DVTI + CAM

User Manual

English version v5.8.1b
from 13.01.2025

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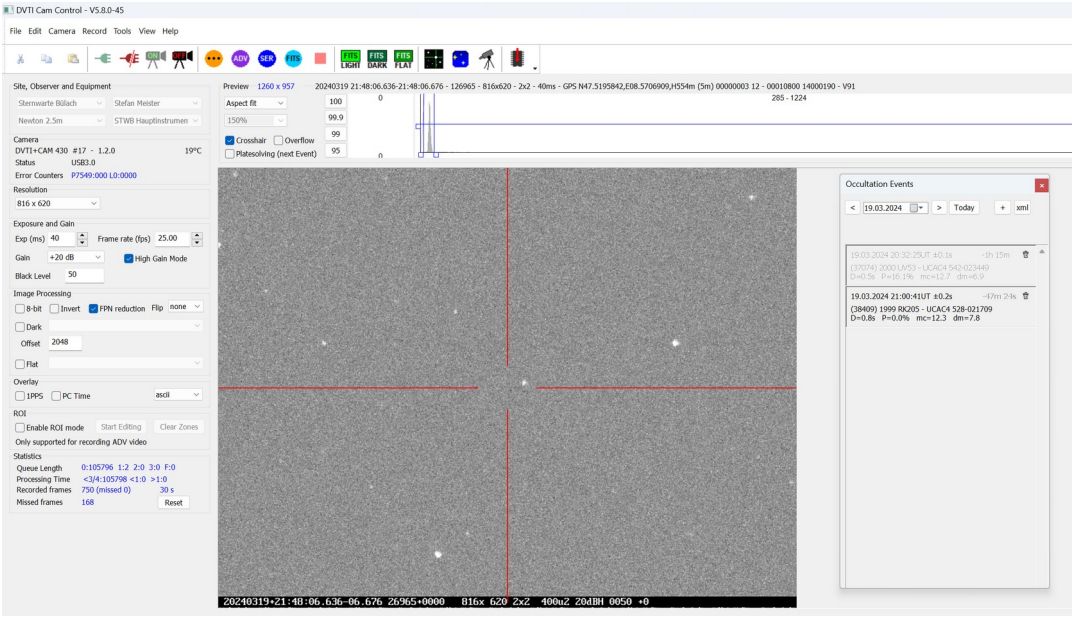
1 Overview

The DVTI camera was created by two active amateur astronomers for recording stellar occultations. It contains a receiver module for navigation satellites, which integrates the high-precision[1] time signal in UTC into the digital data stream from the image sensor. The time signal is therefore not added in the recording software, as is usually the case with digital astro cameras, but directly in the camera. This avoids uncontrollable delays caused by data transfer and running operating system processes, which can play a role in time-critical events and short-exposure video frames, as is common in the case of stellar occultations. How large these delays can actually be in individual cases can be measured with the camera control software. See the section 4 (menu item "PC Time") or section 7.7.

The term "DVTI" means "Digital Video Time Insertion" and is derived from the various "VTI" devices that were previously used in connection with analogue video cameras. One example is the IOTA-VTI[2] , which entered the market around 2012.

To benefit from all camera features in conjunction with the precise time signal, the DVTI camera is primarily operated using the "DVTI Cam Control" software developed for this purpose. This software (hereinafter simply referred to as the "tool") runs under the Microsoft Windows operating system. As this is a USB3 camera, Windows 10 or higher should be used, as the USB3 standard is only fully supported by the operating system from this version onwards.



With appropriate restrictions, the camera can also be operated under macOS or Linux (via USB UVC standard driver). We have tested the SharpCap and oaCapture recording tools, but there are certainly others that work. However, full control over the timestamp and recordings in ADV format, which offers many advantages over others, are only possible with the tool under Windows.

[1]The "time stamp" on the GPS signals must be imprinted with an accuracy of one billionth of a second in order to guarantee a positional accuracy of around one metre. (Source: DLR)
[2]IOTA-VTI in version 3: https://videotimers.com/home.html

2 First Steps

2.1 Setting up the connections

- Connect the GPS antenna to the camera’s ANT connector. Make sure that the antenna has a clear view of the sky. (The camera also works without satellite reception, but in this case of course no precise time stamps are available).
- Connect the camera to the computer (Windows 10 or 11 system) using a USB 3 cable. Make sure that you use a high-quality, SuperSpeed-capable cable (SuperSpeed-capable cables are marked with blue color on the A-connector side).

Windows should automatically recognise the camera as a new device and set it up. The red "SYS" LED should flash twice after the connection has been established. You do not need to install a separate driver as the standard Windows camera driver is used. The camera appears in the device manager as a video device. Note: There is no separate power supply. The camera draws its power from the computer via the USB cable. The "GPIO" connection is a service connection and is not normally required.

2.2 Setting up the control software

- Download the DVTI Camera Control software (hereinafter referred to as "tool") from our website[3] and install it on your computer. A setup programme will guide you through the installation. If possible, select a directory on an SSD hard drive for saving the video files. The camera generates large amounts of data at a high transfer rate.
- If the camera is connected to the computer and the control software is running, you should be able to establish a connection to the camera via the "Camera" menu (top menu item) and start streaming ("Start Streaming" menu item). The camera image should then be displayed in the preview area.
- Configure the camera settings as required, e.g. exposure time, gain, resolution.
- You can now start recording ADV, SER and FITS single-frame videos via the menu.

Important: Make sure that as few other programmes and processes as possible are running and accessing the hard drive while the recording is running so that as much computing power as possible is available for the control software. Otherwise, frames may be lost in the recording at high frame rates.

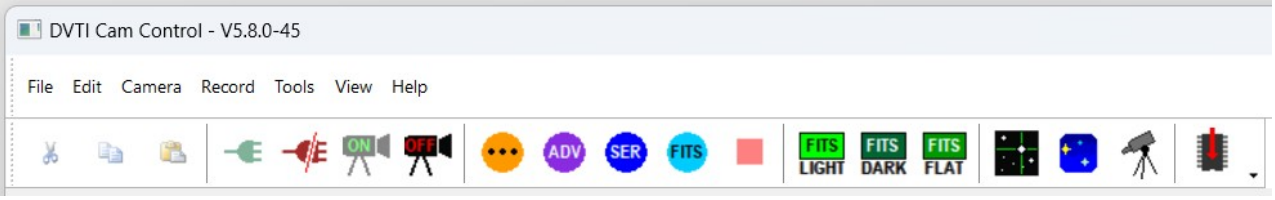
2.3 OccultWatcher integration

- Download the OccultWatcher plugin from our website[3] and place it in the OccultWatcher programme directory.
- After restarting OccultWatcher, you can send the corresponding entry to the control software via the "Forward event to DVTI control tool" entry in the context menu (right-click on an event).
- If the control software is running and the event window is open, the event appears in the window. The information from the event can be used, among other things, to automatically start and stop the recording and to generate the European declaration form.

[3] https://dvticam.com/support

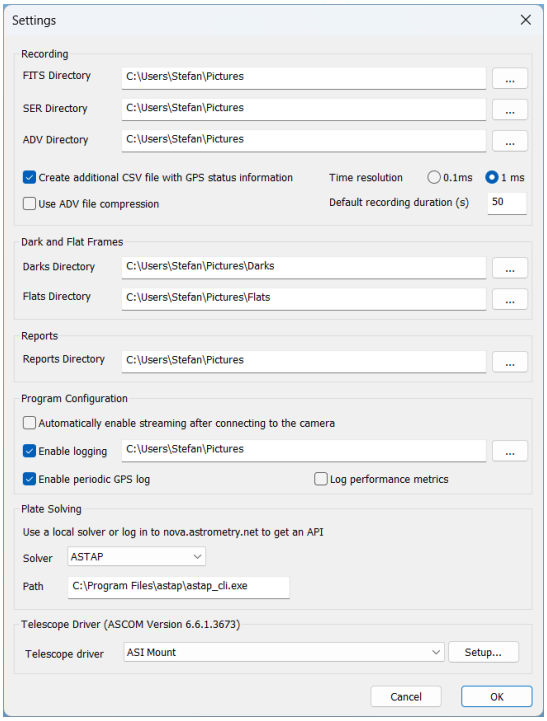
3 Menu structure of the tool

The most important menu items of the tool are described below. Coloured icons are also available in the top line for the most frequently required actions:



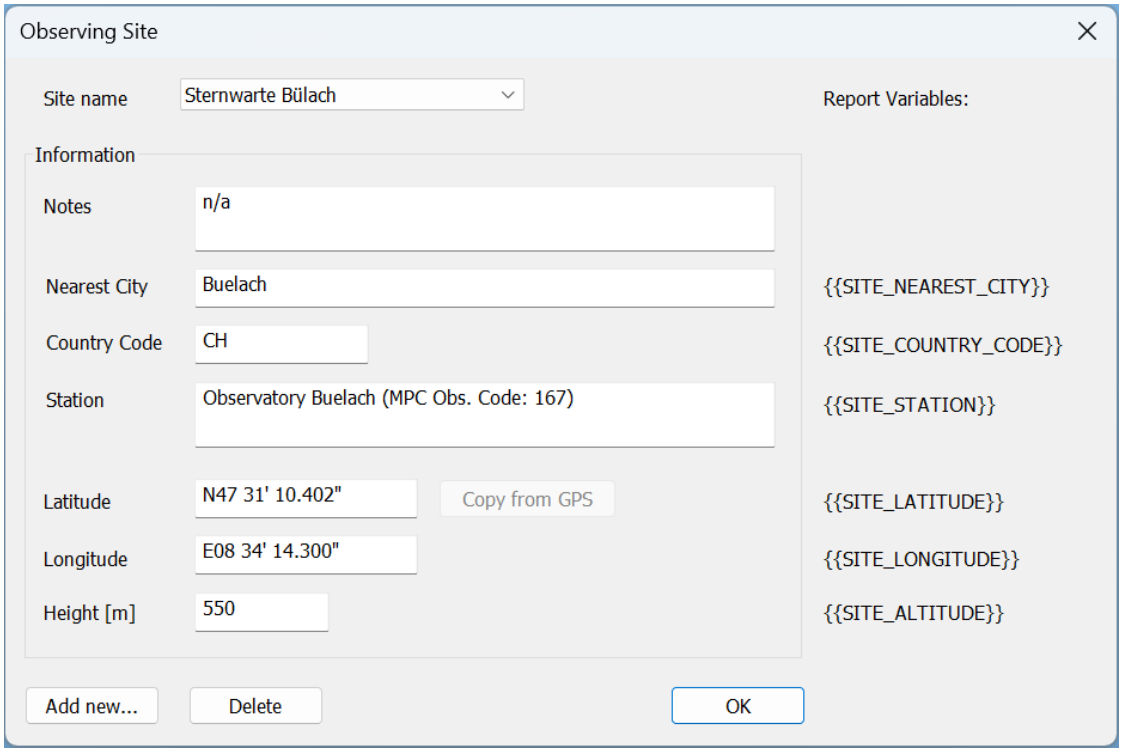
Edit > Settings...: Set the paths where video and image data as well as darks and flats are to be saved. The recording files are then automatically given a unique name and stored in the appropriate directories depending on their type. The "Time resolution" radio button can be used to switch the resolution of the timestamps between 1ms and 0.1ms. As a rule, a resolution of 1ms is sufficient. The "Default recording duration" input field is used to set the default duration in seconds for automatically triggered recordings ("Record with options" function, see below). Log files can also be activated here (see section 10.6), Platesolving and the standard ASCOM telescope driver can also be set here, if desired. Useful to know: If "Platesolving" is used later, the automatic images from the platesolving are also saved as a FITS file preceded by the letter P under the image directory specified here. These images can also be analysed again later using the Platesolving function without the camera having to be connected.

