IRBE-1 (InfraRed Balloon Experiment) infrared images application in national economy

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ABSTRACT

IRBE-1* (***I****nfra****R****ed* ***B****alloon* ***E****xperiment*) is the first high altitude balloon launched by Ventspils University College (VUC) from Ventspils airport on 10th April, 2015. More than 1000 infrared images were captured during its 195 minute flight. The main mission of IRBE-1 was to take near-infrared images using a modified general purpose digital camera *Canon PowerShot A490*. Pictures would be used to assess quality of agricultural fields and determine urbanized areas. The goal of this experiment is to see if HAB photography can be used to help planning cities and minimizing harvest loss thus stimulating Latvia's economy.

INTRODUCTION

After the solving problem with payload's structure and 2 hour launch delay IRBE-1 high altitude balloon was launched. Balloon took off from Ventspils airport in Latvia and landed in "Striukai" (see figure 1) a small village in Lithuania. The ground track IRBE-1 was approximately 200 km in 195 min. It reached approximately 23 km altitude and took HD videos and 1255 near-infrared images with a modified general purpose digital camera *Canon PowerShot A490*.

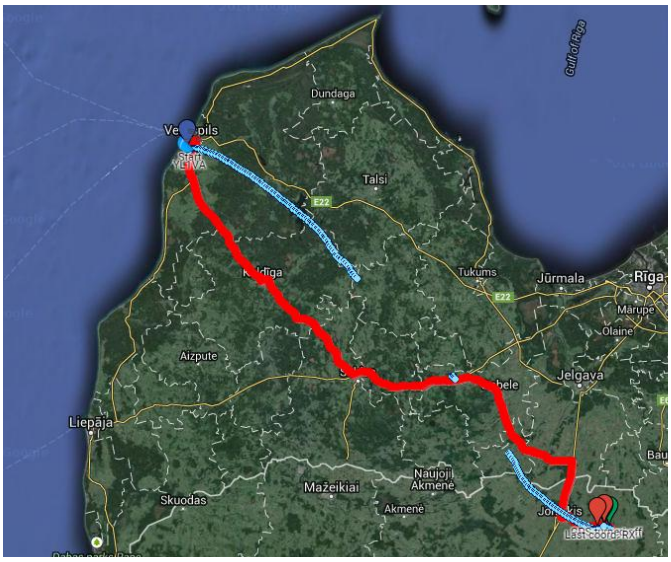

Figure 1. IRBE-1 trajectory (blue line) and IRBE-1 rescue mission path (red line)

* IRBE is partridge in Latvian language and its local river name. Also, Irbe is last name of legendary Latvian hockey player Artūrs Irbe.

A portion of radiation that is just beyond the visible spectrum is referred to as near-infrared. Rather than studying an object's emission of infrared, scientists can study how objects reflect, transmit, and absorb the Sun's near-infrared radiation to observe health of vegetation and soil composition (see Figure 2) [1].

Our eyes perceive a leaf as green because wavelengths in the green region of the spectrum are reflected by pigments in the leaf, while the other visible wavelengths are absorbed. In addition, the components in plants reflect, transmit, and absorb different portions of the near-infrared radiation that we cannot (see Figure 4). Healthy vegetation absorbs blue- and red-light energy to fuel photosynthesis and create chlorophyll. A plant with more chlorophyll will reflect more near-infrared energy than an unhealthy plant. Thus, analyzing a plants spectrum of both absorption and reflection in visible and in infrared wavelengths can provide information about the plants' health and productivity [1].

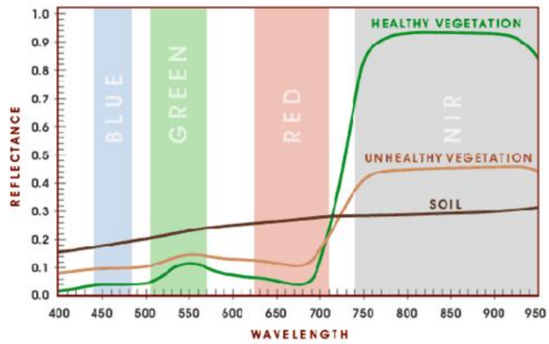

Figure 2. Graphic of healthy vegetation, unhealthy vegetation and soil reflectance versus wavelength [3]

Infrared images can be also used to determine city vegetation index in order to determine urbanization areas in city [2]. The acquired data would be helpful information which would serve as a development plan for cities. Additionally, water absorbs more infrared light, thus it makes easy to determine flooded areas using near-infrared photography.

CAMERA MODIFICATION

Reflected near-infrared radiation can be sensed by a general propose digital camera if it`s modified. Most digital cameras have an image sensor (CCD or CMOS) which can detect infrared radiation, but has in front of it an IR blocking filter (see Figure 3). Replacing the IR blocking filter with an IR passing filter (see Figure 4), the digital camera can sense near-infrared radiation [2].

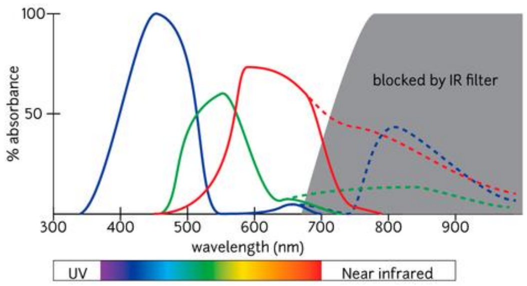

Figure 3. Digital camera image sensor with IR blocking filter absorbance versus wavelength [3]

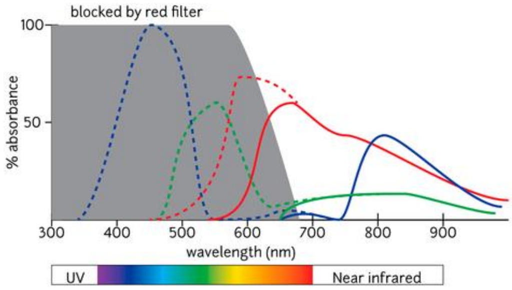

Figure 4. Digital camera image sensor with IR passing filter absorbance versus wavelength [3]

During the preparation for IRBE-1 experiment a *Canon PowerShot A490* digital camera was modified and its IR blocking filter was replaced by Rosco *#2007 VS Blue* [4] filter which passes near-infrared radiation [5]. In order to take the images automatically, a script writen in UBASIC was developed and uploaded into IRBE-1. The camera with this script takes images every 5 seconds and saves the shooting time in log file in order to determine GPS coordinates after payload recovery.

