STRATO 02/2015 – The Perseids 2015 stratospheric balloon mission

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In this paper we present the first results of the MeteorCam03 experiment that allowed the observation of meteors from the stratosphere. The experiment provides a new perspective of meteor observations, mainly due to the lower extinction in these layers of the Earth's atmosphere. For the implementation of the experiment the Perseid meteor shower maximum was chosen, since the Perseids (together with the Geminid meteor shower) are one of the most active streams observable from the northern hemisphere. The MeteorCam03 experiment was part of a stratospheric balloon flight with platform JULO-X codenamed STRATO 02/2015, whose launch was carried out by the Slovak Organization for Space Activities (SOSA).

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1 Introduction

The Slovak Organization for Space Activities (SOSA) sixteenth stratospheric balloon launch, codenamed STRATO 02/2015, was scheduled to start on the night 2015 August 12/13 during the peak activity of the Perseid meteor shower. A joint experiment of Valasske Mezirici Observatory and the Society for interplanetary matter (SMPH), called MeteorCam03, was prepared for this flight in one of the three hung on gondolas. The aim of the experiment was to record meteors from the stratosphere and subsequently calculate their atmospheric trajectories (in combination with ground-based observations from European viDeo Meteor Observation Network cameras).

2 The history of meteor observations from stratospheric balloons

The pioneering observations of meteor shower activity from stratospheric balloons were carried out at the time of the predicted strong returns of the Leonid meteor shower in 1998 and 1999. The first stratospheric balloon was launched on 1998 November 17 (Noever et al., 1999) from the Marshall Space Flight Center (MSFC) at Redstone Arsenal (Huntsville, Alabama). MSFC is a leading research center for National Aeronautics and Space Administration (NASA). The maximum altitude achieved by the meteorological balloon used for this flight was 30 500 m. Most of the flights that took place were equipped with aerogel capsules whose aim was to capture small dust particles. Meteor registration during the flight was carried out by sensitive CCD cameras and recording devices. The success of the mission in 1998 led to the commissioning of further flights in 1999 and 2000[a], also during the expected returns of Leonids. In 1999, flights were also carried out to monitor the eta Aquarids (1999 May 7, start near Johnson Space Center) and Perseid (1999 August 12, the balloon reached an altitude only of 18 898 meters) activity. In later years, further flights were carried out by NASA including, for example, during the 2012 Lyrids (Moser et al., 2013). European examples included meteor observation by means of a stratospheric balloon implemented, for example, during the expected increased activity of the 2011 Draconid meteor shower and during the 2012 Geminid meteor shower (Sánchez de Miguel et al., 2013). These flights were coordinated by the Spanish Meteor Network (SPMN). These meteors were recorded by a Watec 902 H2 CCD camera and data was stored on a DVR (Digital Video Recorder). These experiments were all only designed to carry out actual meteor registration from the stratospheric balloon gondola, and/or collection of small particles (in the order of micrometers) in the stratosphere.

3 JULO-X (STRATO 02/2015) – Experiment and technical data

The STRATO-02/2015 stratospheric balloon was launched on 2015 August 13 at 00^h52^m CEST after local midnight (August 12, 23^h52^m UT) from the Malé Bielice airport (near Partizanske, Slovakia, Figure 1). The maximum height during this flight was reached at $00^h55^m40^s$ UT. After the balloon blow out at an altitude of 34 444 m the subsequent downward phase ended with a landing at 00^h34^m UT at coordinates N 48.°4471 and E 18.°1058 (near village Preseľany, Slovakia (Figure 1). In addition to MeteorCam03 (see Section 4) other experiments were installed to be carried out dur-

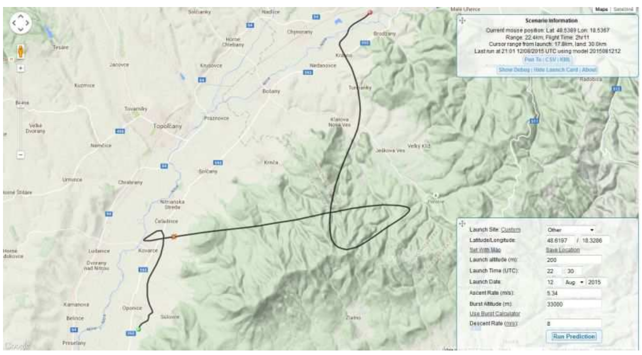

Figure 1 – Projected flight trajectory of stratospheric balloon STRATO 02/2015 to the Earth surface.

