Co-funded by the European Union

A2.2. Toolkit: Meteor Camera Kit

Resources: INAF - Italian National Institute for Astrophysics - Osservatorio Astrofisico di Torino
Curated by: Dario Barghini, Daniele Gardiol, Chiara Lamberti

This manual provides a comprehensive guide to install, operate and maintain the StAnD Meteor Camera Kit, dedicated to the detection of bright meteors (fireballs and bolides) during night-time. This kit is provided within the StAnD Toolkit to schools participating in the StAnD project. Still, it is also available to be purchased by other schools, institutions, associations, and whoever is interested in joining the project. The StAnD Toolkit comes also with a Data Analysis Tool, to visualize and analyze the data acquired by the all-sky camera.

Language: English

Suitable for age: 7-18 years

Keywords: Meteors, bolides, fireball network, all-sky cameras

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Table of Contents

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

1. Introduction

This manual serves as an installation and user guide for the StAnD Meteor Camera Kit, developed to **automatically detect bright meteors** (otherwise known as fireballs and/or bolides) during night-time, if weather conditions are favorable.

The camera module used in the StAnD Meteor Camera Kit is **all-sky**, i.e. it is able to image the whole observable sky (down to ~10° above the local horizon) in only one acquisition. This module is operated at **30 frames per second** (fps) during night-time by the mini-PC that is provided in the kit. Data of meteor observations are automatically saved when the system recognizes the occurrence of a bright source moving in the Field of View (FoV) of the camera.

The data, configuration and control of the StAnD Meteor Camera Kit are accessible through standard SSH (Secure Shell Protocol) or a **browser interface**, either locally or remotely. The data acquired by the StAnD cameras are also **shared among all the project participants** on a cloud service, to enable the triangulation of the meteors observed by more than one station of the network and to allow teachers and students from other schools to join the StAnD project, even if they do not have access to a camera by themselves.

Finally, the data acquired by the StAnD Meteor Camera Kit can be analyzed through the **Data Analysis Tool** (PWwidget) provided with the kit. This tool enables **visualizing** and **exporting** animation or timelapse of the data acquired by the camera and their **scientific analysis**, with the final objectives of unveiling the **origin of the observed object** within the Solar System and understanding if a fragment of it, i.e. a **meteorite**, has survived the atmospheric flight and fell to the ground.

The idea of StAnD originated from the experience of PRISMA (Prima Rete Italiana per la Sorveglianza sistematica di Meteore ed Atmosfera, i.e. First Italian Network for the systematic Surveillance of Meteors and the Atmosphere), a professional **fireball network** in Italy run by **INAF**, the Italian National Institute for Astrophysics. PRISMA is part of FRIPON (Fireball Recovery and InterPlanetary Observation Network), an international collaboration that involves many national meteor and fireball networks around Europe and worldwide.

Figure 1 – The first all-sky camera of the PRISMA network in Italy, installed in 2016 on the roof of the office building of the Astrophysical Observatory of Torino, part of INAF - the National Institute of Astrophysics.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Co-funded by the European Union

The following sections of this introduction provide a short summary covering the topics of meteoroids, meteors and meteorites and the methods to observe meteors, with a focus on the optical ones. For a complete overview about these topics, please refer to the **StAnD Teacher's Manual**.

1.1. Meteoroids, Meteors and Meteorites

Apart from our central star (the Sun), the eight major planets, and their satellites (like the Moon) the Solar System is populated by a vast class of **minor bodies** (see Teacher's Manual, Chapter 3 and 4). Such bodies are usually **classified according to their size**:

- Predominantly round and large-sized objects orbiting around the Sun are called **dwarf planets**. This is the case of 1 Ceres, known as the first discovered asteroid and that has a diameter of about 940 km.
- Irregularly shaped rocky bodies orbiting around the Sun (that are neither planets nor dwarf planets) are called **asteroids**. A famous asteroid today is 101955 Bennu, a "small" 480 m asteroid that was visited by the NASA **sample-return mission** OSIRIS-REx.
- Minor objects like asteroids but made of more fragile material, like ice and dust, are called **comets**. They are the most famous objects because they exhibit a **tail of dust particles** when approaching the vicinity of the Sun, sometimes visible from the Earth.
- Objects that qualify as asteroids or comets but that are smaller than 1 m are called **meteoroids**. These objects are so small that ground-based telescopes cannot systematically observe them, but only if they are very close to the Earth. Meteoroids are usually **fragments of asteroids** (or particles ejected from comets) that were ejected from the **parent asteroid** after a collision with another object. Similarly, meteoroids can also originate from major planets.

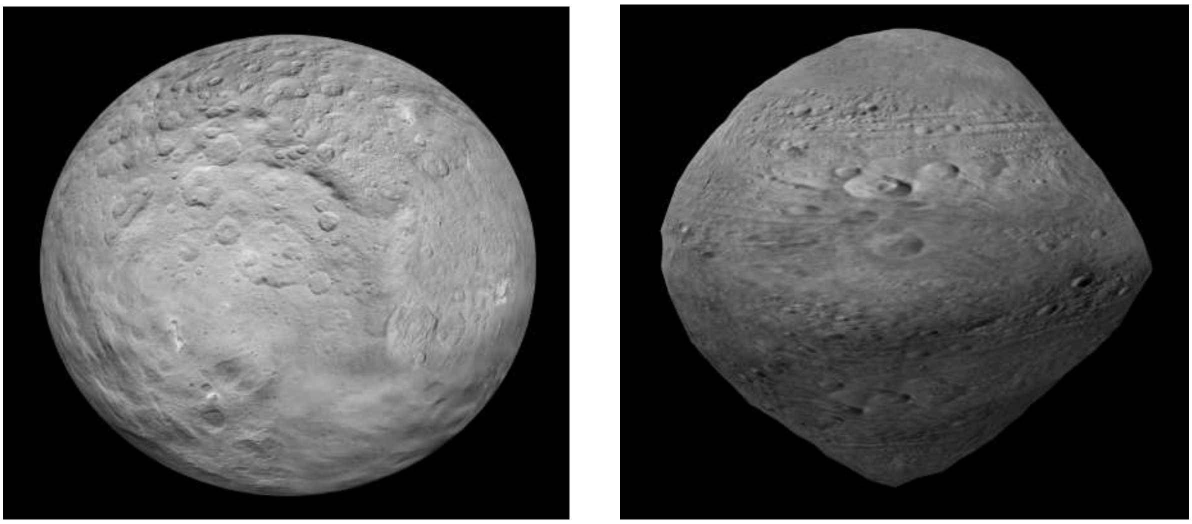

Figure 2 – The 3D models of 1 Ceres (left panel) and 101955 Bennu (right panel) coming from direct observation of these asteroids. Small asteroids and meteoroids can have very irregular shapes. They usually rotate on themselves at fast rates (1 turn every 4.3 hours in the case of Bennu). The effect of such fast rotation often leads to top-shaped asteroids (like Bennu). Credits: NASA Visualization Technology Applications and Development (VTAD) - link

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Figure 3 – The first direct imaging of the comet 1P/Halley, taken in 1986 by the European spacecraft Giotto. As a scale for the image, the nucleus has an average diameter of ~11 km. Credits: Halley Multicolor Camera Team, Giotto Project, ESA - link

Minor bodies orbit around the Sun on more (comets) or less (asteroid) eccentric orbits. Most of the population of asteroids and meteoroids orbits within the Main Belt of Asteroids, between Mars and Jupiter. If their orbit is close to the one of the Earth, they are called **Near-Earth Objects** (NEOs, see Teacher's Manual, Chapter 5.1).

For such objects, it can happen that they **approach the Earth's position** and deviate from their original orbit, pulled by the Earth's gravitational attraction. In this case, the interaction between the meteoroid and the Earth's atmosphere originates a phenomenon called **meteor**. In specific terms, a meteor is "[...] **the light and associated physical phenomena** (heat, shock, ionization), which results from the high-speed entry of a solid object from space into a gaseous atmosphere", as of the definition of the International Astronomical Union. The most evident feature of a meteor is its **light emission**, originating from the heating of the meteoroid material and of the surrounding atmosphere mostly due to the high friction caused by the supersonic atmospheric entry. Indeed, meteoroids from the Solar System can impact the Earth's atmosphere with a **speed between 11 and 72 km/s**, that is from **35 to 240 times the speed of sound** in air at standard temperature and pressure (see Teacher's Manual, Chapter 5.2).

Meteors can have either an **asteroidal or cometary origin**. Since asteroids usually orbit around the Sun with a **prograde orbit** (i.e. counterclockwise looked from above the Sun, as all the major planets do), asteroidal meteors usually have a slower impact speed (11 - 40 km/s). On the contrary, since comets usually have a **retrograde orbit** (i.e. clockwise), cometary meteors usually impact the Earth's atmosphere at higher speed (40 - 72 km/s). Cometary meteors usually originate from **meteoroid streams**, produced by comets that release particles along their orbit due to the effect of the solar wind, and producing **meteor showers** when the Earth crosses the orbit of the comet (see Teacher's Manual, Chapter 5.3).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Further terminology is used in meteor science. A meteor that shines brighter than Venus (the second brightest object in the night sky) is called a **fireball**. It can also happen that the meteoroid fragments in different pieces during its atmospheric flight, due to the very high pressure that originates from the hypersonic flight. These fragmentation events usually correspond to bright flashes (**flares**) of the fireball, which are called **bolides** when such events occur. Such flares release in the atmosphere a large quantity of meteoritic dust that slowly deposits downwards to the Earth's surface. Such µm- to mm- sized particles can be recovered on the ground and are called **micrometeorites**. They can originate also from very microscopic meteoroids (< 30 µm in size) that are also called **Interplanetary Dust Particles** (IDPs), which do not ignite as meteors when impacting the Earth's atmosphere

On rare occasions, in about 0.1% of the cases of fireballs occurring on Earth, a small residue of the meteoroid survives the atmospheric flight. The bright, visible phase of the meteor ends at about 20-30 km of altitude from the ground, and the surviving fragments eventually fall to the ground after the so-called **dark flight**. These stones are called **meteorites**. The recovery of meteorites and the analysis of their composition is fundamental to understand the formation and evolution of minor and major bodies, since they preserve pristine samples from the early stages of the Solar System.

Figure 4 – The first photograph of a meteor, taken on 27th November 1885 by the astronomer Ladislaus Weinek in Prague. Credits: AMS - link

1.2. Observational Methods

The first scientific observation of a meteor dates back 140 years (see Figure 4) and, since then, systematic or sporadic observations of meteors have been carried out by both the professional and amateur community of astronomers. To date, meteor observations are the only way to **probe the population of small-sized asteroids** and meteoroids. Indeed, the smallest asteroid ever detected by a direct, ground-based telescopic observation is 2015

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Co-funded by
the European Union

TC25, with an estimated size of 2 m, but this observation was possible only thanks to its unusually high albedo (i.e. the fraction of Sunlight that the asteroid surface is able to reflect) of about 60%. Current estimations suggest that we observed >90% of the NEO population above 1 km in size. On the other hand, the population of small asteroids below 100 m is poorly constrained.

The most fruitful method to observe meteors is by **optical observation**, that is detecting the light emitted by the meteor with a telescope or a camera. **Wide-field telescopes**, and especially **all-sky cameras**, are preferable in this case in order to cover the highest portion of the observable sky and maximize the detection efficiency of meteors, since meteors not originating from known comets are sporadic events (*i.e.* the observer does not know, a priori, when and where in the sky a meteor will occur).

All-sky cameras are typically built using commercially available camera modules equipped with a **fish-eye objective**, able to capture the whole visible hemisphere. Such a result can be obtained by **distorting the FoV** into the focal plane of the camera in a circular image, for which the outer circumference is the local horizon.

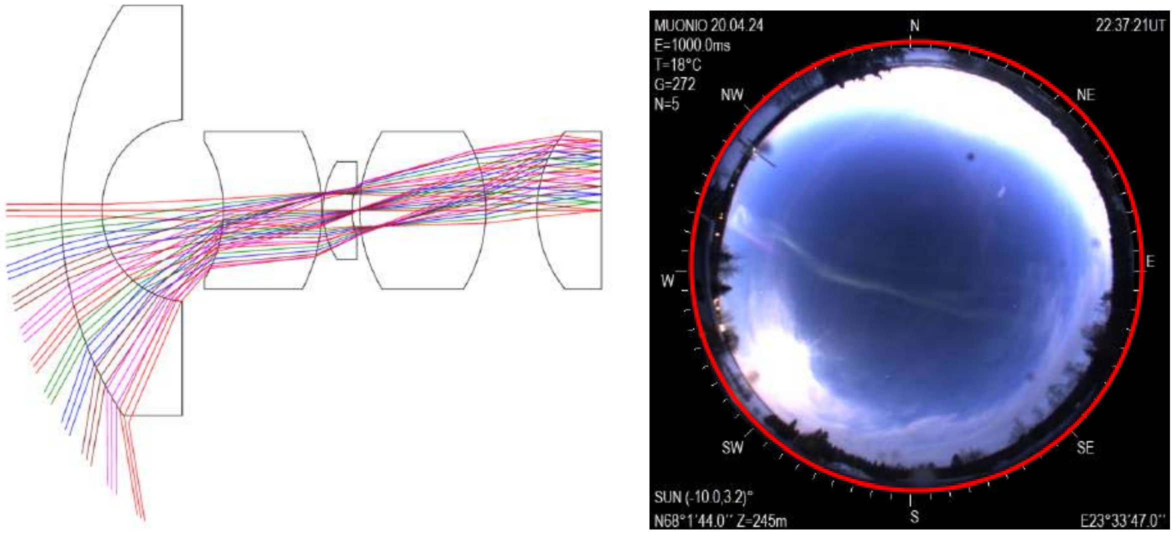

Figure 5 – The functioning principle of all-sky cameras equipped with a fish-eye objective. A composite optic system (left panel) focuses the light incident onto the outer lens towards the focal plane, introducing significant distortion. The resulting image acquired by the camera is circular (right panel). Light rays coming from the horizon are focused towards the outer border of the image (red circle), while the ones coming from the zenith direction are directed towards the centre of the image. Credits: (left) Frogget, B. C. et al, "A fisheye lens as a photonic Doppler velocimetry probe", Proceedings of SPIE, 2012 - link, (right) Avaruussääkeskus, RWC Finland - link

Optical observations of meteors are carried out in two possible ways:

- **Photographic observations**: the objective is left open to incoming light for a certain amount of time (a few minutes to the whole night, depending on the sensitivity of the instrument). During the night, stars apparently rotate around the North Pole and appear as circular **star trails**, while meteors and fireballs produce **slanting straight and bright strikes** with respect to the background of star trails. To obtain a relative indication of the time, such devices are usually equipped with **a rotating shutter** that

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

periodically obscures the objective, leaving equally spaced dark ticks along star trails and meteor strikes.

- **Video observations**: the camera performs short and consecutive acquisitions, being operated at **high frame rates** (30 - 60 fps) and capturing the image and motion of the meteor at each instant, with an **absolute time reference**. Due to the short exposure times, video observations are mostly used for the detection of fireballs and bolides. On the contrary, high-sensitivity professional cameras must be used to capture faint meteors by video observations.

