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## A2.2. Toolkit: Meteor Camera Kit Manual

**Resources:** INAF - Italian National Institute for Astrophysics - Osservatorio Astrofisico di Torino  
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This manual provides a comprehensive guide on how to install, operate, and maintain the StAnD Meteor Camera Kit, dedicated to the detection of bright meteors (i.e. fireballs and bolides) during night-time. This kit is provided, as part of the StAnD Toolkit, to all schools participating in the StAnD project. Still, it is also made available to other schools, institutions, associations, and to whoever is interested in joining the project. The StAnD Toolkit implements the latest meteor detection technology developed by PRISMA, the First Italian Network for the Systematic Surveillance of Meteors and the Atmosphere.

**Language:** English

**Suitable for age:** 7-18 years

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



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## 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 favourable.

The camera module used in the StAnD Meteor Camera Kit is an **all-sky camera** (see [Figure 1](#)), i.e. it is able to capture the whole observable sky (down to  $\sim 10^\circ$  above the local horizon) in a single acquisition. This module is operated at **30 frames per second** (fps) during night-time by the mini-PC included in the kit. Data of meteor observations are automatically saved when the system recognises the occurrence of a bright source moving within the camera's Field of View (FoV).

The data, configuration, and control of the StAnD Meteor Camera Kit are accessible through standard SSH (Secure Shell Protocol) or through 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 analysed through a data analysis tool (named **PASCAL**) provided with the kit. This tool enables **visualizing** and **exporting** animations or timelapses of the data acquired by the camera, as well as performing their **scientific analysis**. Its ultimate objectives are to unveil the **origin of the observed object** within the Solar System and to determine if a fragment of it, i.e. a **meteorite**, has survived the atmospheric flight and fallen to the ground.

The idea of the StAnD project originated from the experience of [PRISMA](#) (Prima Rete Italiana per la Sorveglianza sistematica di Meteore e Atmosfera, i.e. First Italian Network for the Systematic Surveillance of Meteors and the Atmosphere), a professional **fireball network** in Italy operated 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.**





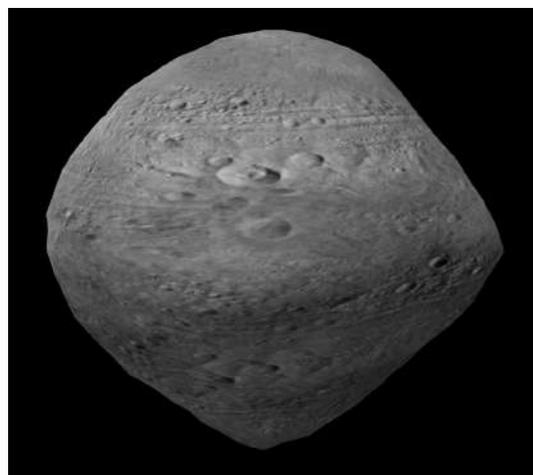
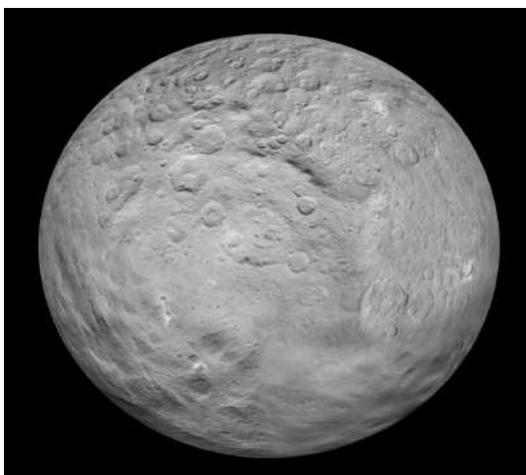
The following sections of this introduction provide a brief summary covering the topics of meteoroids, meteors, and meteorites, as well as the methods used to observe meteors, with a focus on the optical ones. For a complete overview of these topics, please refer to the **StAnD Teacher's Manual**.

## 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, Chapters 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 for [1 Ceres](#) (see [Figure 2](#), left panel), known as the first discovered asteroid, which has a diameter of about 940 km.
- Irregularly shaped rocky bodies orbiting around the Sun (which are neither planets nor dwarf planets) are called **asteroids**. One of today's well-known asteroids is [101955 Benu](#) (see [Figure 2](#), right panel), a "small" 480 m asteroid, visited by NASA's **sample-return mission OSIRIS-REx**.
- Minor objects similar to asteroids but made of more fragile materials, such as ice and dust, are called **comets** (see [Figure 3](#)). They are the most well-known objects because they exhibit a **tail of dust particles** when approaching the Sun, which is sometimes visible from the Earth.
- Objects that qualify as asteroids or comets but are smaller than 1 m are called **meteoroids**. These objects are so small that ground-based telescopes cannot systematically observe them, unless they are very close to the Earth. Meteoroids are usually **fragments of asteroids** (or particles released 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 Benu (right panel) based on direct observation of these asteroids. Small asteroids and meteoroids can have very irregular shapes. They usually rotate around their axis at fast rates (1 rotation every 4.3 hours in the case of Benu). The effect of such fast rotation often leads to top-shaped asteroids (like Benu).** Credits: NASA Visualisation Technology Applications and VTAD) - [link](#)





**Figure 3 – The first direct image of the comet 1P/Halley, taken in 1986 by the European spacecraft Giotto. For scale, 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 (asteroids) eccentric orbits. Most of the population of asteroids and meteoroids orbits within the Main Asteroid Belt, between Mars and Jupiter. If their orbit is close to that of the Earth, they are called **Near-Earth Objects** (NEOs; see Teacher's Manual, Chapter 5.1).

Such objects may **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 produces 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", according to the definition of the [International Astronomical Union](#). The most evident feature of a meteor is its **light emission**, which originates 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 at speeds 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 when viewed 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 speeds (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, resulting in **meteor showers** when the Earth crosses the comet's orbit (see Teacher's Manual, Chapter 5.3).



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



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**. The meteoroid may also fragment into several pieces during its atmospheric flight due to the very high pressure generated by the hypersonic flight. Fireballs that exhibit fragmentation events are often called **bolides**. These fragmentation events usually correspond to bright flashes (**flares**), and they release a large quantity of meteoritic dust into the atmosphere, which slowly deposits downwards to the Earth's surface. Such  $\mu\text{m}$ - to  $\text{mm}$ - sized particles can be recovered on the ground and are called **micrometeorites**. They can also originate from very microscopic meteoroids ( $< 30 \mu\text{m}$  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 fireball events occurring on Earth, a small residue of the meteoroid survives the atmospheric flight. The bright, visible phase of the meteor ends at an altitude of about 20-30 km from the ground, and any 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 are fundamental to understand the formation and evolution of both minor and major bodies, since they preserve pristine samples from the early stages of the Solar System.

## 1.2. Observational Methods

The first scientific observation of a meteor dates back to 140 years ago (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 through direct, ground-based telescopic observation is [2015](#)

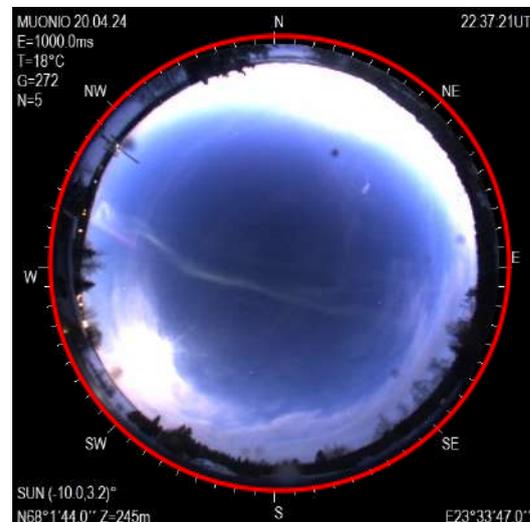
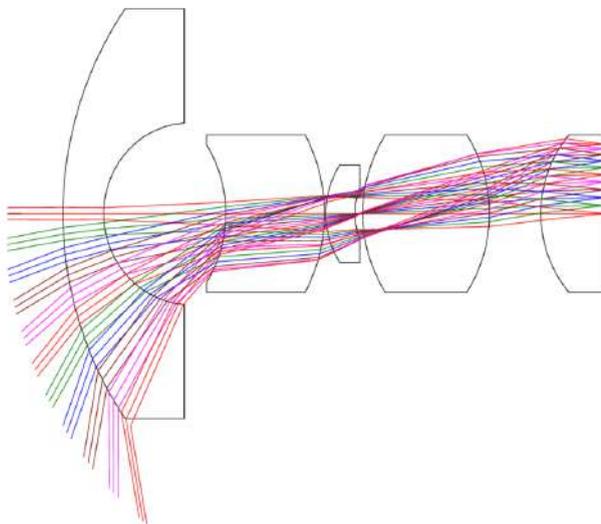


[TC25](#), with an estimated size of 2 m. However, this observation was possible only thanks to its unusually high albedo (i.e. the fraction of sunlight that the asteroid surface is able to reflect) of about 60%. Current estimations suggest that we have observed >90% of the NEO population above 1 km 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** (see [Figure 5](#)), are preferred in this case in order to cover the largest portion of the observable sky and maximize meteor detection efficiency, 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** onto the focal plane of the camera in a circular image, where the outer circumference corresponds to 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 edge of the image (red circle), while those 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 (from a few minutes up to the whole night, depending on the instrument's sensitivity). 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** against the background of star trails. To obtain a relative



indication of the time, such devices are usually equipped with a **rotating shutter** that periodically obscures the objective, leaving equally spaced dark ticks along star trails and meteor strikes. An example of photographic observation of a fireball is shown in [Figure 6](#).

- **Video observations:** the camera performs short and consecutive acquisitions, operating 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 other hand, high-sensitivity professional cameras must be used to capture faint meteors by video observations.

