The Auroral Balloon Camera Experiment

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1. Short background

This document describes the development of a weather balloon auroral camera system. A prototype is proposed launched from The Kjell Henriksen Observatory (KHO) in the moon down period of November to mid December 2021. The main purpose is to be able to optically detect aurora even if there are low altitude clouds obscuring our field of view from the ground.

The cloud layer altitude at Svalbard is typically 2-3 km above KHO during the winter (personal communication Torgeir Mørk). Our aim is to use a Helium filled balloon to lift the optical payload above this level for a limited time to check the sky conditions.

2. The payload

Technology developed for radio-controlled aircrafts using First-Person View (FPV) analog video cameras are used in this experiment. The Audio Video (AV) signal is transmitted to our ground receiving stations located at KHO.

The frequency for the first prototype is 1.3GHz with a transmitting power of 250 mW. The payload parts are assembled using a 3D printed mount frame. Fig. 1 shows the assembled prototype payload. Table 1 list all the components used.

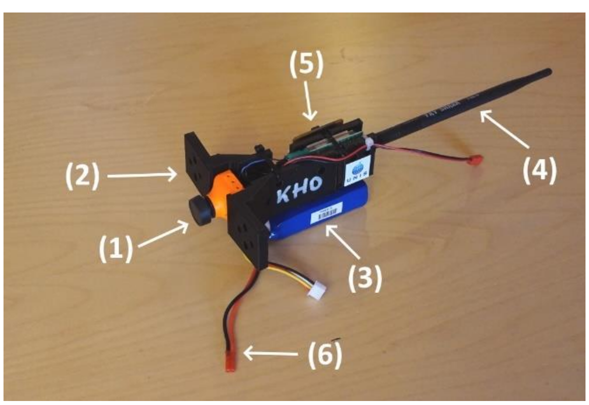


Figure 1. Camera mounted to 3D printed mount frame. (1) RunCam, (2) 3D printed mount frame, (3) 11.1V 3S 1000mAh LiPo battery, (4) 1.3Hz 250mW A/V – Tx Video Transmitter, (5) camera OSD setup mouse, and (6) battery power cord.

Item	Description 1.3 GHz prototype 2	Cost [EUR]
1	RunCam Night Eagle 2 PRO	72.65
2	1.3Gz 250mW A/V-Tx	36.19
3	RMRC 900MHz-1.3 GHz-Rx	49.92
4	Camera battery (11.1V 3S 1000mAh LiPo)	6.60

Table 1. Main camera parts to prototype 2 with links and costs.

The 3D printed camera mount frame is Y shaped with a slot to mount electronic accessories. The cameras are press fit mounted. Camera mass is 96 g. The mass is increased to 183 g with the battery (87 g). The total component cost is only 115 EUR for one payload unit. Item 3 is a one-time only investment.

3. Video range calculations

Frequency	Tx Power (mW)	Range (km)
900MHz	500	21.03
1.2GHz	500	15.77
1.3GHz	250	10.29
2.4 GHz	500	7.88
5.8GHz	600	3.57

Table 2. Typical video range calculations from http://www.maxmyrange.com.
Tx and Rx antennas are pigtails (rubber ducky-whip-3dBm).

Note that the range of the video signal is highly dependent on type of antennas. Using a Crosshair tracker receiver antenna and a simple whip transmitter antenna should increase the range up to 16 km. Optical video tracking of the balloon may easily be conducted by the Svalpoint tracking system at KHO. The narrow beam video receiver antenna (Crosshair) could either be mounted to our existing optical trackers or to a designated stepper motor tracker.

4. Experimental setup with active HF tracking

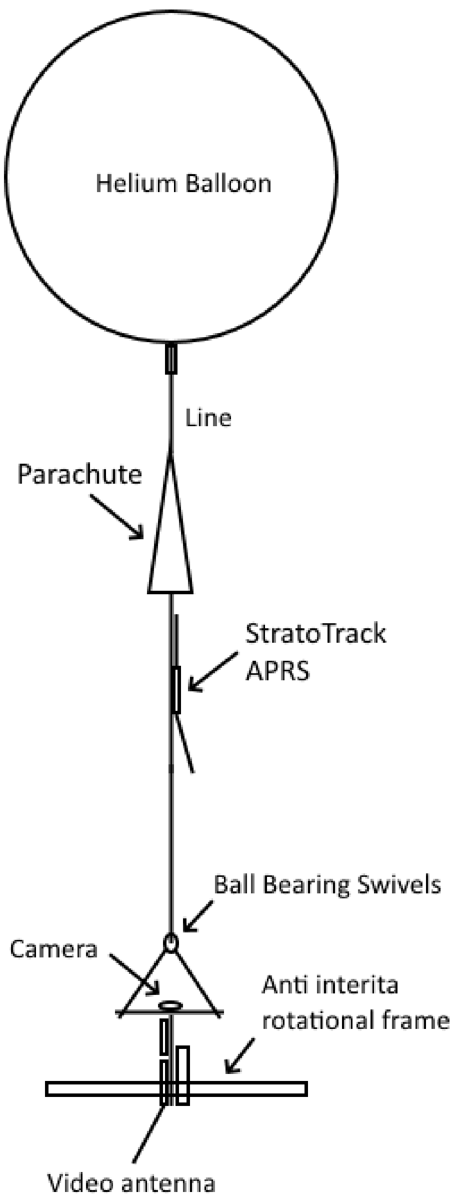


Figure 2. The Auroral Balloon camera experimental setup.