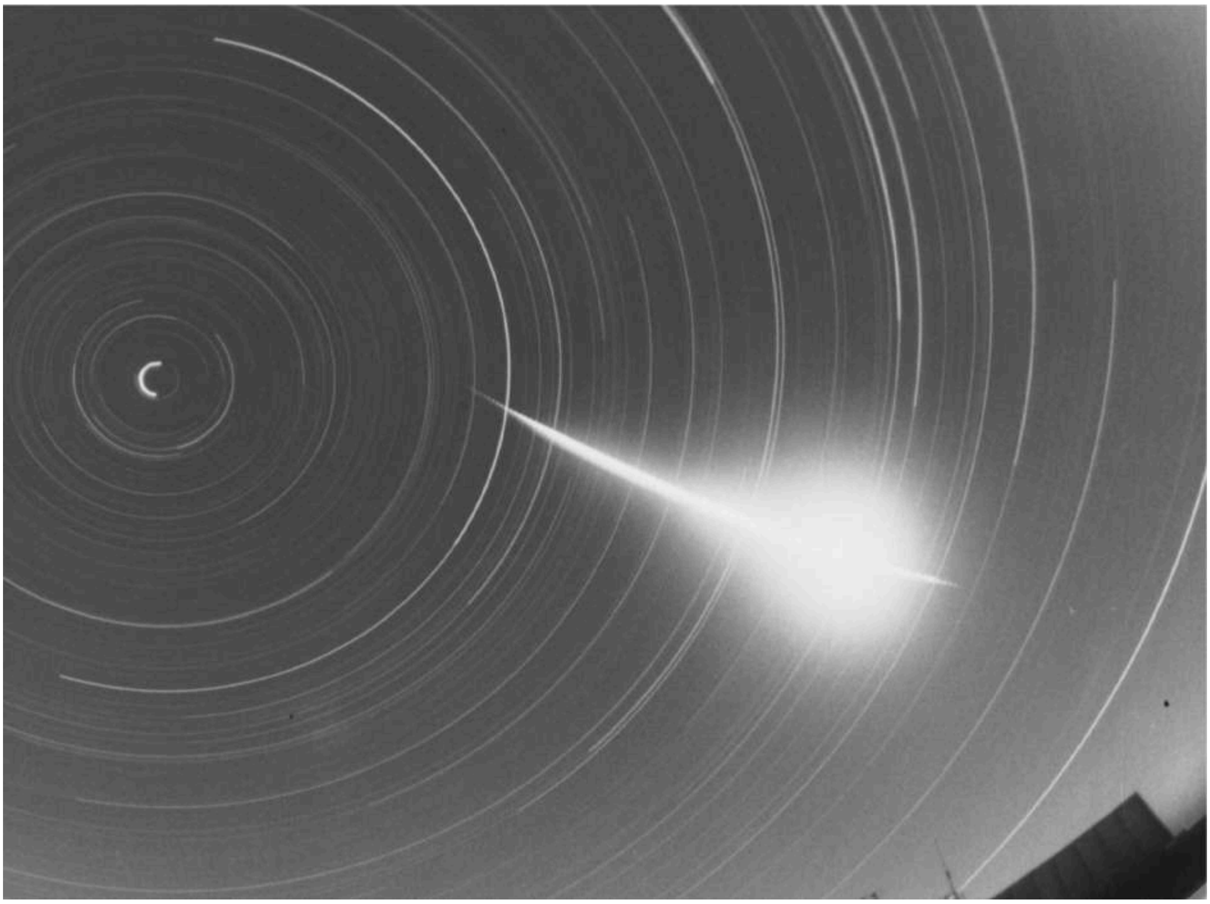

Figure 6 – Photograph of a fireball detected on 21 January 1999 by the Czech station No. 16 of the European Fireball Network camera system. Star trails are visible as circular arcs centred on the North Pole. The bright fireball crosses the star trails almost perpendicularly. Credits: ISSI Bern - [link]

Observations of meteors can be carried out on other channels as well. For example:

- **Radio**: detecting radio waves (from military or communication infrastructures) **reflected** by the plasma channel generated by the meteor.
- **Acoustic**: detecting the **shock waves** generated by the hypersonic motion of the meteor, either in air (by **infrasound** detectors) or when they impact the Earth's surface (by **seismic** stations).
- **Spectroscopy**: the intensity of the light emitted by the meteor at different wavelengths can unveil the **meteoroid composition**.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Co-funded by
the European Union

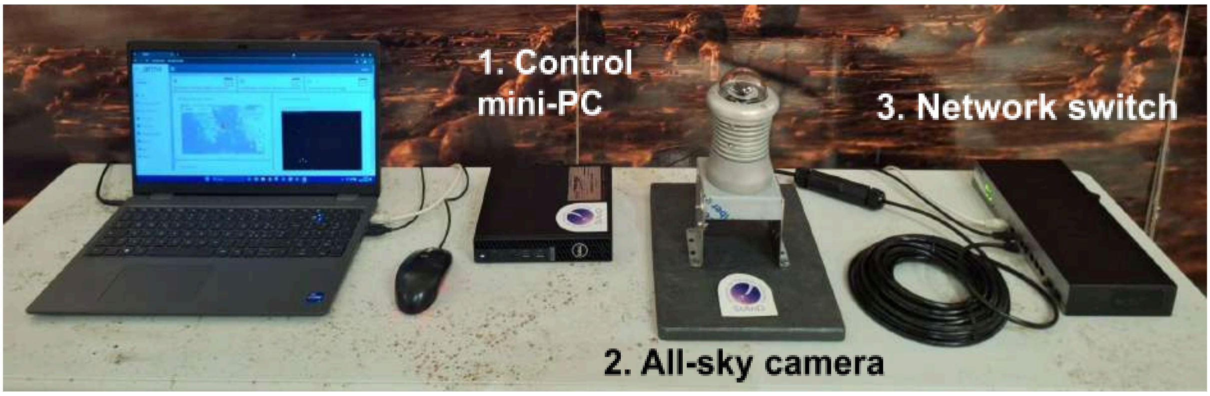

Figure 7 – The StAnD Meteor Camera Kit installed and displayed in the lecture room of the first StAnD Summer School on 30 June - 05 July in Marathons, Greece. In this case, the camera module is installed on a wooden support just to display the kit indoors. Since no Ethernet wall plug was available in the room, the kit network is connected to the Internet through the Ethernet plug of a laptop, which operates as a router and from which one can access the system interface directly.

2. StAnD Meteor Camera Kit

The StAnD Meteor Camera Kit is designed to autonomously monitor the night sky in order to detect fireballs and bolides. The kit consists of three main components:

1. The **control mini-PC**: it controls the whole system through an open-source program named FreeTure, a Free software to capTure meteors. This program operates the camera, handles the data **acquisition schedule** during day and night and, most importantly, it runs the **trigger for meteor data** (the video stream acquired during night-time at 30 fps) to recognize the passage of a fireball in the FoV of the camera. A trigger is an algorithm that automatically checks for the occurrence of particular events in some data. In this case, the algorithm checks for **bright sources moving on a straight line with a high angular speed**, compatible with the speed range of meteors in the Earth's atmosphere (11 - 72 km/s, see Section 1.1). In such a case, FreeTure saves a portion of the video stream (a few seconds before and after the fireball detection) and marks this occurrence as a **detection** (i.e. the data of a fireball captured by one camera). It is connected to the other components and to the Internet through an Ethernet cable going to the network switch.
2. The **all-sky camera**: a PoE (**Power over Ethernet**) camera module coupled with a fish-eye objective, enclosed in a **passive-cooling case** and exposed through a plastic dome to protect the camera and optics. In its operative configuration, the camera is **installed on the roof / balcony** of the building, through its mounting system. The camera is connected to the whole system through a **5-m Ethernet cable** (attached to the case with a waterproof extender) through the network switch, which also provides power to the camera.
3. The **network switch**: a network **hub** that connects the whole system locally, providing power to the camera and Internet to the mini-PC. It is connected to the Internet through an Ethernet cable going to the wall Ethernet plug, or directly to the router. The data acquired by the kit are then handled by the INAF - PRISMA servers.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Both the mini-PC and the network switch are connected through their own power supply adapter to a wall power outlet, while the all-sky camera is powered through the switch by PoE. The connection scheme is presented below.

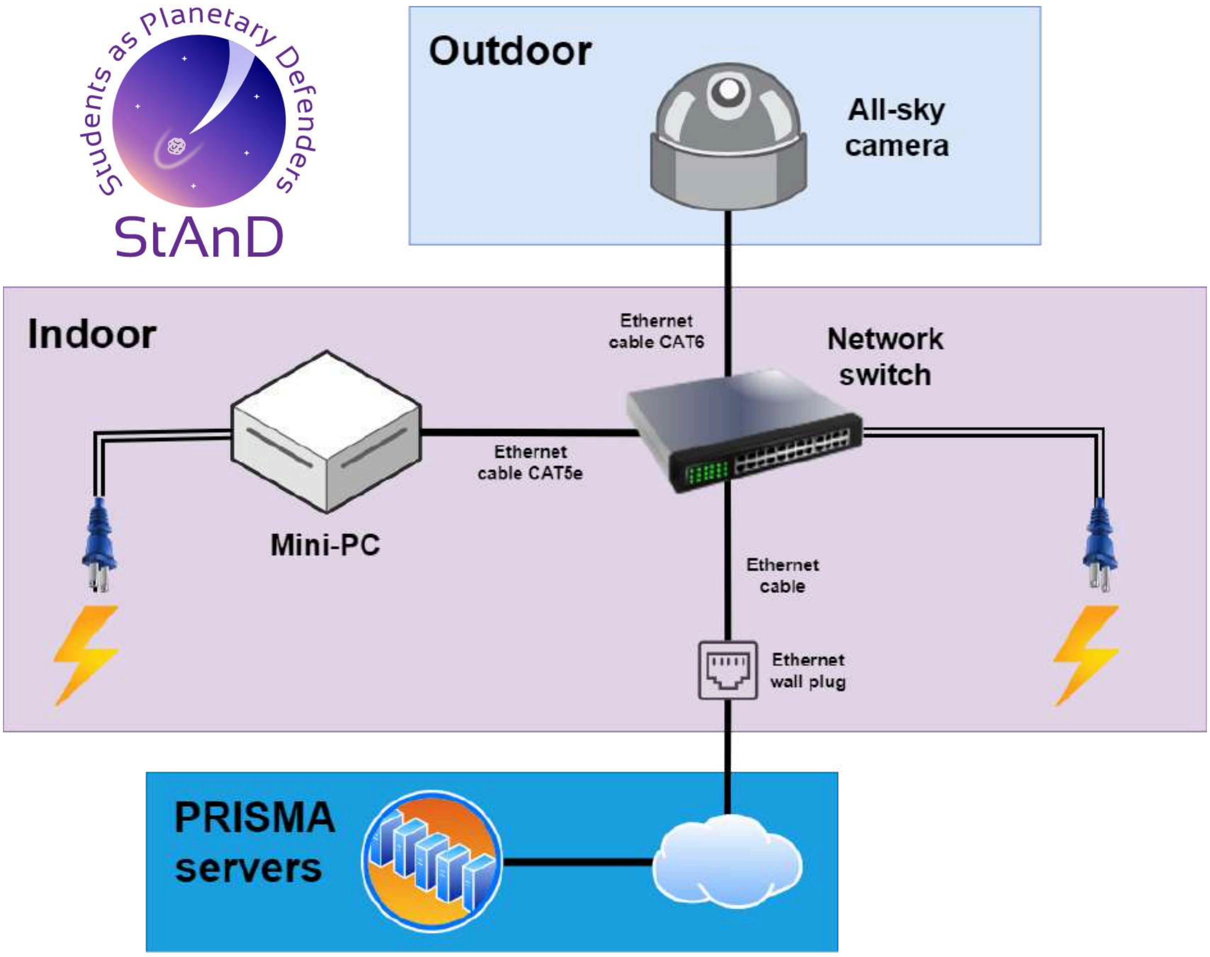

Figure 7 – Schematic representation of the StAnD Meteor Camera Kit. The light violet box encloses components installed indoors, while components in the light blue box are installed outdoors (only the all-sky camera). Ethernet cables are represented as single solid black lines and power cables as double solid black lines. The system is connected to the Internet through the network switch, and data are synced and ingested by the servers of the PRISMA fireball network (hosted at INAF - Osservatorio Astronomico di Trieste).

2.1. Hardware Description

The kit is assembled and shipped by N-3 srl.

A. All-sky Camera

The all-sky camera consists of several parts:

- The **protective case and dome**, produced by Shelyak instruments (Figure 8, left panel);
- The **camera module** - Lucid Visions Phoenix 3.2 MP (model PHX032S-MS), equipping a Sony IMX265 **CMOS sensor** (Figure 8, central panel);

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

- The **fish-eye lens**, model [BQ1550B-12MP](), with 1.55mm focal length **F2.8** (Figure 8, right panel).

Figure 8 – The main components of the all-sky camera included in the StAnD Meteor Camera Kit. From left to right: the protective case and plastic dome from Shelyak Instruments, the camera module Lucid Visions Phoenix 3.2 MP and the fish-eye lens.

B. Mounting System of the All-Sky Camera

The camera is provided with a mounting system made of stainless steel parts, which allows it to be mounted on a level or inclined surface, on a wall, or a pole, depending on the configuration of the installation site. It is made of:

- A **main body** (a stainless steel flange, see Figure 9, top left panel) over which the bottom of the camera is screwed;
- Two **side panels** (two stainless steel parts, see Figure 9, top central panel) that support the main body;
- A **pole mounting plate** (see Figure 9, top right panel) to be inserted under the two side panels if the camera has to be mounted on a pole (**not recommended**).

The system is complemented by the needed screws, two pole mounting rivets, a **junction box**, and an ethernet RJ4 coupler (see Fig. 10).

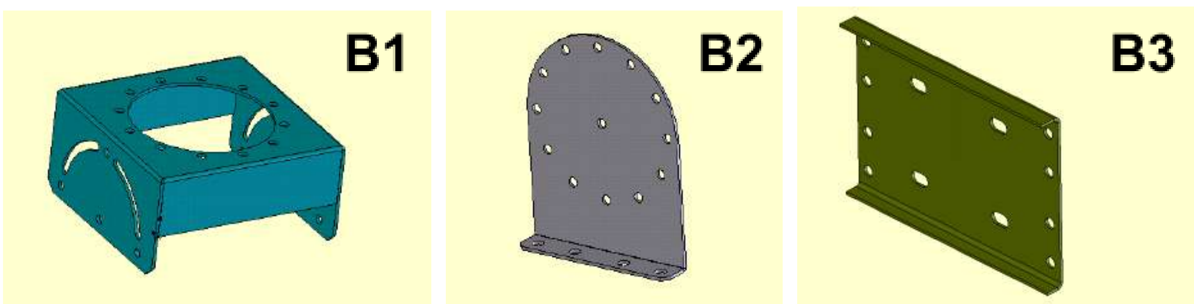

Figure 9 – 3D rendering of the main components of the mounting system for the all-sky camera. From left to right: the main body (B1), two side panels (B2) and the pole mounting plate (B3). Credits: FRIPON - [link]()

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Figure 10 – Pictures of the accessory components of the mounting system for the all-sky camera. From left to right: bolts, nuts and rings to fix the camera support (M4 bolts - small ones, B4a) and the pole mounting support (M5 bolts - big ones, B4b), two pole mounting rivets (B5), junction box (B6), and a female-to-female Ethernet RJ4 coupler.