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[a]http:// http://science.nasa.gov/science-news/science-at-nasa/

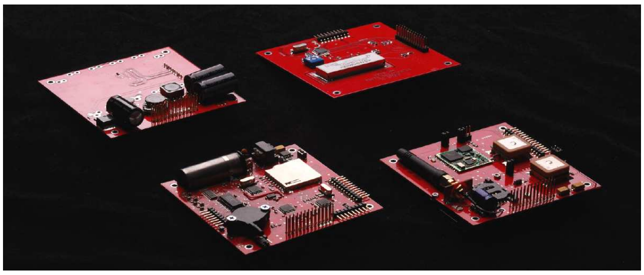

Figure 2 – Individual modules of the stratospheric platform JULO-X.

Figure 3 – Stratospheric balloon STRATO 02/2015 payload: cosmic ray particles detector (left); MeteorCam03 (middle); modules of JULO-X probe, transmitter for SkCube and Geiger-Müller tubes (right).

ing the flight: the detection of cosmic rays (combination of Geiger-Müller tubes and detector for charged particles via modern smartphones with special software developed by Crayfis company[b]); the testing of transmitters for the first Slovak satellite SkCube; and a student experiment ISCEAC (influence of stratospheric conditions on seed germination). The precise location of the balloon in flight was measured by two GPS modules; position and height were recorded every 30 seconds (Figure 3).

The stratospheric balloon platform JULO-X, on which all experiments were accommodated, was developed within the scope of the SkBalloon project (started in 2008). The first flight of the experimental platform JULO1 took place in October 2010. Based on the knowledge gained from the launch of the first series, the second generation of the platforms has been developed (called JULO2). The first start of stratospheric balloon with this platform took place in April 2012. JULO-X is the 3rd generation platform, which was developed for multi-start usage and reliability for scientific experiments. Stratospheric probe JULO-X consists of five modules: the transceiver module, radio-beacon module (short range tracking), power supply module (PSU board), sensors board (also carrying the main processor/computer) and the system for real time positioning (GPS module). Bus hardware is based on CubeSat microsatellites (Figure 2).

The transceiver module is a HX1 transmitter with frequency 144.800 MHz. Transmitted packets are com-

[b]`http://crayfis.io`

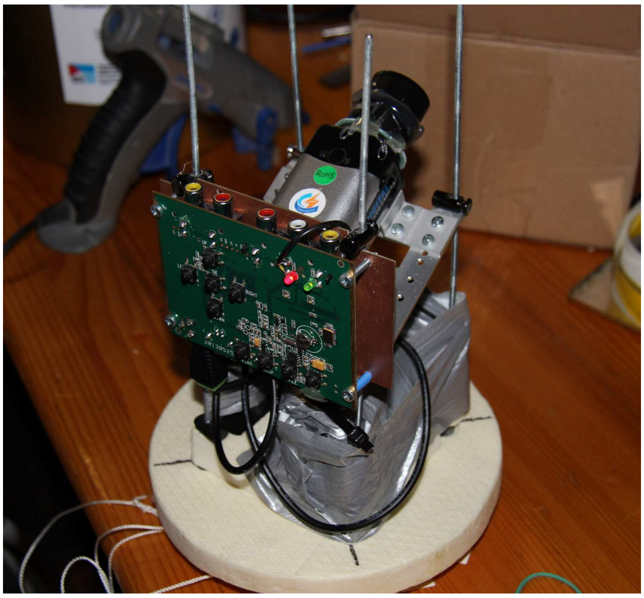

Figure 4 – Camera KPF131HR with DV recorder (MeteorCam03).