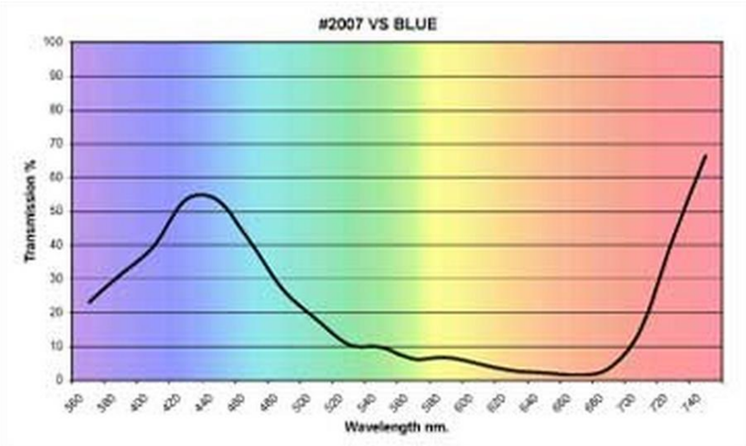

Figure 5. Rosco *#2007 VS Blue* filter transmission versus wavelength [4]

IMAGE PROCESSING

Using a simple image processing tool (*Infragram*) [6] infrared images can be processed and a Normalized Differenced Vegetation Index (NDVI) can be determined (see Figure 7 and equation (1)).

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)} \quad (1)[7]$$

, where NIR is sensed near-infrared radiation, but VIS – sensed red light.

Vegetation healthiness can be determined by NDVI. Vegetation is healthier when NDVI is closer to +1.

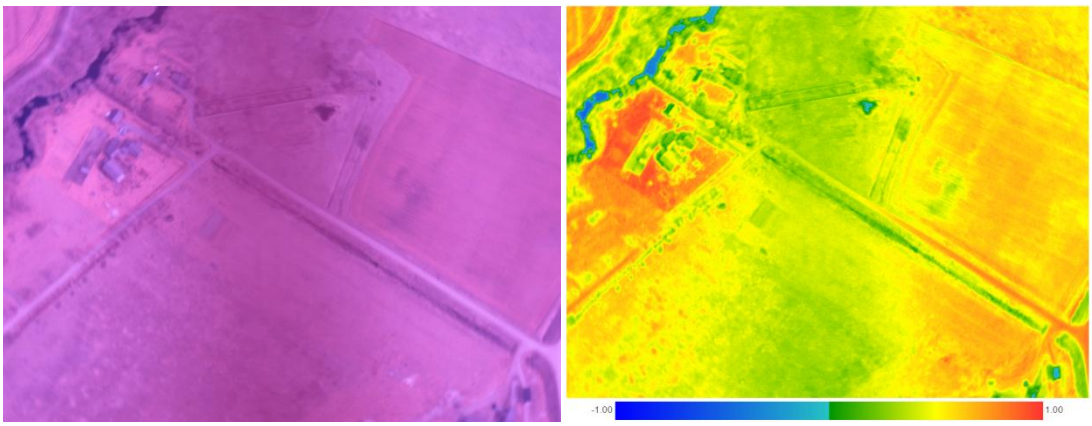

Figure 6. IRBE-1 captured (*left*) and processed (*right*)

RESULTS

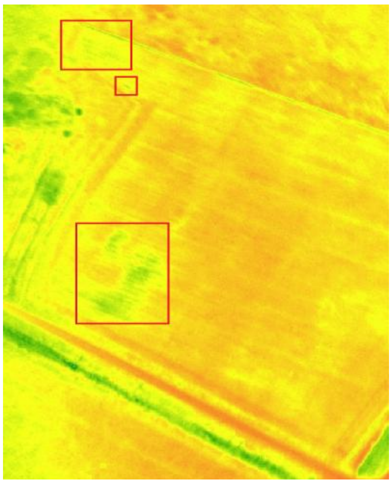

Figure 7. Processed image can determine flooded and/or unhealthy field areas (*red squares*)

In result IRBE-1 took 1255 near-infrared images from which approximately 40 % was of no use because the images were taken at the beginning of the launch (237 images) or they were blurred because higher altitude (257 images). 37 images were taken of team's home town Ventspils, 124 images of rivers and lakes, 330 images of forest and 170 images of fields. It should be noted that some images have defective middle region, indicating less near-infrared intensity. This due to the fact the payload's repairs included additional ropes securing payload and one of the ropes got in the way of camera.

An image of field can be seen in Figure 7. Image shows areas of the field where puddles have caused crops to die out. Also, the overall health state of the crops can be easily evaluated. When receiving this information, farmer can improve field's drainage and re-sow certain parts of the field in order to increase the harvest.

The distinct difference of near-infrared light intensity reflected by water, buildings makes near-infrared images very useful for city planning. Figure 8 shows a village just outside Ventspils. Image indicates that area to the right of river bank has fewer buildings. One of possible reasons for this could be that this area is subjected to spring floods and it would not be possible to build any conventional buildings. Also, it can be seen that there is very healthy vegetation near buildings. This can be explained due to the fact that most of these houses have gardens with lawns, flowerbeds and other man sustained greenery.

This spring, rivers in Latvia were not flooded due to warm winter and lack of ice. The detection of water is very effective using this method and it could be used to quickly assess flooded areas and develop individual area plans of natural disaster hazard preventions.

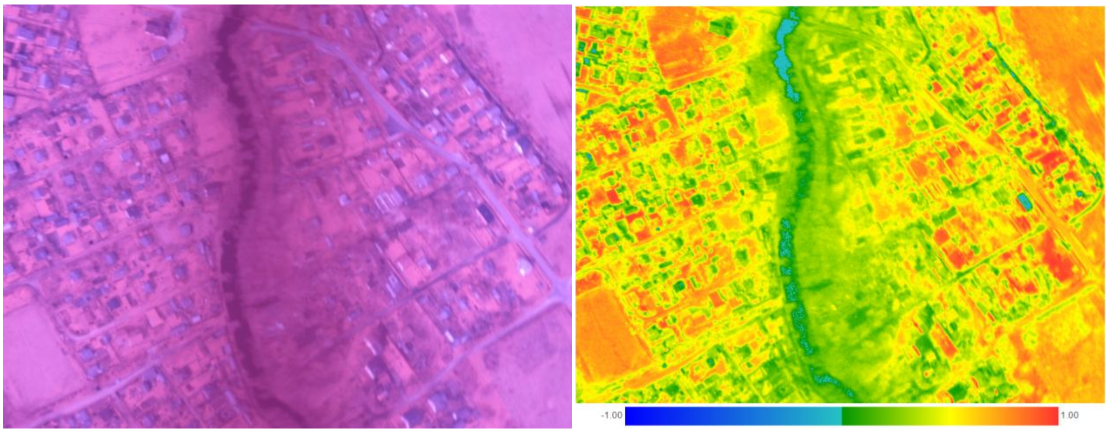

Figure 8. Image used to determine urbanized areas. Original image (*left*) and processed image (*right*)

CONCLUSSION

This paper describes the conducted experiment by team during IRBE-1 mission. The first VUC HAB was launched and safely recovered by its team along with 1255 near-infrared images. Although many pictures were taken only a fraction could be used further in experiment, because at approximately 8550 meter altitude the lens of near-infrared camera fogged and also the payload continuously swung around the whole flight. Improvements like increased battery capacity, anti-fog techniques and payload stability control would significantly increase number of quality near-infrared images recovered. Also pictures from higher altitudes are needed to cover larger areas of cities.