C. Control mini-PC

The mini-PC included in the Meteor Camera Kit has the following specifics:

[DELL OptiPlex Micro Form Factor](#)
(producer code 08XD1, EAN:5397184800867)

- Processor Intel **i5-13500T**
- **8 GB RAM**
- Storage 256 GB SSD, custom upgraded to **1 TB SSD** before shipping (KINGSTON NV2 SSD 1 TB M.2 NVME 2280 PCIE 4.0)
- Operating Systems: Windows 11 Pro (from factory), **Debian GNU/Linux 11** (installed before shipping)
- **1 year warranty**

The mini-PC is pictured in Figure 11. It comes with its own power supply adapter, which specifics are highlighted in the figure to avoid confusion while installing the kit. Figure 12 illustrates all the ports on the front and back of the mini-PC.

Figure 11 – Pictures of the Mini-PC provided in the StAnD Meteor Camera Kit. From left to right: the Mini-PC in display mode (C), its power supply adapter (C1) and the specifics of the power adapter.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Figure 12 – Pictures of the front (top panel) and back portion (bottom panel) of the Mini-PC with ports and buttons highlighted.

D. Network Switch

The network switch included in the Meteor Camera Kit has the following specifics:

[DLINK - Smart Switch Gigabit 10P GIGABIT] 8 ports PoE + 2 Mini-GBIC
(producer code DGS-1210-10P, EAN:0790069467721)

- 8 ports 1000Base-T 802.3af/802.3at PoE
- 2 SFP ports
- 65 W PoE Budget
- Fanless

The switch is pictured in Figure 13. It comes with its own power supply adapter, which specifics are highlighted in the figure to avoid confusion while installing the kit. Figure 14 illustrates all the ports on the front and back of the switch.

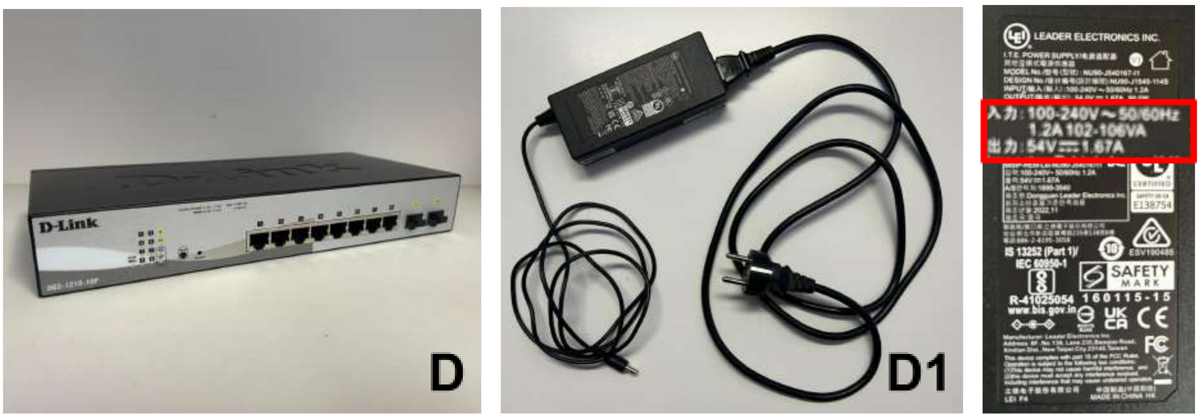

Figure 13 – Pictures of the network switch provided in the StAnD Meteor Camera Kit. From left to right: the network switch in display mode (D), its power supply adapter (D1) and the specifics of the power adapter.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

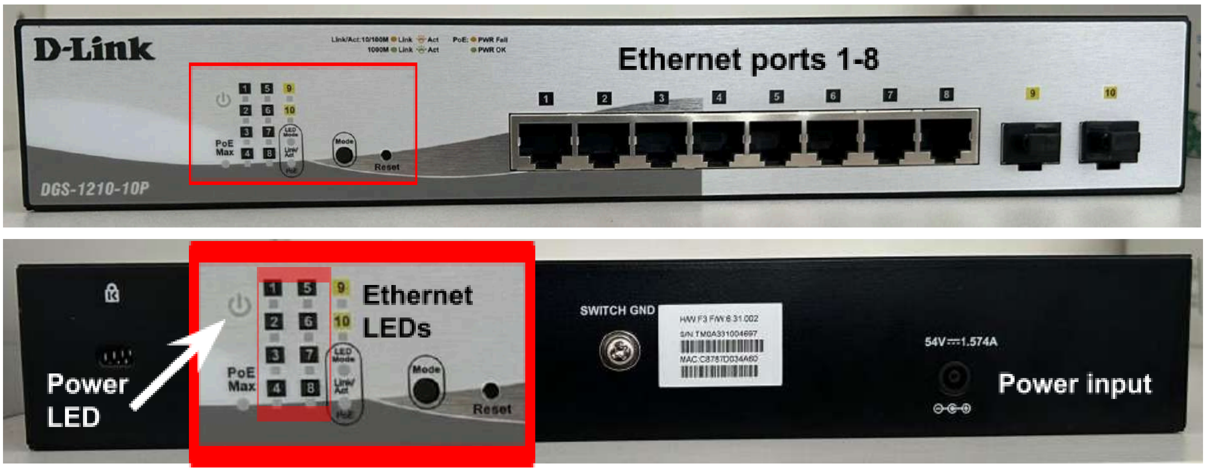

Figure 14 – Pictures of the front (top panel) and back portion (bottom panel) of the network switch with ports highlighted. The red box highlights the LED panel, with one LED for each Ethernet port (1 - 8). Each LED will flash a steady green light if the corresponding port is currently connected to a device via an Ethernet cable. Ports 9 and 10 are SFP ports and will not be used in the current configuration.

E. Ethernet Cables

The Ethernet cables to connect the all-sky camera, mini-PC and network switch are provided in the Meteor Camera Kit. They are shown in Figure 15. In particular:

- **2 m Ethernet cable Cat5e** to connect the mini-PC to the network switch (E1);
- **5 m Ethernet cable Cat6** (LZSH fireproof) to connect the all-sky camera to the network switch (E2);
- A **waterproof RJ4 Ethernet coupler** (E3) to join the 5 m Ethernet cable to the short one embedded in the case of the all-sky camera.

The detailed scheme of the connections is highlighted in Figure 7. An additional Ethernet cable is needed to **connect the network switch to the Ethernet wall plug** (not included in the kit). No particular technical requirements are needed for this cable.

Figure 15 – Pictures of the Ethernet cables provided in the StAnD Meteor Camera Kit. From left to right: the 2 m CAT5e cable to connect the mini-PC to the switch (E1), the 5 m CAT6 fireproof cable to connect the all-sky camera to the network switch (E2), and the waterproof Ethernet RJ4 coupler to join the Ethernet cables to the all-sky camera (E3).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

F. Packaging

The whole kit is delivered by mail in a cardboard box with a StAnD branded sleeve (Figure 16), with internal bubble wrap padding to prevent damage to the hardware during shipping.

Figure 16 – The cardboard box used to deliver the StAnD Meteor Camera Kit by mail. Credits: N-3 srl - [link]

3. Installation Guide

This chapter covers the installation of the StAnD Meteor Camera Kit. The process can be subdivided into four main steps:

1. Verification of the **technical requirements**;
2. **Assembly and installation of the all-sky camera mounting system (B)**;
3. **Installation of the all-sky camera (A)** and connection to the room where the control mini-PC and network switch will be located (and, if necessary, installation of the electrical junction box);
4. **Installation of the control mini-PC (C) and network switch (D)** and connection to the Internet network;
5. **First boot** of the Meteor Camera Kit.

3.1. Technical Requirements

The following technical requirements have to be taken into account when identifying the location where to install the StAnD Meteor Camera Kit.

3.1.1. Camera Positioning

The all-sky camera should be installed on the **roof of a building**, preferably **without prominent obstacles** in its FoV (i.e. down until the visible horizon). Therefore, the building should be the **tallest in its proximity**.

The last 10° above the horizon are not very important, usually because of light pollution that does not allow to detect stars (and even meteors if not too bright) anyway in this region.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Small obstacles (such as chimneys, antennas, flags etc..) close to the camera are not a deal breaker (a workaround is possible via software by masking them) but should be avoided.

3.1.2. Light Pollution

The StAnD Meteor Camera Kit **can work properly even in light-polluted sites** near large and medium-sized cities. This is because the targets of observation are bright objects (fireballs and bolides).

To check the quality of the sky in your installation site, please refer to the **Light Pollution Map** - World Atlas 2015. For optimal observations, one should **avoid installing the kit in areas in class 8-9** of the Bortle Dark Sky Scale, identified with the colors white to light violet on the World Atlas 2015. You can check this value by left-clicking on your position in the web map (see Figure 17).

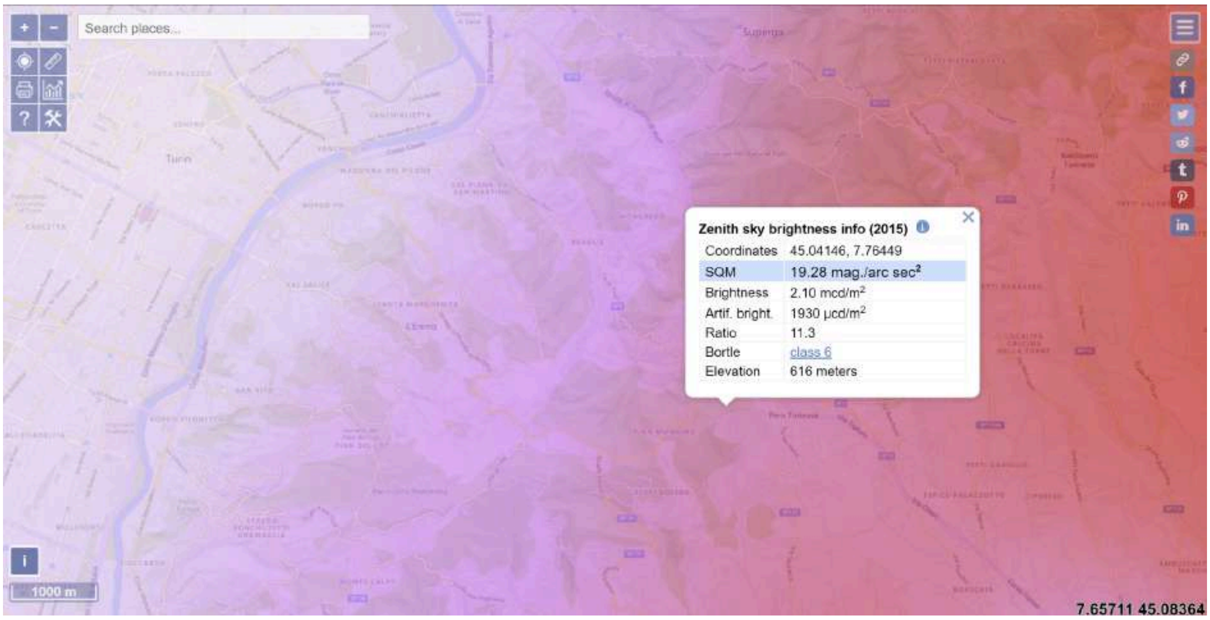

Figure 17 – Checking the classification of the sky quality according to the Bortle Dark Sky Scale on World Atlas 2015 for the Astrophysical Observatory of Torino, on the hills East of Torino in the municipality of Pino Torinese. The site is in class 6 (bright suburban area), with a naked eye limiting magnitude between 5 and 5.5 mag. These conditions are enough to ensure that the StAnD Meteor Camera Kit can work properly. Sites in the class 8-9 should be avoided. Credits: Light Pollution Map, World Atlas 2015 - link

Of course, installation sites with lower light pollution are preferable. More importantly, you should check that there are **no direct light sources** (light poles, signs...) pointing toward the camera or that can produce diffuse light in its vicinity (~50 m from the camera)

3.1.3. Camera Mounting

The mounting system of the all-sky camera can be adapted to an installation on a flat surface (e.g. on a rooftop terrace), an inclined surface (e.g. on the roof), or on a pole (see Section 3.2). The **mounting on a pole must be avoided** if there are other viable solutions. In this case, the camera will be more **subject to vibrations due to wind**.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

The camera should be **leveled** (parallel to the ground), and the mounting should be **as stable as possible** (for both hardware integrity and stability of the calibration).

3.1.4. Mini-PC and Network Switch Positioning

The mini-PC and network switch must be **installed inside a building** (protected from the weather). The Ethernet cable connecting the all-sky camera and switch (E2) can be **a maximum of 20 meters long** (otherwise the connection delay between the camera and PC is too large), and the one provided in the kit is 5 m long.

Therefore, another Ethernet cable of **maximum length of 15 m can be added**, using the junction box and the RJ4 couple provided in the kit (Figure 10, B6 and B7).

3.1.5. Internet Connection and Power Supply

There must be an **Internet connection** and at least **two power sockets** available in the room where the mini-PC and network switch are installed. The electric grid should guarantee the **continuity of the power supply**. If either the mini-PC or the network switch is disconnected, the kit will stop working.

The network switch must be connected to the Internet via a **stable connection**; it doesn't have to be particularly fast, but stability is more important to ensure a constant connection to the central servers.The Internet connection has to be delivered by an **Ethernet cable to the network switch**. If this is not possible, you can use an Ethernet dongle with a WiFi antenna (**WiFi/Ethernet bridge** - example). On the network you are using to provide an internet connection to the switch, a **DHCP server** (Dynamic Host Configuration Protocol) must be available to issue the IP address to the mini-PC and the all-sky camera.

3.1.6. Tools Required for the Installation

- one Phillips **screwdriver**;
- a **7 mm wrench** to assemble the all-sky camera mounting system;
- 4 to 8 **wall plugs** to install the all-sky camera mounting system;
- a standard **Ethernet cable** to connect the network switch to the wired Internet connection of the building.