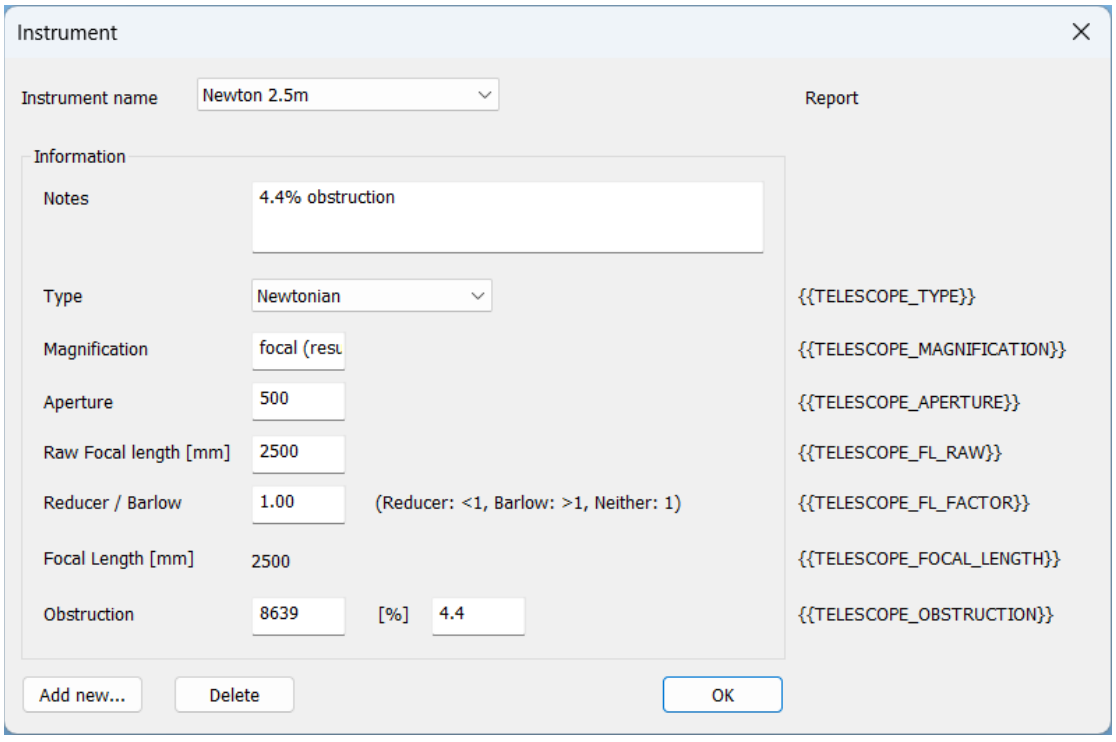
A newer function is the "**Use ADV file compression**" checkbox. If this is ticked, then each frame of an ADV recording is compressed (multiple passes over all pixels and for each frame during operation). The lossless LAGARITH16 algorithm is used for this. There are advantages and disadvantages to this: On the one hand, this reduces the size of the saved files without compromising the data quality, but on the other hand it requires a lot more computing power for this operation (especially at high frame rates). If in doubt, you should therefore first test up to which frame rates your own computer can still cope with this and at what point "missed frames" occur (see the section on "Statistics" in chapter 4).



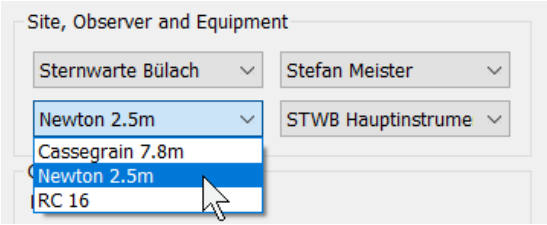
Edit > Observers... / Observing Sites... / Telescope Mounts... / Instruments...: The content of the four selection boxes in the top left-hand corner is defined here. This data is primarily important for automatically filling in the IOTA report or the upload file for the SODIS database after an occultation. However, some data is also used by the software itself, for

example to calculate the image scale when platesolving. The unit of "Height" is m, while "Aperture", "Focal length" and "Obstruction" are specified in mm or mm^2 . The latter value can also be entered as a %, in which case the other value is calculated:





If several instruments are used or if observations are occasionally made from mobile locations, it is advisable to record all the data here so that you can quickly switch between the different setups later:

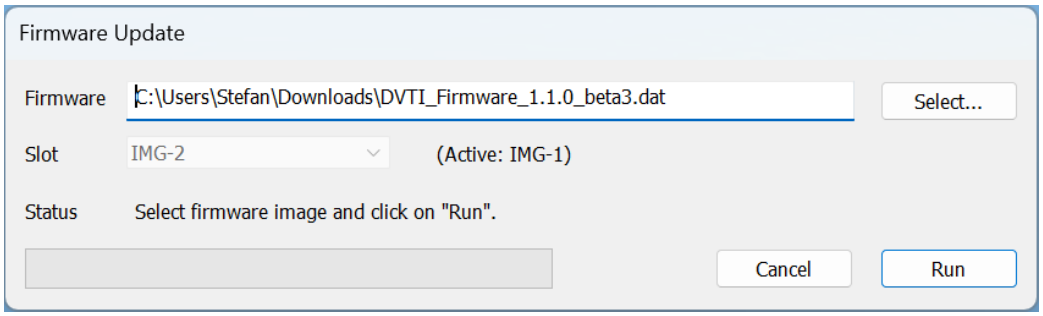


Please note that the setup selection must be made before streaming starts (boxes are then greyed out and changes are deactivated). Otherwise, the streaming would have to be briefly interrupted later to change these selection fields.

Camera > Connect DVTI-CAM: Only appears active at the beginning if the camera is not yet connected. The connection is complete with "Connect DVTI-CAM" and then "Start streaming" (or faster via the two icons at the top of the toolbar with the green plug and camera ON).

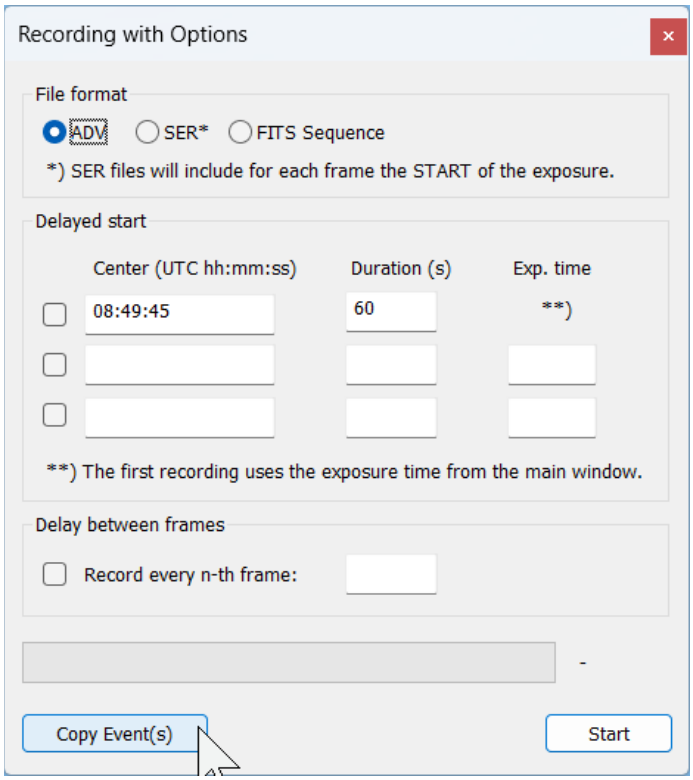
Camera > Disconnect: The camera is deactivated again in reverse order. So first "Stop streaming" and then "Disconnect" (or faster via the two icons at the top of the toolbar with Camera OFF and the red plug):

Camera > Update firmware...: New firmware can be installed here if required. The firmware file is the software for the electronics in the camera (microcontroller, etc.). If we develop new functions for the camera, e.g. higher binning 3x3 or 4x4, or higher frame rates, bug fixes etc., then there is a new firmware file that can be loaded into the camera using the control software. The procedure is described in detail in section 9.



Record: This menu item is used to start image or video recording. The first three entries (SER, ADV, FITS Sequence) and "Stop recording" are for video recordings, while "FITS Light" is used for single images. It is recommended to use the new ADV format for video recordings if possible. This format combines all image files in a single video file (in contrast to FITS series), which simplifies handling and improves writing performance, and also contains various metadata such as the precise GPS time per frame (see section 5.2.2). In addition, darks and flatfields can also be recorded for calibration, which can later be applied to the video recording during operation, for example.

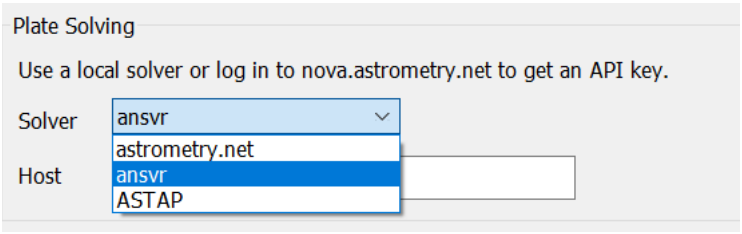
A special but very useful option is "**Record with option**" to automatically schedule a future recording (e.g. for pre-pointing): The file format is first set at the top and then the recording centre **point** (not the start time!) and duration are specified. The recording centre point usually corresponds to the predicted occultation time and can be automatically adopted when using the OccultWatcher plug-in (see also Tools > Event Data...). If there is a future event after the import, a "Copy Event(s)" button appears to automatically copy the correct time. Up to three future events are possible. The software then starts the recording half of the "Duration" before the "Central time". The basis for this is the system time of the computer and not the GPS time stamp, which can be relevant in the event of large deviations. The "Duration" should be selected sufficiently long depending on the duration of the occultation and the inaccuracy of the forecast (see error information). The default value can be specified in the settings (input field "Default recording duration").