After conducting IRBE-1 experiment authors can verify that near-infrared images can be used in agriculture, assessment of urbanization areas and flood hazard avoidance. Due to lack of control and strong dependence of whether conditions, it is clear that HAB's might not be the best type of aircraft used in aerial photography, but it was an easy and relatively cheap way to test the idea. The processed images gave valuable information that can be applied to increase efficiency of agriculture and to optimize habitable areas. Although for commercial use this technique would require a high resolution near-infrared or infrared camera and different type of aircraft, this experiment proves the concept. Authors are convinced that results of this experiment can be used as a starting point of making Latvia's No.1 industry – agriculture, much more efficient. Additional images and graphs regarding IRBE-1 mission are added in annex. Videos, more pictures and technical details about IRBE-1 can be found in [8][9] and [10].

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ANNEX

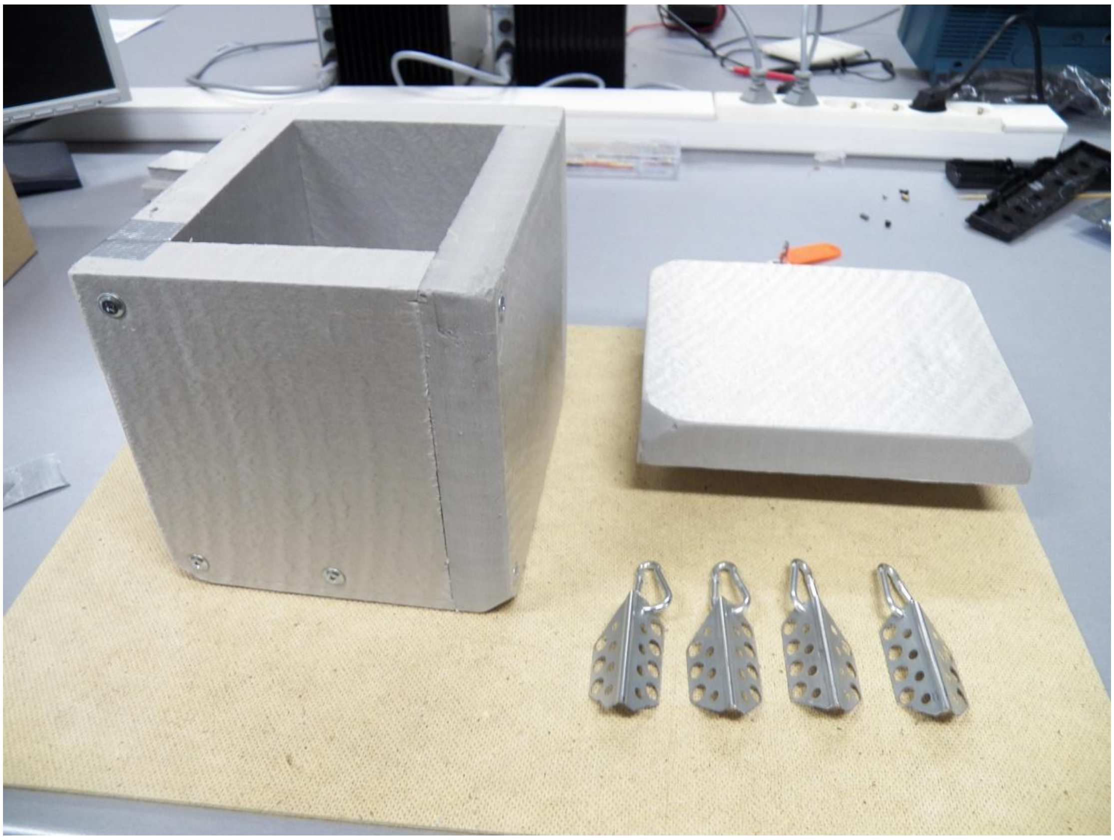

Figure 9. Styrofoam capsule and rope carbines

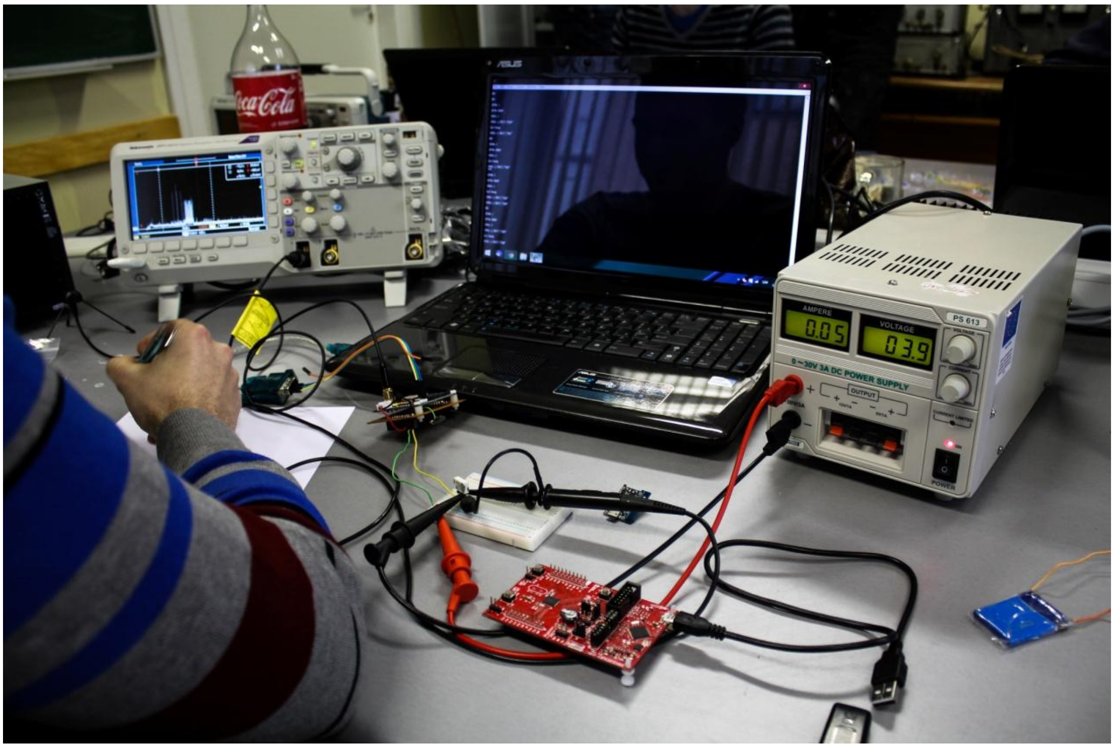

Figure 10. GSM modules power consumption tests

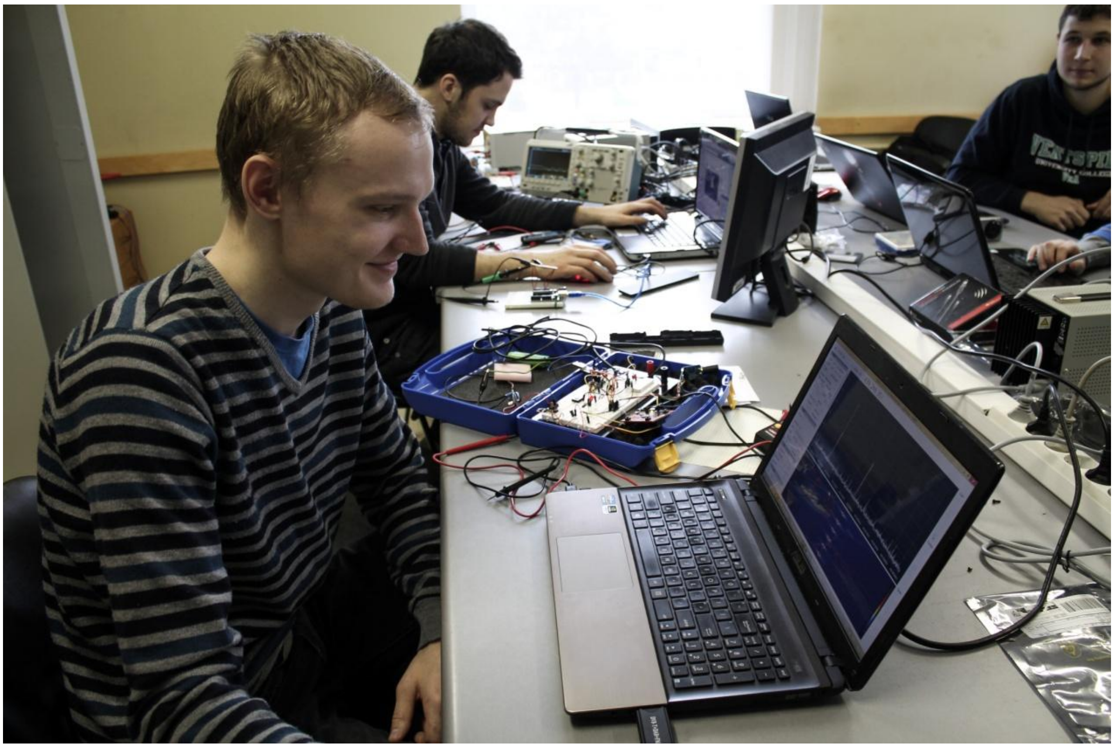

Figure 11. RTTY transmitter first test

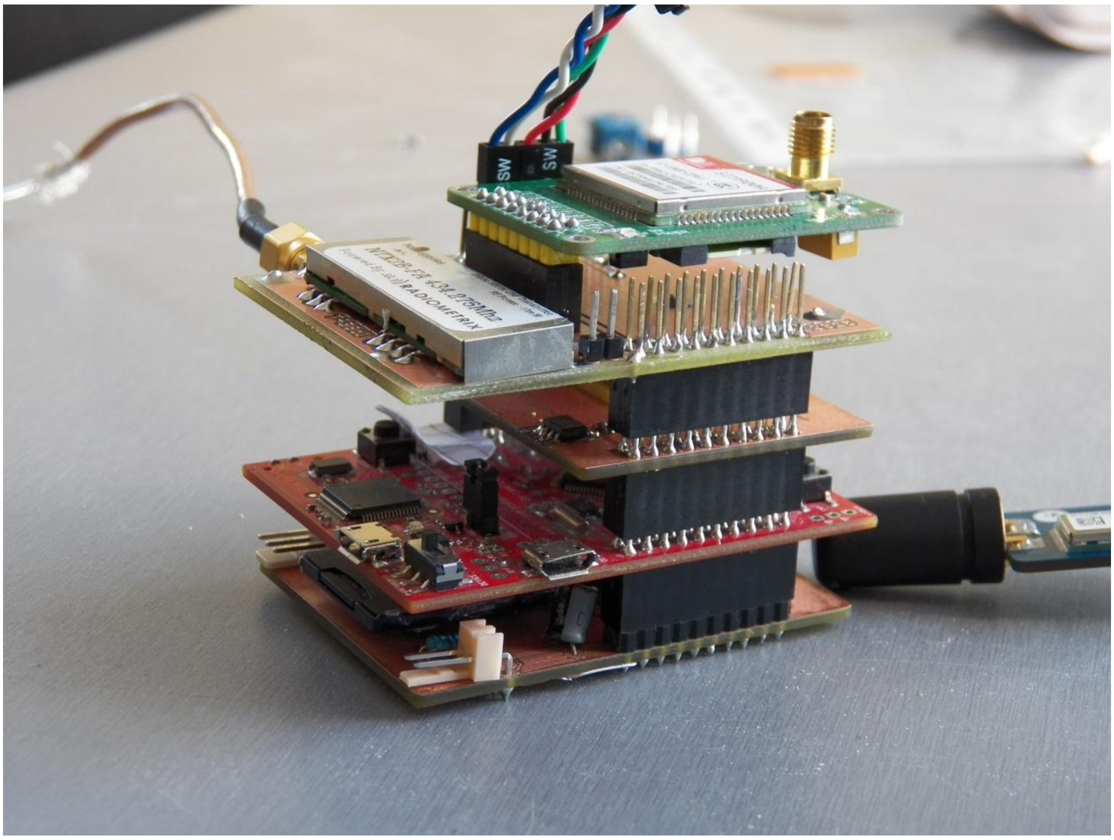

Figure 12. Complete flight module with RTTY transmitter, GSM module, GPS, temperature and other sensors