3.2. Installation of the Mounting System of the All-sky Camera

3.2.1. Assembly

The mounting system for the all-sky camera (B) can be assembled in several configurations, depending on the features of the installation site:

a) Installation on level ground is the **most preferable option**, if a flat and leveled surface is available on the rooftop of your building;
b) When installing the mounting system on a wall, you should make sure that said wall will **not obstruct the FoV of the camera**;
c) When installing the mounting system on an inclined surface, pay particular attention to **level the system during installation** (See Section 3.2.2).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

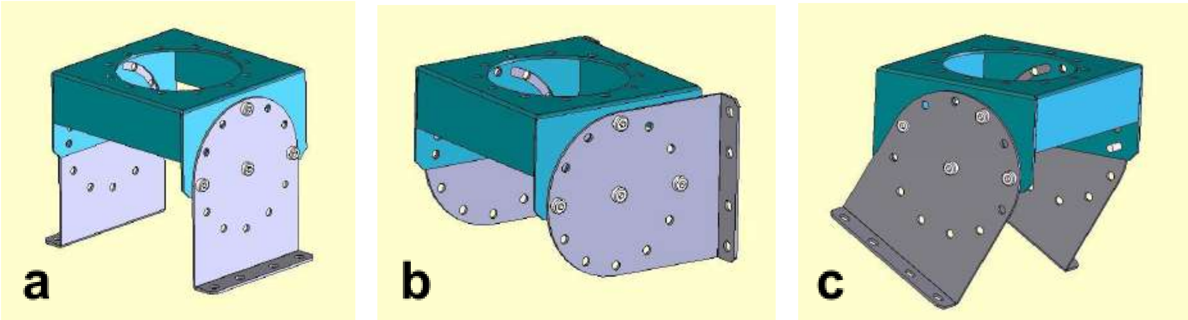

Figure 18 – The assembly options for the mounting system of the all-sky camera provided in the StAnD Meteor Camera Kit. From left to right: on level ground (e.g. terrace), on a wall (top of the side wall of the building), and on an inclined plane (e.g. roof). Credits: FRIPON - link

---

Step 1 - After having identified the suitable configuration, assemble the mounting system as shown in Figure 18. Mount the **two side panels** (**B2**) on the **main body** of the system (**B1**) in the desired position. Use **four M4 bolts**, nuts and rings (**B4a**) per side panel, tightening them with the 7 mm wrench.

The mounting system can be also installed on a pole, as shown in Figure 19. **Do not choose a long mounting pole**. The longer it is, the worse it will be subject to oscillations due to wind and vibrations, which can disrupt the measurements and damage the hardware inside the camera. For pole mounting, follow **steps 1a and 2a**.

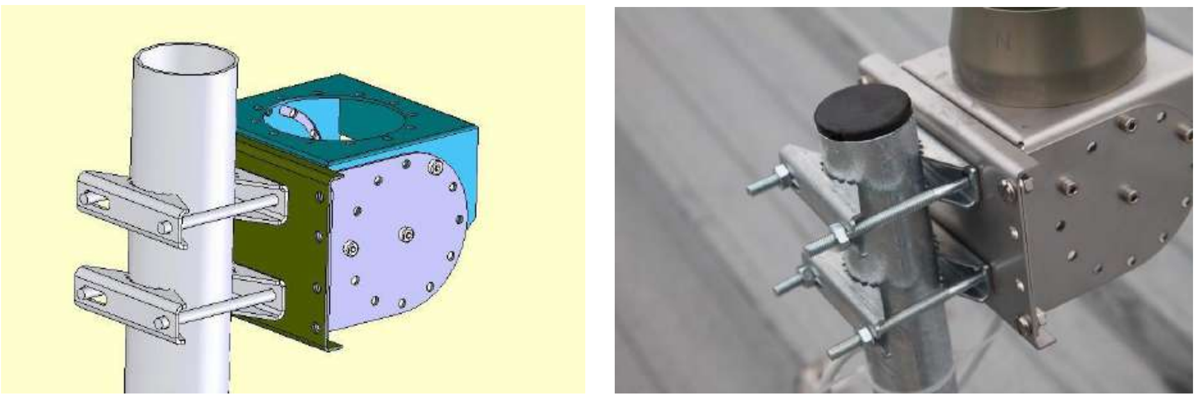

Figure 19 – A scheme of the pole mounting system for the all-sky camera provided in the StAnD Meteor Camera Kit (left) and a picture of the system correctly mounted (right). Credits: FRIPON - link

---

Step 1a - If necessary, attach the **pole mounting plate** (**B3**) to the mounting system. Use **M5 bolts**, nuts and rings (B4b) to attach B3 **to the bottom of the side panels** (**B2**). In this case, the mounting system has to be assembled in the **same way as for wall mounting** (**b**). Then, mount the **two rivets** (**B5**) on the pole and fix them to B3, as shown in Figure 19. Use the 7 mm wrench to tighten every bolt.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

3.2.2. Installation of the Mounting System

At the time of installation, check the following (see also Section 3.1):

- The upper side of the camera mounting system must be horizontal. Check this with a **spirit level**;
- The camera mounting system must be installed so that the **horizon is as clear as possible**;
- The camera mounting system must be **firmly secured** and should not move even in case of strong winds;
- **Avoid sources of turbulence and noise** (e.g. flags, chimneys, antennas) as much as possible;
- **Avoid direct urban lighting**, which may come from unshielded lamps and ball lights, because of the risk of reflections on the objective lens;
- If needed, the **junction box** must be installed in a place **reachable with the 5 m Ethernet cable** that attaches to the all-sky camera.

Step 2 - Fix the assembled mounting system to the floor (Figure 18a), to the wall (Figure 18b), or to the roof (Figure 18c). Use **4 - 8 wall plugs** (2 - 4 per side) to fix the two side panels (B2). The holes on B2 are suitable for **M5 screws**. Use the Phillips screwdriver to tighten the screws.

Step 2a - For pole mounting (Figure 19), fix the **two side panels (B2)** to the **pole mounting plate (B3)** with **4 - 8 M5 bolts** (2 - 4 per side), nuts and rings (B4b). Use the 7 mm wrench to tighten the bolts.

3.3. Installation of the All-sky Camera

During the installation of the all-sky camera (A), pay very close attention not to scratch the camera dome. **Remove the protective film as the very last step of the process**, after the installation of the camera has been completed. The protective case is **hermetically sealed with desiccant** to prevent the formation of condensation inside of it. Therefore, **the camera module must not be opened**.

At this stage, the aim is to install the camera on the camera support and to **bring the Ethernet cable where the control mini-PC (C) and network switch (D) will be located**. It is therefore a matter of completing the installation outdoors, while the next steps will be completely indoors.

The camera support and the protective case have a dozen holes to allow the camera to be **oriented to the North** (within approximately 15°). Before the installation of the camera, check which direction is North in order to position the camera accordingly (see Figure 20).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Figure 20 – A picture showing how to correctly orient the all-sky camera of the StAnD Meteor Camera Kit to the North. The camera protective case has two bolts vertically arranged showing outwards (marked with the red line on the picture), with which the camera module is fixed to the inside of the case itself. Due to the internal arrangement of the components, the bottom portion of the CMOS is always facing this direction. Therefore, if one aligns such direction towards the North, an approximate reference frame can be defined a priori, and all cameras of the network can have the same approximate orientation.

Step 3 - After having identified the North direction and the closest orientation of the camera to match this direction (See Figure 20), secure the **all-sky camera module (A)** to its **support of the mounting system (main body, B1)** with **at least three M4 bolts**, nuts and rings (B4a). Depending on the installation, it may be easier to remove the camera support to secure the camera to it and then reposition it afterward. The short Ethernet cable attached to the camera module has to go through the central hole of B1.

Finally, the **Ethernet connection from the camera module must be delivered inside the building**, to the room in which the mini-PC and network switch will be installed.

Step 4 - After having secured the camera module to its support, **install the waterproof Ethernet RJ4 coupler (E3)**, one side to the short Ethernet cable coming from the camera module, to **join with the 5 m Cat6 Ethernet cable (E2, see Figure 15)**. Then, **secure the Ethernet cable** to the pole, floor, or roof (depending on your installation configuration) according to the safety requirements of your building. The cable must **reach the room in which the mini-PC and network switch** will be installed.

3.3.1. Installation of the Junction Box

It may happen that the 5 m Ethernet cable (E2) provided is not long enough to reach the room in which the mini-PC and network switch will be installed. Then, there are two options to solve this problem.

The first option is to **replace the provided Ethernet cable** with another one that is long enough to reach the said room. In doing so, make sure that the new cable **fulfills the requirements** (Cat6, suitable for outdoor installation, LZSH fireproof). It can have a **maximum length of 20 m**.

Otherwise, a **junction box (B6)** is provided and can be mounted outdoors to extend the Ethernet cable provided in the kit to a **maximum additional length of 15 m**. The junction box serves to protect the junction between the two Ethernet cables by the **female-to-female Ethernet RJ45 coupler (B7)**.

The junction box has to be installed in a place reachable with the 5 m Ethernet cable provided in the kit. It should preferably be **vertically fixed** (on a wall). At least two screws are required on the inside of the junction box in order to fasten it to the wall. In order to prevent

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

rainwater infiltration, the junction box must be placed so that the **holes through which the cables will pass face downwards** (see Figure 21). All holes (both for fixing the junction box to the wall and for passing the cables) are sealed and must be pierced with scissors or a screwdriver before or during the installation.

Figure 21 – Pictures of a correct installation of the junction box (B6) provided in the StAnD Meteor Camera Kit to extend the 5 m Ethernet cable with a second one. The junction box has to be installed vertically and the cables are to be inserted from the bottom holes, to avoid water infiltration. Credits: FRIPON - link

---

Step 4a - If needed, **install the junction box (B6)** in a vertical configuration (e.g. on a wall) and in a place reachable **within 5 m from the camera module**. Remove the top panel (by unscrewing the 4 screws at the corners) and use at least two wall screws with plugs (not provided) to secure the box to the wall. After having pierced the two bottom holes of the junction box, let the **two Ethernet cables** (**E2** and the extension cable) join into the junction box through the **female-to-female Ethernet RJ45 coupler (B7)** as shown in Figure 21**.**

3.4. Installation of the Mini-PC and Network Switch

Provided that the Ethernet cable from the camera module now reaches the room where the rest of the hardware of the Meteor Camera Kit will be located, it is now necessary to install the control mini-PC (C) and the network switch (D). Both these components are almost **self-installing**. The two main steps are the connection of both components to the power supply and the Ethernet connection through the network switch (see Figure 22).

Step 5 - Connect the **control mini-PC (C) and the network switch** (D) to the power supply through their **respective power adapter (C1 and D1, be careful not to mix them)**. Both plugs of the power adapters have to be inserted into the respective power input (see Figure 12 and 14). The **power LEDs for both devices will start blinking**. If the power LED does not blink on the mini-PC after few seconds, press the power button. The network switch does not have a power button and it always turns on when plugged into the power socket).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Step 6 - Three Ethernet cables have to be connected to the network switch. The ports order is not relevant but, referring to Figure 22:

- port 1 - Ethernet cable coming **from the Ethernet wall plug** (delivering the Internet connection of the building);
- port 3 - Ethernet cable **(E1) connecting the mini-PC to the network switch**;
- port 5 - Ethernet cable **(E2) coming from the camera module** installed outside.

If a port is plugged in and the communication via the Ethernet cable is fine, the corresponding **Ethernet LED** (see Figure 14) will be turned on with a green (the port is running at 1000 Mbps) or orange/amber (10 or 100 Mbps) light, and blinking if transferring data. **LEDs 3 and 5 should always be green while LED 1 may be orange** if the Internet connection of the building is slower. This is not an issue. However, if LEDs 3 and/or 5 are orange, there might be some issues with the Ethernet cable installation. If some LEDs are not turning on, try to reconnect the cable and switch off/on the corresponding device.

Finally, to check if the camera module is correctly powered via PoE, **press the "Mode" button on the front of the network switch** for about 1 second (see Figure 14). LEDs 1 and 3 should be turning off, and **only LED 5 should remain on with a green light**. This indicated that the power supply to the camera module is ok and stable. To go back to the previous LED configuration, press the "Mode" button again.

Figure 22 – Desk installation of the StAnD Meteor Camera Kit (top panel), picturing that the camera module is installed outside, and with connection specifics (bottom panels). For this installation, the Ethernet cables are plugged into the network switch as follows (bottom right panel). The Internet network is plugged in on port 1, the Ethernet cable from the mini-PC on port 3, and from the camera module on port 5. LEDs 1, 3 and 5 of the network switch are correctly lit up (bottom centre panel) and, when pressing the "Mode" button, only

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

LED 5 is on (bottom centre panel), all with green light. An orange/amber light might indicate a slower connection.

3.5. First Boot of the StAnD Meteor Camera Kit

If everything was installed correctly, **the StAnD Meteor Camera Kit is already working** and nothing else needs to be done with the hardware components.

The final crucial point is to check the Internet connectivity of the kit, ensuring that it is **correctly communicating with the central PRISMA servers**. To do so, it is best to get in touch with your StAnD contact point. For more details about how to connect to the StAnD Meteor Camera Kit locally and from remote, please refer to Chapter 4.

All components are configured to **automatically switch back on** if there is a power shortage, or simply if you plug them off the grid to transfer them somewhere else. However, it is best to always **check the status of the LEDs** after performing these operations and, if needed, force the reboot of the mini-PC by pressing the power button. To have further details about the maintenance of the kit, please refer to Section 4.4.

From the point of view of the software, some intervention might be needed to **complete the installation after the first boot**.

Step 7 - To ensure the correct connectivity and operativity of the StAnD Meteor Camera Kit, you should **get in touch with your IT department** (i.e., the person in charge of managing the Internet network of your building) and **ask to open the following ports of the firewall**:

- **port 1194 / UDP (OpenVPN protocol)**, used for the VPN (Virtual Private Network) connection to the central server of PRISMA;
- **port 80 / TCP (HTTP protocol)**, used to access the StAnD Meteor Camera Kit through its web browser interface;
- **port 443 / TCP (HTTPS protocol)**, used to deliver the updates to the kit.

Depending on the time you received the kit, **some software updates might be required** to ensure its full functionality. Get in touch with your StAnD contact point to know more and schedule the intervention, if needed.

---

4. User Guide

This chapter aims to discuss how to **access the StAnD Meteor Camera Kit** on your local network and from remote, how to operate the kit through the provided **browser user-friendly interface**, how to **access the data** recorded by the kit and of the whole StAnD network, and how to **maintain the hardware and software** to ensure the best preservation and operativity of the kit through time.

Within the PRISMA and StAnD network, each kit (i.e., each **station or node of the network**) is uniquely identified by a **station code**. An example of such a code is “**ITPI01**”, for which:

- **IT** stands for the country (e.g. Italy);
- **PI** stands for the region (e.g. Piemonte);

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

- **01** is a progressive numbering of the stations in that region.

Alongside the code, each node is also identified by a **station name**, usually referring to the city or village where the station is located. For example, the PRISMA station ITPI01 is also called “PinoTorinese”.

4.1. How to Access the StAnD Meteor Camera Kit

The StAnD Meteor Camera Kit can be accessed by **connecting to the mini-PC**, which is the “brain” of the whole system. Knowing the **IP address of the Mini-PC**, access can be made from another PC, laptop, or mobile device through any web browser via a user-friendly interface. There are **two IP addresses** from which the mini-PC can be reached in such a way:

- The **local IP address**, i.e. the address of the mini-PC within the local network of the building, to which the mini-PC is connected through the Ethernet cable going through the switch from the Ethernet wall plug.
- The **VPN IP address of PRISMA**, i.e. the address through which the PRISMA server reaches the mini-PC. This address never changes but is accessible only if you have access to the PRISMA VPN yourself.