After scheduling the recording(s) with "Start", a progress bar at the bottom of the window shows the duration until the recording and during the recording the duration until the end of the recording.

For all entries under "Record" there are also corresponding icons in the toolbar for quick selection:

Tools > Plate solving...: If one of the three available plate solvers is selected and installed/configured at the bottom of the "Settings", an image can be analysed using this option.



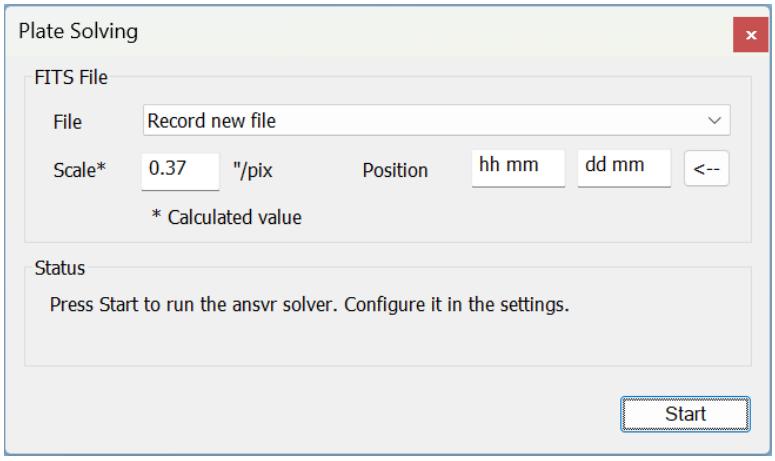
Either a new image can be captured or an existing image (saved as FITS under the predefined FITS path) can be loaded. The following solvers are available for selection:

1. The online plate solver "**astrometry.net" is** also suitable as a so-called blind solver for difficult conditions or small image fields. However, it can take several minutes for a solution to be returned due to the workload. An internet connection and an API key, which can be obtained from the astrometry.net website[4] , are required for operation. "nova.astrometry.net" is then entered in the "Host" field in the "Settings" and the API key received is entered to the right of it in the respective field.
2. The "**ansvr**" plate solver is a variant of the "astrometry.net" online plate solver that can be installed locally (either directly on the PC or on a server in the local network). Internet access is not required to operate the solver. When the solver is active, it provides a web service similar to the online version, which receives the images and returns the results. The host name (or IP address) and port of the service must be entered in the "Host" field in the settings. If the service is installed on the local PC, it runs by default on port 8080 and can be addressed via the host name "localhost", i.e. the entry in the host field in this case is "localhost:8080" (without inverted commas). The installation package and the operating instructions for this solver are available on the Internet at[5] . The installed server can be started manually in the Windows Start menu under Astrometry.net Local Solver > Start Ansvr.
3. The "**ASTAP"** plate solver runs locally on the PC and is activated via a command line call. The solver is part of the "Astrometric STAcking Program" software and offers star catalogues of various sizes, which must be selected depending on the focal length of the telescope. If "ASTAP" is selected as the solver in the settings, an input field with the title "Path" appears, where the path to the command line tool astap_cli.exe must be entered. For a standard installation, this is "C:\Program Files\astap\ astap_cli.exe" (without inverted commas). The installation package and further information on ASTAP can be found on the Internet at hnsky [6]

Our recommendation is to install the "ansvr" plate solver locally for small and medium focal lengths. The solver typically delivers a result within a few seconds (if the position is roughly known) to a few tens of seconds (if the position is unknown).

[4]https://nova.astrometry.net/api_help
[5]https://adgsoftware.com/ansvr/
[6]https://www.hnsky.org/astap

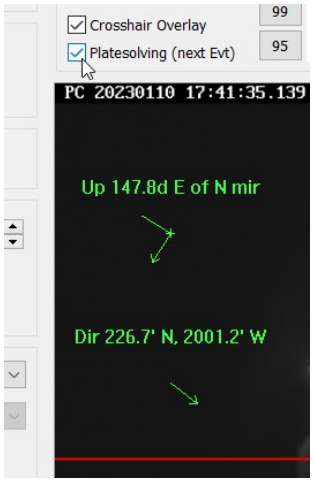
The process can then be started via Tools > Plate solving...:



In the window that pops up next, "Scale" is automatically calculated using the stored instrument focal length and the camera model and binning used, but the image scale can also be overwritten. The "Scale" and an approximate position specification are decisive for how quickly the plate solving works. The "Scale" display is only updated when the instrument is changed if the focal length of the instrument is stored in the settings and a camera is actually connected (reason: this is the only way the software knows the pixel size based on the different models and can calculate the correct image scale).

Important: If a Barlow lens or a reducer is used, the correction factor should be stored in the settings (Edit > Instruments...) so that the actual focal length of the optical system is used to calculate the "Scale" value and so that the image scale is correct.

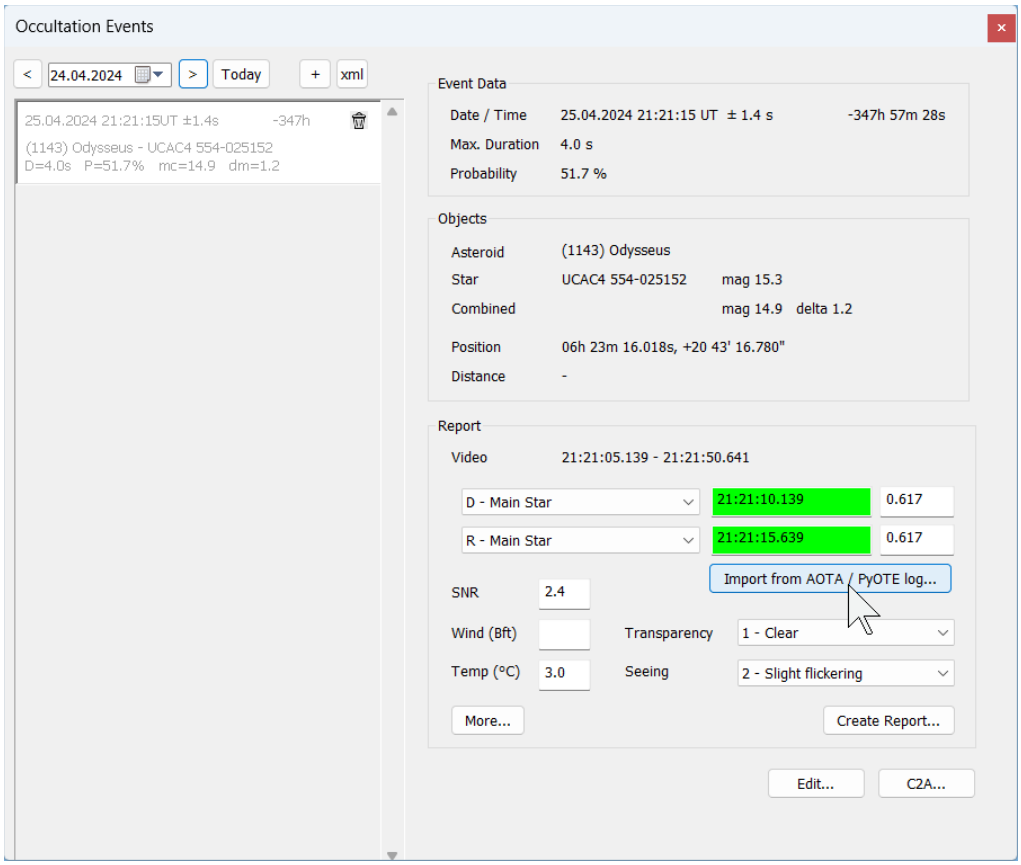
Platesolving is started by clicking on the "Start" button. A solution is now searched for in several runs and the progress is displayed under "Status". If successful, a "Success!" appears and the image coordinates found are displayed under "Status". These remain stored internally. If "Platesolving" is ticked on the main page, the image alignment is now displayed in the preview area using a compass (N and E). If a future object is planned (e.g. by importing from OccultWatcher), the direction and distance to the target object is also displayed. The target object is not the one marked in the "Occultation Events", but explicitly the next one in the list. Hence the addition "next Event":



Tools > Event Data...: To start a recording automatically or to generate the observation report automatically, the Occultation Events can be entered in the tool. There are three different options for this:

- If the OccultWatcher plugin is installed, events can be imported directly by right-clicking in OccultWatcher. This is the simplest procedure.
- In addition, events can also be organised via the Occult XML file ("XML" button) or
- can be entered completely manually (button "+") by entering all data fields.

The events are displayed in a calendar and as a list per day. To show or hide the details of an event, click on the event. This expands the "Occultation Events" window to the right with all the details:

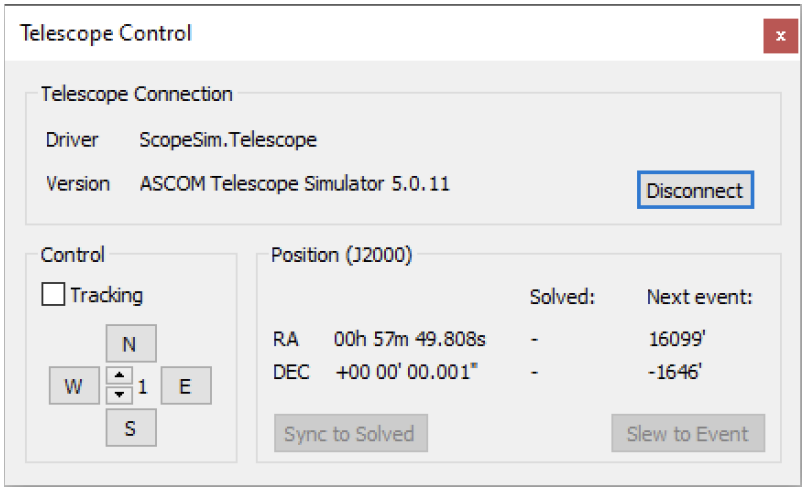


Events can be deleted from the list by clicking on the rubbish bin icon. Once the details have been displayed, they can be edited using the Edit button. The "C2A" button is available to display an event in the C2A planetarium programme.

The result of the occultation, whose exact contact times were determined after an analysis with PyOTE or AOTA, can also be recorded in the event dialogue. For this purpose - similar to SODIS - the fields "Non Detection" for negative or "Main Star" for positive events are available, including the time and accuracy. Alternatively, the determined times can also be imported using drag & drop or by selecting the log file ("Import from..." box). The observation report is then generated using the "Create Report..." button. The text report can be freely configured with keywords (see section 8). For "Create Report..." to work, a report template with the file name report_template.txt must be saved in the programme directory.