Figure 13. Sewed sample for parachute

Figure 14. Testing the parachute by dropping it from 4th floor window

Figure 15. Moring in airport at launch day

Figure 16. Team member Janis Šate giving an interview to TV reporters

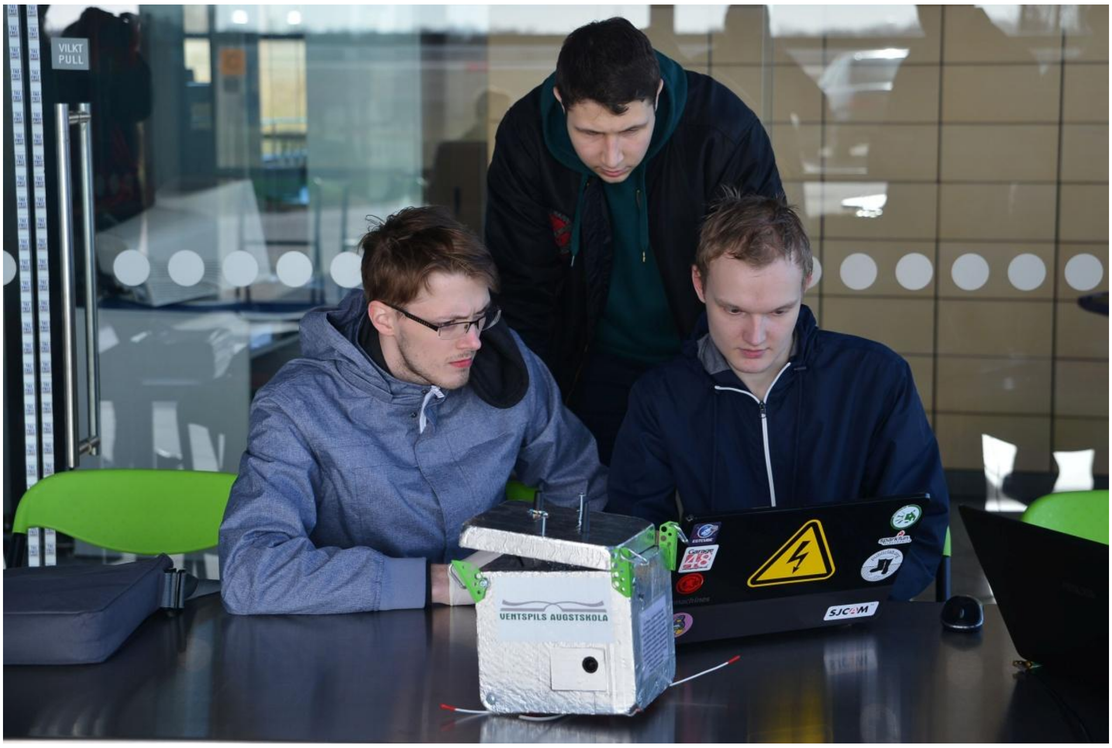

Figure 17. Roberts Trops, Raivis Pabērzs and Mārcis Bleiders trying to solve problems with the GPS

Figure 18. Placing flight module and cameras inside the capsule

Figure 19. Preparing the parachute

Figure 20. The most exciting moment of mission - takeoff

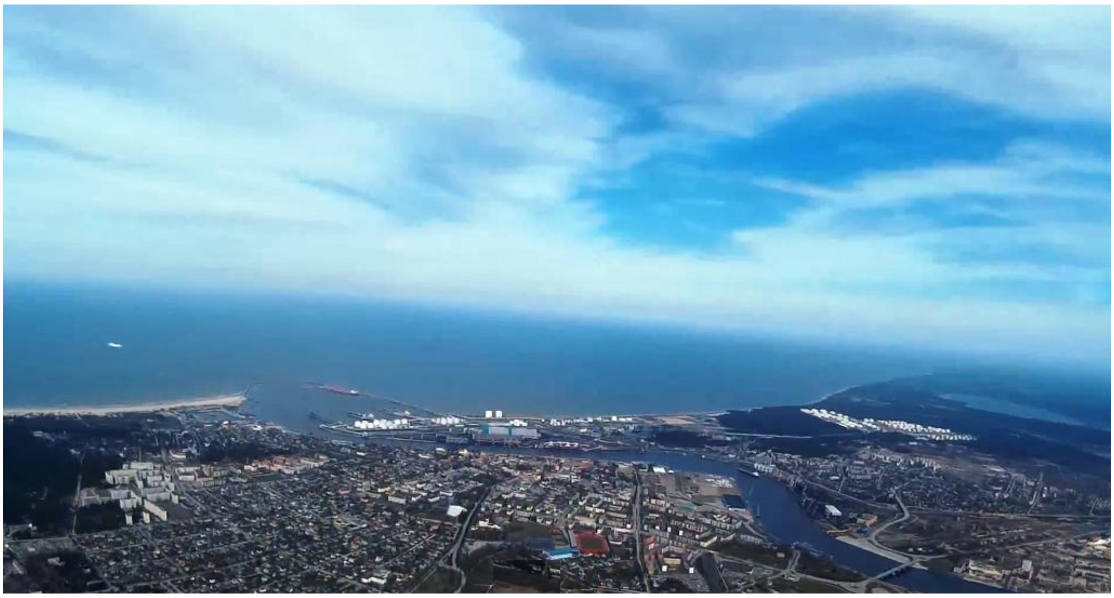

Figure 21. Image of our town Ventspils taken from HD video camera

Figure 22. Another image of taken from HD video camera

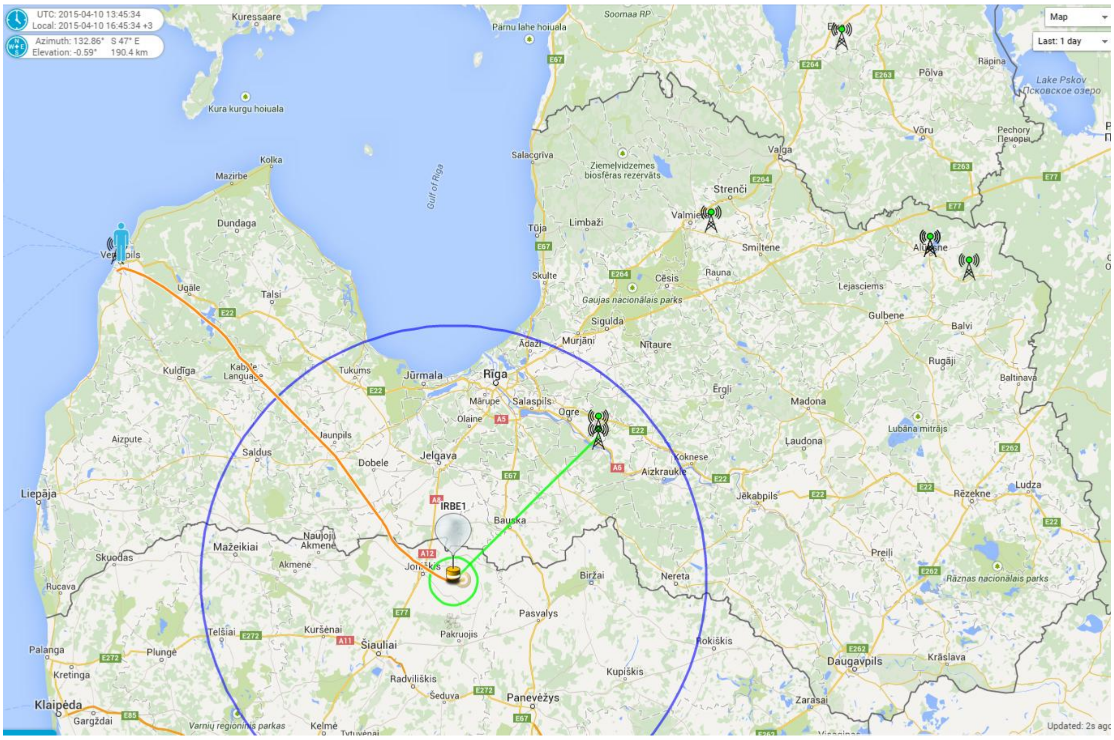

Figure 23. Flight path of IRBE-1

Figure 24. Team members Ravis Pabērzs and Jānis Šate posing with recovered payload

Figure 25. The balloon chase team and farmer Gediminas Ališauskas who found the balloon

