RCM 2020) was more than enough, the analog inputs were not needed because the auxiliary sensors could be read through SPI digital I/O, and the conversion of RS232 to RS485 for tracker control could be implemented in the new interface board (see 2.2), so that with the new head electronics containing the standard microcontroller (RCM 2020), an updated version of the firmware, and the new RB2 relay board it was possible to connect both trackers (FLIR and LuftBLick TR1) without the necessity of a new microcontroller.

Figure 21: RabbitCore RCM4100 controller with up to 40 GPIO (General Purpose Input/Output), 59 MHz – 512K Flash, 256K / 512K Data SRAM (Static random access memory), 8 channels 12-bit A/D converter, Up to 6 CMOS-compatible serial ports

4.6 Apr 2019 - SciGlob Head Sensor Board HSB2

In order to add more auxiliary sensors inside the head, such as the humidity sensor, a new re-desing of the head board was done.

Figures 22 and 23 show the "old" SciGlob Head Sensor Board HSB1 and the new SciGlob Head Sensor Board HSB2 respectively. The new board allows the reading of the following parameters related to the head sensor:

- Temperature in head sensor: this is called "Head-Sensor Temp" in BlickO and has index 15 in the Instrument Operation File (IOF).
- Humidity in head sensor: this is called "Head-Sensor Hum" and has index 53 in the IOF.
- Pressure in head sensor: this is called "Head-Sensor Pres" and has index 71 in the IOF.

In case the instrument is equipped with LuftBlick tracker TR1, the new board also allows to read the following tracker temperatures:

- Azimuth motor temperature: this is called "Azi-Motor Temp" in BlickO and has index 18 in the IOF.
- Zenith motor temperature: this is called "Zen-Motor Temp" in BlickO and has index 19 in the IOF.
- Azimuth driver temperature: this is called "Azi-Driver Temp" in BlickO and has index 20 in the IOF.
- Zenith driver temperature: this is called "Zen-Driver Temp" in BlickO and has index 21 in the IOF.

Additional changes in HSB2 compared to HSB1 are:

- New filterwheel motor drivers, more powerful to avoid filterwheel stuck problems.
- A buffer to protect the microcontroller's digital outputs, so that the power relay (section 2.2) commands are not triggered by mistake

Figure 22: SciGlob Head Sensor Board HSB1

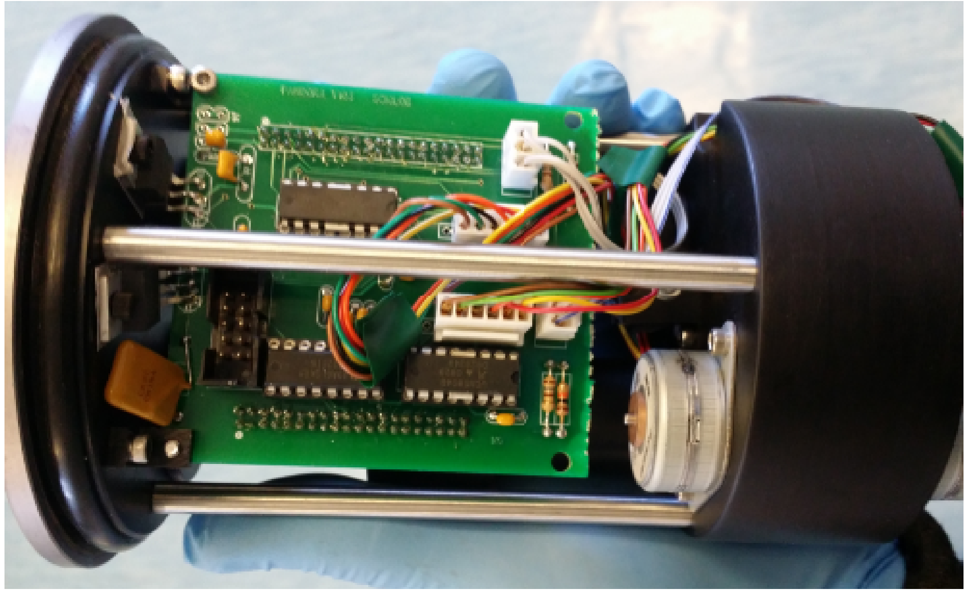
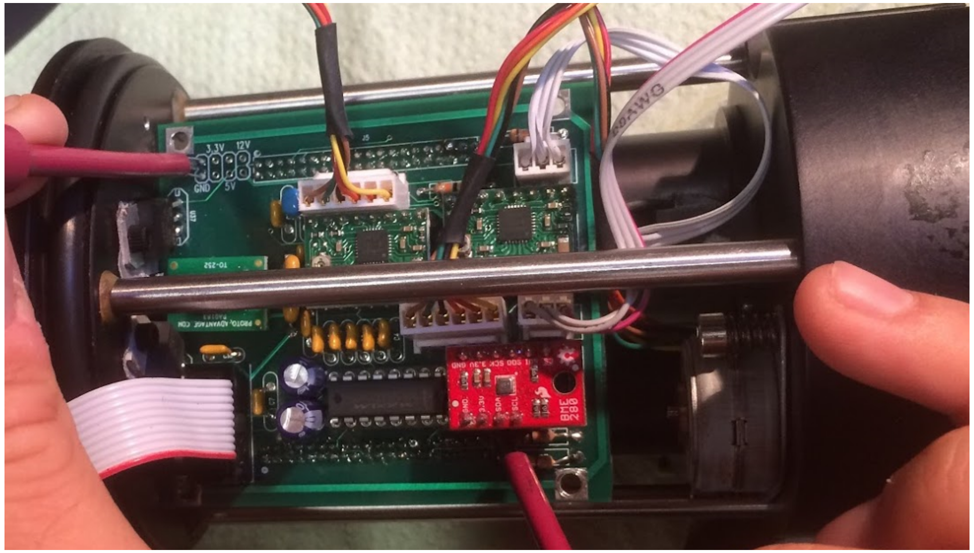