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

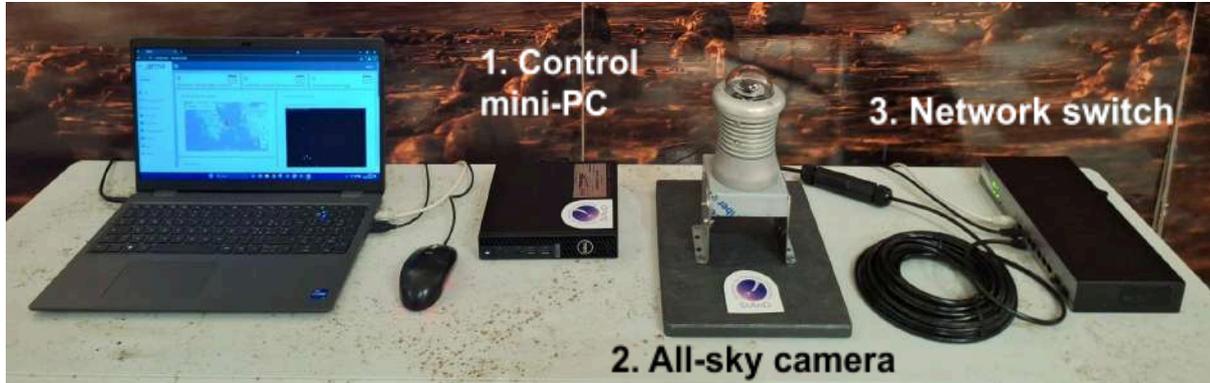
- **Radio:** detecting radio waves (from military or communication infrastructures) **reflected** by the plasma channel generated by the meteor.
- **Acoustic:** detecting the **shock waves** generated by the meteor's hypersonic motion, either in the air (using **infrasound** detectors) or when impacting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

**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](#)





Figure 7 – The StAnD Meteor Camera Kit installed and displayed in the lecture room of the first StAnD Summer School from 30 June to 5 July in Marathons, Greece. In this case, the camera module is installed on a wooden support just for indoor display. Since no Ethernet wall plug was available in the room, the kit network is connected to the Internet through a laptop's Ethernet plug.



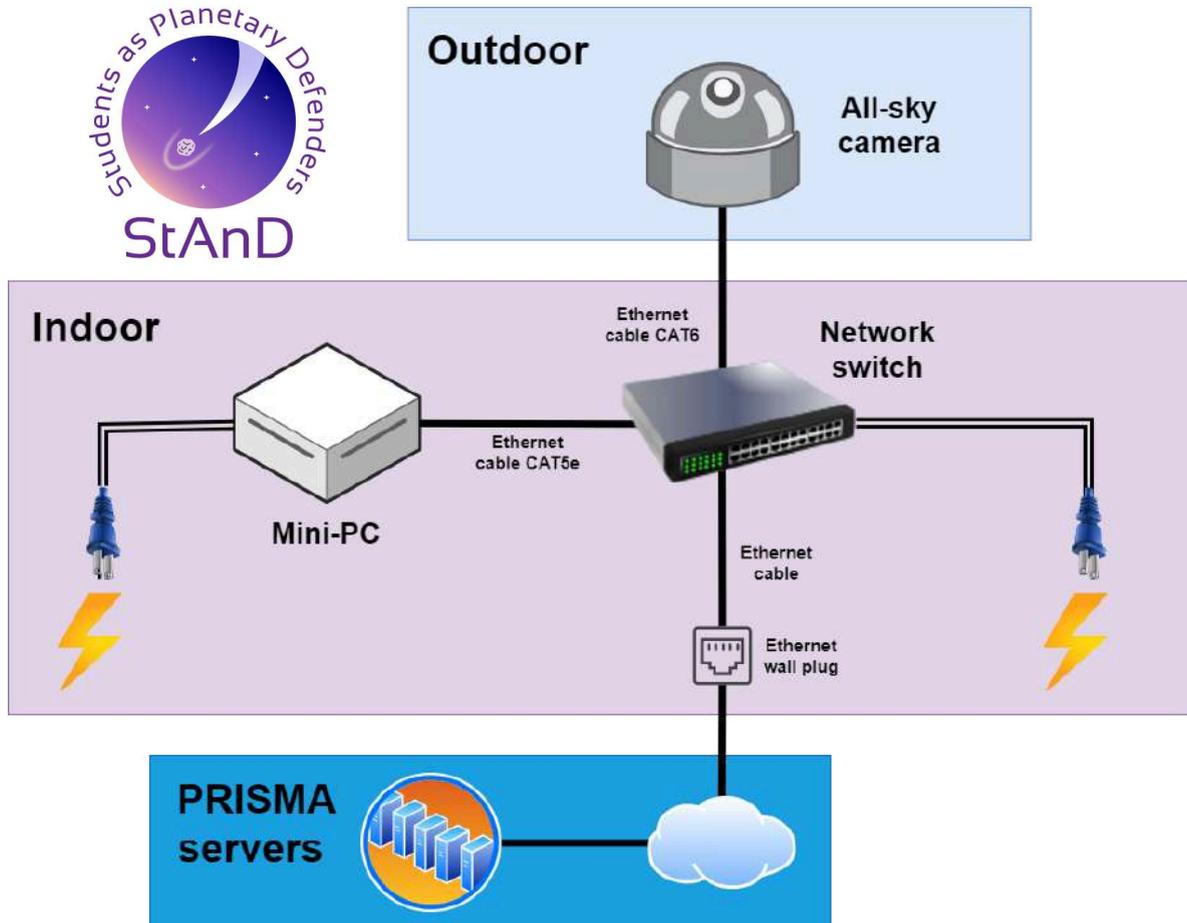
## 2. StAnD Meteor Camera Kit

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, depicted in [Figure 7](#):

- 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, 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 specific events within a dataset. In this case, the algorithm checks for **bright sources moving in 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 segment 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 a single camera). It is connected to the other components and to the Internet through an Ethernet cable linked 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 operational configuration, the camera is **installed on the roof / balcony** of the building, through its mounting system. The camera is connected to the whole system via a **5-m Ethernet cable** (attached to the case with a waterproof extender) and linked to 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 access to the mini-PC. It is connected to the Internet through an Ethernet cable plugged into the wall Ethernet socket, or directly to the router. The data acquired by the kit are then handled by the INAF - PRISMA servers.



Figure 8 – 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).



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 in [Figure 8](#).

## 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](#) (see [Figure 9](#), left panel);
- The **camera module** - [Lucid Visions Phoenix 3.2 MP](#) (model PHX032S-MS), equipped with a Sony IMX265 **CMOS sensor** (see [Figure 9](#), central panel);





- The **fish-eye lens**, model [BQ1550B-12MP](#), with 1.55 mm focal length **F2.8** (see [Figure 9](#), right panel).

**Figure 9** – 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 on a pole, depending on the configuration of the installation site. It is made of:

- A **main body** (a stainless steel flange; see [Figure 10](#), top left panel) onto which the bottom of the camera is screwed;
- Two **side panels** (two stainless steel parts; see [Figure 10](#), top central panel) that support the main body;
- A **pole mounting plate** (see [Figure 10](#), 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 [Figure 11](#)).

**Figure 10** – 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](#)

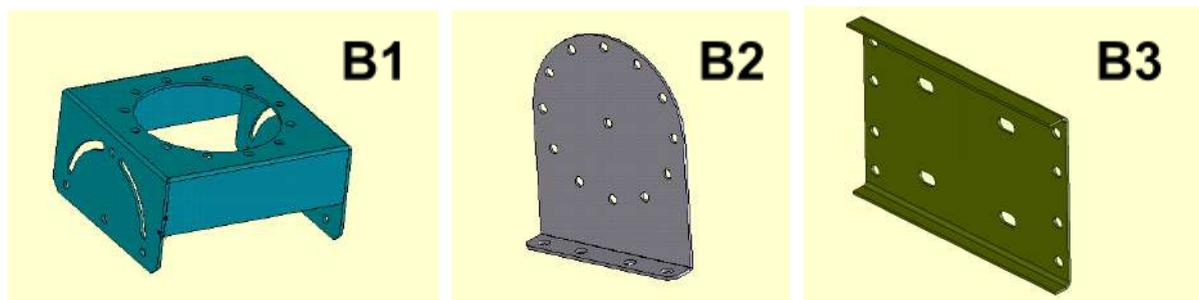




Figure 11 – Pictures of the accessory components of the mounting system for the all-sky camera. From left to right: bolts, nuts and rings to fix the camera support (M4 bolts - small ones, B4a) and the pole mounting support (M5 bolts - big ones, B4b), two pole mounting rivets (B5), junction box (B6), and a female-to-female Ethernet RJ45 coupler.



### C. Control mini-PC

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

[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 12](#). It comes with its own power supply adapter, whose specifications are highlighted in the figure to avoid confusion while installing the kit. [Figure 13](#) illustrates all the ports on the front and back of the mini-PC.

Figure 12 – Pictures of the Mini-PC included in the StAnD Meteor Camera Kit. From left to right: the Mini-PC in display mode (C), its power supply adapter (C1) and the specifications of the power adapter.





Figure 13 – 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 specifications:

[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 14](#). It comes with its own power supply adapter, whose specifications are highlighted in the figure to avoid confusion while installing the kit. [Figure 15](#) illustrates all the ports on the front and back of the switch.

Figure 14 – Pictures of the network switch included in the StAnD Meteor Camera Kit. From left to right: the network switch in display mode (D), its power supply adapter (D1) and the specifications of the power adapter.

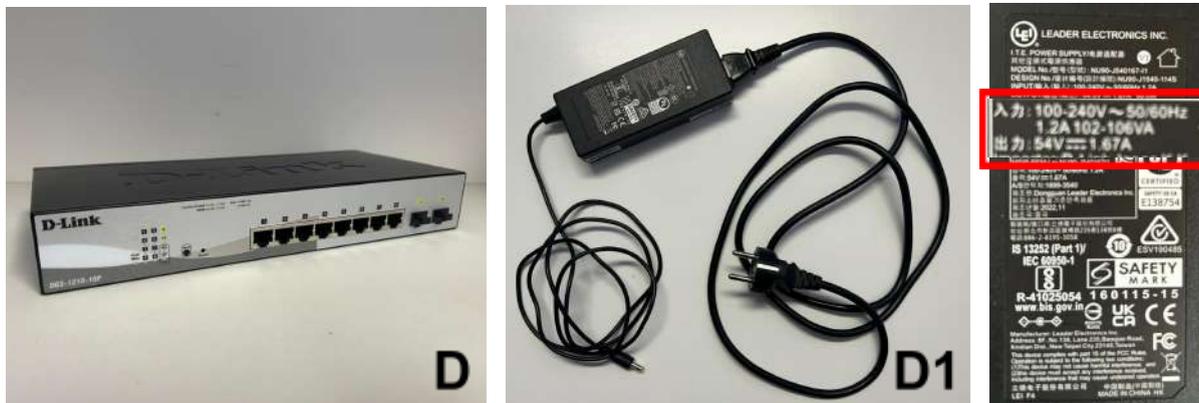
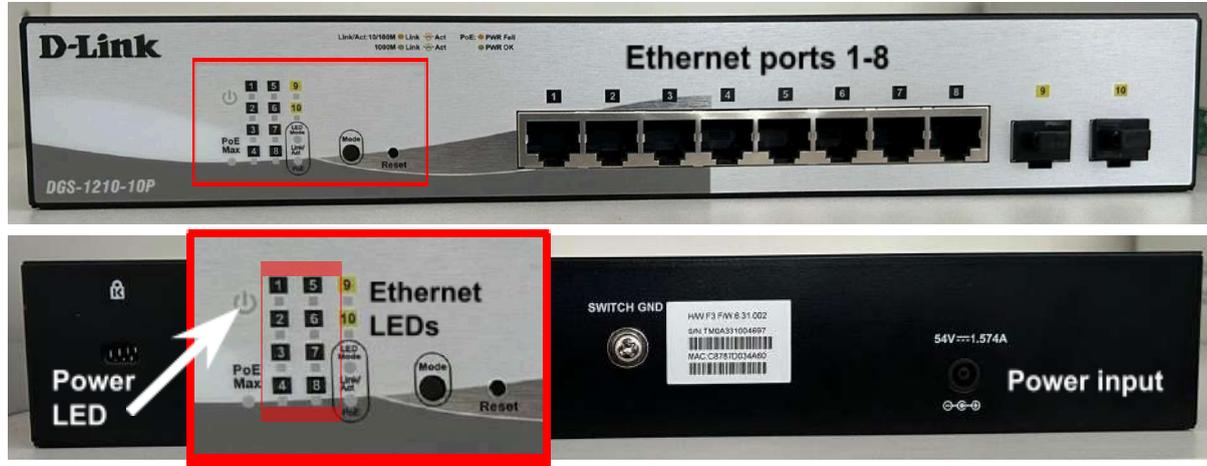