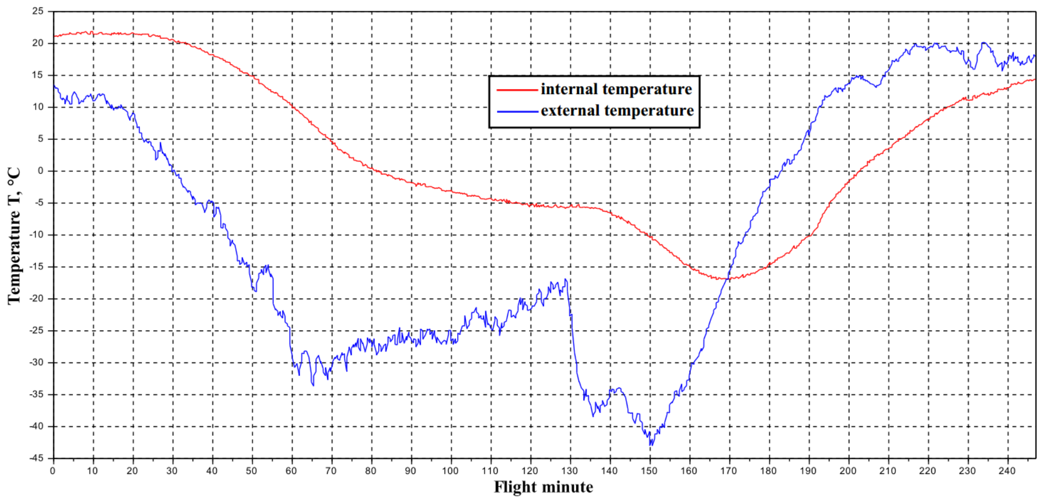

Figure 26. Internal and external temperature graphs over time

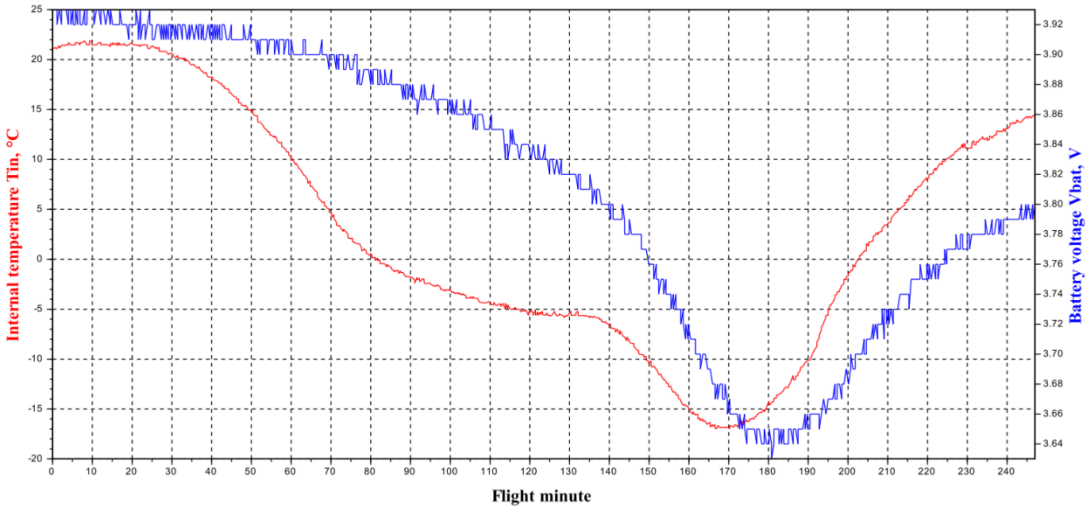

Figure 27. Internal temperature and battery voltage over time

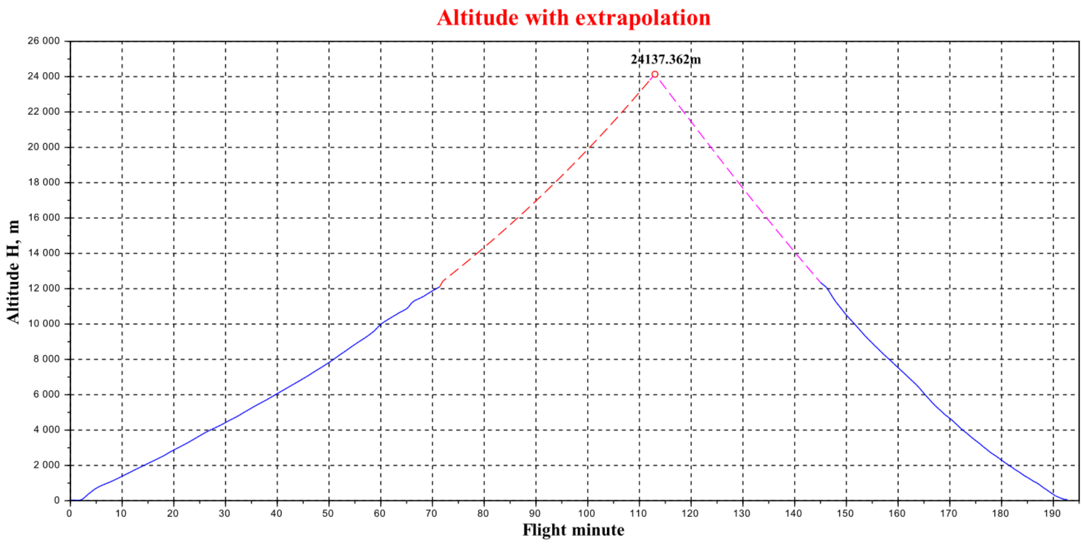