An **IPv4** address is a 32-bit number (for example, 192.168.1.1) divided into four octets (192, 168, 1 and 1)**.** The first three octets refer to the “**network class**” (i.e., 192.168.1). Very roughly speaking, the devices plugged in the Ethernet ports in the same room (e.g. classroom) should all share the same network class.

4.1.1. Finding the Local IP Address of the mini-PC

Through the local IP address, one can reach the StAnD Meteor Camera Kit only from the local network, i.e. if the computer of the user is connected to the same network to which the mini-PC is connected. Be aware that this IP address **can vary over time** (with a period of a couple of hours to a few days) if the local network is managed through a DHCP server (dynamic IP), or it can be a fixed IP address (static IP). To understand whether the kit will have a **dynamic or static IP address**, it is best to ask the IT department or person for your building or institution.

If the mini-PC is assigned with a static IP, you can **ask directly to your IT department** to provide you with this address once and for all. Within the network, they might be able to identify the machine by the station code assigned to your kit. If online, the mini-PC will always be reachable through that static IP address.

In either case, to find out the local IP address of the mini-PC, one can perform the following steps:

1) **Plug your computer** (e.g. a laptop) with an Ethernet cable **directly to the network switch** or in an Ethernet port **in the same network class** (usually in the same room, see above). You might not get access to the Internet this way; this is not a problem.
2) Find out the **IP address assigned to your computer**. To do so, on Microsoft Windows OS v. 10/11, go to *Settings > Network & Internet > Ethernet*, scroll down to the bottom of the page and search for the entry *Address IPv4*. Otherwise, open *Windows Terminal* (or *Windows Powershell*), type *ipconfig /all*, press Enter and search for the

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

entry *Ethernet Adapter Ethernet0 / IPv4 Address*. If you have a Linux or Mac computer, open a Terminal window, type *ifconfig*, press Enter and search for *eth0 / inet*. Write down this address. Let us say that the IP address that you have found is: 192.168.137.124

3) Download **Advanced IP Scanner** from the official website (it might be available in your language as well). Install the program on your laptop by following the installer's instructions, and start the program (see Figure 23).

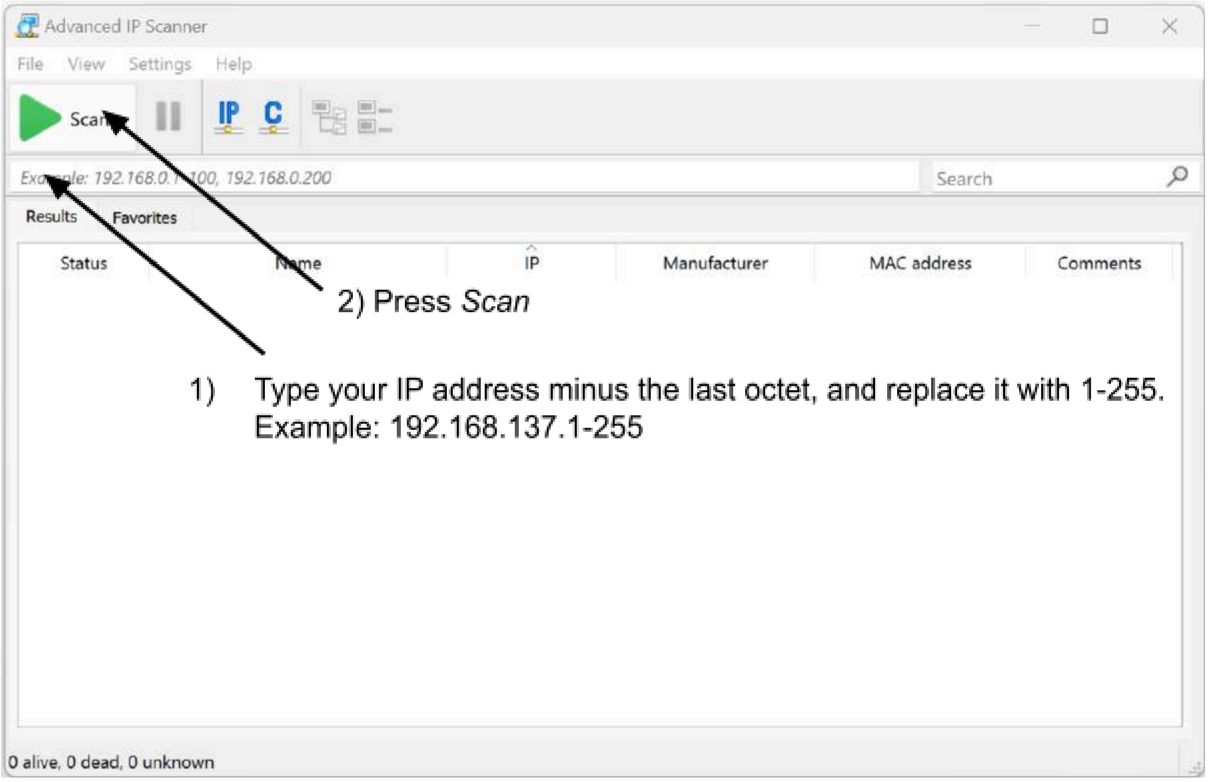

Figure 23 – Starting window of the Advanced IP Scanner program with instructions on how to search for the IP address of the StAnD mini-PC installed on the local network.

4) Enter in the textbox under the *Scan* button the first three octets of the IP address of your laptop, adding the full range for the last octet: **192.168.137.1-255,** and **press *Scan***. Wait about 1 minute to let the program do the network scan.
5) Once the scan is complete, you will have the **list of all the devices** that are plugged into that network. If you plug directly into the StAnD network switch, you should find a few devices. Otherwise, you may find a lot of them. See Figure 24 for an example of such a list displayed on the program.
6) Search for the entries that have a **small arrow on the left side of the IP address**. Those are the machines that you can access. Left-click on them. One of them should display the **code of your StAnD node** (e.g. ELAT01 in Figure 24). That is the IP address of the mini-PC in your local network. You can copy it by right-clicking on the corresponding line and selecting *Copy > IP*.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

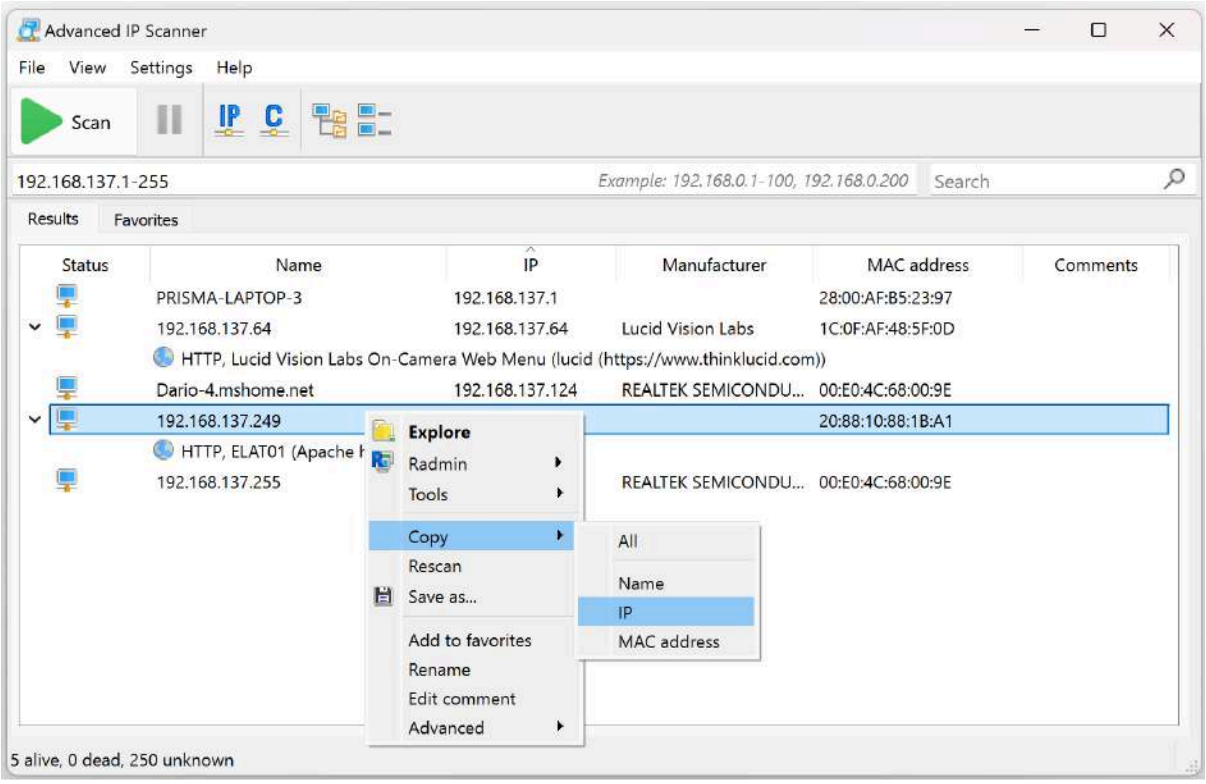

Figure 24 – The result of the network scan to search for the StAnD mini-PC installed on the local network with the Advanced IP Scanner program. To identify which IP address is of the mini-PC, look into all the entries with a small arrow on the left side of the IP and right-click on them. One of them should display the code of your StAnD node (e.g. ELAT01 in this figure). In this case, its IP address is 192.168.137.249.

4.1.2. Connecting to the PRISMA VPN from Remote

If you have access to the VPN of the PRISMA network, you can reach the mini-PC remotely **from your laptop**, provided that you have an Internet connection (which does not filter VPN services). The use of this service is limited to 1 / 2 accesses per StAnD node. Get in **contact with your StAnD contact point** to get more information about this service and to file a request.

Once your request is approved, you will receive a **VPN certificate (.ovpn file)**. **Do not share your certificate with anyone**. Then, follow the next steps:

1) Install **OpenVPN Connect client**. You can **download the installer** from the official website. Install the program on your laptop by following the installer's instructions, and start the program.
2) **Launch OpenVPN Connect** and select *Upload File.* Then, browse to the .ovpn file that you received and select it, then click *Connect*. The imported profile will be saved, and you will be connected to the VPN (see Figure 25).
3) To **disconnect from the VPN, click on the slider**. The next time the client is launched, the imported profile will be there and you will just need to click on the slider again.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

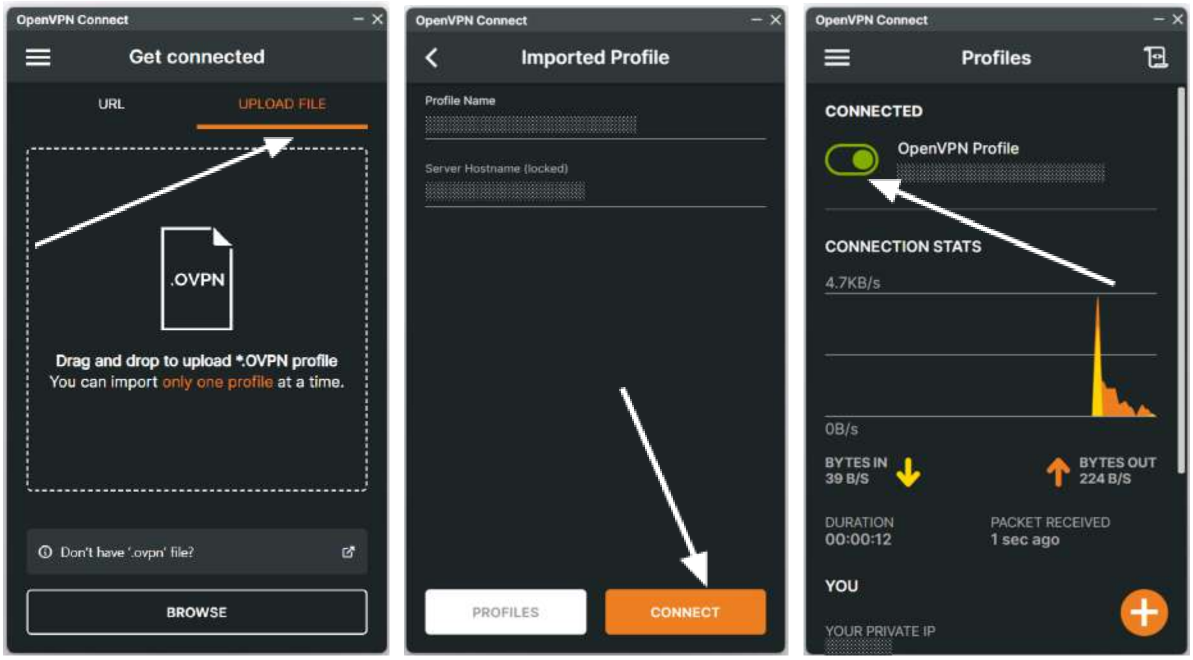

Figure 25 – The interface of the OpenVPN Connect client used to connect to the VPN of PRISMA, with the main steps for the first installation. Import the .ovpn file and click Connect. The imported profile will be saved and, the next time you will launch the client, you will just need to click on the slider to connect and disconnect from the VPN.

If the VPN connection fails, it is most likely that the Internet connection that you are using filters external VPN services. Get in contact with the IT manager
Once you are connected to the VPN, to know the IP address of your StAnD mini-PC, **ask your StAnD contact point**. This address will never change over time.

4.1.3. Accessing the mini-PC from Local or Remote

If you have access to the VPN of the PRISMA network, or you are connected to the local network on which the StAnD mini-PC is connected, **open a web browser**, type the IP address of the mini-PC into the address bar and press Enter. If the connection is successful, you will be presented with the **login page of the StAnD Meteor Camera Kit** (see Figure 26).

If you do not know your login credentials yet, get in touch with your StAnD contact point. There are **two levels of authentication**:

- **Guest** credentials: the user can access, visualize, and download the data acquired by the kit;
- **Admin** credentials: the user has all the privileges of a guest user but can also configure and operate it (turn on and off, reboot, start, and stop acquisitions) and modify the login credentials of authorized users.

You can **select the language** on the right upper corner of the page. **Enter your credentials** and press *Log in*. If nothing happens, you have probably entered the wrong credentials.

Every web browser should work fine. However, the best performance is usually granted by the Mozilla Firefox web browser.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Figure 26 – The login page to access the StAnD Meteor Camera Kit from a web browser.