Figure 23: SciGlob Head Sensor Board HSB2



4.7 May 2019 - SciGlob Camera CA1

SciGlob Camera CA1 is a "piggy-bag" camera, that can be mounted on the head sensor in case the instrument is equipped with LuftBlick tracker TR1. Note that this heardware piece is still a prototype yet and being tested, also in the software side. However, since is has been added to Pandora 126 [13], we have listed it here, but there are no specifications yet.

Figure 24: SciGlob Camera CA1

4.8 Jun 2019 - SciGlob Spring Screws SS2

Since Pandora 138 still had filterwheel problems despite using the SciGlob Spring Screws SS2 (see 4.3 and 17), a new way of mounting the stepper motor for the filterwheels was introduced, which we call SciGlob Spring Screws SS2 (figure 25). This fix was only tested in a few instruments, but the idea was finally discarded later, because it was not needed with the new nylon made filterwheels (see 4.10) and the more powerful filterwheel motor drivers of the new head electronic board (see 4.6).

Figure 25: SciGlob Spring Screws SS2

4.9 Nov 2019 - SciGlob Spring Screws SS3

SciGlob Spring Screws SS3 are a further evolution of SciGlob Spring Screws SS2, which pull the motor more from the side. This makes the filterwheel motion more independent of temperature variations. This fix was only tested in a few instruments, but the idea was finally discarded later, because it was not needed with the new nylon made filterwheels (see 4.10) and the more powerful filterwheel motor drivers of the new head electronic board (see 4.6).

4.10 Jun 2019 - SciGlob Nyon Parts

We discovered in Mar 2019 that HCHO was being produced inside the head sensor, as it outgases from the parts made of Delrin, i.e. the filterwheels and the tubes holding baffles and other optical elements. This prevents Pandora to make correct HCHO measurements from direct sun observations. In the subsequent weeks, SciGlob has developed and tested different replacement materials for these pieces and finally settled on black Nylon. The new parts have exactly the same size as the previous ones, but are made of Nylon instead of Delrin (figure 27). The new filterwheel design has also been optimized (tighter manufacturing tolerances) to avoid filterwheel stuck problems.

Figure 26: SciGlob Spring Screws SS2

Figure 27: SciGlob Head Sensor model HSN3

4.11 Jan 2022 - SciGlob Head Model HSN3

In January 2022, a minor improvement in the design of the front plate of the head sensor was introduced, which consist in the addition of a desiccant port, which allows to replace the desiccant bags of the heads without opening them. This update, together with the sealing reinforcement recommendations added to the installation manual allows to have less interruptions and longer data series, for instruments whose the sealing is not working as expected. This head model, with all delrin pieces replaced to nylon and the desiccant port, is currently named as "HSN3".

5 CIDL

This section is the HW-part of the CIDL. It is a snapshot of the living CIDL-document at the time of the report.

5.1 Hardware Items

Figure 28 gives the different hardware item, that have been added or have changed since project start. Column "First date" lists the date, when the first instrument was equipped with the new hardware.