Figure 28. Received GPS altitude data and maximum altitude

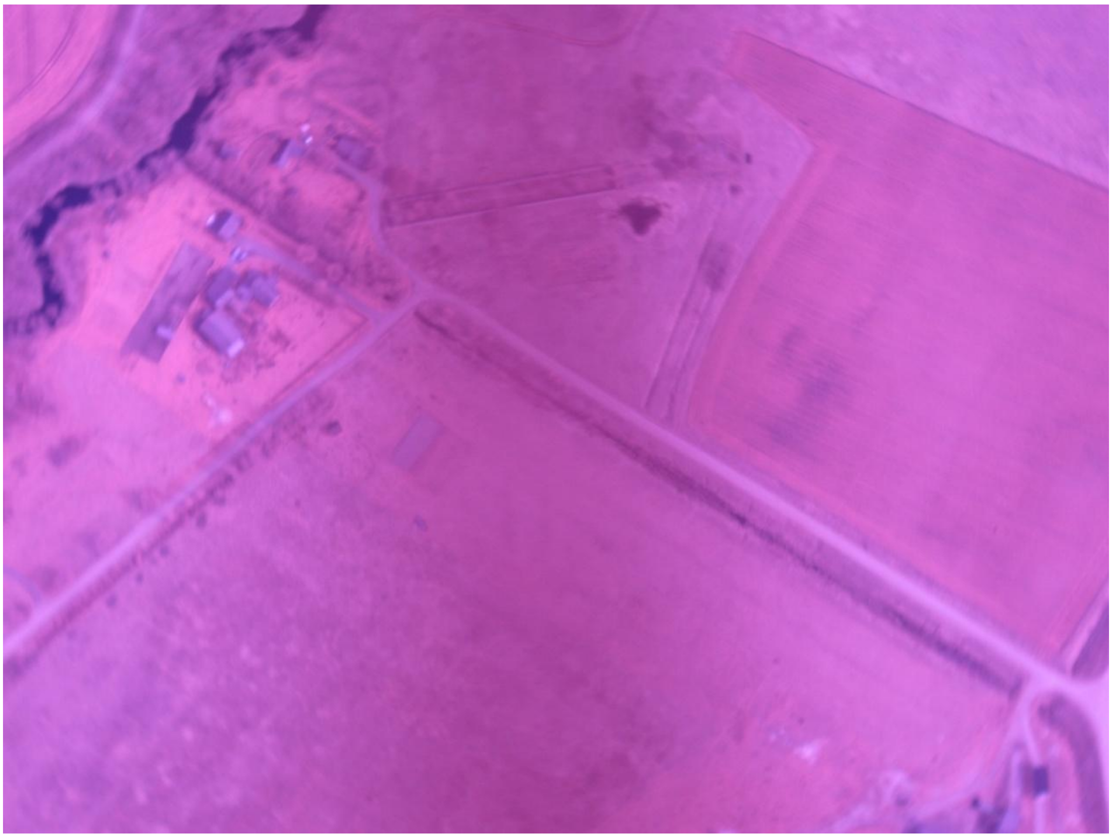

Figure 29. Raw image of fields outside Ventspils

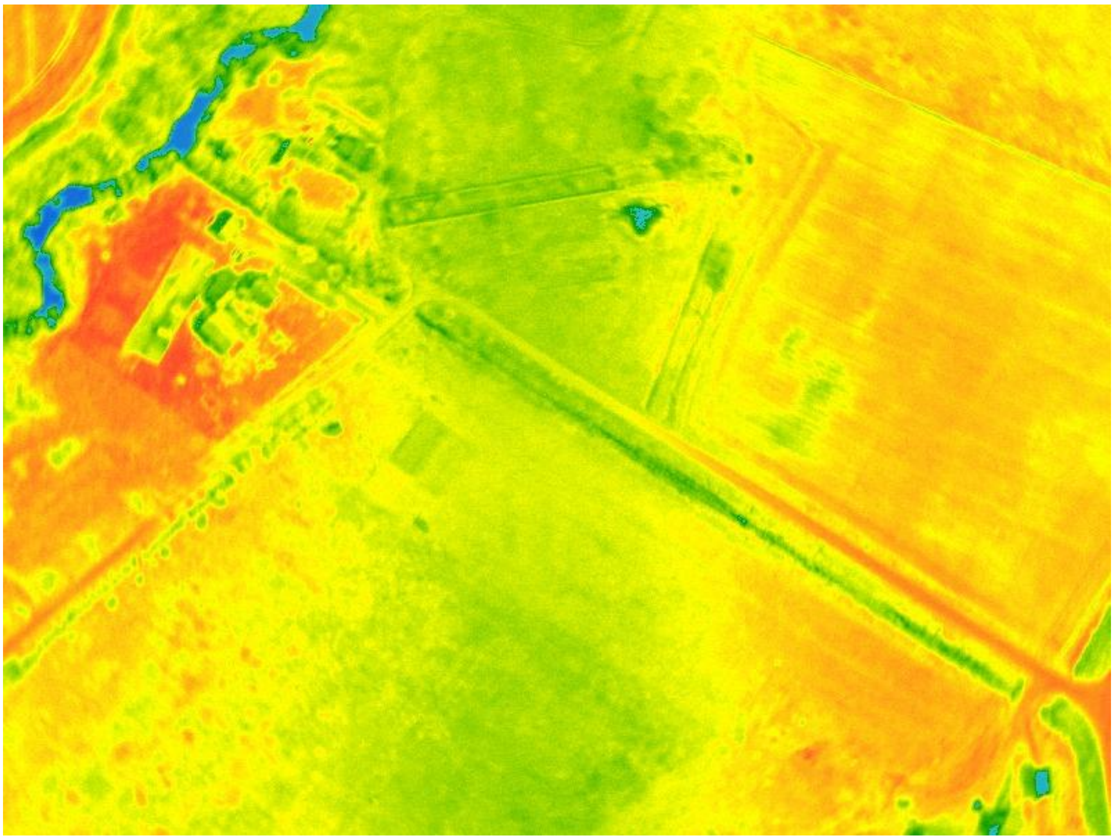

Figure 30. Processed image of fields

Figure 31. Raw image of a village