patible with APRS (Automatic Packet Reporting System). The HX1 transmitter has a power of 500 mW and a data packet is generated every 23 seconds. The module for the close range tracking (radio-beacon) is used to locate the balloon on the ground from distances of several hundred meters. This system is able to work for several weeks regardless of the other systems performance, and is used for close tracking in difficult terrain. The module transmits in the 70 cm band at a frequency of 434 MHz, its output is 10 mW, which is sufficient for detecting until distances of 2 km. The power system of stratospheric platform JULO-X consists of six lithium cells with a capacity of approximately 5 000 mAh and is able to power the probe for 12 hours (without additional experiments). To power the sensor electronics, DC-DC converters (3.3 V and 5 V) are used. The sensor board carries sensors for measuring the basic atmospheric parameters (ambient temperature, relative humidity and atmospheric pressure). The module also includes a sensor for measuring acceleration in all axes (accelerometer) and a digital compass (magnetometer). All recorded data, including battery status, are stored on the internal SD card. The module hosts the main processor which manages the communication and data storage. Up to 8 analog differential signals with voltage range 0–2.5 V can be linked into this module. A system for determining position includes a pair of GPS receivers with an accuracy of approximately 2 m. The system also includes a GSM module for sending SMS messages with the coordinates of the probe, this module is usable only to an altitude of approximately 1 500 m.

The complete stratospheric probe is launched by a meteorological weather balloon filled with helium with an uplift about 6 kg. The diameter of the full-filled balloon on the ground is around 2 m (with total volume about 4 m^3), and 12 m before its break at high altitude. Aerodynamic braking of the payload after the burst is achieved using a parachute with a diameter of 80 cm, the effective aerodynamic braking starts downwards of heights of around 10 kilometers above

Figure 5 – Stacked image of meteor 20150813_005041 from MeteorCam03.

Figure 6 – Stacked image of meteor 20150813_005041 from ground station Maruska SE.

the Earth's surface. The impact speed of the payload is about 20 km/h.

4 MeteorCam03 – equipment

The MeteorCam03 experiment consists of a sensitive CCD camera KPF131HR (1/3" chip Sony Super HAD II CCD, sensitivity 0.002 lx in BW mode and resolution 582 × 500 px) and 4 mm fixed focal length lens Computar (maximum aperture $F/1.2$) (Figure 4). Meteor registration was carried out via a DVR (Digital Video Recorder) with two channels, data saving on the mini-SD memory card with a capacity of 32 GB. For the experiment a frame rate of 25 fps/s was used. Continuous video recording was divided into one-minute long sequences and saved in format `*.avi` with MJPEG codec compression. Elevation of the camera was set at 30 degrees, also for monitoring of the light pollution. This value corresponds to the normal elevation of the ground-based stations in EDMONd (usually around 45 degrees). The camera was installed without a gyroscopic stabilization.

5 Results – Two-station meteor orbits

During the flight total amount of 45 meteors were registered, 23 of them were also identified in ground station data from the EDMONd network (Kornoš et al., 2014a; Kornoš et al., 2014b). Due to significant gondola instability during the flight it was not possible to process data in a conventional way via the commonly used UFOAnalyzer software (SonotaCo, 2007a; SonotaCo, 2009). It was necessary to perform individual astrometric calibration of each recorded meteor, this being based on still image (frame) analysis in the AstroRecord software (De Lignie, 1997) (Figures 5 and 6).