4.2. Browser Interface Description

Once logged in, the browser will show the StAnD Meteor Camera Kit homepage (see Figure 27) which presents the main functionalities of the kit. The elements of the homepage are the following:

- Statistics of **number of detections** in total, of last month and of today;
- **Map** of the station position;
- **Last detected image**;
- Tables of **station data** and today's detection;
- Summary of **node status** (error log and VPN connection status);
- **Data usage** (CPU, RAM and storage of the mini-PC);
- Sidebar **menu options**:
    - Users (users management area) - available to admin only;
    - Containers status (execution of Freeture) - available only to admin;
    - Freeture configuration (update the configuration) - available to admin only ;
    - Maintenance (reboot option) - available to admin only;
    - Calibrations (calibrations data) - available to admin and guest;
    - Stacks (stacks data) - available to admin and guest;
    - Detections (meteors data) - available to admin and guest.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

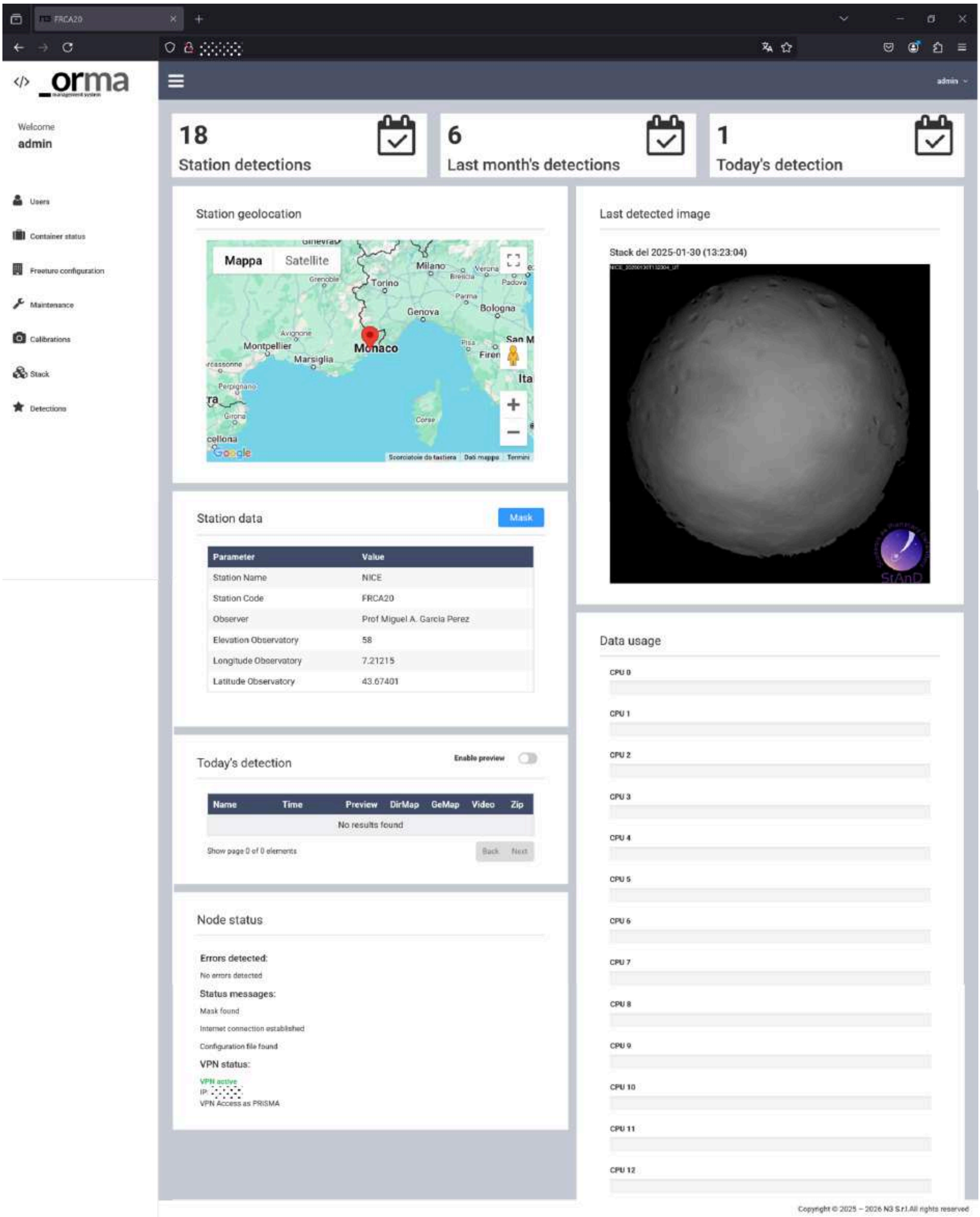

Figure 27 – The homepage of the web browser interface of the StAnD Meteor Camera Kit, illustrating the status of the operation of the kit. The sidebar menu options link to the other web pages of the interface. Only the last three are available to a guest user (to download the data), while they are all available to an admin user.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

In the following sections, the functionality of the kit is detailed by illustrating the content of the web pages linked to the **sidebar menu options**.

4.2.1. Users

This page is available only if you login as **admin**. See Figure 28 for an example of it.

It lets you **modify the password of the users** (guest and admin). To do so, select the user for whom you want to change the password. Press the *Modify* button that pops up near the *Change password* title, then enter and confirm the new password, and press *Confirm*. Wait for a confirmation message (in a green textbox) to pop up at the top right corner of the screen. Otherwise, select *Cancel* to undo the ongoing change.

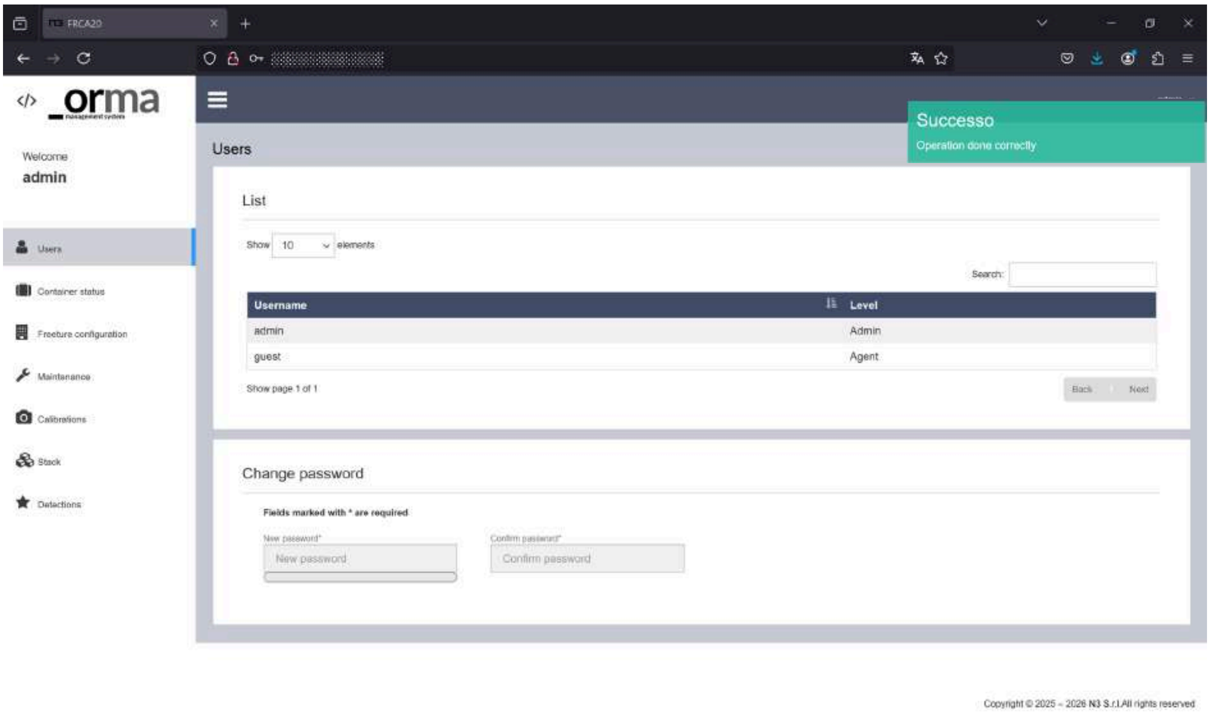

Figure 28 – The *Users* page of the web browser interface for the StAnD Meteor Camera Kit (only available if you login as admin). The green textbox is reported as an example of the confirmation message that the user should receive after a successful operation (e.g. changing an user's password).

4.2.2. Containers Status

This page is available only if you login as **admin**. See Figure 29 for an example of it.

It lets you **monitor and modify the execution status of the Freeture container**, which is the program that runs and controls the whole operativity of the kit (acquisition schedule, trigger for meteor detection, etc…). If can monitor the status of the container under the *List* section. The status can be:

- **Up** - the Freeture container is running;
- **Exited** - the Freeture container is paused (the data acquisition is stopped);
- **Restarting** - the Freeture container is rebooting (recently restarted or rebooting to load a configuration change, see Section 4.2.3).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

You can **start, stop or restart the container** through the **three buttons** available on the right side of the status column. After pressing the corresponding button, wait for a confirmation message (in a green textbox) to pop up at the top right corner of the screen. For example, you might want to stop the execution of the Freeture container if you plan to perform some maintenance on the camera installation without unplugging the whole kit.

Under the section *Freeture logs*, the user can monitor the details of the last operations performed by the kit, and **download the log** by clicking the *Download* button.

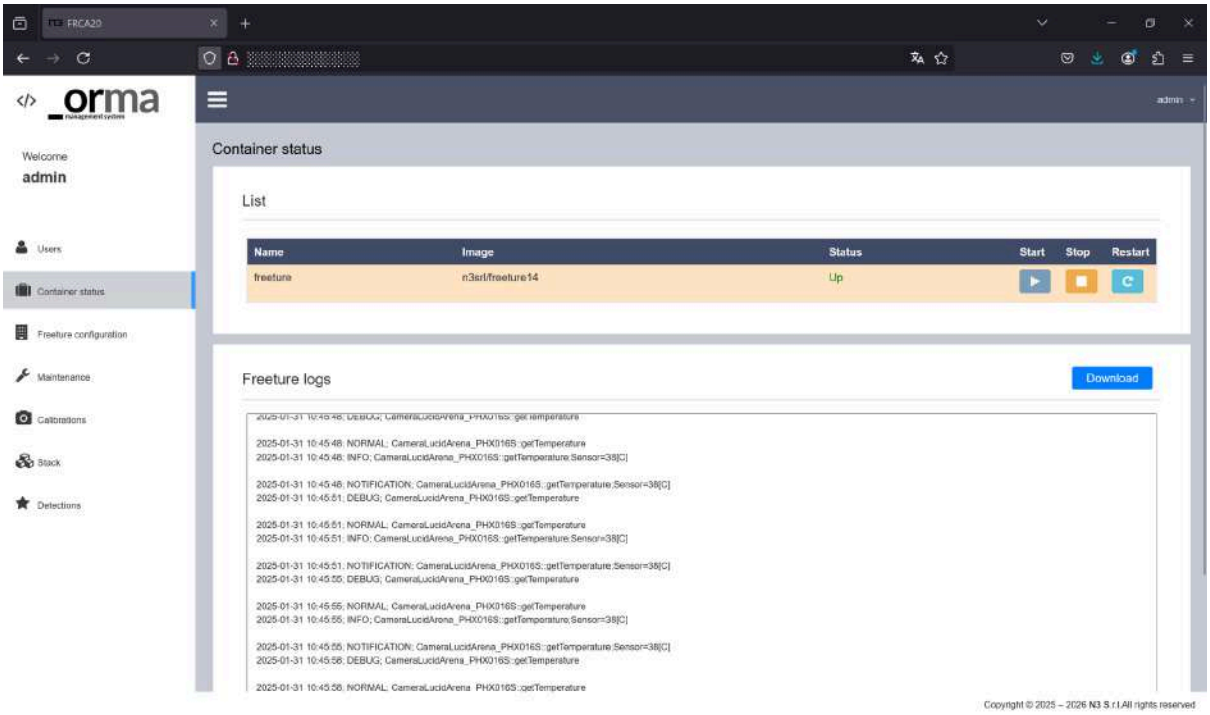

Figure 29 – The *Containers status* page of the web browser interface for the StAnD Meteor Camera Kit (only available if you login as admin).

4.2.3. Freeture Configuration

This page is available only if you login as **admin**. See Figure 30 for an example of it.

It lets you **modify the configuration parameters** of the Freeture program executing on the kit through three sections.

The first section is *Load file* and **allows you to modify the whole configuration file**, with the option *Upload new Freeture configuration file*, and to **upload a new mask file**, with the option *Load new mask*. The first options should be used for **debug purposes only** and by skilled users (it requires to manually modify the field on the config file but may crash Freeture if not configured correctly). On the other hand, the second option is used to upload for the first time or modify the mask used by Freeture to **filter false positives** at the horizon of the all-sky camera (see Section 4.3.1). For both options, select a new file with the dedicated button, press the *Load* button on the right side of the file textbox and wait for a confirmation message (in a green textbox) to pop up at the top right corner of the screen.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

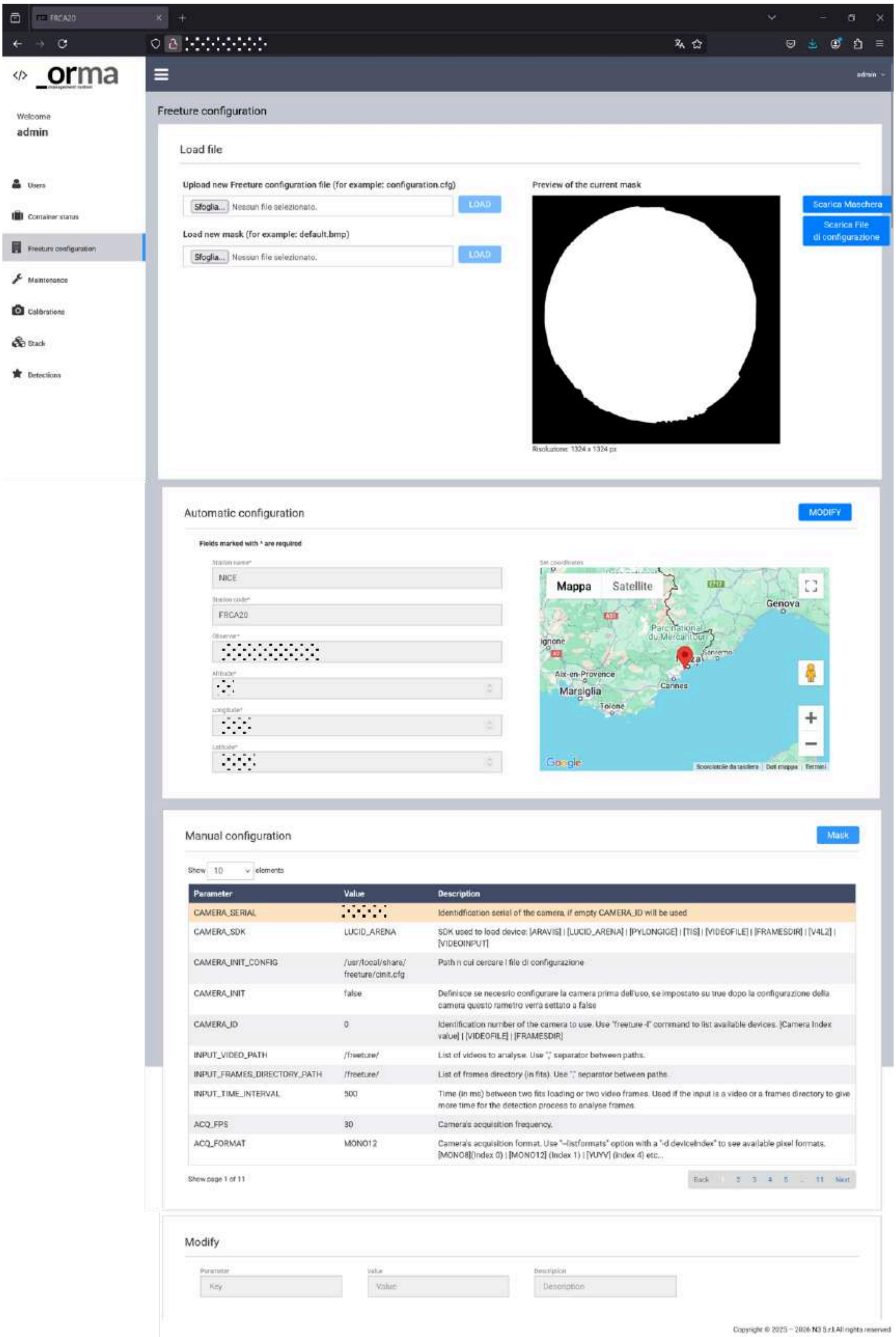

Figure 30 – The *Freeture configuration* page of the web browser interface for the StAnD Meteor Camera Kit (only available if you login as admin).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

In the second section, *Automatic configuration*, you can **modify the most important parameters of the kit**:

- **Station name and code**: please do not modify these entries by yourself. If you think they are wrong, get in touch with your StAnD contact point first;
- **Observer**: the name of the person in charge for the kit;
- **Altitude**: the altitude from the sea level of the all-sky camera installation position, measured in metres;
- **Longitude**: the geographic longitude of the all-sky camera installation position, measured in decimal degrees (E), with at least 4 - 5 decimal digits;
- **Latitude**: the geographic latitude of the all-sky camera installation position, measured in decimal degrees (N), with at least 4 - 5 decimal digits;

To modify one or more parameters, click the Modify button and edit the corresponding fields. Once you made all the changes, press Save and wait for a confirmation message (in a green textbox) to pop up at the top right corner of the screen.