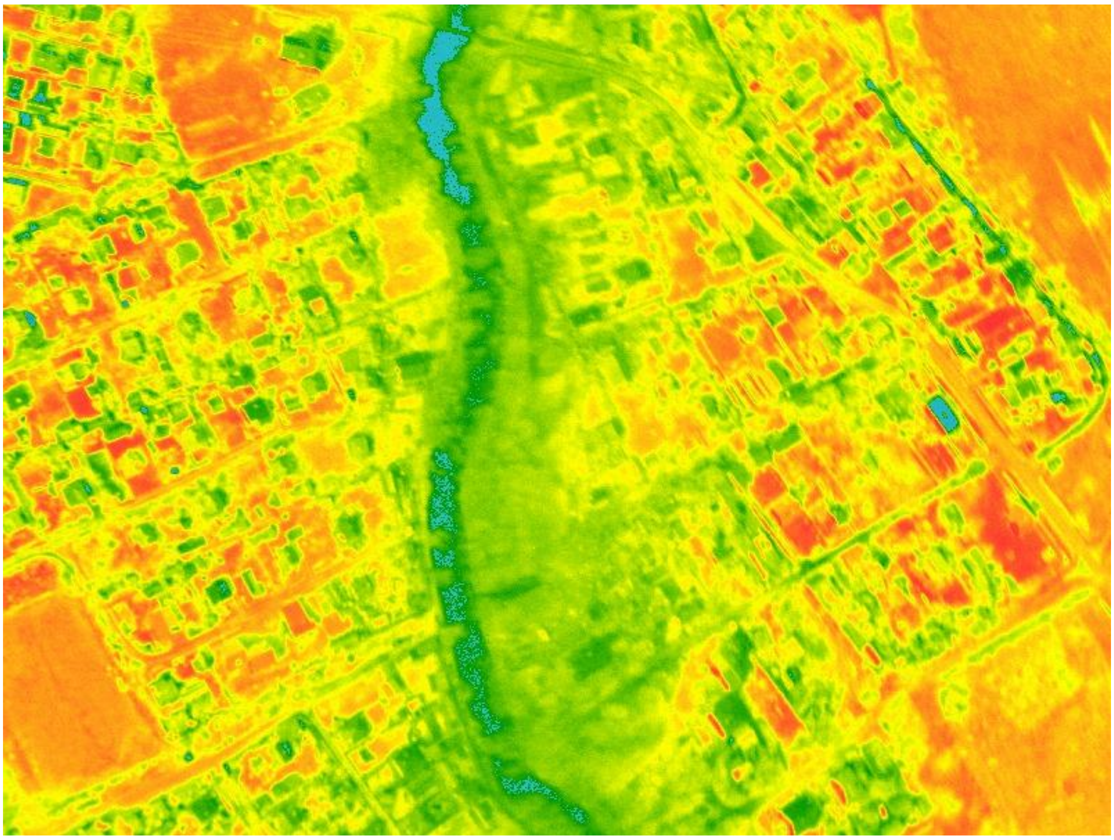

Figure 32. Processed image of village

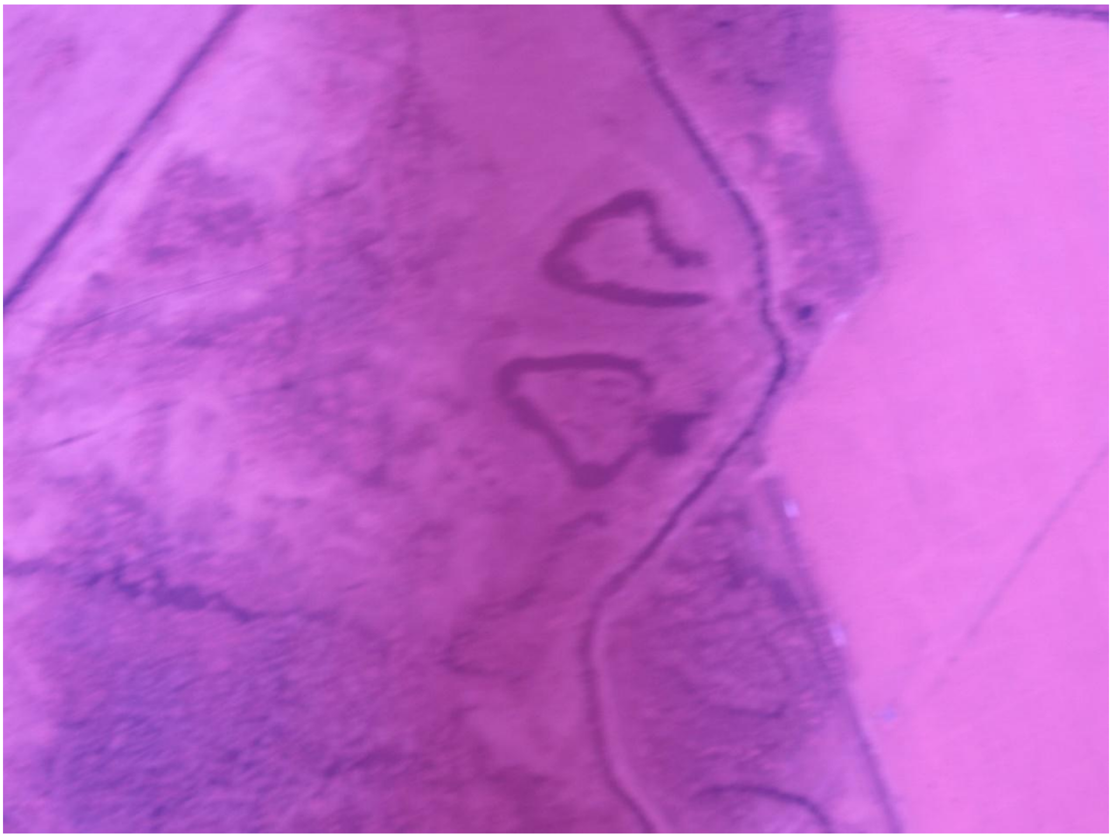

Figure 33. Raw image of swampy area

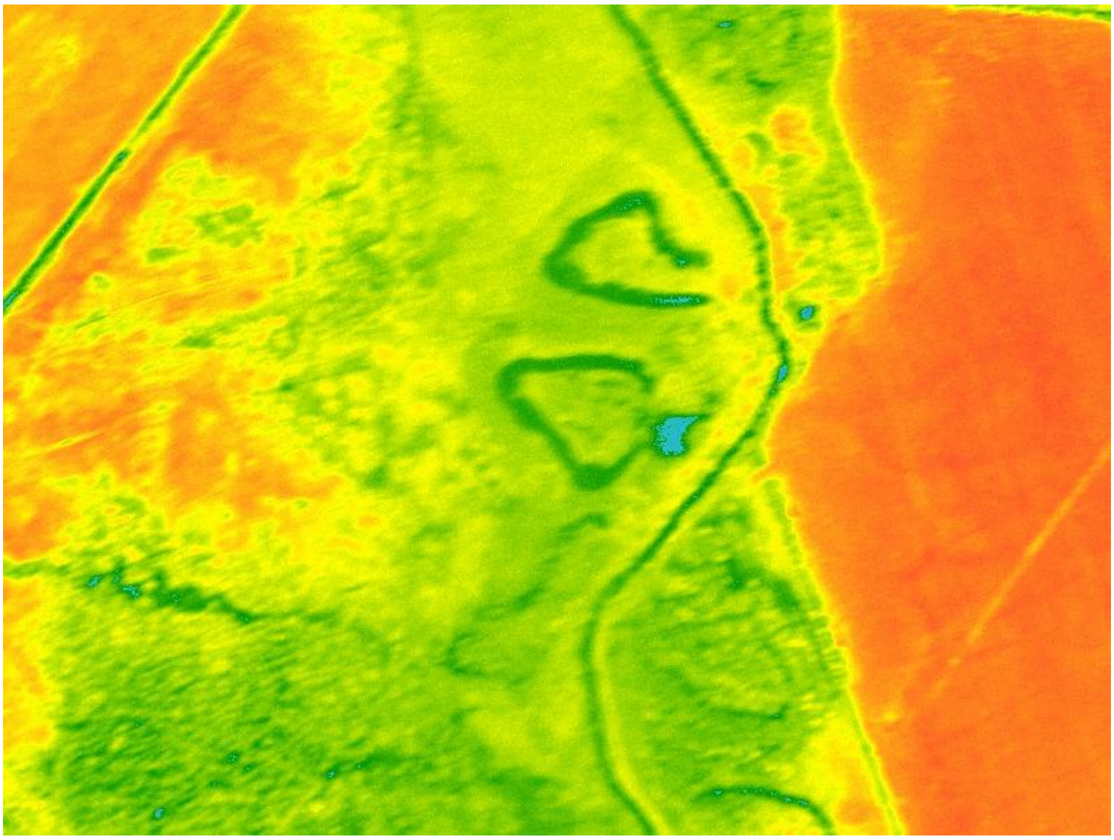

Figure 34. Processed image of swampy area