Figure 15 – Pictures of the front (top panel) and back portion (bottom panel) of the network switch, with ports highlighted. The red box highlights the LED panel, with one LED for each Ethernet port (1 - 8). Each LED flashes a steady green light when the corresponding port is connected to a device via 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 included in the Meteor Camera Kit. They are shown in [Figure 16](#). 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 RJ45 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 connection scheme is shown in [Figure 8](#). An additional Ethernet cable is required to **connect the network switch to the Ethernet wall plug** (not included in the kit). No particular technical requirements apply to this cable.

Figure 16 – Pictures of the Ethernet cables included 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 RJ45 Ethernet coupler used to join the Ethernet cables to the all-sky camera (E3).





Figure 17 – The cardboard box used to deliver the StAnD Meteor Camera Kit by mail. Credits: N-3 srl - [link](#)



## F. Packaging

The whole kit is delivered by mail in a cardboard box with a StAnD branded sleeve ([Figure 17](#)), with internal bubble wrap padding to protect the hardware from damage during shipping.

## 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

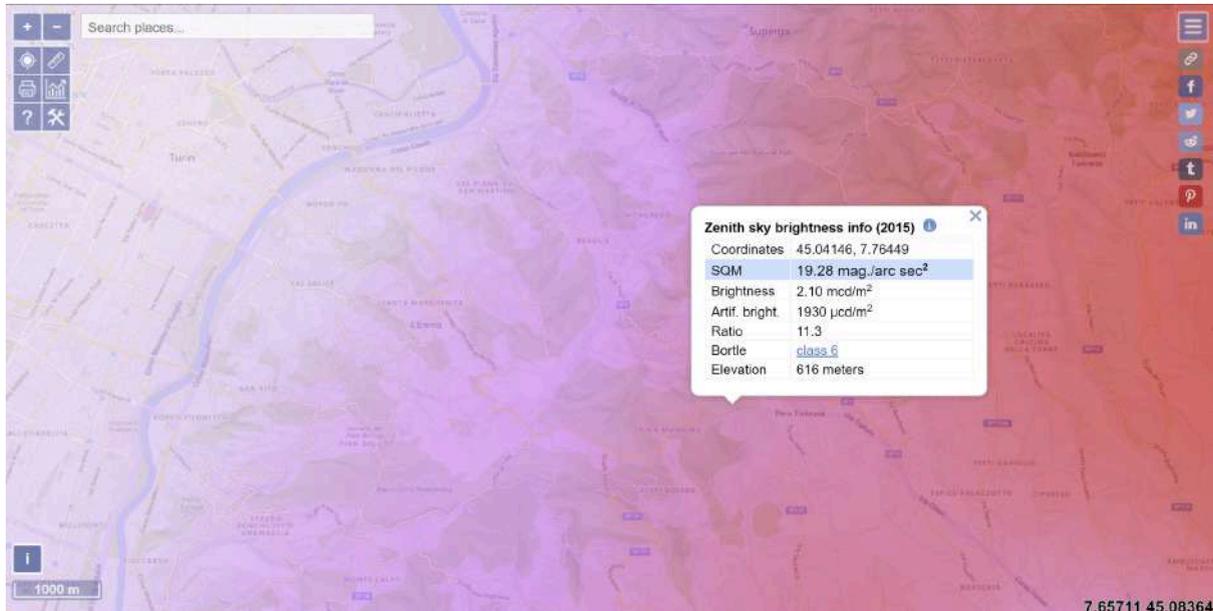
The following technical requirements have to be taken into account when identifying the location where the StAnD Meteor Camera Kit will be installed.

#### 3.1.1. Camera Positioning

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



Figure 18 – Checking the sky quality classification according to the Bortle Dark Sky Scale on World Atlas 2015 for the Astrophysical Observatory of Torino, located on the hills East of Torino in the municipality of Pino Torinese. The site is classified as 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 classified as class 8 or 9 should be avoided. Credits: Light Pollution Map, World Atlas 2015 - [link](#)



The last 10° above the horizon are usually not very important due to light pollution, which prevents the detection of stars (and even meteors unless very bright) in this region. **Small obstacles** (such as chimneys, antennas, flags etc..) close to the camera are not a deal breaker (a workaround is possible by masking them via software) 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 observation targets are bright objects (fireballs and bolides).

To check the sky quality at your installation site, please refer to the [Light Pollution Map - World Atlas 2015](#). For optimal observations, one should **avoid installing the kit in areas classified as 8 or 9** on the [Bortle Dark Sky Scale](#), identified by the colors white to light violet on the World Atlas 2015. You can check this value by left-clicking on your position on the web map (see [Figure 18](#)).

Of course, installation sites with lower light pollution are preferable. More importantly, you should ensure that there are **no direct light sources** (such as light poles, signs...) pointing towards the camera or producing 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 for installation on a flat surface (e.g. a rooftop terrace), an inclined surface (e.g. a roof), or on a pole (see [Section 3.2](#)).



Mounting **on a pole must be avoided** if there are other viable solutions. In this case, the camera will be more **susceptible to vibrations caused by wind**.

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

#### **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 metres long** (otherwise, the connection delay between the camera and the PC becomes too high), and the one included in the kit is 5 m long.

Therefore, another Ethernet cable of up to **15 m in length can be added**, using the junction box and the RJ45 coupler included in the kit ([Figure 11](#), 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 electrical grid should guarantee **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**; high speed is not required, but stability is more important to ensure a constant connection to the central servers. The Internet connection must be delivered by an **Ethernet cable to the network switch**. If this is not possible, an Ethernet dongle with a WiFi antenna (**WiFi/Ethernet bridge** - [example](#)) can be used. The network you are using to provide Internet access to the switch must have a **DHCP server** (Dynamic Host Configuration Protocol) available to assign the IP address to both 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 building's wired Internet connection.

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

### **3.2.1. Assembly**

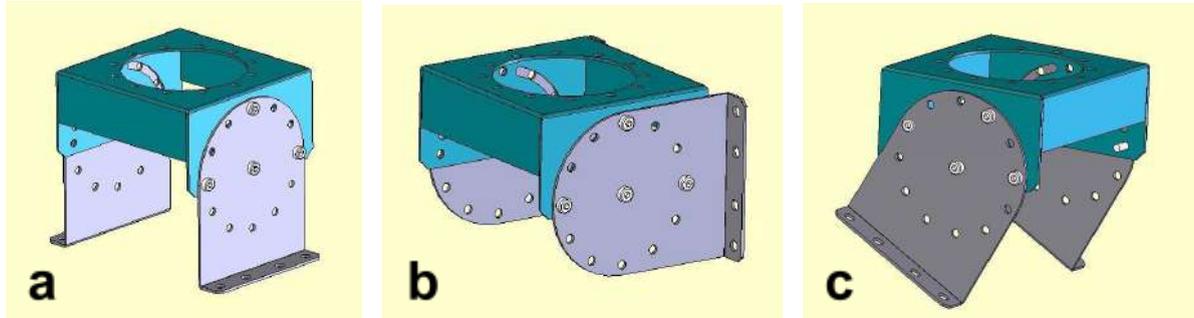
The mounting system for the all-sky camera (B) can be assembled in several configurations, depending on the features of the installation site, as shown in [Figure 19](#):

1. Installation on level ground is the preferred **option**, if a flat and level surface is available on the rooftop of your building;
2. When installing the mounting system on a wall, you should make sure that said wall does **not obstruct the camera's FoV**;



- When installing the mounting system on an inclined surface, pay particular attention to **levelling the system during installation** (See [Section 3.2.2](#)).

Figure 19 – The assembly options for the mounting system of the all-sky camera included 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](#)

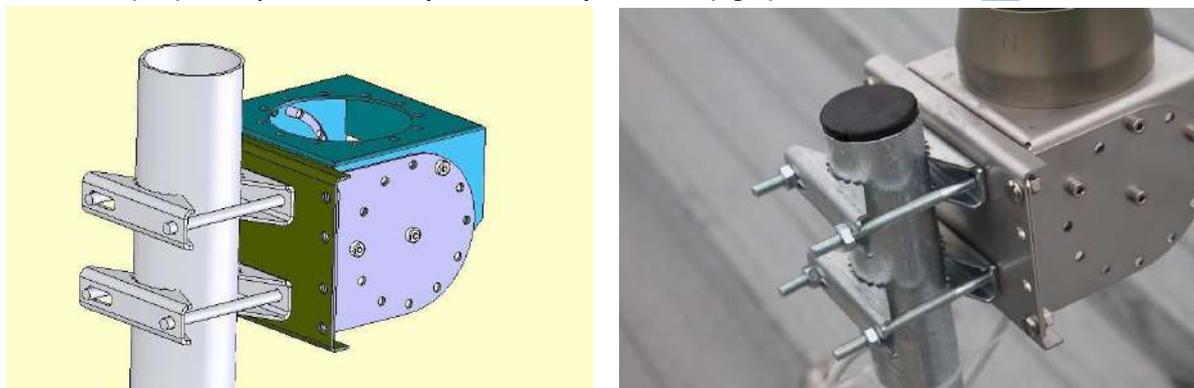


**Step 1** - After identifying the suitable configuration, assemble the mounting system as shown in [Figure 19](#). Mount the **two side panels (B2)** onto the **main body** of the system (**B1**) in the desired position. Use **four M4 bolts**, nuts and rings (**B4a**) per side panel, tightening them with the 7 mm wrench.