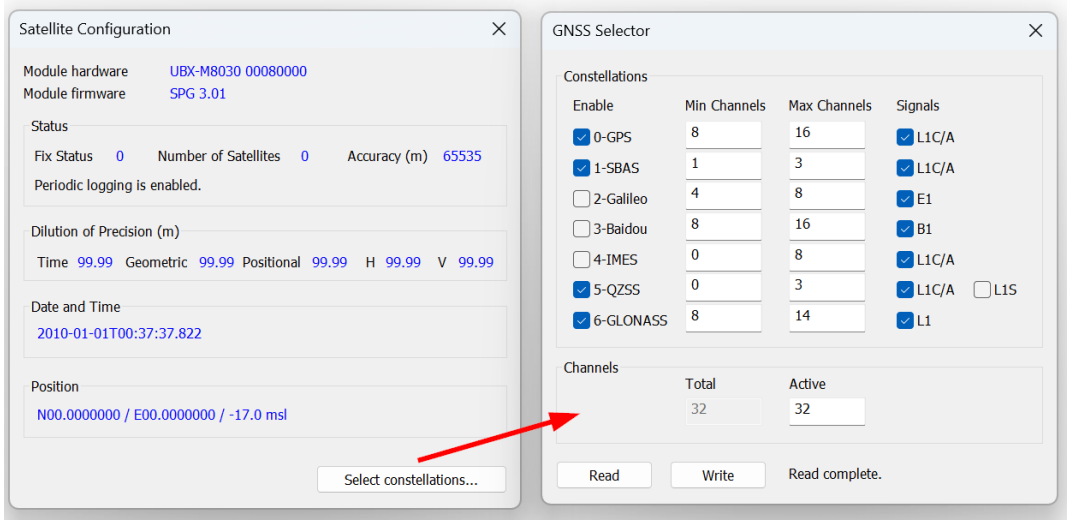
Current report templates for the new SODIS database or the old Euraster format can be downloaded from the support area[7] of our website.

Tools > Telescope...: A simple dialogue is available to control the telescope. An ASCOM driver must be installed for this. The driver is set up via Edit > Telescope Mounts...



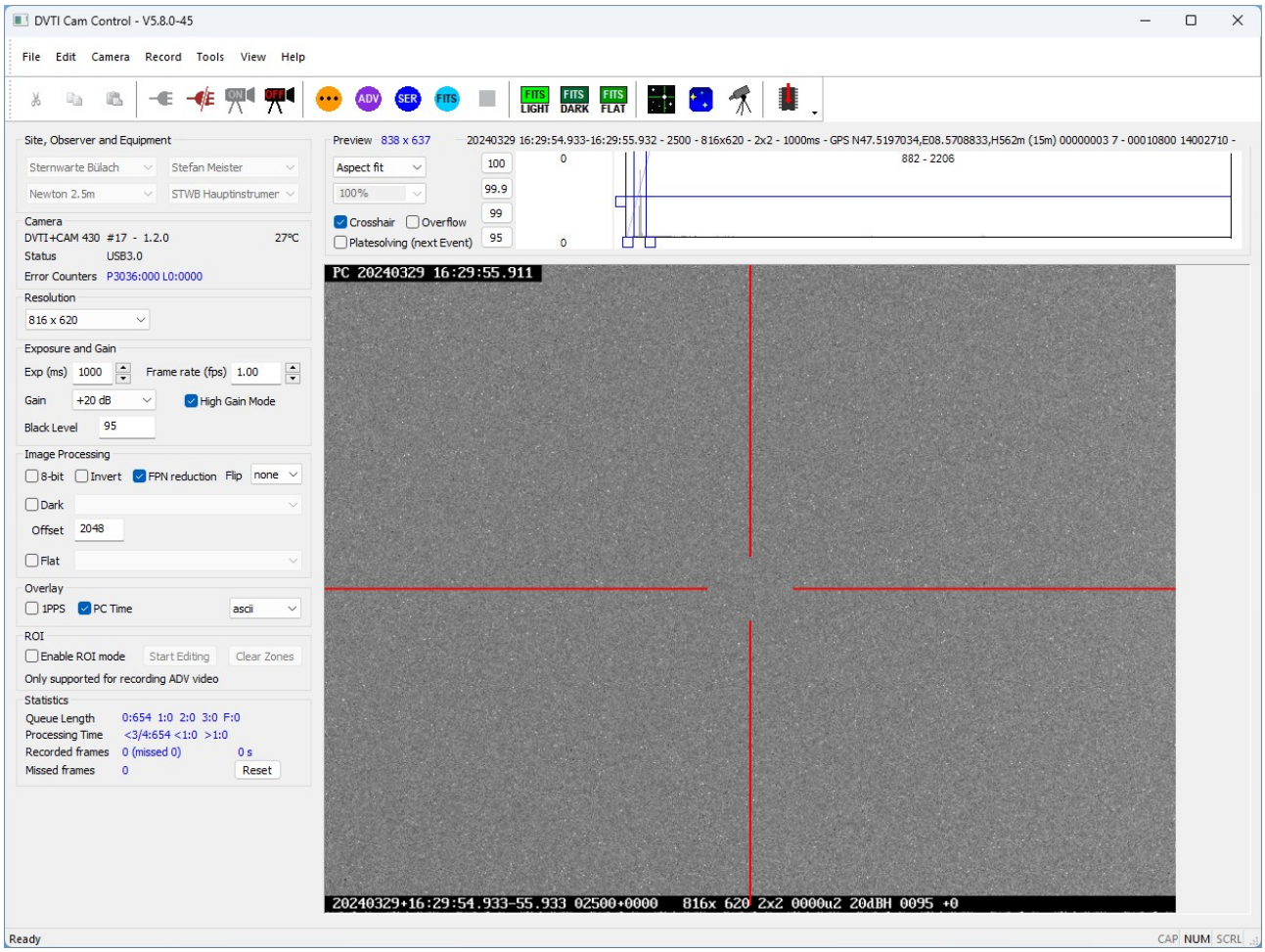
In the "Control" area on the left, tracking can be switched on and off (checkbox "Tracking") and the telescope can be moved in RA and DEC (buttons "N", "S", "W" and "E" as well as the speed selection). The current position of the telescope and the distance to the next event are displayed in the "Position" area. The "Slew to Event" button can be used to execute a GOTO to the next event. After a plate solving, the "Sync to Solved" function is also available, which calibrates the telescope to the position determined in the plate solving.

Tools > Satellite Configuration...: The "Satellite Configuration" dialogue shows information on the GPS module, the firmware it contains and data on the current fix. Click on "Select constellations..." to open a sub-dialogue in which the desired satellite constellations can be selected and the number of channels assigned. The satellite module is set for GPS and GLONASS by default. As a rule, no adjustments are required here.



[7] At https://dvticam.com/support

4 The main window



Camera: The first line below the "Camera" entry contains information about the camera (model), its serial number and the currently loaded firmware version. The line under "Status" shows whether there is actually a USB3 connection.

Error counters: The transmission errors on the USB interface are displayed here: There are two numbers here, one is the number of physical errors on the connection between "P" and the colon (here 156) and the logical errors between "L" and ":" (here 0). Ideally, these numbers no longer change when streaming is running and the camera is generating an image. However, if these values change while the streaming is running, the connection is faulty. This can happen if the cable is of poor quality or if a previously good cable has been damaged over time, e.g. kinked or exposed to strong temperature differences. In addition, such problems can occur if you "wiggle" the cable or if it is not plugged in correctly. Individual faults are not a problem,

but if the numbers count up continuously, then something is wrong with the connection and it will break sooner or later.

Resolution: The resolution and the associated software binning are set here. A resolution reduced by half also means double binning. Special resolutions with a reduced image section enable recording with high frame rates for very bright objects. These resolutions are labelled with the suffix "fast". See also the section 5.4.2 (Fixed ROI).

Exposure and Gain:

Exp (ms) and frame rate (fps): Either the exposure time or the desired frame rate can be set here. After entering the value using the arrow keys or simply entering the value followed by "Enter", the second field adjusts accordingly. If the frame rate is set too high, a small warning triangle appears on the right to indicate that the data can no longer be transmitted in full. How high these maximum frame rates without frame loss are for the 174 and 430 models is shown in the table in section 7.1 can be seen. Although a shorter exposure time is possible, this results in time "gaps" during which nothing is recorded, as the maximum throughput is limited. Such "gaps" should be avoided at all costs for star occultations. These limits will be optimised in future firmware versions so that even shorter frame rates are possible without losses.

Gain: Signal amplification +00dB to +24dB. Even higher values with "D" after them mean additional digital signal amplification. The extent to which digital signal amplification still has an effect should be tested on a case-by-case basis. Basically, increasing the gain also increases the noise and hot pixels, which makes the use of dark frames more important. The 430 model has a "**High Gain Mode**" checkbox on the right-hand side, which can be used to increase the gain by a factor of 2.2. This additional amplification should normally be switched on, unless the target star is very bright.

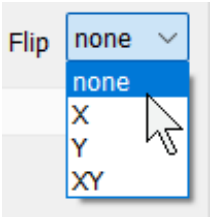
Black Level: This area is used to define the black level if the signal is too close to the lower or left edge of the histogram. The field usually remains empty. The value is always calculated automatically, but can be overwritten.

Image Processing:

8-bit: For 16-bit recordings, the tick must be removed here (this should be the rule).

Invert: Inverts the image if desired (black stars on a light background).

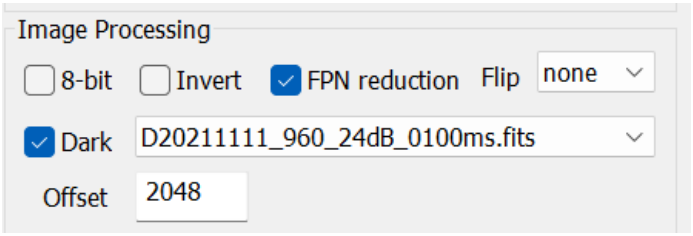
Flip: Mirror the X or Y axis or both combined (rotate the image by 180°). For star occultations, it is recommended to align the image with north up, east left. This makes it much easier to identify surrounding and comparison stars later on.



FPN reduction: This compensates for the sensor-related "fixed pattern noise" (FPN) or horizontal banding. The correction should generally be switched on at a higher gain, especially with the 174 model (if sufficient processing power is available). FPN cannot be corrected by dark

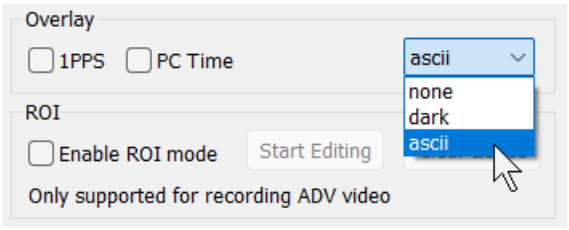
frames. The correction used here is similar to the "Median Projection FPN Correction" (mFPNc)[8] .