The experimental setup is shown in Fig. 2. A standard 350 g weather balloon filled with Helium is used. A 1m diameter parachute is attached to the balloon line to deaccelerate the payload on return to prevent damage when it lands.

Below the parachute, an APRS (Automatic Packet Reporting System) transmitter with an internal GPS (Global Position System) is installed to keep track of the balloon during flight. The frequency of the StratoTrack APRS is set to 144.800 MHz. The transmitting power is typically 20 dBm. The receiver station is connected to internet (APRS iGate) Rx and installed close to the SuperDarn radar at Breinosa (JW5JUA-10), respectively. It reports the position of the balloon each minute to the website http://aprs.fi . The callsign of the balloon is JW5JUA-12. The balloon may be tracked on-line in a regular web browser with URL:

https://aprs.fi/#!lat=78.150&lng=16.04

The items described above are well tested and used for near-space flights the last decade by the weather balloon community. The balloon parts are listed in Table 3 below.

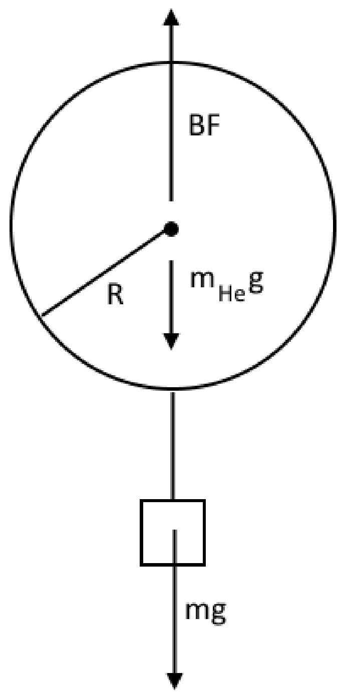
Item	Detailed description	Cost[$]
1	StatoTrack APRS	199.00
2	Flight Train Kit	15.00
3	Weather Balloon 350g	35.00
4	Near Space Parachute 1.0 m	35.00

Table 3. Balloon part list with links and costs.

Note that all balloon parts are ordered from the company High Altitude Science to keep the logistics simple.

The payload is located at least 4m below the StratoTrack to allow it to transmit freely without interference as recommended by High Altitude Science. A ball bearing swivel and a light weight pool noodle is used to minimize rotation of the camera mount.

5. Size of Balloon?



Basic balloon equations

$$BF = m_{He}g + mg$$

$$\rho_{air} V g = m_{He}g + mg$$

$$\rho_{air} V = (m_{He} + m)$$

$$m_{He} = \rho_{He} V$$

$$V = \frac{m}{\rho_{air} - \rho_{He}} \quad (1)$$

$$V = \frac{4}{3}\pi R^3 \quad (2)$$

$$\rho_{air} = 1.20\ kg/m^3$$

$$\rho_{He} = 0.18\ kg/m^3$$

Figure 3. Basic balloon equations.

Case	Total mass (kg)	Volume m^3	Radius (m)
1	0.1	0.098	0.286
2	0.2	0.196	0.360
3	0.3	0.294	0.413
4	0.4	0.392	0.454
5	0.5	0.490	0.489
6	0.6	0.588	0.520
7	0.7	0.686	0.547
8	0.8	0.784	0.572
9	0.9	0.882	0.595
10	1.0	0.980	0.616
11	1.1	1.078	0.636
12	1.2	1.176	0.655

Table 4. Helium balloon size calculations.

The radius R of the Helium balloon may be calculated from equations (1) and (2). A payload of m = 183 g with a balloon weight of 350 g and parachute of 75 g gives us a total mass of 608 g. A factor of 1.5 should be applied to create sufficient lift (guesswork), which corresponds to a positive lift of 304 g. Total mass then becomes m = 1.5 x 608 g = 0.912 kg using a R = 0.62 m radius balloon with volume V = 0.98 m^3. These values are compatible with the Balloon Performance Calculator by High Altitude Science listed in Table 5.

Key parameters	Prototype
Balloons size (g)	350
Payload mass (g)	258
Positive lift (g)	304
Volume (m3)	0.93
Burst altitude (km)	28
Ascent rate (m/s)	4.1
Ascent time (minutes)	114

Table 5. Balloon Performance

Note that a 50 L Helium cylinder at pressure 200 bar will according to Boyle's law provide ~10 m^3 of Helium at 1 atm.

Preliminary conclusion

Our Helium balloon powered payloads will travel at an average ascent rate of approximately 4 m/s up to bursts altitudes of 28 km. The ascent time is in the order of 2 hours. Descent is approximately 45 minutes with the 1 m diameter parachute. The camera video signal will be lost on ascent after about 42 minutes using simple Rubber ducky antennas, which should give us sufficient time to decide whether it is aurora above the cloud layer.