The mounting system can also be installed on a pole, as shown in [Figure 20](#). **Do not choose a long mounting pole**. The longer it is, the more prone it will be to oscillations caused by wind and vibrations, which can disrupt the measurements and damage the hardware inside the camera. For pole mounting, follow **steps 1a and 2a**.

**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 must be assembled in the **same way as for wall mounting (b)**. Then, mount the **two rivets (B5)** onto the pole and fix them to B3, as shown in [Figure 20](#). Use the 7 mm wrench to tighten all bolts.

Figure 20 – A scheme of the pole mounting system for the all-sky camera included in the StAnD Meteor Camera Kit (left) and a picture of the system correctly mounted (right). Credits: FRIPON - [link](#)





### **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 elements of obstruction** , in particular moving ones (e.g. flags, chimneys, antennas), that could create noise in the images captured by the camera;
- **Avoid direct urban lighting**, which may come from lights right above the camera or unshielded lights in its surroundings, because of the risk of reflections on the objective lens;
- If needed, the **junction box** must be installed **within reach of the 5 m Ethernet cable** connected to the all-sky camera.

---

**Step 2** - Secure the assembled mounting system to the floor ([Figure 19a](#)), to the wall ([Figure 19b](#)), or to the roof ([Figure 19c](#)). 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 20](#)), fix the **two side panels (B2)** to the **pole mounting plate (B3)** using **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 only as the final step of the process**, after the installation of the camera has been completed. The protective case is **hermetically sealed with desiccant** to prevent condensation forming inside. Therefore, **the camera module must not be opened**.

At this stage, the aim is to install the camera on its support and to **route the Ethernet cable to where the control mini-PC (C) and network switch (D) will be located**. This part of the installation is therefore carried out outdoors, while the next steps will take place entirely indoors.

The camera support and the protective case have a dozen holes to allow the camera to be **oriented towards the North** (within approximately 15°). Before the installation of the camera, verify the direction of North in order to position the camera accordingly (see [Figure 21](#)).



Figure 21 – A picture showing the correct orientation of the all-sky camera of the StAnD Meteor Camera Kit towards the North. The camera's protective case has two vertically arranged bolts pointing outwards (marked with the red line in the picture), which attach the camera module to the interior of the case. Due to the internal arrangement of the components, the bottom portion of the CMOS is always facing this direction. Therefore, by aligning this direction towards the North, an approximate reference frame can be defined a priori, allowing all cameras in the network to share the same approximate orientation.

---

**Step 3** - After identifying the North direction and the closest orientation of the camera to match it (See [Figure 21](#)), secure the **all-sky camera module (A)** to its **support of the mounting system (main body, B1)** using **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 afterwards. The short Ethernet cable attached to the camera module must pass through the central hole of B1.

---

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

---

**Step 4** - After securing the camera module to its support, **install the waterproof RJ45 Ethernet coupler (E3)**, connecting one side to the short Ethernet cable coming from the camera module, to **join with the 5 m Cat6 Ethernet cable (E2; see [Figure 16](#))**. Then, **secure the Ethernet cable** to the pole, floor, or roof (depending on your installation configuration) in accordance with the safety requirements of your building. The cable must **reach the room where the mini-PC and network switch** will be installed.

---

### **3.3.1. Installation of the Junction Box**

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

The first option is to **replace the provided Ethernet cable** with a longer one that can reach the said room. When doing so, make sure that the new cable **meets the requirements** (Cat6, suitable for outdoor installation, LZSH fireproof). It can be up to **20 m in length**.

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

The junction box must be installed in a place that can be reached using the 5 m Ethernet cable included 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 secure it to the wall. In order to prevent rainwater infiltration, the junction box must be placed so that the **holes through which the cables pass face downwards** (see [Figure 22](#)). All holes (both for fixing the



junction box to the wall and for routing the cables) are sealed and must be pierced with scissors or a screwdriver either before or during the installation.

**Figure 22** – Pictures showing the correct installation of the junction box (B6) included in the StAnD Meteor Camera Kit, used to extend the 5 m Ethernet cable with an additional one. The junction box must be installed vertically and the cables are to be inserted through the bottom holes, to prevent water infiltration. Credits: FRIPON - [link](#)



**Step 4a** - If needed, install the junction box (B6) in a vertical position (e.g. on a wall) at a location **within 5 m of 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 piercing the two bottom holes of the junction box, insert the **two Ethernet cables (E2 and the extension cable)** into the junction box and connect them using the **female-to-female Ethernet RJ45 coupler (B7)** as shown in [Figure 22](#).

### 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 Meteor Camera Kit hardware will be located, it is now time to install the control mini-PC (C) and the network switch (D). Both 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 23](#)).

**Step 5** - Connect the **control mini-PC (C) and the network switch (D)** to the power supply through their **respective power adapters (C1 and D1, be careful not to mix them)**. Both plugs of the power adapters must be inserted into their respective power inputs (see [Figure 13](#) and [Figure 15](#)). The **power LEDs on both devices will start blinking**. If the mini-PC's power LED does not blink after a 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.



**Step 6** - Three Ethernet cables must be connected to the network switch. The order of the ports is not relevant but, with reference to [Figure 23](#):

- port 1 - Ethernet cable coming **from the Ethernet wall plug** (delivering the building's Internet connection);
- 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 communication via the Ethernet cable is working properly, the corresponding **Ethernet LED** (see [Figure 15](#)) will be turned on with a green (the port is running at 1000 Mbps) or orange/amber (10 or 100 Mbps) light, and blinking when data is being transferred. **LEDs 3 and 5 should always be green, while LED 1 may be orange** if the building's Internet connection 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 any LEDs do not light up, try reconnecting the cable and switching the corresponding device off/on.

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 15](#)). LEDs 1 and 3 should be turning off, while **only LED 5 should remain on with a green light**. This indicates that the power supply to the camera module is stable and functioning correctly. To go back to the previous LED configuration, press the "Mode" button again.

**Figure 23** – Desk installation of the StAnD Meteor Camera Kit (top panel), along with connection specifics (bottom panels). For this installation, the Ethernet cables are plugged into the network switch as follows (bottom left panel): the Internet network is connected to port 1, the Ethernet cable from the mini-PC to port 3, and the cable from the camera module to port 5. LEDs 1, 3 and 5 of the network switch are correctly lit (bottom centre panel) and, when pressing the "Mode" button, only LED 5 remains on (bottom right panel), all with green light. An orange/amber light might indicate a slower connection. Notice that, of course, the camera module must be installed outdoors as shown in [Section 3.1.1](#).





### 3.5. First Boot of the StAnD Meteor Camera Kit

If everything has been installed correctly, **the StAnD Meteor Camera Kit is already working** and no further action is required regarding 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 representative. For more details on how to connect to the StAnD Meteor Camera Kit locally and remotely, please refer to [Section 4.1.3](#).

All components are configured to **automatically switch back on** in the event of a power shortage, or when unplugged from the grid to be relocated 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. For further information regarding the maintenance of the kit, please refer to [Section 4.3](#).

The software might require some additional intervention to **complete the installation after the first boot**.

---

**Step 7** - To ensure the correct connectivity and operability 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 in your building) and **ask them to open the following ports of the firewall**:

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

Depending on when you received the kit, **some software updates might be required** to ensure its full functionality. Get in touch with your StAnD representative 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 remotely, how to operate the kit through the provided user-friendly **browser interface**, how to **access the data** recorded by the kit and by the entire StAnD network, and how to **maintain the hardware and software** to ensure the best preservation and operability of the kit over 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”, in which:

- **IT** stands for the country (e.g. Italy);
- **PI** stands for the region (e.g. Piemonte);
- **01** is a progressive number assigned to 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:

- 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 via the Ethernet cable passing 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 into 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

The StAnD Meteor Camera Kit can be reached via the local IP address only from the local network, i.e. if the user’s computer is connected to the same network as the mini-PC. Be aware that this IP address **can vary over time** (from a couple of hours up 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 determine whether the kit will have a **dynamic or static IP address**, it is best to ask the IT department or person responsible for your building or institution.

If the mini-PC is assigned a static IP, you can **ask your IT department directly** 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. When 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, you can perform the following steps:

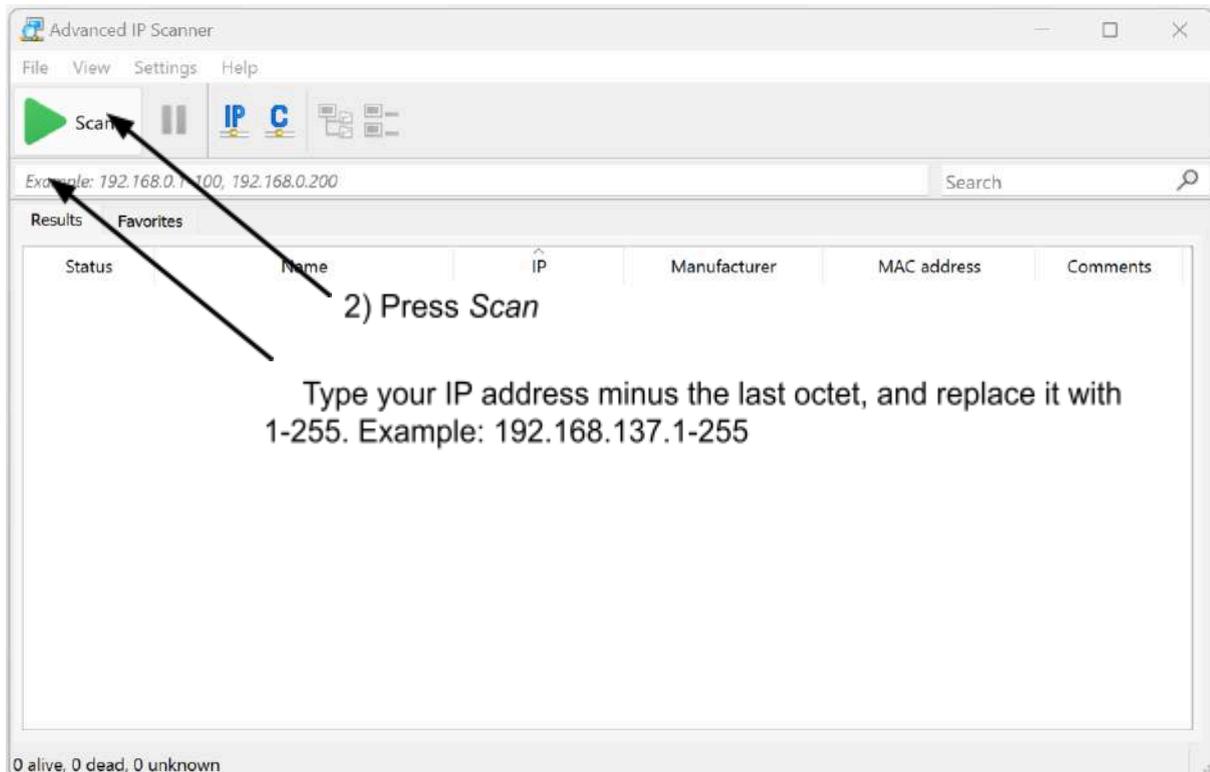
1. **Plug your computer** (e.g. a laptop) **directly into the network switch** or into an Ethernet port **within the same network class** (usually in the same room; see above) using an Ethernet cable. You might not have Internet access this way; this is not a problem.
2. Find out the **IP address assigned 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 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 you have found is: 192.168.137.124