Dark or Flat: A previously created dark frame can be activated and selected here as a FITS single image recording. This is then automatically subtracted from the other images. When creating the dark frame, the telescope aperture must be covered as the camera does not have a shutter. The files are recorded via Record > FITS (Dark). The subsequent window asks for the number of images to be taken with the selected settings and averaged to create a master. The created file is saved with an automatically generated name consisting of the date, time and some setting parameters. After ticking Dark or Flat, the desired master files can then be selected from the selection menu on the right-hand side. The current stream is then calibrated in real time with these files:



Offset: An offset value may be necessary when using dark frames in order to avoid negative values. The "Black Level" value from above directly affects the image from the chip, while the offset performs a mathematical operation (pixel new = pixel old - dark + offset).

Overlay:



1PPS: Display of the "1 pulse per second" signal. Small markers (dashes) are displayed on the left edge of the screen. The time interval between the lines is exactly 1 ms. In addition, the left edge of the image is coloured white if the 1PPS signal of the GPS module is active while the image is being downloaded (= end of exposure). The 1PPS signal itself is highly precise and deviations are usually less than 1 ns.

PC Time: The "PC Time" box can be ticked as an alternative time measurement. The (inaccurate) system time of the PC is displayed at the top left of the image and is also recorded during a recording. However, the recording is only made graphically in the image and the data is not transferred to the digital time stamp or the metadata. Use cases:

- Measurement of the actual delay/jitter between the PC time and the actual GPS recording time (recorded video frames can be run through and compared frame by frame later).
- If for some reason there is no GPS fix shortly before a star occultation (or too little time remains for successful synchronisation), the recording can still be evaluated afterwards

[8] See https://piscat.readthedocs.io/Tutorial3/Tutorial3.html

with corresponding restrictions in terms of accuracy. As with the GPS time stamp, the "PC Time" is displayed in ms and refers to the start time of the respective frame.
When using this "PC Time" option, it is always advisable to synchronise the system time via NTP shortly beforehand.

Note: The PC Time is added to the image after it has been received by the video driver in the DVTI software. It therefore represents the time after exposure and after the image has been transferred via the USB connection and has passed through all software layers. Consequently, PC Time is not suitable for precise time measurement. It has a high and indeterminate jitter, which is exacerbated by the fact that Windows Time itself is very inaccurate (typically in the region of 10 or 100 milliseconds).

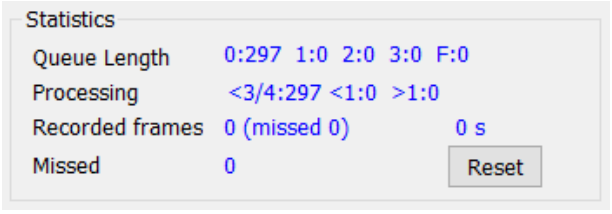
Res(olution) 0.1ms: For high-precision measurements (especially for very short exposures), you can switch to a display of seconds with 4 decimal places (i.e. 0.1 ms accuracy) in the menu under Edit > Settings... > Time resolution. This can also be useful to reduce rounding errors.

Selection window (to the right of PC Time)**:** In addition to "ascii" (default), "none" and "dark" are also possible. "none" is the setting to completely switch off the time stamp at the bottom of the image. With "dark", dark images can be created which are then subtracted during operation (see the menu item "Dark or Flat" under "Image Processing" above). The entire area of the timestamp (lowest 16 pixels) is overlaid with a black bar so that nothing is subtracted in this area when a dark image is printed. With "ascii", the time stamp is superimposed. How the time stamp is structured is explained below in section 5.1 below. It is worth mentioning that regardless of these settings, a binary timestamp is always transferred to the metadata when using the ADV, SER or FITS file formats and therefore the visual "ascii" timestamp is not absolutely necessary, but can often be useful for evaluation. This binary-coded time stamp can be recognised by the small, sometimes flashing pixels in the bottom line of the image at higher magnifications.

ROI:

To reduce the amount of data in the ADV video format, so-called regions of interest (ROI) can be defined via "Enable ROI mode". See chapter 5.4.1.

Statistics:



Queue Length: The processing of the frames is realised via a ring buffer of size 3. Ideally, each incoming frame should only be counted up after the "0:". This means that sufficient computing power was available on the PC to process the frames immediately after they arrived. If other programmes require a lot of computing power for a short time, the frames may have to wait until they are processed. In this case, the values behind "1:" and the subsequent buffers also increase. If the frame rate is so high for a long time that the image

processing cannot keep up and the memory is no longer sufficient, frames are ultimately discarded. This is the case if the number after "F:" and the value after "Missed frames" increases.

Processing Time: The "Processing Time" line shows how long it took to process the frames. The counter behind "<3/4" indicates how many frames could be processed within 75% of the available time. If only this number increases during streaming, then there is sufficient computing power available on the PC. The number after "<1" indicates how many frames between 75% and 100% of the available time have been used up. Values in this range are still OK. It becomes problematic when the number after ">1" regularly increases - which means that more than the available time was used for image processing (processing of darks, timestamps, FPN Red., storage, etc.). If this happens regularly, frames are lost and the number of "Missed Frames" increases.

If frames are lost, then there is not enough computing power available for the set configuration. There can be many different reasons for this, e.g. other programmes running on the system that require temporary or permanent performance, active energy-saving options that clock down the processor, or a system that is generally too slow. Here it helps, for example, to switch on binning (select a lower resolution under "Resolution"), set a lower frame rate or perform fewer calculation steps (dark frame subtraction, FPN correction, etc.). More information on avoiding "missed frames" can be found in section 10.4.

Recorded frames: Recorded and lost frames during recording and the recording duration in seconds further down.

Missed frames: Frames lost during the entire streaming period. This value can be reset using the reset button on the right.

Preview: [incl. specification of the current preview resolution]

Scale to fit: The image is scaled so that it fills the entire available space. This can result in the image being displayed distorted in the preview.

Aspect fit: The image is scaled so that one side (the shorter one) fills the available space. The second side is scaled so that the correct aspect ratio is used.

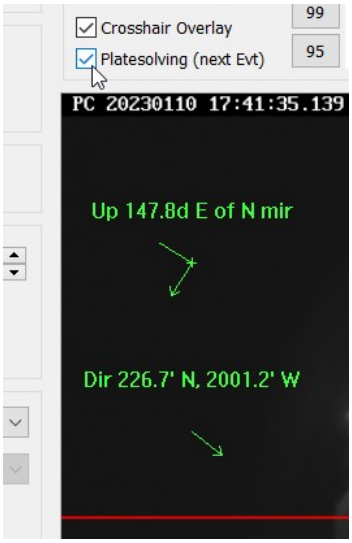
Aspect scale: (with % specification). Values either from the list or manual input from 0 - 400, while maintaining the correct aspect ratio.

Crosshair overlay: This allows a red crosshair to be displayed, which represents the centre of the image. This crosshair is not recorded. The image can be moved with the mouse if the entire area is not visible at a higher zoom level.

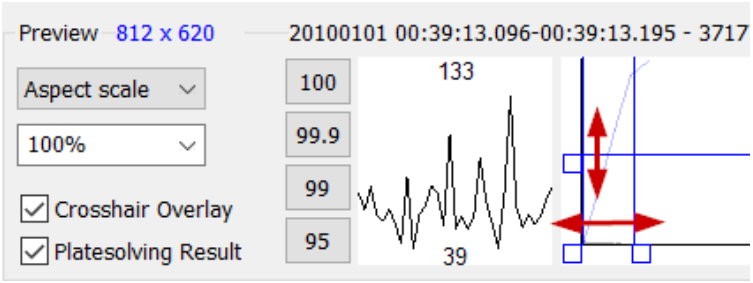
Overflow: The different saturation levels are highlighted in colour in the preview window. From 90% of the fullwell value, the pixels are coloured yellow and from 98% red.

Platesolving (next event): The "Platesolving (next event)" checkbox can be used to display the orientation of the image field and (if an event is imminent) the direction and distance to the next event based on the last successful plate solving. The information appears in the preview area, but is not saved with the image.

Important: The event information is determined when the checkbox is ticked. If another event is to be observed later, the checkbox must be deleted and set again.



Cursor display in the square to the left of the histogram: If the mouse pointer is located within an image capture, the brightness of the pixels is displayed here graphically directly at the cross of the mouse pointer and to the left and right of it. The two values above and below the boundary of the square are the measured minimum and maximum values. The measurement range extends over 16 pixels on both sides of the mouse pointer. If you point the mouse pointer to the centre of a star, the horizontal cross-section of the pixel values through the star appears here (ideally a Gaussian curve). Burnt-out stars reach pixel values of 65535, which should be avoided with comparison stars, e.g. by reducing the exposure time.



Histogram: The area to be displayed in the histogram can be adjusted here for the display. The brightness range can be selected using the vertical bars ("handle" on the small square, select and drag with the mouse, or left-click for the left bar and right-click or shift-click for the right bar). The horizontal slider can be used to bend the curve into the non-linear range (gamma function). On the left side of the histogram there are a few clickable presets (100%, 99.9% 99% and 95% of the current histogram range). The two numbers above the centre of the histogram show the range selected for the preview: 0 - 65535 for the full width. If individual pixel values reach the maximum, which is the case with "burnt out" stars, this is indicated in the histogram by a red line at the right-hand end.

Important: the settings on the histogram have no influence on the recorded image data, but only on the current preview display and are useful, for example, to be able to identify and position a faint star.

There are currently two control elements in the software:

- The "Background" field, which configures the black value directly in the image sensor. This defines what is "black" for the sensor.
- The "Offset" field, in which you can configure the dark frame. This is a constant value that is added to each pixel before the dark frame is subtracted.

For the "Background" field, you should try to position the left part of the histogram a little away from the left edge. If the value is too small, the dark pixels disappear into the black. If the value is too large, the dynamics on the right-hand side of the histogram, where the very bright stars are located, will be wasted.

The gain of both image sensors (IMX174, IMX430) works in such a way that values from 0 dB to +24 dB cause an "analogue gain", which increases the analogue voltage of the pixel before it is digitised. If the value is set higher than +24 dB, a "digital gain" is added, i.e. the digitised value is multiplied by a factor. The effect of digital amplification is therefore that the pixel values are scaled up and the dynamic range is lost somewhat at the higher pixel values.