At the first installation, **check the geographical coordinates with a GPS** (the typical precision of a **smartphone** should be ok, otherwise check the position on **Google Maps**). If you need to move your camera, get in touch with your StAnD contact point first, and then change the coordinates on this page.

The last section is *Manual configuration* and let you **modify all the parameters** enclosed in the configuration file of Freeture. The table can show 10 - 100 elements at once and gives an overview of the parameters, their corresponding values and a short description for each parameter. When first delivered, the camera will be **already configured for its normal working conditions**. Every modification of these parameters (apart from the ones listed in the Automatic configuration section) may disrupt the working flow of the camera, and **the user takes responsibility for it when performing such modifications**.

4.2.4. Maintenance

This page is available only if you login as **admin**. It lets you reboot the whole system by clicking the (only) red button *Start the reboot*. You will need to **login again into the browser interface after the reboot** is complete. Be aware that a reboot might change the local IP address if it is managed as dynamic.

4.2.5. Calibrations

This page is available to **both admin and guest**. See Figure 31 for an example of it.

It lets you **preview and download the calibration data** (also called **captures**), which are images taken with the camera exposed for **5 seconds every 10 minutes** during the day and night. Captures are acquired because the exposure time of the meteor videos (detections, see Section 4.2.7) is not enough to image stars, which are needed to **perform the astrometric and photometric calibration of the camera**.

The first section, *List*, of the page displays two interactive tables to let you **browse through the calibration data**. The first table displays the last 10 days of acquisition (you can scroll back in time with the page Back / Next buttons) and the number of captures acquired during each day. A regularly functioning camera should acquire **about 144 captures per day**.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Co-funded by
the European Union

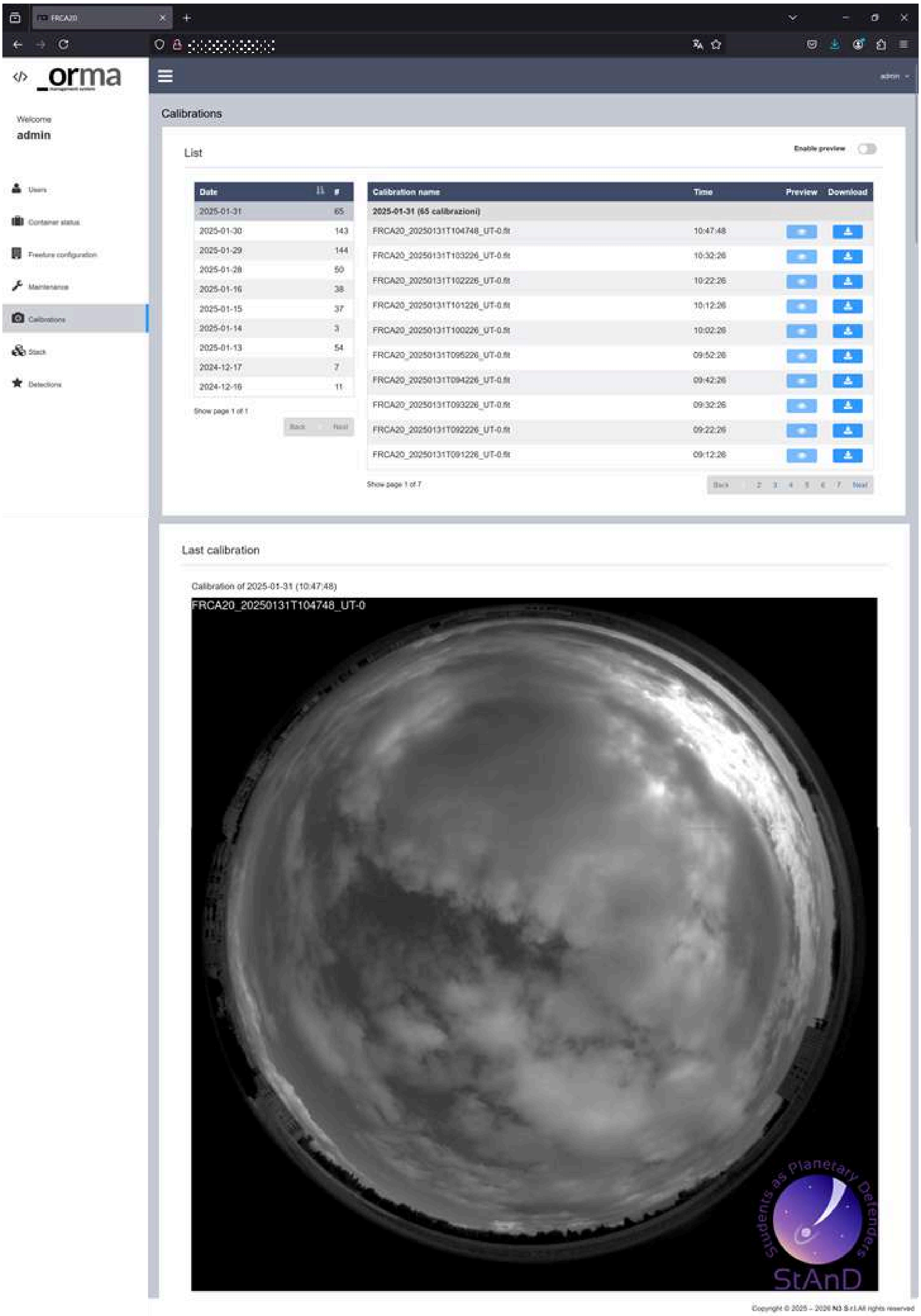

Figure 31 – The *Calibrations* page of the web browser interface for the StAnD Meteor Camera Kit (available to both admin and guest users).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Co-funded by the European Union

By clicking on one entry of the first table, you select that particular day and display in the second table, on the right side, all the captures acquired during that day. Each entry reports the name of the image (in .fit format), the time of acquisition, and two buttons to **preview and download the image**.

The **preview must be enabled** beforehand with the dedicated slider on top of the table. You can download the preview (.png format) by right-clicking on the image on your browser and selecting the *Save image* option. Since the previews are generated on request and make use of some computational power of the mini-PC to be produced, it is **strongly recommended to not generate previews during night-time**. The preview generation can be disabled by the admin (see Section 4.3).

The second section of this page is *Last calibration* and displays the **preview of the last capture** acquired by the camera.

Captures are **preserved on the mini-PC for about two months**. After this time, they are erased to free disk space for the new acquisitions. If the station is correctly online, captures are **continuously synced to the PRISMA servers**, on which they are stored and processed.

4.2.6. Stacks

This page is available to **both admin and guest**. See Figure 32 for an example of it.

It lets you **preview and download the stack data**, which are data generated by stacking (i.e. summing) the images acquired by the meteor detection algorithm (30 fps, see Section 4.2.7) in 1 minute. Therefore, each stack image is the **sum of 1800 frames acquired at 30 fps**.

The layout of this page is the same as the one of the captures data (see Section 4.2.5).

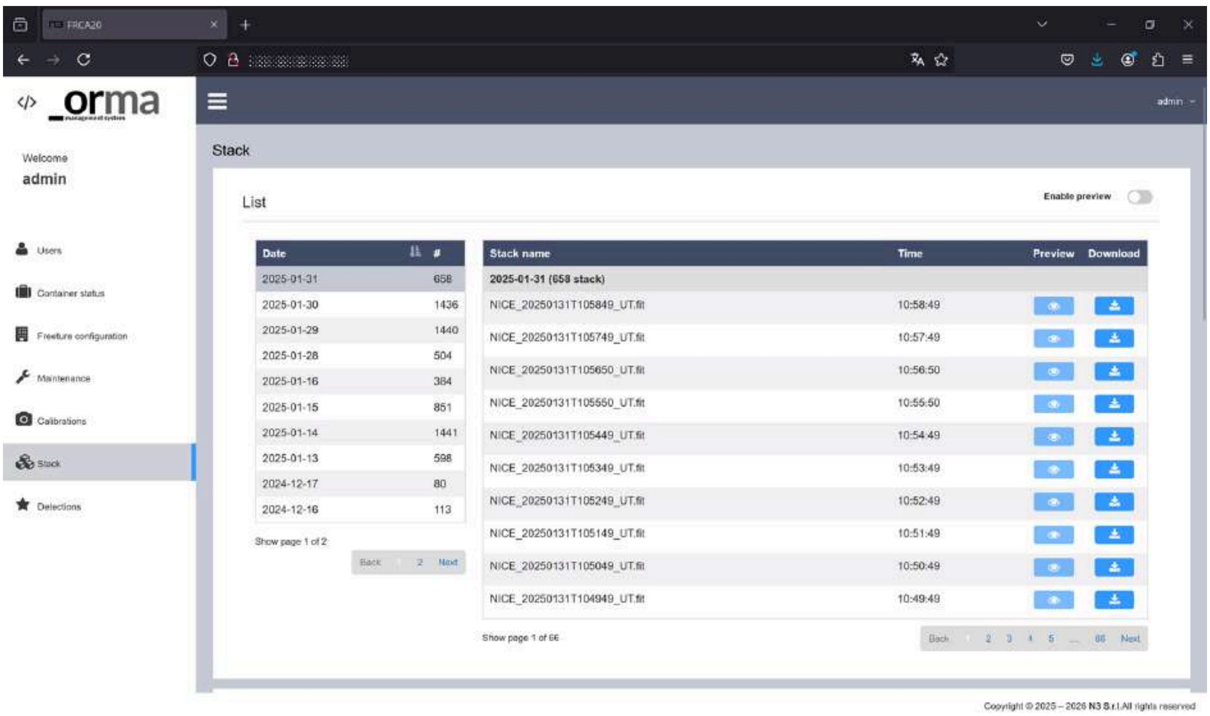

Figure 32 – The *Stack* page of the web browser interface for the StAnD Meteor Camera Kit (available to both admin and guest users).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

You can download the preview (.png format) by right-clicking on the image on your browser and selecting the *Save image* option. Since the previews are generated on request and make use of some computational power of the mini-PC to be produced, it is **strongly recommended to not generate previews during night-time**. The preview generation can be disabled by the admin (see Section 4.3).

Stack images are saved to have live-time feedback of what is happening within the FoV of the camera, but are not included in the scientific processing. Therefore, they are **not synced to the PRISMA servers**. Stacks are **preserved on the mini-PC for about two months and erased afterward**.

4.2.7. Detections

This page is available to **both admin and guest**. See Figure 33 for an example of it.

It lets you **preview and download the detection (meteor) data**, which are videos of meteors captured by the Freeture software. As already mentioned, the camera is continuously operated at 30 fps to check for the passage of meteors in its FoV. This is done by an **automatic trigger software** operating within Freeture, which checks (during night-time) for the presence of **fast-moving bright sources** in subsequent images on the 30 fps video stream, which may be meteors or fireballs. In such a case, Freeture saves the portion of the video over which the meteor was detected.

The layout of this page is similar to the one of calibration and stack data. The first section, *List*, lets you **browse the list of detections during each day**. For each detection, you can preview and download the following:

- Preview: an integrated image of the video, over which the meteor track should be visible (see Figure 34);
- DirMap: an image with dots indicating the estimated and approximated position of the meteor within each frame during the video, computed by the trigger algorithm (see Figure 34);
- GeMap: a black-white image indicating the region in the frame where the meteor was detected by the trigger algorithm (see Figure 34);
- Video: a video of the meteor generated by the browser interface in .mkv format;
- Zip: the data of the meteor detection acquired by Freeture in .fit format.

You can download the preview (.png format), DirMap and GeMap (.bmp format) by right-clicking on the image on your browser and selecting the *Save image* option. The preview generation can be disabled by the admin. Also, the **download of video and zip files must be activated by the admin** (see Section 4.3). Since the previews and videos are generated on request and make use of some computational power of the mini-PC to be produced, it is **strongly recommended to not generate previews and download videos and zip files during night-time**.

Being an automatic software, detections **may contain false positives**, that is, a detection may be due to other natural or artificial events occurring in the FoV of the camera. For example, the **lights of a car passing by** may trigger a detection on the horizon of the camera in a

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

particularly dark observational site, if not filtered by the application of a mask (see Section 4.2.3 and 4.3.1).

Detections are **preserved on the mini-PC for about two months**. After this time, they are erased to free disk space for the new acquisitions. If the station is correctly online, detections are **continuously synced to the PRISMA servers**, on which they are stored and processed.

The second section of this page is *Last detection* and displays the **preview of the last detection** captured by the camera. On the right side, you can also see a graph of the number of detections made during the last days.