Figure 28: Pandora HW items as of 22nd Dec 2022

Hardware Items

First Date	Short name	Full name	Short description
15-Jun-2017	LuftBlick FG1	LuftBlick Fiber Guide FG1	"Self-bent" fiber guide with metal rod
17-Jul-2017	Cincoze DC1100	Rugged Pandora operating computer Cincoze DC-1100	Improved temperature resistance, improved processor, serial connections, improved performance for HW interfaces
23-Feb-2018	LuftBlick FG2	LuftBlick Fiber Guide FG2	3d printed nylon; Improved radiometric stability, easier setup of the instrument
4-Jul-2018	SciGlob SS1	SciGlob Spring Screws SS1	Added in the head sensor to avoid filterwheel rotation problems
1-Aug-2018	EO34-242	Wedged entrance window Edmunds Optics #34-242	Further reduce the unwanted spectral signal compared to the coated flat window
14-Oct-2018	SciGlob RB2	SciGlob Relay Board RB2	Electronics board in Pandora Box, which can operate both the old tracker (FLIR) and also Tracker LuftBlick TR1
14-Oct-2018	RabbitCore RCM4100	RabbitCore Microcontroller RCM4100	Microcontroller on head sensor electronics board, which can operate Tracker LuftBlick TR1
25-Oct-2018	LuftBlick TR1	LuftBlick Tracker TR1	Better tracking performance, motion range and durability than the previous tracker from FLIR
3-Apr-2019	SciGlob HSB2	SciGlob Head sensor board HSB2	Electronics board in head sensor, which includes temperature, pressure and humidity sensors
28-May-2019	SciGlob CA1	SciGlob Camera CA1	"Piggy-back" camera to be mounted on the head sensor; only to be used with tracker LuftBlick TR1
20-Jun-2019	SciGlob SS2	SciGlob Spring Screws SS2	Improved from SS1 with softer springs for even less friction
1-Jun-2019	Nylon Parts	Nylon parts for head sensor	Nylon wheels and gears to be delrin free; necessary for direct sun HCHO
20-Nov-2019	SciGlob SS3	SciGlob Spring Screws SS3	Further improved spring screws which pull the motor from the side. This is more independent of temperature variations.
15-Jul-2021	Kingdel NC4000	Rugged Pandora operating computer Kingdel NC4000	New rugged computer since the Cincoze DC1100 is not available anymore and also shows durability issues
8-Aug-2021	Hunsn 8GB	Rugged Pandora operating computer HUNSN 8GB	New rugged computer with better preformance than the Kingdel NC4000
15-May-2022	Rosahl Dehumidifier	Rosahl Thin Dehumidifying Element	Dehumidifier added to the spectrometer box

5.2 Hardware Upgrades

Figure 29 lists the dates, when a new HW part of a Pandora instrument was changed or updated. Note that this is not the full list of PGN instruments, but a selection of instrument including all Pandoras, which were sponsored by ESA, and most other Pandora owned by European institutions. The column header can be either in light green or light blue. Light green means the costs for this are covered by FRM4AQ. Light blue means the costs for this are covered by POp. The names of each column correspond to the "Short Name" from figure 28.