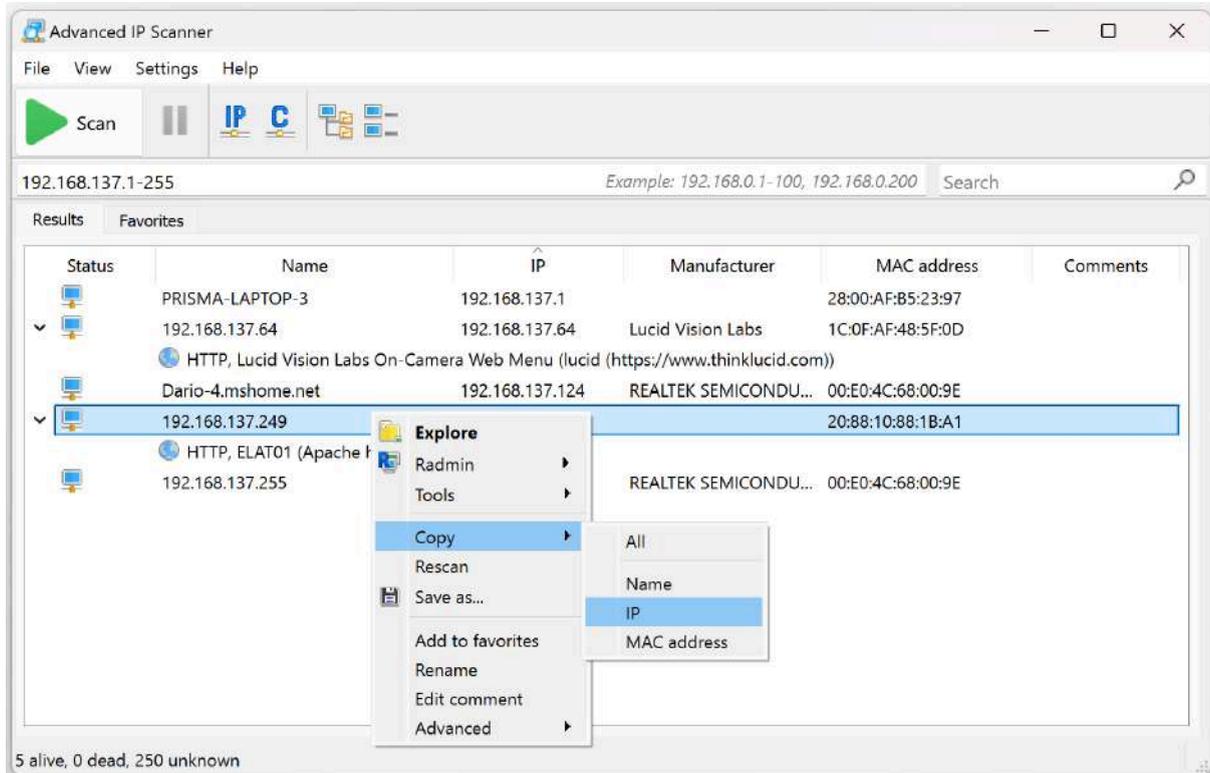
3. Download **Advanced IP Scanner** from the [official website](#) (it might be available in your language as well). Install the program on your laptop by following the installer's instructions, and start the program (see [Figure 24](#)).
4. Enter into the textbox under the *Scan* button the first three octets of your laptop's IP address, adding the full range for the last octet: **192.168.137.1-255**, and **press Scan**. Wait about 1 minute to let the program complete the network scan.
5. Once the scan is complete, you will have a **list of all the devices** connected to that network. If you plug directly into the StAnD network switch, you should find a few devices. Otherwise, you may find many. See [Figure 25](#) 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 25](#)). 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*.

**Figure 24 – Starting window of the Advanced IP Scanner program, showing instructions on how to search for the IP address of the StAnD mini-PC connected to the local network.**





**Figure 25** – The result of the network scan searching for the StAnD mini-PC connected to the local network using the Advanced IP Scanner program. To identify the IP address of the mini-PC, look through 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 Remotely**

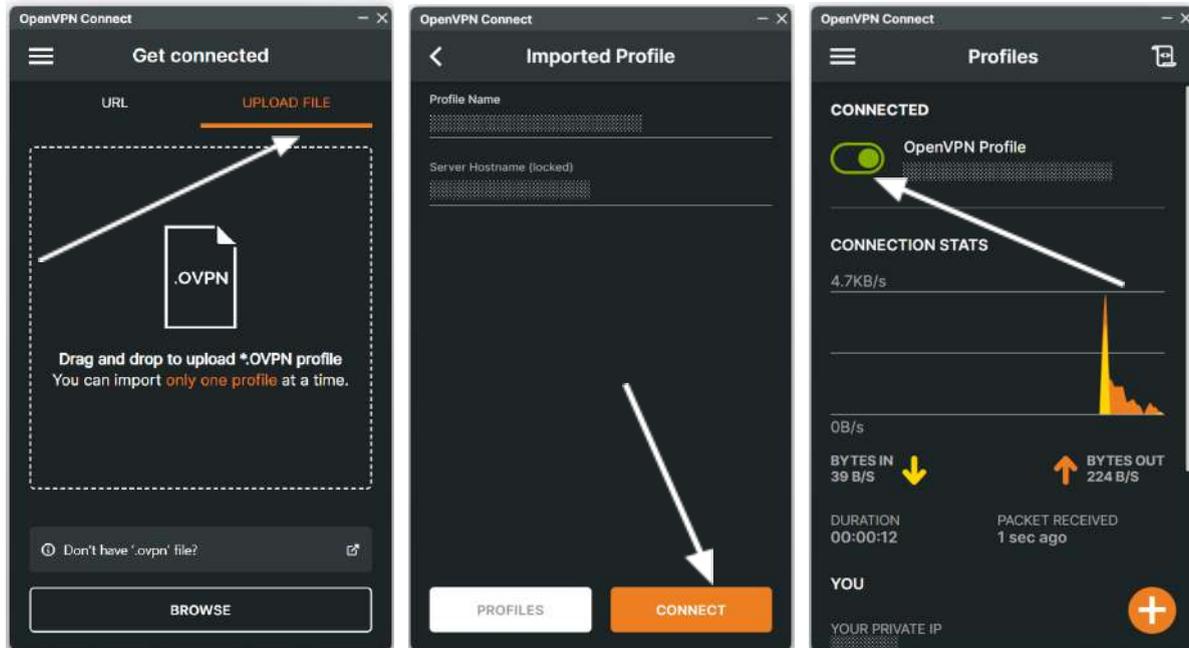
If you have access to the VPN of the PRISMA network, you can reach the mini-PC remotely **from your laptop**, provided that you have an Internet connection (which does not block VPN services). The use of this service is limited to 1 / 2 accesses per StAnD node. Contact **your StAnD representative** for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

Once your request is approved, you will receive a **VPN certificate (.ovpn file)**. **Do not share your certificate with anyone**. Then, follow these 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 26](#)).
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.



Figure 26 – The interface of the OpenVPN Connect client used to connect to the PRISMA VPN, showing 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 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 because the Internet connection that you are using blocks external VPN services. Contact your IT manager.

Once you are connected to the VPN, to know the IP address of your StAnD mini-PC, **ask your StAnD representative**. This address will never change.

#### **4.1.3. Accessing the mini-PC Locally or Remotely**

If you have access to the VPN of the PRISMA network, or you are connected to the local network where the StAnD mini-PC is connected, **open a web browser**, type the mini-PC's IP address into the address bar and press Enter. If the connection is successful, the **login page of the StAnD Meteor Camera Kit** will be displayed (see [Figure 27](#)).

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

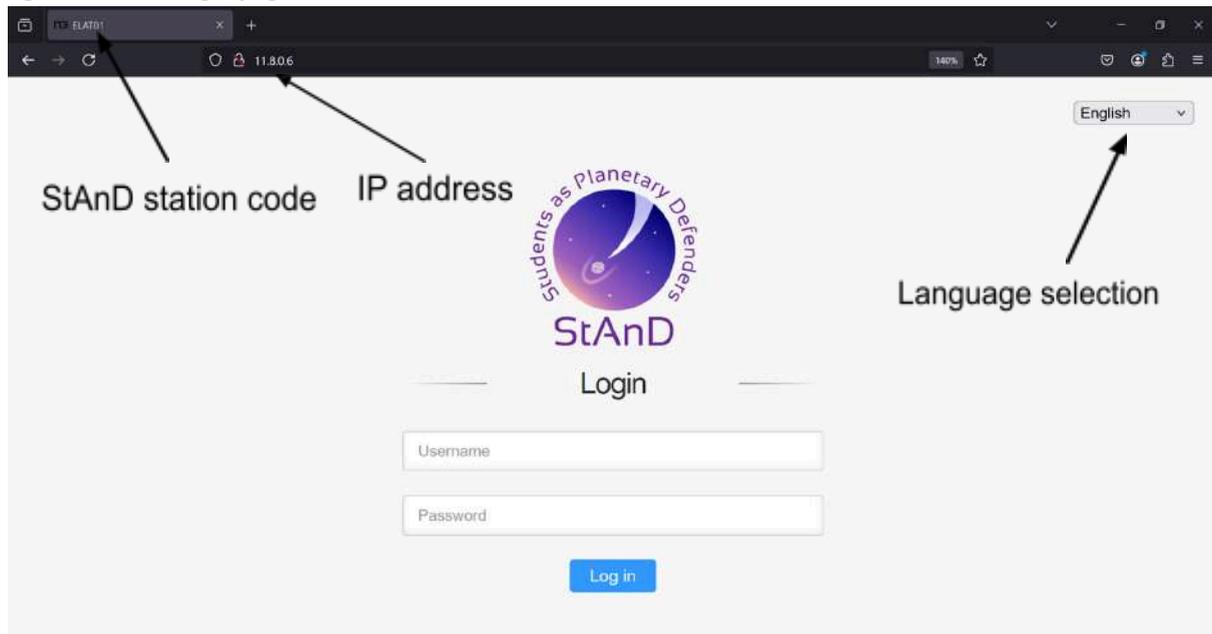
- **Guest** credentials: the user can access, view, and download the data acquired by the kit;
- **Admin** credentials: the user has all the privileges of a guest user but can also configure and operate it (turn it on and off, reboot, start, and stop acquisitions) and modify the login credentials of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

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

Any web browser should work fine. However, the best performance is usually provided by the [Mozilla Firefox](#) web browser.