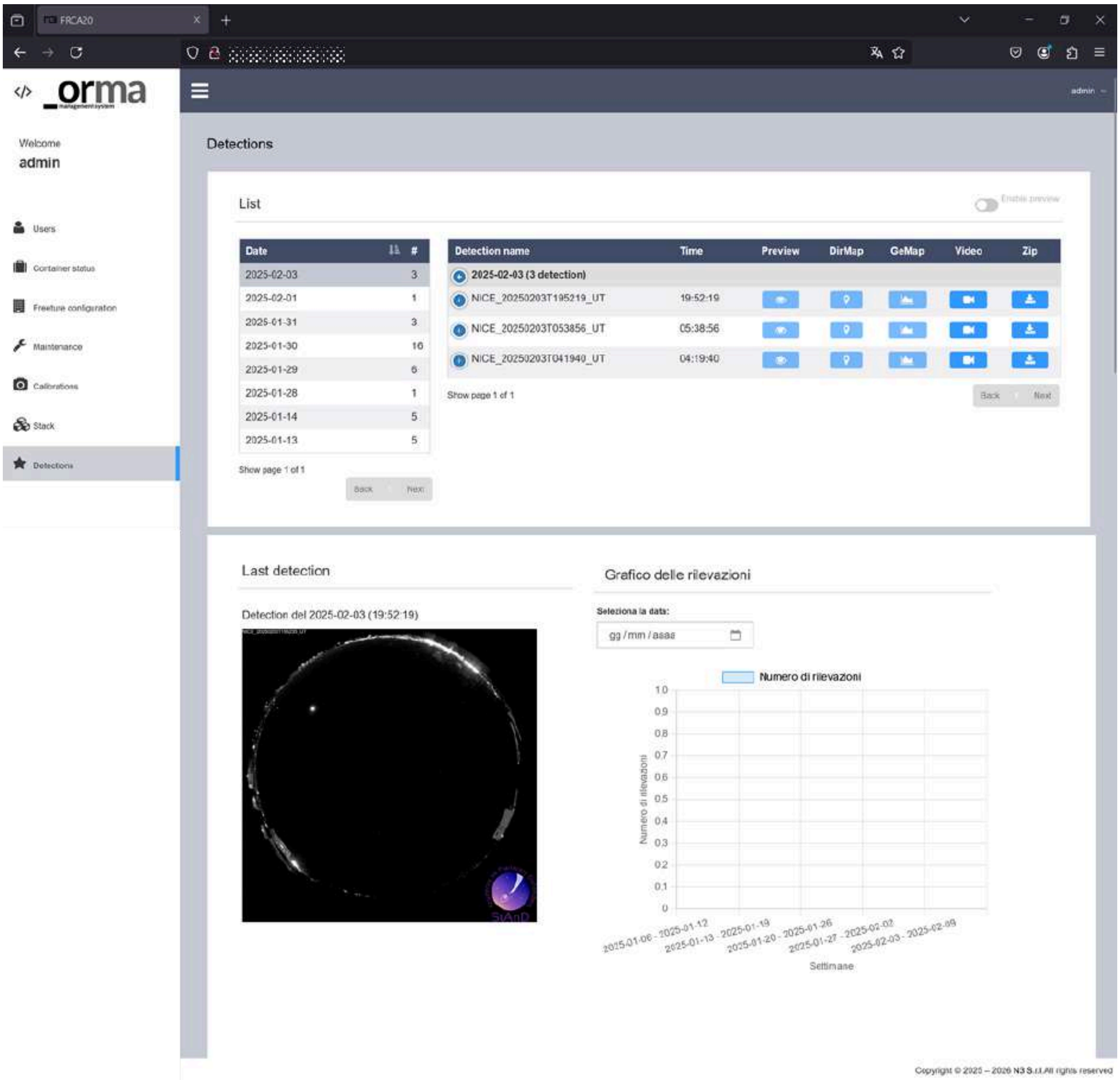

Figure 33 – The *Detections* page of the web browser interface for the StAnD Meteor Camera Kit (available to both admin and guest users).

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Co-funded by
the European Union

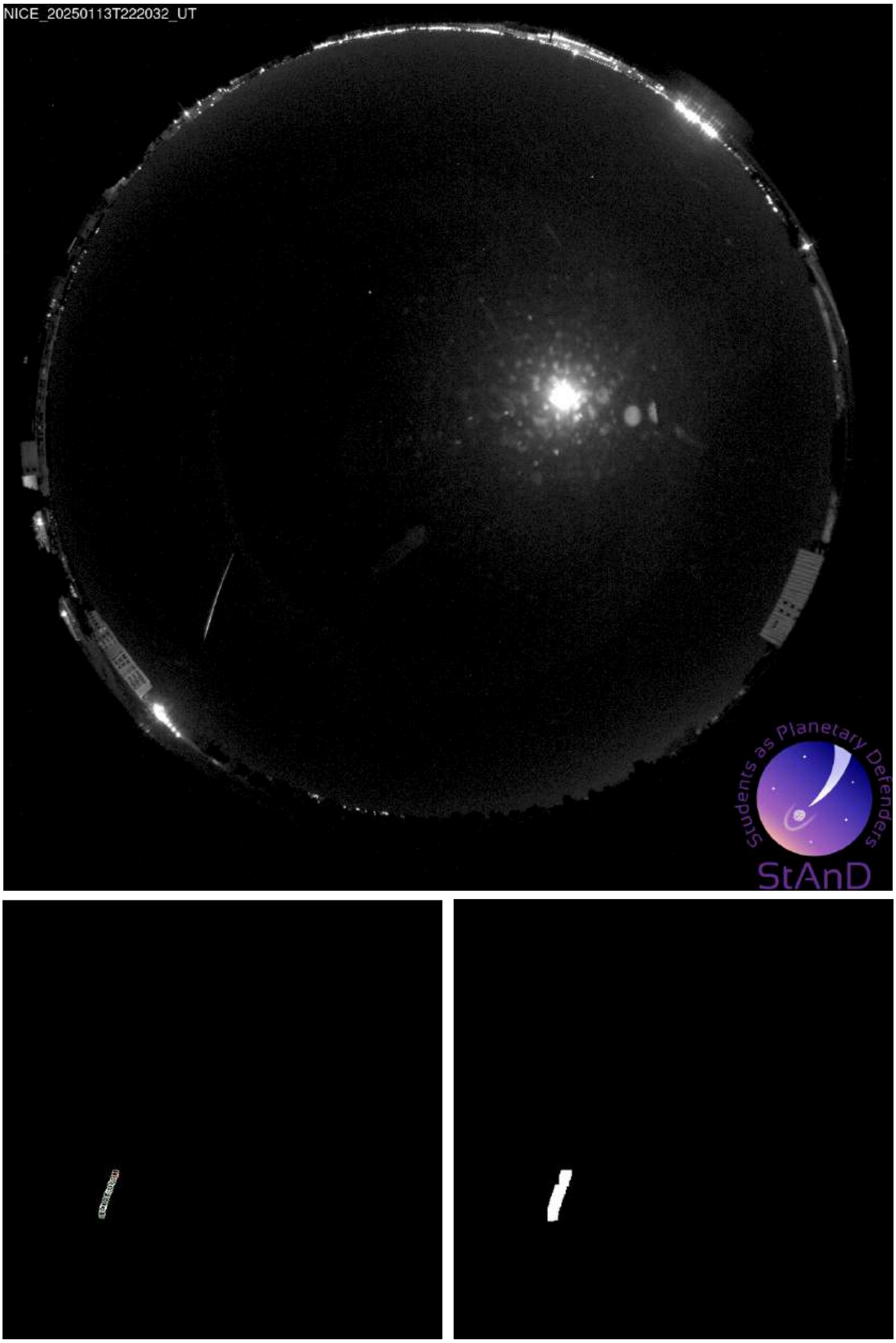

Figure 34 – An example of preview images for a detection made by the FRCA20 - Nice camera of the StAnD network on 13th January 2025 at 22:20:12 UT. The top panel displays the meteor track from an integrated image of the video, while the bottom panels display the DirMap (left) and GeMap (right) bitmaps, on which one can observe the approximated position on the frame of the meteor detected by the trigger algorithm.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

4.3. Maintenance of the Kit

4.3.1. Detection Mask

After the first boot of the StAnD Meteor Camera Kit, once you verified that the kit is connected correctly to the Internet (see Section 3.5), you will need to **update the detection mask to minimize the number of false positives** detected by the Freeture trigger software (see Section 4.2.3 and 4.2.7). Such detections are due to various artificial sources and typically happen at the horizon of the FoV, for example due to flickering lights or cars passing by during night-time.

An increased number of false positives in the detection dataset might cause the **HDD of the mini-PC to fill up faster than two months**, resulting in a lower performance of the kit and in a shorter timespan before data are erased from the mini-PC locally.

Depending on the configuration parameters (see Section 4.2.3), it may also happen that **Freeture will not start correctly without a mask being uploaded**. In this case, if you would like to start the operation of the kit regardless, login into the browser interface, go to *Freeture configuration* and change the parametre **ACQ_MASK_ENABLED to false** (under the **Manual configuration** section of the page). Remember to **set this parametre back to true** after having uploaded the mask.

The detection mask has to be an **8-bit black-white .bmp image** with the same resolution of the frame acquired by the camera. In this image, the **black portion will mark the region where triggers should be excluded by Freeture**, and the white portion will be the region where the software will look for triggers.

The detection mask needs to be uploaded after the first installation of the kit, if you move the camera installation position or if you modify the orientation of the camera. To do so:

- you can **ask to your StAnD contact point** to do it for you;
- If you wish to do it yourself, you can **download a night-time capture preview** from the browser interface and use it to create your own mask. You can modify it by using any image manipulation program, such as GIMP. You can follow these steps:
    1) After having installed this software, launch it and select *FIle > Open* from the menu bar, and select the downloaded .png capture preview;
    2) You can use the *Free Selection (Lasso)* tool to **highlight the area to be masked** (i.e. the border of the horizon to be masked, see Figure 35);
    3) Once you are done, press *Enter* and **sharpen the border of the selection** (*Select > Sharpen* from the menu bar) and **fill it with white color** with the *Bucket Fill* tool;
    4) Then, **invert the selection** (*Select > Invert* from the menu bar) and **fill it with black color** with the *Bucket Fill* tool;
    5) Go to *Image > Mode* from the menu bar and select *Grayscale mode*, then again *Image > Precision* and select *Integer 8-bit*;
    6) To **export the image**, go to *File > Export as* to save the image, select the .bmp format and save it on your computer;

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

Co-funded by
the European Union

7) Finally, you can **upload it through the browser interface** (as admin) and, if needed, reset the Freeture parameter ACQ_MASK_ENABLED to true in the Manual configuration of the Freeture configuration page (see Section 4.2.3).

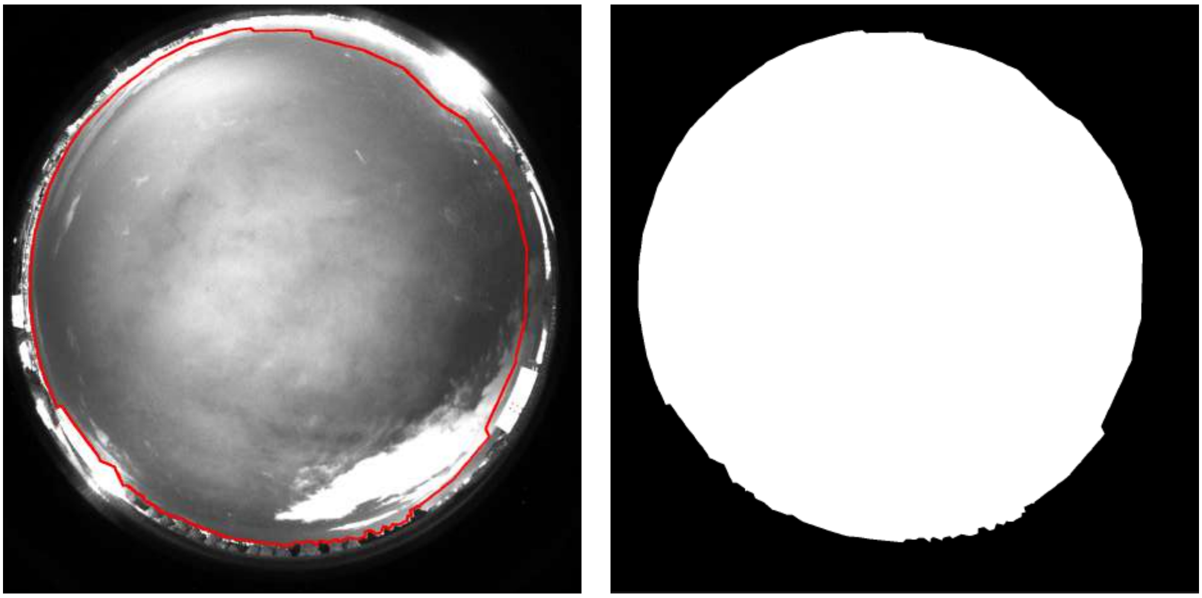

Figure 35 – An example of the detection mask for the StAnD camera FRCA20 - Nice. The left panel highlights the border that was selected on GIMP to define the masked region, and the right panel shows the final result (where the white portion of the image marks the region where trigger are possible, and the black part the excluded region) . One may notice the the upper-right horizon is on the image is masked with a thicker margin, because there is an intense light from a street lamp. Also, the lights from cars passing in that direction by were found to be triggering false positives during night-time.

After having changed the detection mask, you can **monitor if the camera is frequently detecting false positives** during night-time from the browser interface. If so, you can adjust the mask, for example **raising the border over the horizon** to mask a bit more pixels and exclude the region that is causing such false positives.

4.3.2. Software Monitoring

To ensure the best operativity status of the StAnD Meteor Camera Kit, you should periodically check the functionality of the software by logging on the browser interface (as admin) and check the status of the following pages (at least every 10 - 15 days if possible):

- On the **homepage**, check if any **errors are reported under the *Node status* section**. If you see some errors, report the issue to your StAnD contact point.
- On the ***Containers status*** page, check if the **Freeture container is up and running**. If not, check for errors in the log and try to restart the container. If this attempt fails, report the issue to your StAnD contact point.
- On the ***Calibrations* and *Stack*** pages, check if **data are being acquired regularly** everyday. You should see about 144 captures per day and about 1440 stacks per day. If you see lower numbers, report the issue to your StAnD contact point.

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.

4.3.3. Hardware Monitoring

To ensure the best operativity status of the StAnD Meteor Camera Kit, you should periodically check the status of the hardware of the kit (at least each 10 - 15 days if possible):

- Check the status of the protective plastic dome of the all-sky camera. **Water droplets are not a problem**, especially during summer time. If you see some dirt piling up on the dome, **clean it very gently with a wet microfiber cloth**, trying not to alter the orientation of the camera.
- Check the **status of the Ethernet cables** (and junction box if installed) that are exposed to atmospheric agents. A degraded Ethernet cable may not be able to withstand the data traffic, especially for the one connecting the all-sky camera module to the mini-PC.
- Check the **status of the mini-PC and network switch**. They should be powered on, with all the cables correctly plugged in, and showing the correct lights on their front (see Section 3.4). If you know that the power went down in the building, check if the mini-PC is back on, otherwise power it on by pressing the power button on its front (see Figure 12).

5. Data Analysis Tool

Forthcoming (June 2025)

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein. Project No. KA220-SCH-F3BE36BB.