To summarise, the following steps are recommended to obtain an optimal histogram:

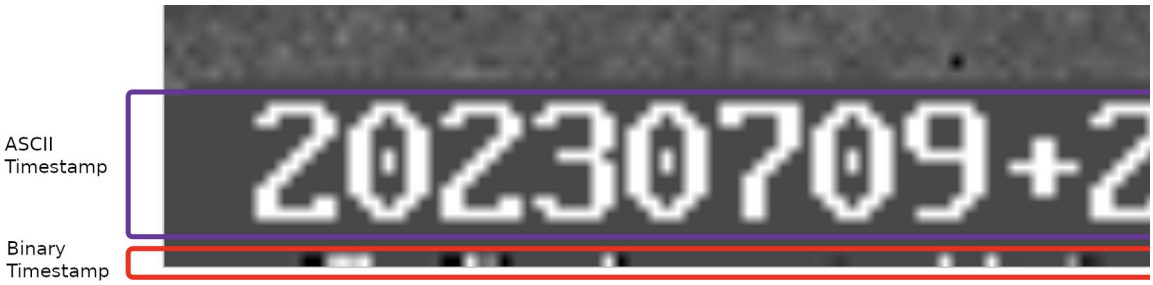
- Start with Offset = 0, Background = 100, Gain +24 dB (or lower gain for bright stars).
- If the histogram is cut off at the left edge, increase the background, perhaps to 200, and then reduce it until the histogram is nicely above the left edge.
- If you activate a dark frame, you will notice that the histogram shifts to the left. In this case, you can move it back to the right with an offset so that faint stars do not disappear in the black background; the value 2048 usually works well.

5 All about the recording

5.1 The time stamp

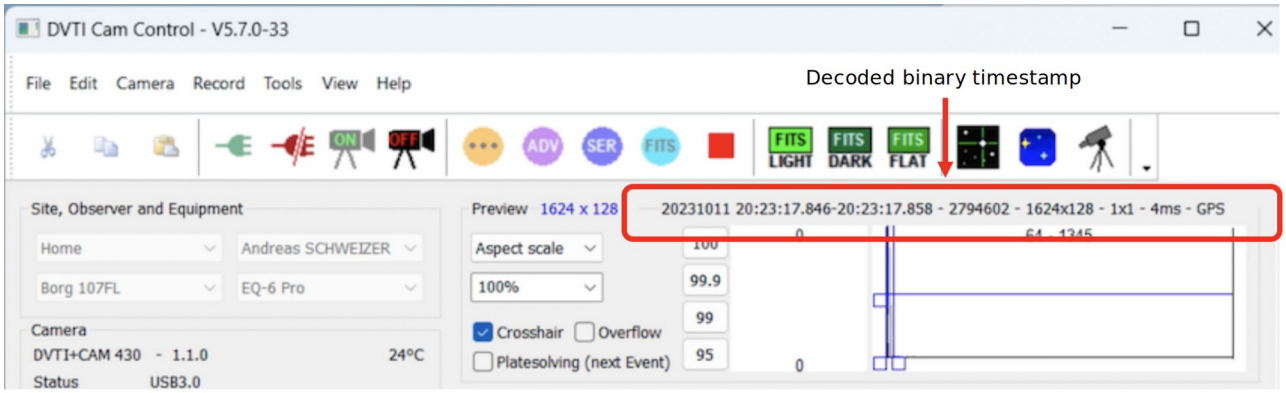
Each frame is provided with a digital time stamp in the camera. The time stamp contains various information about the frame, such as the start and end time of the exposure, longitude and latitude, information about the configuration of the sensor and the satellites received.

The **binary timestamp** is always integrated as a single line at the bottom of the screen in the form of binary data. In addition, an **ASCII timestamp** can be displayed above it in readable form.



For many values in the time stamp it is necessary to have a GPS fix with sufficient satellites.

An evaluation of the binary time stamp is displayed above the histogram in the tool:



This display is also shown if the ASCII timestamp is switched off.

5.1.1 The binary timestamp

The binary time stamp is integrated in the pixels of the bottom line of each frame. A single byte of 8 bits is stored for each pixel.

The binary time stamp comprises 128 bytes, which are inserted left-justified at the line and repeated over the entire line.

The following table provides an overview of the information contained.

Position	Description
0..3	Preamble, fixed to 0x00 0x00 0x54 0x53 (In version 5 and earlier, byte 2 contained the value 0x5C).
4..5	Format of the timestamp. - Fix 0x00 0x06 from firmware version 0.x.75 - Fix 0x00 0x07 from firmware version 0.9.77
6..7	Version of the FPGA firmware.
8..19	Start time of the exposure in the format YY MM DD HH MM SS ns ns ns ns flags - ns specifies the fraction of a second in nanoseconds and is a 4-byte field with values 0..999999999. - Bit 0 in the flags is set (1) if the timestamp contains a valid time.
20..31	End time of the exposure. Format identical to the start time.
32..35	Reserved, currently fixed 0x00 0x00 0x00 0x00 0x00.
36..39	Frame number as an unsigned 32-bit number.
40..41	Width of the frame in pixels.
42..43	Height of the frame in pixels.
44	Horizontal binning (minus 1). The value is 1 for 2-binning, 3 for 4-binning, etc.
45	Vertical binning (minus 1).
46..47	Reserved, currently fixed 0x00 0x00.
48..49	Multiplier M for the correction of the gain during binning. Pixels are multiplied by the factor (M/D) before they are sent to the host computer.
50..51	Divisor D for the correction of the gain during binning.
52..59	Integration time in the format ss ss ss ss ss nn nn nn nn nn - ss is the seconds part as an unsigned 32-bit number - nn is the nanoseconds part
60..61	Configured gain of the image sensor. - Bits 6..0 indicate the gain in dB. - Bit 7 is 1 if the high gain mode is active.
62..63	Configured black level of the image sensor.
64..67	Latitude of the current position. The highest bit is 1 in the southern hemisphere, 0 in the northern hemisphere. The value must be divided by 1E7 to obtain a value in degrees.
68..71	Longitude of the current position. The highest bit is 1 for west, 0 for east. The value must be divided by 1E7 to obtain a value in degrees.
72..73	Position accuracy in meters.
74	GNSS fix status. - Bit 0 is set if there is a valid fix. - Bit 1 is set if the date and time are valid. (With GPS, it takes up to 15 minutes for this bit to be set if a fix is available, as the difference between UTC and GPS time is then transmitted. With satellite systems such as GLONASS, which transmit the time directly in UTC, the valid time is available immediately after the fix).
75	Number of satellites.
76..79	Height above sea level of the current position, in millimetres.
80..83	Status flags. Bits with the value 0 are reserved for future extensions. - Byte 0: [0 | 0 | Marker1 | Marker2 || 0 | Markers on | Overlay mode:2] - Byte 1: [0 | 0 | 4-Digit-Mode | 0 || GPO-Mode:2 | LED-Mode:2] - Byte 2: [0 | 0 | 0 | High-Gain-Mode || Clamp | 8-bit | Invert | 0] - Byte 3: [0 | 0 | 0 | 0 || Flip-Mode:2 | 0 | 0]
84..87	Extended status information. Bits with the value 0 are reserved for future extensions. - Byte 0: Gain

- Byte 1: 0x00
- Byte 2..3: Exposure time

88..91 Status of the USB physical layer. -
Byte 0..1: [tooManyErrors | 0 | phyErrCtr:14]
- Byte 2..3: [phyErrFlags:16]

92..95 Status of the USB link layer. -
Byte 0..1: [UsbVersion:2 | lnkErrCtr:14]
- Byte 2..3: [lnkErrFlags:16]

96..97 Sensor temperature. The MSB contains the number of centigrade Celsius, the LSB the fraction. Bit 0 is set if the temperature is valid.

98..101 GPS DOP Time (from version 6 of the timestamp)

102..111 GPS DOP Data (from version 6 of the timestamp)
- GDOP, PDOP, TDOP, VDOP, HDOP in the range 0..65535, projected to 0.00..655.35.

112..125 Reserved, currently fixed at 0x00 ... 0x00.

126..127 Checksum in Fletcher16 format (M=255) over the bytes 0..125.

5.1.2 The ASCII timestamp

If switched on, the ASCII timestamp shows part of the information of the binary timestamp in readable form. It is divided into a left and a right area. The left-hand area contains the fixed start and end of the exposure time. The right-hand area alternately shows status information about the camera and satellite reception.

The left-hand area contains the following elements:

- Current date in the format YYYYMMDD
- Separator (+)
- Exposure start time in the format HH:MM:SS.mmm
- Separator (-)
- End time of the exposure in SS.mmm format
- Frame counter
- Number of seconds since the last time synchronisation

If status information is displayed, the right-hand area contains the following elements:

- Resolution in pixels (width x height)
- Binning (H x V)
- Exposure time
- Gain in dB, with trailing H if the high gain mode is active
- Black Level
- Shift for brightness scaling when binning is switched on

If satellite data is displayed in the right-hand area, it contains the following elements:

- Accuracy of the position
- Longitude and latitude
- List of satellites including their number and signal strength. The signal strength is displayed as a box. The higher the box, the stronger the signal. A full box indicates that there is a GPS fix for the satellite.

5.2 File variables

When recording the files, various variables are also saved, which are described below.

5.2.1 SER file

Header unique:

- Camera series: 0 (not used)
- Colour: 0 (mono)
- Data format: 0 (16-bit big endian)
- Width in pixels
- Height in pixels
- Pixel per plane: 16
- Frame counter
- Name of the observer, max. 40 characters
- Name of the camera, max. 40 characters
- Name of the telescope, max. 40 characters
- Local time of the first frame (UTC is saved)
- UTC timestamp (start of exposure of the first frame)
- List with UTC timestamps of all frames (**start** of exposure; is written **at the end of the recording**)

5.2.2 ADV file

Values in bold are fixed.

Variable	**Value**	**Description of the**
SECTION-DATA-COMPRESSION	UNCOMPRESSED	Compression, either UNCOMPRESSED or LAGARITH16
IMAGE-BYTE-ORDER	**LITTLE-ENDIAN**	
IMAGE-MAX-PIXEL-VALUE	**65535**	
IMAGE-BAYER-PATTERN	**MONOCHROME**	
UTC timestamp accuracy (ns)	**1000000**	Accuracy of the timestamps is 1ms
RECORDER SOFTWARE	**DvtiCamControl**	
RECORDER SOFTWARE VERSION	5.6.2-16	Current programme version
CAMERA MODEL	**DVTI+CAM**	
CAMERA-SERIAL-NO	56	Serial number of the camera
CAMERA-VENDOR-NAME	**DVTI**	

CAMERA-SENSOR-INFO	Sony IMX430LLJ-C (1.1" 1624x1240 4.5um CIS)	
CAMERA-FIRMWARE-VERSION	1.0.2	Firmware version of the camera
CAMERA-DRIVER-NAME	**UVC**	
LATITUDE	47.5195171	GPS position at the start of recording
LONGITUDE	8.5706464	
ALTITUDE	560.1	
BINNING-X	2	Set binning
BINNING-Y	2	
ACQUISITION-DELAY	**0.0**	
AUTHOR	Toni TESTER	Name of the observer
COMMENT		The comment field is empty.
INSTRUMENT	DVTI+CAM #56 FW 1.0.2, IMX430 sensor	Name of the camera
OBSERVER	Toni TESTER	Name of the observer
TELESCOPE	50cm Newton	Name of the telescope
RA		Telescope position, if a valid position is known.
DEC		
OBJNAME		Object name
HEIGHT	620	
WIDTH	812	
StartOfFrame timestamp		
EndOfFrame timestamp		
Gain	+24 dB	Set gain in DB
SystemTime	2023-06-05 23:26:56.845	
VideoCameraFrameId	8530	
TrackedSatellites	12	
FixStatus	3	
Temperature	33.75	
DOPTime	163628000	
GDOP	1.63	
PDOP	1.42	
TDOP	0.80	
VDOP	1.18	
HDOP	0.80	