Figure 27 – 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 display the StAnD Meteor Camera Kit homepage (see [Figure 28](#)), which presents the main functionalities of the kit. The elements of the homepage are as follows:

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



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Figure 28 – The homepage of the StAnD Meteor Camera Kit web browser interface, illustrating the operational status of the kit. The sidebar menu options link to the other web pages within the interface. Only the last three are available to guest users (to download the data), while they are all available to admin users.

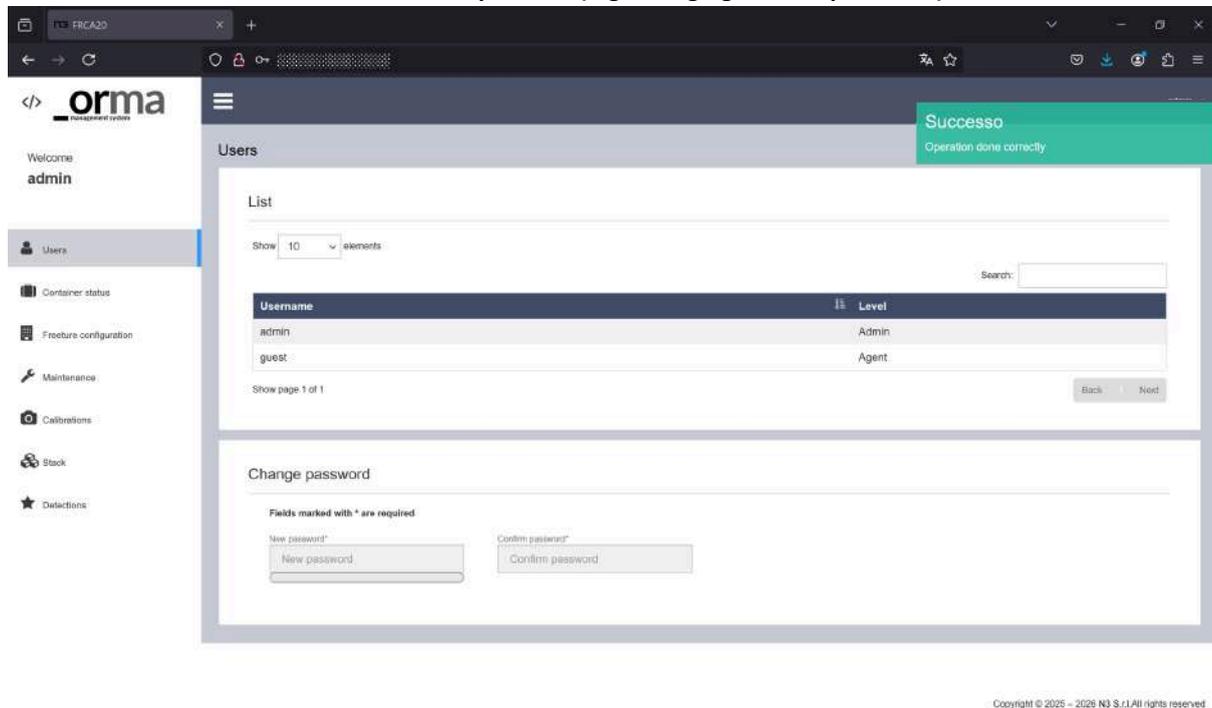
The screenshot displays the StAnD Meteor Camera Kit web browser interface. The browser address bar shows 'FRCA20'. The interface includes a sidebar menu with options: Welcome admin, Users, Container status, Firmware configuration, Maintenance, Calibrations, Stack, and Detections. The main content area features three detection summary cards: '18 Station detections', '6 Last month's detections', and '1 Today's detection'. Below these are two main sections: 'Station geolocation' with a map of Monaco and 'Last detected image' showing a meteor image from 2025-01-30. The 'Station data' section includes a table with the following information:

Parameter	Value
Station Name	NICE
Station Code	FRCA20
Observer	Prof Miguel A. Garcia Perez
Elevation Observatory	58
Longitude Observatory	7.21215
Latitude Observatory	43.67401

The 'Today's detection' section shows a table with columns: Name, Time, Preview, DirMap, GeMap, Video, Zip. It currently displays 'No results found'. The 'Node status' section reports: 'Errors detected: No errors detected', 'Status messages: Mask found, Internet connection established, Configuration file found', and 'VPN status: VPN active, IP: [IP address], VPN Access as PRISMA'. A 'Data usage' section on the right lists CPU 0 through CPU 12 with corresponding progress bars. The footer contains the text: 'Copyright © 2025 – 2026 N3 S.r.l. All rights reserved.'



Figure 29 – The *Users* page of the web browser interface for the StAnD Meteor Camera Kit (only available when logged in as an admin). The green textbox is shown as an example of the confirmation message that the user should receive after a successful operation (e.g. changing a user’s password).



In the following sections, the functionality of the kit is described by illustrating the content of the web pages accessible via the **sidebar menu options**.

#### 4.2.1. Users

This page is available only when logged in as an **admin**. See [Figure 29](#) for an example.

It allows **modification of user passwords** (both guest and admin). To do so, select the user whose password you want to modify. 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 in the top right corner of the screen. Otherwise, select *Cancel* to undo the ongoing change.

#### 4.2.2. Containers Status

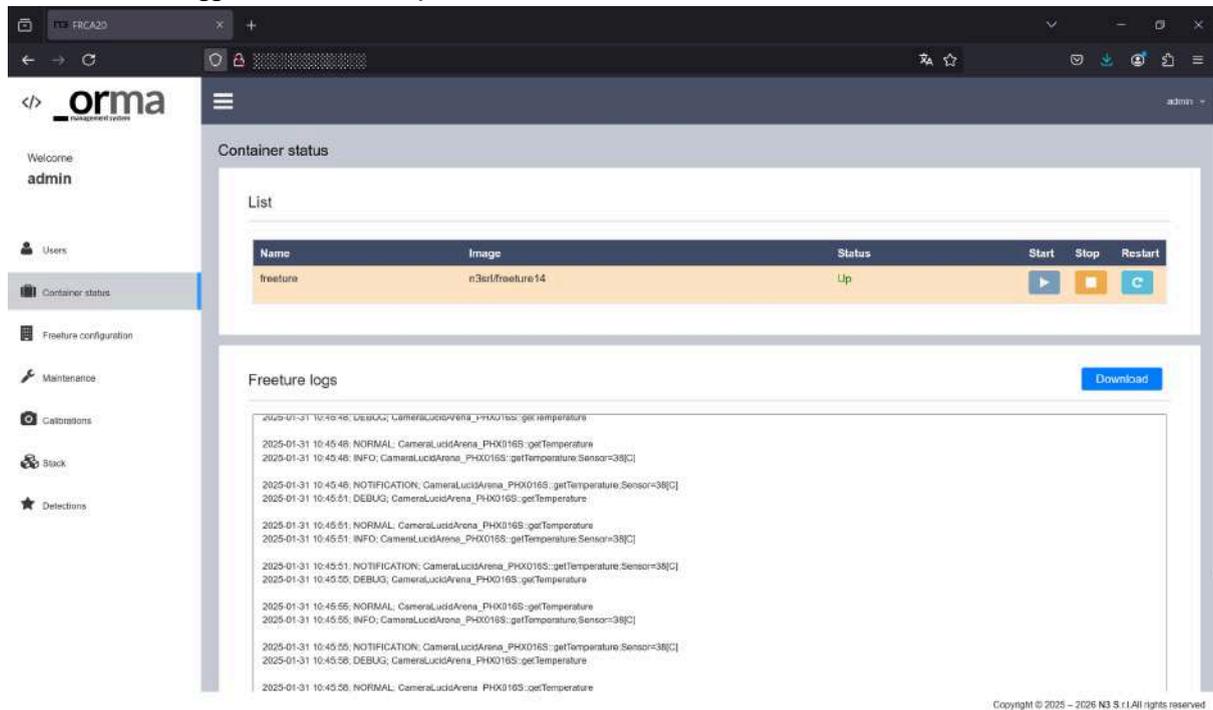
This page is available only when logged in as an **admin**. See [Figure 30](#) for an example.

It allows monitoring and modification of **the execution status of the FreeTure container**, which is the program that runs and controls the whole operability of the kit (acquisition schedule, trigger for meteor detection, etc.). It 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](#)).



Figure 30 – The *Containers status* page of the web browser interface for the StAnD Meteor Camera Kit (only available when logged in as an admin).



You can **start, stop or restart the container** using 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 in 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 maintenance on the camera installation without unplugging the whole kit.

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

### 4.2.3. Freeture Configuration

This page is available only when logged in as an **admin**. See [Figure 31](#) for an example.

It allows **modification of the configuration parameters** of the FreeTure program running on the kit through three sections.

The first section is *Load file* and allows **modification of the whole configuration file**, using the option *Upload new FreeTure configuration file*, and uploading a **new mask file**, using the option *Load new mask*. The first option should be used for **debug purposes only** and by skilled users (it requires manual modification of the field in the config file but may cause FreeTure to crash 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 in the top right corner of the screen.



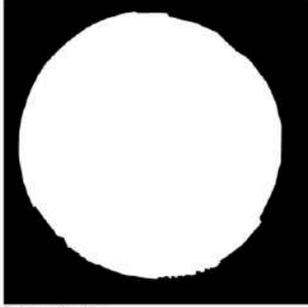
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Figure 31 – The *FreeTure* configuration page of the web browser interface for the StAnD Meteor Camera Kit (only available when logged in as an admin).