Figure 29: Pandora HW upgrades as of 22nd Dec 2022

Upgrades of selected Pandoras

Pan ID	Location	LuftBlick FG1	Cincoze DC1100	LuftBlick FG2	SciGlob SS1	EO34-242	SciGlob RB2	LuftBlick TR1	SciGlob HSB2	SciGlob CA1	SciGlob SS2	SciGlob SS3	Nylon Parts	remarks
ESA instruments (upgrades in green columns paid by FRM4AQ, rest by POp)														
106	Innsbruck		2018-7-24	2017-8-12		2018-8-20	2021-3-1	2021-3-1	2021-3-1				2021-3-1	Already upgraded, operational at Innsbruck
110	Innsbruck		2018-6-5	2018-11-6	2018-9-1	2018-6-14*	2018-11-7	2018-11-8	2019-4-3		2018-11-4		2023-3-1	A new head was ordered with all parts replaced to Nylon. The expected arrival date is March 2023
111	Bucharest	2017-12-2	2019-2-1	2019-2-1	2018-7-11	2020-5-15	2020-5-15	2020-2-28	2020-5-15				2023-5-1	An upgrade to replace the delrin parts was proposed, but they are currently participating in a campaing, and they prefer to wait until the end of the campaign.
115	Rome	2018-9-26	2018-9-26			2021-3-12	2021-3-12	2021-3-12	2021-3-12			2021-3-12	2021-3-12	Already upgraded, operational at Rome-ISAC
117	Rome	2018-9-7	2018-9-10			2019-11-15	2020-9-29	2020-9-29	2019-11-15				2019-11-15	Already upgraded, operational at Rome-SAP
120	Davos	2017-12-2	2019-12-2	2019-1-17		2019-1-17	2019-11-18	2019-11-18	2018-12-15		2018-12-15		2018-12-15	Already upgraded, operational at Davos
121	Izana			2017-08-12		2018-8-1	2020-2-13	2020-2-28	2019-11-6				2021-2-1	Already upgraded, operational at Izaña
126	Mobile		Unknown	2019-5-28	2018-11-21	2018-11-21	2018-11-21	2018-11-21	2019-11-18	2019-5-28			2019-11-18	Already upgraded, it was operational temporarily at ShipSonne2, but now is stopped.
127	Palau		2017-5-30	2018-12-5	2018-11-23	2018-11-23	2018-12-5	2018-12-5	2021-9-24				2021-9-24	Already upgraded, at SG, ready to be shipped. Note: P131 is now at Palau, so this instrument will probably be shipped to another location.
128	Alice Springs	2018-03-19	2021-2-1	2019-09-20		2021-2-1	2021-2-1	2021-2-1	2021-2-1			2021-2-1	2021-2-1	Already upgraded, being tested at SciGlob. To be determined where to ship it.
129	Canberra	2018-03-19	2021-8-1	2019-09-20		2021-8-1	2021-8-1	2021-8-1	2021-8-1			2021-8-1	2021-8-1	Already upgraded, planning to ship it to Australia: AliceSprings
130	Lindenberg		2018-7-9	2018-7-9		2021-8-1	2021-8-1	2021-8-1	2021-8-1				2021-8-1	Already upgraded, operational at Lindenberg.
131	Nashville		2018-7-9			2021-8-1	2020-4-9	2019-11-15	2019-11-15				2019-11-15	Already upgraded, operational at Palau
132	Berlin	2018-7-9	2018-7-9			2020-7-24	2020-7-24	2020-7-24	2020-7-24				2020-7-24	Already upgraded, operational at Berlin
133	Namibia		2018-7-26	2018-10-25		2018-10-25	2018-10-25	2018-10-25	2023-2-1				2023-2-1	1) Arrived in IBK 24th Nov 2022. 2) It was shipped to SG after recalibration. 3) headsensor is being upgraded.
138	Rome		2017-7-17	2019-6-15	2018-7-4	2018-10-12	2018-10-14	2020-9-22	2019-6-20			2019-6-20	2019-6-20	Already upgraded, operational at Rome-IIA
Other instruments (where repair or upgrade was paid by POp)														
101	Izana	2017-2-22	2022-6-28	2022-6-28		2019-3-7	2022-6-28	2023-2-1	2022-6-28				2022-6-28	1) At sciglob, full upgrade of the head was finished on 20220628. 2) New tracker parts have still not arrived. It probably will be ready around Feb 2023.
105	Helsinki		2020-2-14	2019-06-20		2019-11-21	2020-11-3	2020-11-3	2019-11-21				2019-11-21	Already upgraded, operational at Helsinki
113	Bariloche		2021-08-11	2021-08-11		2021-08-11	2021-08-11	2021-08-11	2021-08-11				2021-08-11	Already upgraded, ready to be shipped from SciGlob to Buenos Aires, waiting for local staff to solve the customs paperwork.
114	Buenos Aires		2019-3-19	2019-3-19		2021-07-23	2021-07-23	2021-07-23	2021-07-23				2021-07-23	Already upgraded, ready to be shipped from SciGlob to Buenos Aires, waiting for local staff to solve the customs paperwork.
118	Cabauw		2018-9-4	2019-9-20									2020-2-19	Already upgraded, the instrument was upgraded to EO34-242+RB2+TR1+HSB2+Nylon around 2020/02/19, but the upgrade was not paid through ESA
119	Athens		2018-11-27			2020-9-1	2020-9-1	2020-9-1	2020-9-1			2020-9-1	2020-9-1	Already updated, operational at Athens
103	Downsview			2019-9-20										Sent fiber Guide
104	Downsview			2019-9-20										Sent fiber Guide
Remarks														
* Currently still another brand (from Thorlabs)														
Note from SciGlob: New instruments from P152 already comes with Delrin parts replaced to Nylon.														
	planned dates													