5.2.3 FITS file

Variable	**Value**	**Description of the**
SIMPLE	**T**	
BITPIX	**16**	
NAXIS	**2**	
NAXIS1	960	
NAXIS2	600	
BSCALE	**1.0**	
BZERO	**32768**	
OBJECT		
TELESCOP	Newton 2.5m	
INSTRUME	DVTI+CAM #20 FW 1.0.1, IMX174 sensor	
OBSERVER	Toni TESTER	
DATE-OBS	2023-06-05 23:26:56.845	

EXPTIME	0.05	Exposure time in seconds
CCD-TEMP	38.7	Sensor temperature, if available
IMAGETYPE	Dark Frame	Dark Frame, Flat Frame, Light Frame
HISTORY	AVG_32	For dark frame and flat frame: number of averaged frames

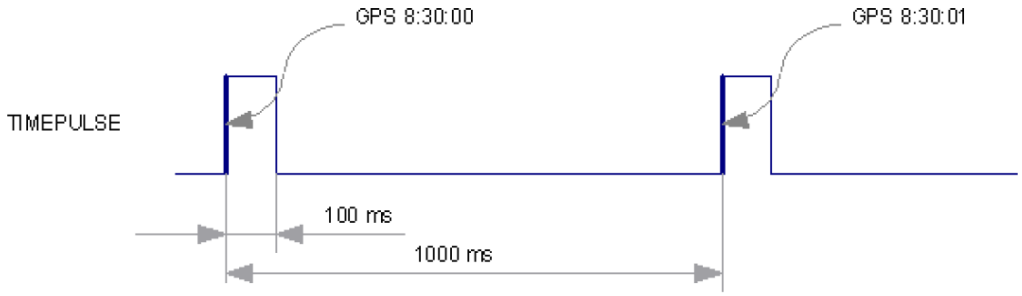
5.3 Checking the GPS connection

If streaming is running but the GPS cable is not yet connected (or a sufficient signal is not yet being received), a corresponding warning about the missing GPS fix will appear in the top right-hand corner of the screen:

At the same time, the current time stamp shows a date from 1 January 2010 00:00 UTC and no coordinates. As soon as a signal is available, the actual values are inserted in the time stamp and the accuracy of the GPS signal is displayed in metres. The red warning then disappears automatically.

The duration until the first GPS fix varies and depends on several factors. During operation, it is important that the magnetic receiver part of the GPS mouse is placed in the open air if possible. After a "cold start", it can take several minutes to achieve the GPS fix. A clean signal must be received and read from several (at least four) satellites. However, the DVTI camera has several receivers for GPS, GLONASS, Galileo and BeiDou satellites and analyses the received signals in parallel, which considerably shortens the time it takes to achieve the first fix.

The 1PPS signal can also be read directly on the camera via the red LED. The LED lights up for 100ms after the start of a second. It indicates the status of the TIMEPULSE output of the GNSS module (MAX M8C) in the camera. The following diagram[9] shows the time sequence:

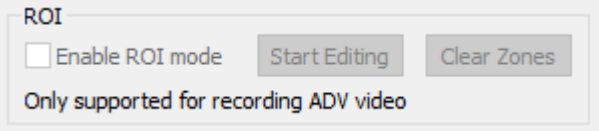


[9]Source: https://content.u-blox.com/sites/default/files/products/documents/u-blox8-M8_ReceiverDescrProtSpec_UBX-13003221.pdf - page 75 below.

5.4 ADV and ROI

5.4.1 User-defined multi-ROI

When recording in ADV format, it is possible to define so-called "Regions of Interests" (ROI) in order to limit the amount of data in the recorded file. The "Enable ROI Mode" checkbox is activated for this purpose.

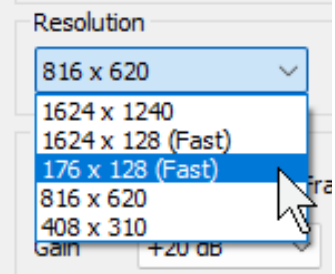


The ROI editor can be activated with the "Start Editing" button. Zones of the frame that are to be included in the recording are clicked with the mouse in the preview area and then appear with a green background. The zones can be deactivated again by clicking on them again, and all zones are deleted using the "Clear Zones" button. Once the ROIs have been defined, the "Stop Editing" button is used to stop editing the zones.

Note: Currently, the entire frame is always transferred from the camera to the computer via USB. The function only causes the saved ADV file to be smaller than without ROI, but does not reduce the amount of data transferred via USB. A corresponding extension is planned for firmware 2.0.0. As the zones are calculated on the PC, switching on this function can lead to an increase in the number of dropped frames. For this reason, the use of this function is currently not recommended.

5.4.2 Fixed ROI with high frame rate

Two fixed ROIs can be selected via the drop-down menu with the resolutions. The entries are labelled "Fast" and support higher frame rates:

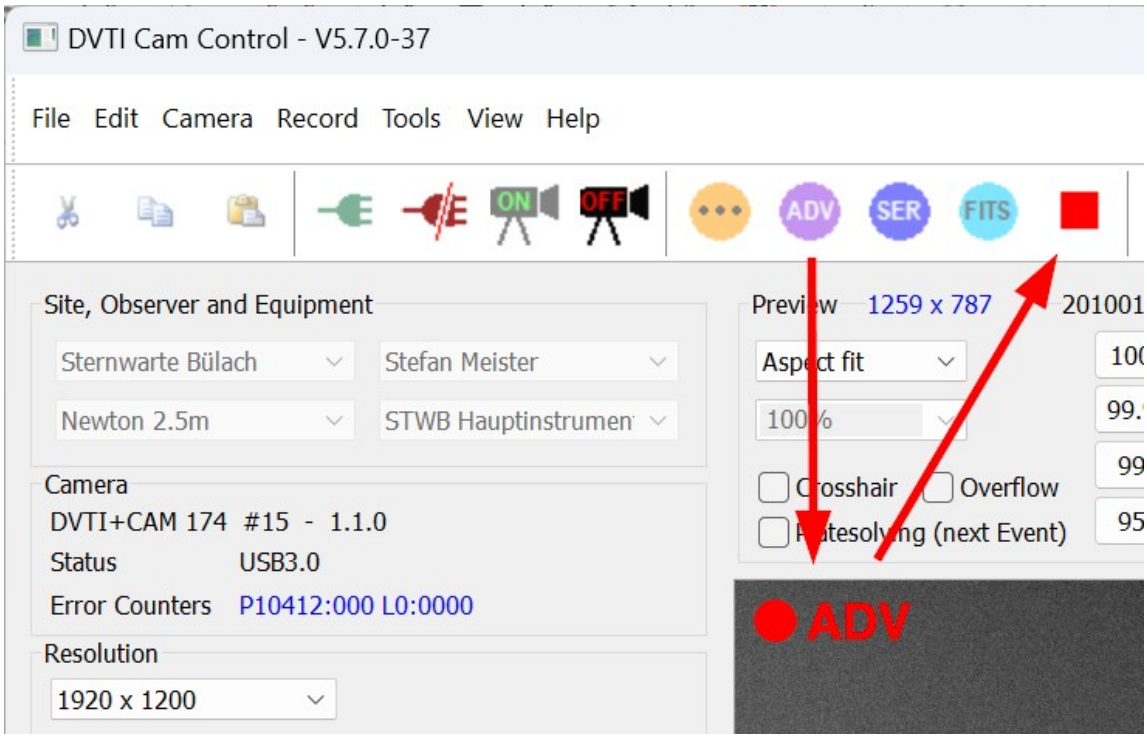


The ROIs are centred on the middle of the image.

5.5 Recording in progress: On Air!

5.5.1 Recording a video (sequence of images)

To start recording, click on one of the 4 recording buttons (..., ADV, SER, FITS) in the tool box or select a corresponding entry from the "Record" menu. While recording, the tool displays a red circle with the name of the recording format at the top left of the preview window:



To stop recording, select Record > Stop Recording or click on the rectangular red button in the tool bar.

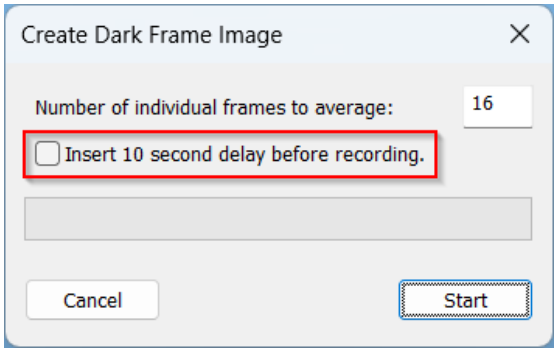
Note: When selecting the video format, we recommend using ADV over SER because it offers several advantages. These become clear later when analysing and creating the report. In particular, ADV no longer requires a visual time stamp for the analysis, as each individual frame contains the exact time of the start and end of the exposure.

We recommend scheduling the recording of occultations using the button with the three dots (or Record > Record with options...), as described in Chapter 3. This ensures that the recording runs exactly over a specified time window (e.g. one minute) and that the expected time of occultation is exactly in the center of this recording.

5.5.2 Recording a single image

The tool supports recording individual images as FITS files. In addition to light frames, dark and flat frames can be recorded. These can be used to correct the image stream on the fly.

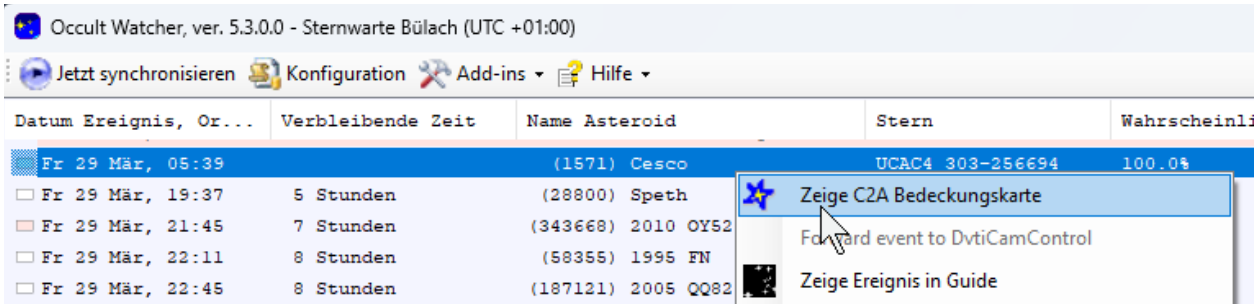
It should be noted that the same settings are used for the dark and flat image as for the actual recording. A time delay of 10 seconds can be selected for the FITS (Dark) / (Flat) single images, which can be helpful if, for example, the telescope aperture has to be covered for a short time for the dark image:



6 A typical workflow...

Below is a typical workflow that shows how we ourselves proceed when observing our star occultations with a Goto mount.