**Load file**

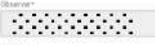
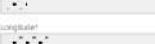
Upload new FreeTure configuration file (for example: configuration.cfg)  
Sfoglia... Nessun file selezionato. **LOAD**

Load new mask (for example: default.bmp)  
Sfoglia... Nessun file selezionato. **LOAD**

Preview of the current mask  
  
Risoluzione: 1324 x 1324 px

**Automatic configuration** **MODIFY**

Fields marked with \* are required

Station name\* NICE  
Station code\* FRCA20  
Observer\*   
Affiliator\*   
Longitude\*   
Latitude\* 

Set coordinates  


**Manual configuration** **Mask**

Show: 10 elements

Parameter	Value	Description
CAMERA_SERIAL		Identification serial of the camera, if empty CAMERA_ID will be used
CAMERA_SDK	LUCID_ARENA	SDK used to load device: [ARAVIS]   [LUCID_ARENA]   [PYLONGIGE]   [TIS]   [VIDEFILE]   [FRAMESDIR]   [V4L2]   [VIDEOINPUT]
CAMERA_INIT_CONFIG	/usr/local/share/freeture/cmit.cfg	Path in cui cercare i file di configurazione
CAMERA_INIT	false	Definisce se necessario configurare la camera prima dell'uso, se impostato su true dopo la configurazione della camera questo parametro verrà settato a false
CAMERA_ID	0	Identification number of the camera to use. Use 'freeture -f' command to list available devices. [Camera Index value]   [VIDEFILE]   [FRAMESDIR]
INPUT_VIDEO_PATH	/freeture/	List of videos to analyse. Use ";" separator between paths.
INPUT_FRAMES_DIRECTORY_PATH	/freeture/	List of frames directory (in fits). Use ";" separator between paths.
INPUT_TIME_INTERVAL	500	Time (in ms) between two fits loading or two video frames. Used if the input is a video or a frames directory to give more time for the detection process to analyse frames.
ACQ_FPS	30	Camera's acquisition frequency.
ACQ_FORMAT	MONO12	Camera's acquisition format. Use "--listformats" option with a "d deviceIndex" to see available pixel formats. [MONO8][Index 0]   [MONO12] (Index 1)   [YUYV] (Index 4) etc...

Show page 1 of 11 Back 1 2 3 4 5 - 11 Next

**Modify**

Parameter: Key Value Description: Description

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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, contact your StAnD representative first;
- **Observer**: the name of the person responsible for the kit;
- **Altitude**: the altitude above sea level of the all-sky camera installation site, measured in metres;
- **Longitude**: the geographic longitude of the all-sky camera installation site, measured in decimal degrees (E), with at least 4 - 5 decimal digits;
- **Latitude**: the geographic latitude of the all-sky camera installation site, 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 all changes have been made, press *Save* and wait for a confirmation message (in a green textbox) to pop up in the top right corner of the screen.

At the first installation, **verify the geographical coordinates using a GPS** (the typical accuracy of a **smartphone** should be sufficient; otherwise, check the position on **Google Maps**). If you need to move your camera, contact your StAnD representative first, then change the coordinates on this page.

The last section is *Manual configuration* and allows **modification of all the parameters** contained in FreeTure's configuration file. The table can show 10 - 100 elements at once and provides an overview of the parameters, their corresponding values and a short description for each parameter. When first delivered, the camera will already be **configured for normal operating conditions**. Any modification of these parameters (apart from those listed in the *Automatic configuration* section) may disrupt the operation of the camera, and **the user assumes responsibility for any modifications performed**.

#### **4.2.4. Maintenance**

This page is available only when logged in as an **admin**. It allows rebooting of the whole system by clicking the (only) red button *Start the reboot*. You will need to **log in again to the browser interface once 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 32](#) for an example.

It allows previewing **and downloading of 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 capture 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 that allow browsing **through the calibration data**. The first table displays acquisitions from the last 10 days (you can scroll back in time using the page Back / Next buttons) and the number of captures acquired each day. A regularly functioning camera should acquire **about 144 captures per day**.



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

The screenshot shows a web browser interface for the StAnD Meteor Camera Kit. The browser address bar shows 'FRCA20'. The page title is 'Calibrations'. On the left, there is a sidebar with the 'orma' logo and a navigation menu. The main content area is titled 'Calibrations' and contains a table of calibration records. Below the table, there is a section for the 'Last calibration' which displays a large circular image of a meteor camera's field of view. The image shows a wide, curved horizon with a bright meteor streak across the sky. The text 'FRCA20\_20250131T104748\_UT-0' is visible above the image. In the bottom right corner of the image, there is a logo for 'Students as Planetary Defenders StAnD'.

Date	#	Calibration name	Time	Preview	Download
2025-01-31	65	2025-01-31 (65 calibrations)			
2025-01-30	143	FRCA20_20250131T104748_UT-0.9f	10:47:48		
2025-01-29	144	FRCA20_20250131T103226_UT-0.9f	10:32:26		
2025-01-28	50	FRCA20_20250131T102226_UT-0.9f	10:22:26		
2025-01-16	38	FRCA20_20250131T101226_UT-0.9f	10:12:26		
2025-01-15	37	FRCA20_20250131T100226_UT-0.9f	10:02:26		
2025-01-14	3	FRCA20_20250131T095226_UT-0.9f	09:52:26		
2025-01-13	54	FRCA20_20250131T094226_UT-0.9f	09:42:26		
2024-12-17	7	FRCA20_20250131T093226_UT-0.9f	09:32:26		
2024-12-16	11	FRCA20_20250131T092226_UT-0.9f	09:22:26		
		FRCA20_20250131T091226_UT-0.9f	09:12:26		

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By clicking on an entry in the first table, you select that particular day and all the captures acquired during that day are displayed in the second table on the right. Each entry shows 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 using the dedicated slider on top of the table. You can download the preview (.png format) by right-clicking on the image in the browser and selecting the *Save image* option. Since the previews are generated on request and make use of some of the mini-PC's computational power to be produced, it is **strongly recommended not to generate previews during night-time**. Preview generation can be disabled by the admin (see [Section 4.3](#)).

The second section of this page, *Last calibration*, displays a **preview of the latest capture** acquired by the camera.

Captures are **stored on the mini-PC for about two months**. After this time, they are deleted to free up disk space for new acquisitions. If the station is properly connected to the network, captures are **continuously synchronised to the PRISMA servers**, where they are stored and processed.

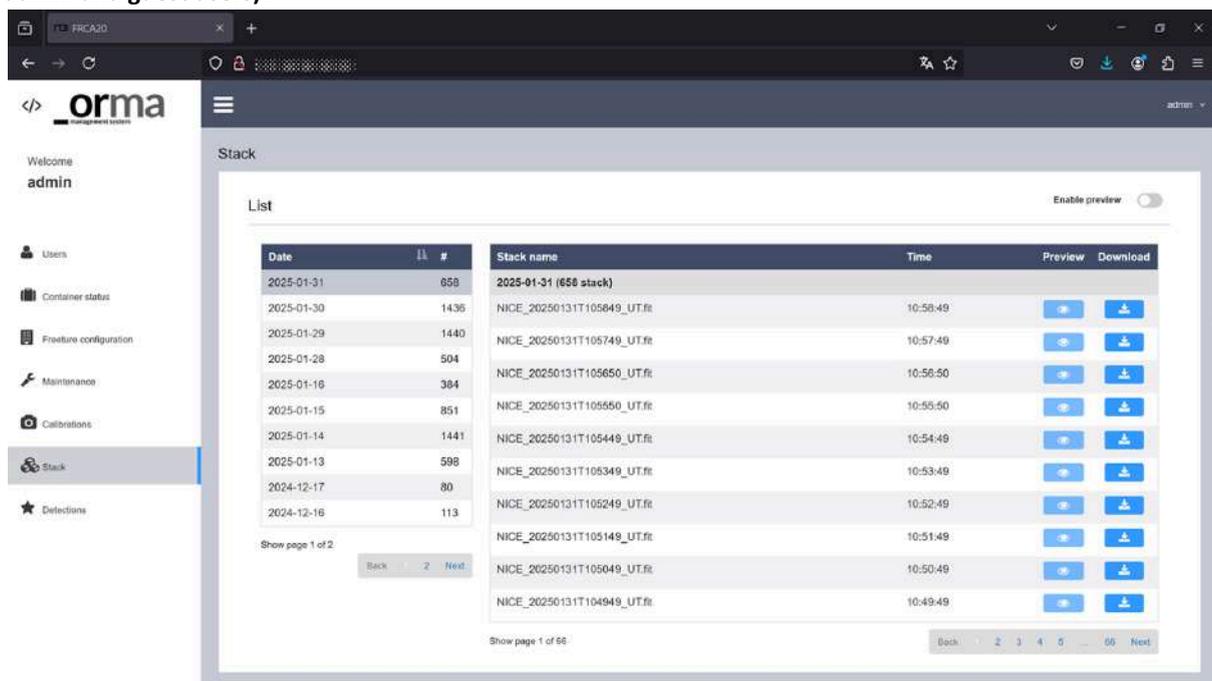
#### 4.2.6. Stacks

This page is available to **both admin and guest**. See [Figure 33](#) for an example.

It allows previewing **and downloading 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](#)) over a period of 1 minute. Therefore, each stack image is the **sum of 1800 frames**.

The layout of this page is the same as that of the captures data (see [Section 4.2.5](#)).

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





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

Stack images are saved to provide live-time feedback on what is happening within the camera's FoV, but they are not included in the scientific processing. Therefore, they are **not synchronised with the PRISMA servers**. Stacks are **stored on the mini-PC for about two months and then deleted**.

#### **4.2.7. Detections**

This page is available to **both admin and guest**. See [Figure 34](#) for an example.

It allows **previewing and downloading the detection (meteor) data**, which are videos of meteors captured by the FreeTure software. As already mentioned, the camera operates continuously at 30 fps to check for the passage of meteors within 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 in the 30 fps video stream, which may be meteors or fireballs. In such a case, FreeTure saves the portion of the video in which the meteor was detected.

The layout of this page is similar to that of the calibration and stack data pages. The first section, *List*, allows **browsing through the list of detections recorded each day**. For each detection, you can preview and download the following:

- **Preview**: an integrated image of the video, on which the meteor track should be visible (see [Figure 35](#), top panel);
- **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 35](#), bottom left panel);
- **GeMap**: a black-white image indicating the region of the frame where the meteor was detected by the trigger algorithm (see [Figure 35](#), bottom right panel);
- **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 in your browser and selecting the *Save image* option. The preview generation can be disabled by the admin. Additionally, 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 of the mini-PC's computational power to be produced, it is **strongly recommended not to generate previews and download videos and zip files during night-time**.

As this is an automatic system, detections **may contain false positives**, that is, a detection may be caused by other natural or artificial events occurring within the camera's FoV. For example, the **lights of a car passing by** may trigger a detection on the horizon of the camera



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

Detections are **stored on the mini-PC for about two months**. After this time, they are deleted to free up disk space for new acquisitions. If the station is properly connected to the network, detections are **continuously synchronised to the PRISMA servers**, where they are stored and processed.