Measured equatorial coordinates (Ra, Dec) of the beginning (first frame) and end (last frame) of each meteor were inserted into the calculation procedure of the UFOOrbit software (SonotaCo, 2007b; SonotaCo, 2009) in photographic format (with the known time of the meteor event, equatorial coordinates of the beginning and end of the meteor, geographical coordinates and altitude of stratospheric balloon gondola at the time of event and duration of the phenomenon as determined from the recorded video of the meteor). Due to the large amount of data collected during the MeteorCam03 experiment, only 3 meteors have now been fully analyzed. For these, two-station orbits were calculated, using the mobile station located in the stratospheric balloon gondola and the ground station Maruska SE (Figures 7 and 8). In all three cases meteors were members of the Perseid stream. The orbital elements are shown in Table 1, including the position of the geocentric radiant of the meteor and the initial and end height of the meteor atmospheric trajectory.

6 Summary and conclusions

In presenting these initial results from the MeteorCam03 experiment we demonstrate the possibility of using sensitive CCD cameras located in a stratospheric balloon gondola for the calculation of two-station (or more stations) orbits of meteors in combination with ground based data. In the event of unfavorable weather conditions during interesting events (for example predicted outburst of meteor showers) the stratospheric balloon based observation can provide valuable data. We consider this experiment to have been very successful, due to the recorded number of meteors on MeteorCam03 camera and also due to a successful calculation of two-station orbits in collaboration with ground based stations organized in the EDMONd network.

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References

De Lignie M. (1997). "Astro record 3.0". *Radiant, Journal of the Dutch Meteor Society*, **19**, 28–30.

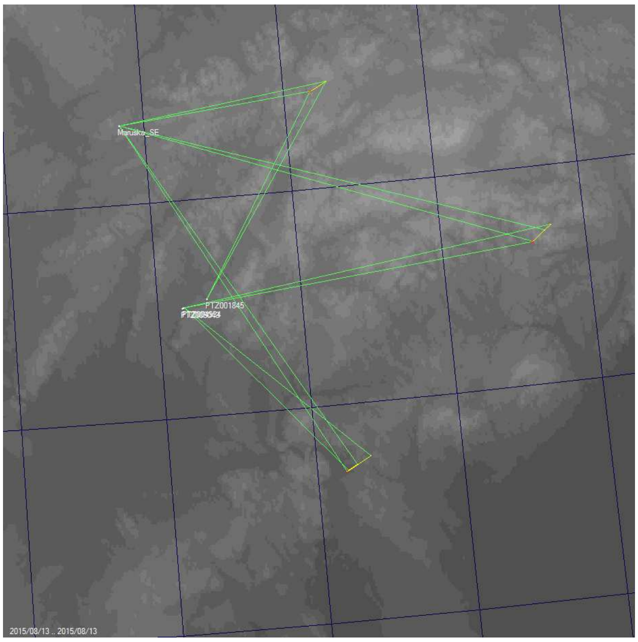

Figure 7 – Ground projection of the meteoroids atmospheric trajectories, two-station calculation from MeteorCam03 and Maruska SE (ground based).

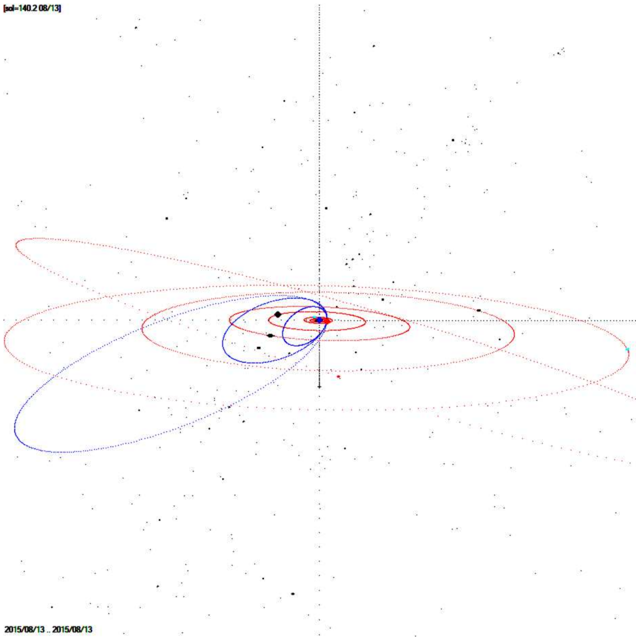

Figure 8 – Orbits of the meteoroids in the Solar System, two-station calculation from MeteorCam03 and Maruska SE (ground based).

Kornoš L., Koukal J., Piffl R., and Tóth J. (2014a). "EDMOND Meteor Database". In Gyssens M., Roggemans P., and P. Z., editors, *Proceedings of the International Meteor Conference, Poznań, Poland, Aug. 22-25, 2013*. International Meteor Organization, pages 23–25.

Kornoš L., Matlovič P., Rudawska R., Tóth J., Hajduková, Jr. M., Koukal J., and Piffl R. (2014b). "Confirmation and characterization of IAU temporary meteor showers in EDMOND database". In Jopek T. J., Rietmeijer F. J. M., Watanabe J., and Williams I. P., editors, *Proceedings of the Meteoroids 2013 Conference, Aug. 26-30, 2013, A.M. University, Poznań, Poland*. pages 225–233.

Moser D. E., Suggs R. M., Cooke W. J., and Blaauw R. (2013). "The 2012 Lyrids from non-traditional observing platforms". In Gyssens M. and Roggemans P., editors, *Proceedings of the International Meteor Conference, La Palma, Canary Islands, Spain, Sep. 20-23, 2012*. International Meteor Organization, pages 146–149.

Noever D. A., Phillips J. A., Horack J. M., Jerman G., and Myszka E. (1999). "An ET origin for stratospheric particles collected during the 1998 Leonids meteor shower". (arXiv preprint astro-ph/9910391).

Sánchez de Miguel A., Ocaña F., Madiedo J. M., Ortuño F., Conde A., León P., Gómez Sánchez-Tirado M. A., Mayo D., Raya R., Zamorano J., Izquierdo J., and Trigo-Rodríguez J. M. (2013). "The 2012 Geminids balloon-borne mission over Spain". In *44th Lunar and Planetary Science Conference, 2013*. page 2202.

SonotaCo (2007a). "UFOAnalyzer V2 Users Manual". `http://sonotaco.com/soft/download/UA2Manual_EN.pdf` .

SonotaCo (2007b). "UFOOrbit V2 Users Manual". `http://sonotaco.com/soft/UO2/UO21Manual_EN.pdf` .

SonotaCo (2009). "A meteor shower catalog based on video observations in 2007-2008". *WGN, Journal of the IMO*, **37:2**, 55–62.

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Table 1 – Orbital elements and radiant data of analyzed meteors. The following parameters for each meteor are listed: a – semi-major axis, q – perihelion distance, e – eccentricity, peri – argument of perihelion, node – ascending node, i – inclination, v_g – geocentric velocity, a_{mag} – absolute magnitude, RA, DEC – geocentric radiant position, H_1 – beginning height, H_2 – terminal height.

Date	UT	a	q	e	peri	node	i	v_g	a_{mag}	RA	DEC	H_1	H_2
YYYY MM DD	HH MM SS	AU	AU		deg	deg	deg	km/s		deg	deg	km	km
2015 08 13	00 18 44	2.95	0.9663	0.672	152.213	139.755	120.51	58.60	−1.67	45.19	52.01	108.3	95.1
			±0.0031	±0.061	±1.720		±0.55	±0.83		±0.14	±0.10		
2015 08 13	00 49 32	20.15	0.9881	0.868	161.193	139.775	119.39	60.44	−2.51	42.26	53.29	103.4	92.7
			±0.0017	±0.087	±1.165		±0.66	±1.08		±0.19	±0.26		
2015 08 13	00 50 41	30.74	0.9695	0.968	155.811	139.776	112.73	59.28	−3.37	44.45	58.10	110.1	87.4
			±0.0015	±0.053	±0.787		±0.44	±0.66		±0.12	±0.14		