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

**Figure 34 – The *Detections* page of the web browser interface for the StAnD Meteor Camera Kit (available to both admin and guest users).**

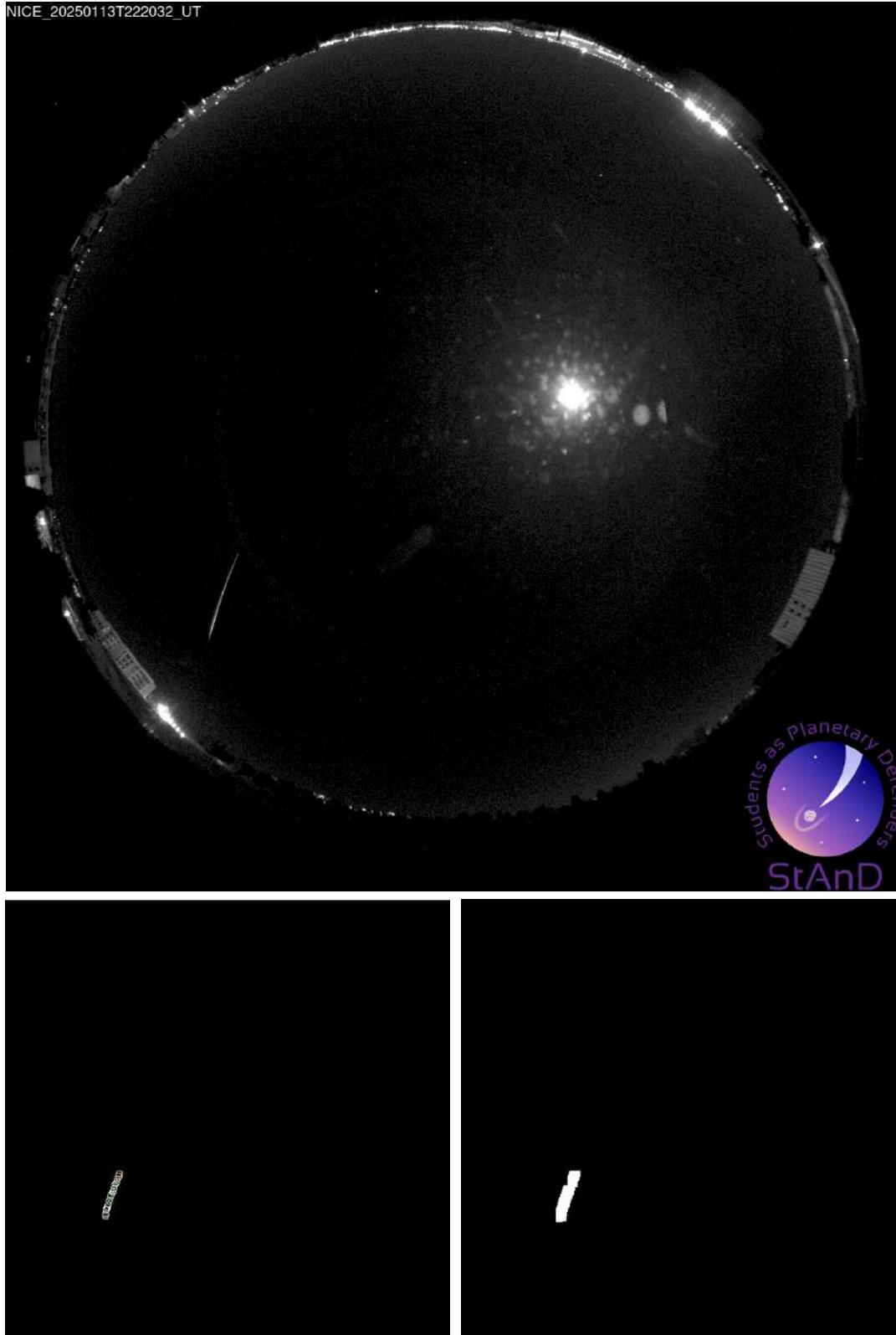
The screenshot displays the 'Detections' page of the web browser interface. The page is titled 'Detections' and features a sidebar with navigation options: Welcome admin, Users, Container status, Feature configuration, Maintenance, Calibrations, Stack, and Detections (selected). The main content area is divided into three sections:

- List:** A table showing a list of detections. The table has columns for Date, #, Detection name, Time, Preview, DirMap, GeMap, Video, and Zip. The data is as follows:

Date	#	Detection name	Time	Preview	DirMap	GeMap	Video	Zip
2025-02-03	3	2025-02-03 (3 detection)						
2025-02-01	1	NICE_20250203T195219_UT	19:52:19					
2025-01-31	3	NICE_20250203T053856_UT	05:38:56					
2025-01-30	10	NICE_20250203T041940_UT	04:19:40					
2025-01-29	6							
2025-01-28	1							
2025-01-14	5							
2025-01-13	5							
- Last detection:** A section titled 'Last detection' showing a detection from 2025-02-03 at 19:52:19. It includes a camera image of a meteor streak.
- Grafico delle rilevazioni:** A line graph titled 'Grafico delle rilevazioni' showing the number of detections over time. The y-axis is labeled 'Numero di rilevazioni' and ranges from 0 to 1.0. The x-axis is labeled 'Settimane' and shows dates from 2025-01-06 to 2025-02-09. The graph shows a single data point at 1.0 for the week of 2025-02-03 to 2025-02-09.



Figure 35 – An example of preview images for a detection made by the FRCA20 - Nice camera of the StAnD network on the 13th of 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 the approximate position of the meteor detected by the trigger algorithm can be visualised.





## 4.3. Maintenance of the Kit

### 4.3.1. Detection Mask

After the first boot of the StAnD Meteor Camera Kit, once you have verified that the kit is correctly connected to the Internet (see [Section 3.5](#)), you will need to **update the detection mask to minimise the number of false positives** detected by the FreeTure trigger software (see [Section 4.2.3](#) and [Section 4.2.7](#)). Such detections are caused by various artificial sources and typically occur 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 mini-PC's **HDD to fill up faster than two months**, resulting in a lower performance of the kit and in a shorter timespan before data are locally deleted from the mini-PC.

Depending on the configuration parameters (see [Section 4.2.3](#)), **FreeTure may fail to start properly without a mask being uploaded**. In this case, if you wish to start the operation of the kit regardless, log in to the browser interface, go to *FreeTure configuration* and change the parameter **ACQ\_MASK\_ENABLED to false** (under the **Manual configuration** section of the page). Remember to **set this parameter back to true** after uploading the mask.

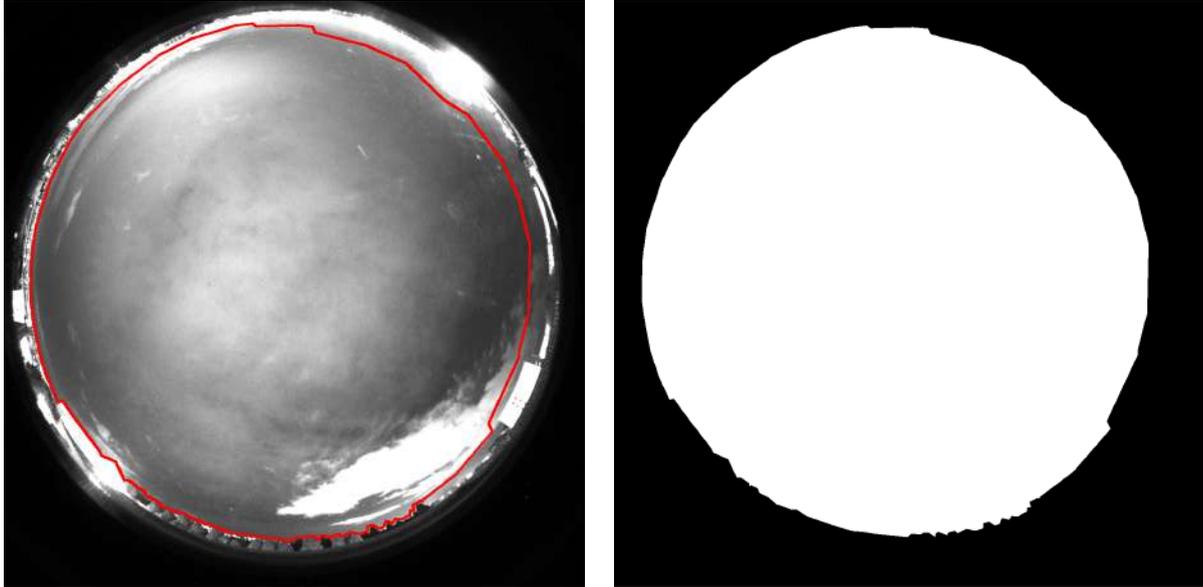
The detection mask must be an **8-bit black-white .bmp image** with the same resolution as the frame acquired by the camera. In this image, the **black portion indicates the region where triggers should be excluded by FreeTure**, while the white portion marks the region where the software will look for 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 its orientation. To do so:

- you can **ask your StAnD representative** 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 installing this software, launch it and select *File > Open* from the menu bar, then 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 36](#));
  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 colour** using the *Bucket Fill* tool;
  4. Then, **invert the selection** (*Select > Invert* from the menu bar) and **fill it with black colour** using the *Bucket Fill* tool;
  5. Go to *Image > Mode* from the menu bar and select *Grayscale mode*, then again, go to *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;
  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 36 – An example of the detection mask for the StAnD camera FRCA20 - Nice. The left panel highlights the border that was selected in GIMP to define the masked region, while the right panel shows the final result (where the white portion of the image marks the region where triggers are possible, and the black part represents the excluded region). Notice that the upper-right horizon in the image is masked with a thicker margin due to intense light from a street lamp. Additionally, the lights from cars passing in that direction were found to be triggering false positives during night-time.



After modifying the detection mask, you can **monitor whether the camera is frequently detecting false positives** during night-time via the browser interface. If so, you can adjust the mask - for example, by **raising the border above the horizon** to mask additional pixels and exclude the region that is causing such false positives.

#### **4.3.2. Software Monitoring**

To ensure the best operational status of the StAnD Meteor Camera Kit, you should periodically check the functionality of the software by logging into 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 for any **errors reported under the *Node status* section**. If any errors are detected, report the issue to your StAnD representative.
- On the ***Containers status*** page, check whether 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 representative.
- On the ***Calibrations and Stack*** pages, check whether **data are being acquired regularly** every day. 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 representative.
- If needed, you can **disable the display of the preview and the download of video and zip files**. In order to do so, go to the homepage and, from the user menu in the upper-right corner, select *Settings*. Both options can be enabled or disabled under the *Media View* section.



### **4.3.3. Hardware Monitoring**

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

1. Check the condition of the protective plastic dome of the all-sky camera. **Water droplets are not a problem**, especially during summertime. 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.
2. 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 the one connecting the all-sky camera module to the mini-PC.
3. Check the **status of the mini-PC and network switch**. They should be powered on, with all cables correctly plugged in, and displaying the correct lights on their front panels (see [Section 3.4](#)). If you know that the power went down in your building, check whether the mini-PC is back on; if not, power it on by pressing the power button on its front panel (see [Figure 13](#)).