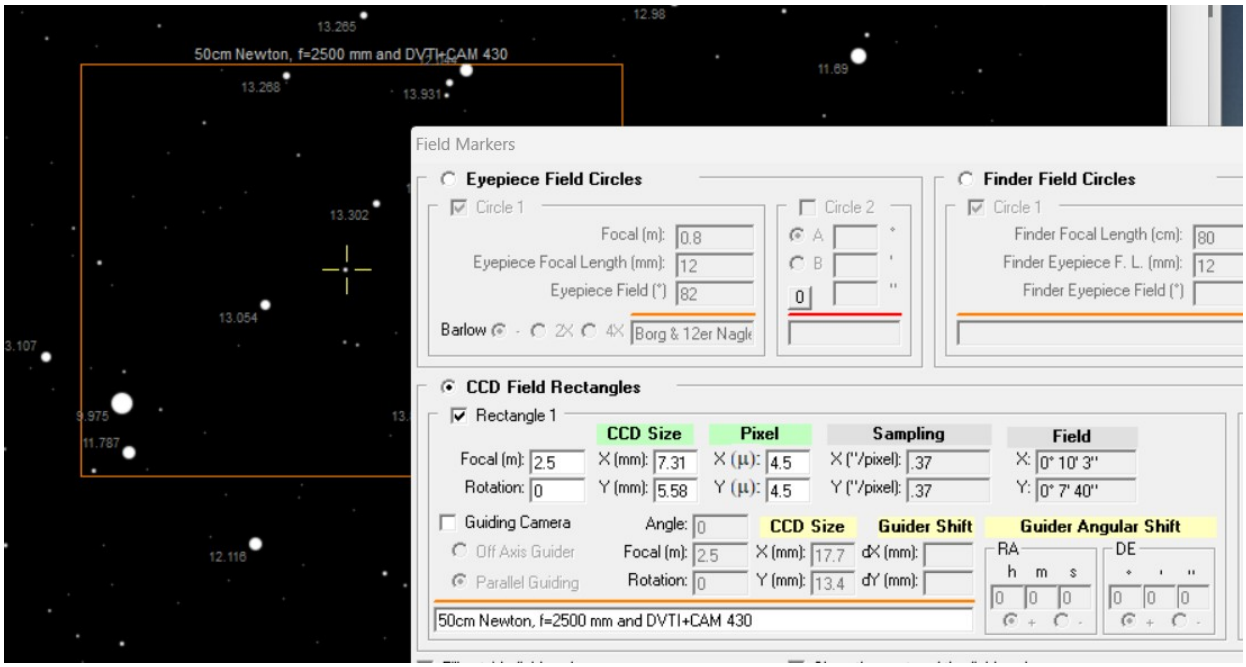
- Open OccultWatcher[10] > Right-click on the event to be observed > Show C2A occultation map:



- C2A opens centred on the target object (the object is now saved as a "landmark" and can be centred again at any time with Edit > Go to Landmark), then connect the telescope to C2A via the ASCOM interface: Telescope > Connect to Telescope.
- To position and focus, move to a brighter star in the vicinity of the object.
- If necessary, position the star on the eyepiece first, otherwise insert the camera into the focuser and connect it to the PC using the USB-C cable.
- Connect the antenna cable and attach the GPS mouse (magnetic) to the top of the tube to ensure good satellite reception.
- Turn the camera in advance so that north is at the top of the image (this makes identification and image field comparisons much easier later). If necessary, also set the known back focus to get close to the focus. Both are telescope-dependent empirical values that need to be tried out and possibly marked.
- Start the "DVTI Cam Control" software on the PC. Check for updates if necessary.
- Set the settings for "Site, Observer and Equipment" correctly (if not already saved correctly from the last observation).
- Connect camera via two green buttons: Connect to Camera & Start streaming
- Briefly check whether the connection data and status are OK in the top left-hand corner under "Camera" and that the USB3 transfer does not return any errors (which has already happened with defective cables). An image from the camera should appear and a time stamp should be visible at the bottom. If necessary, switch to "Aspect fit" in the preview if not everything is displayed.
- Focus on the star that was previously approached and now position it exactly in the centre ("Switch on crosshair overlay").
- If necessary, set the optimum exposure time (fps) and gain.
- First set the histogram at the top using the buttons (100/99.9/99/95) or position the vertical limits by hand using the mouse. The settings on the histogram are only for better visibility and have no influence on the subsequent recording.

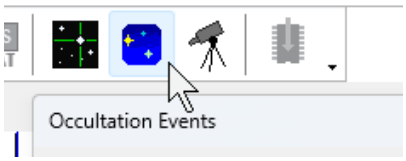
[10]Links to the OccultWatcher and C2A programmes can be found in section 11.2.

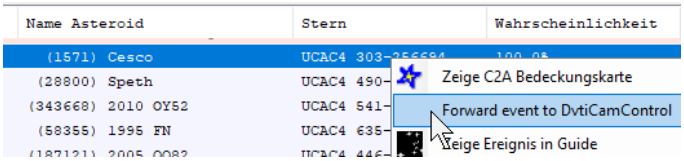
- If the star is positioned in the centre, then sync in C2A (right-click on the star, Telescope > Calibrate on Position/Object). The telescope position in C2A should now correspond exactly with the set star.
- Now switch to the actual location of the star occultation. In C2A: Edit > Go to Landmark. If necessary, set the appropriate magnification in C2A (e.g. 30' field of view). Right-click on the centre object > Telescope > Slew to Position. The telescope moves to the target object.
- At the target position, compare the C2A map with the image recording to see if everything fits. Correct the positioning if necessary. It is useful to show the actual image size in C2A. This is possible under Tools > Field Markers... . It is also advisable to add a labelling text for the displayed field, especially if different setups/focal lengths are used (these can be saved individually in C2A and called up quite quickly):

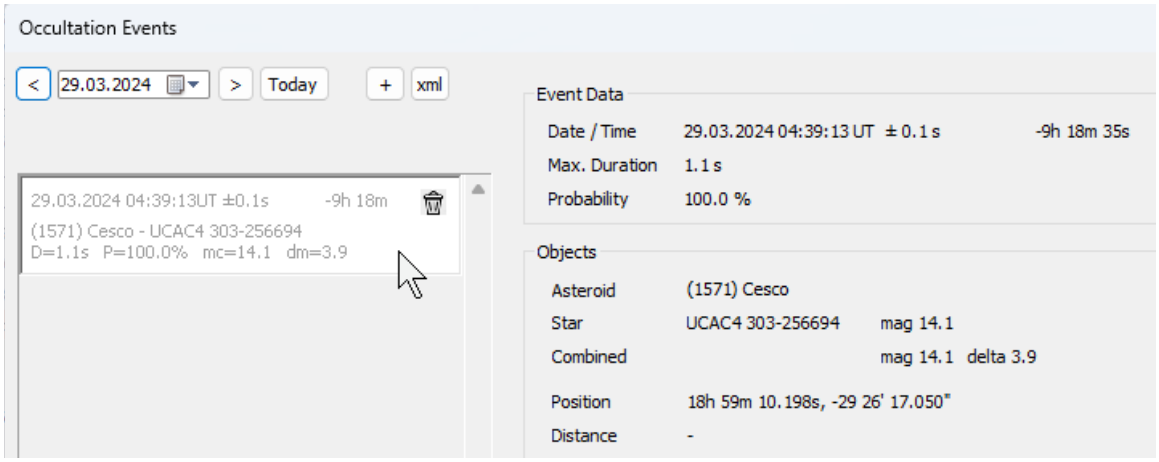


- If necessary, rotate/mirror the image in the tool (flip in Image Processing) so that north is at the top and west is on the right as on the C2A map. This setting also usually only needs to be made once.
- Optimise resolution/binning, exposure time and gain for the target object. The following applies: Expose as short as possible (shorter = higher temporal resolution), but as long as necessary (observe SNR).
- The fainter the object, the more the "resolution" is reduced (higher binning).
- For fainter objects, create darks and, if necessary, flats, integrate them and set the appropriate offset according to the histogram if the peak is too close to the left edge.
- Don't forget: As soon as changes are made to the exposure time/gain/resolution, the procedure with the darks must be repeated. Therefore, if possible, only create darks and flats once you have found the right settings.
- Switch on "FPN reduction". Image display is normally set to "Aspect fit". "PC Time" can be displayed at the top left as an additional backup, but is not usually necessary if there is a GPS signal and the "No GPS fix" message at the top right has disappeared.

- Now import the event data from OccultWatcher into the tool. To do this, you must first download and install the OW plugin[11] : 1. in the tool, open the window under Tools > Events (or blue icon in the top right-hand corner) to be able to accept the data. 2. open OccultWatcher > right click on Event > Forward event to DvtiCam... 3. the event should then appear in the tool under "Occultation Events" and can be selected to display more details (see large screenshot below). A countdown shows the remaining time until the event. Any other events can also be added.







- If possible, schedule the recording a few minutes before the event with "Record with Option" (orange icon with the three dots).
- Usually record in ADV format (SER/FITS only in exceptional cases). ROI topic: If necessary, define fields to save storage space.
- Copy the event using the centre "Copy Event" button and schedule the recording. Adjust the "Duration" depending on the duration of the event and the accuracy of the prediction.
- The recording then starts automatically at the right time. As a rule, 45s-60s recording around the planned centre of the event is sufficient.
- After recording: Save the report (click on the "Create Report" button for the previous event), take screenshots for documentation if necessary, analyse the event with the evaluation tools, complete and upload the report to SODIS.

[11]Available for download at https://dvticam.com/support

Our "home base" at the Bülach Observatory (MPC Observatory Code 167).

7 Technical data

7.1 Camera specifications

Comparison of the specs[12] of both DVTI cameras:

Model	DVTI+CAM 174	DVTI+CAM 430
Sensor	IMX174LLJ	IMX430LLJ
Sensor Generation	SONY Pregius Gen. 1	SONY Pregius Gen. 3
Sensor Type	CMOS	CMOS
Pixel Size	5.86 µm × 5.86 µm	4.5 µm × 4.5 µm
Effective Pixel Area	1920 × 1200	1624 × 1240
Effective Pixels	2.35MP	2MP
Effective Image Area	11.34 × 7.13 mm	7.31 × 5.58 mm
Diagonal	13.4 mm	9.2 mm
FOV @ 1000mm focal lengh	0.64° × 0.4°	0.42° × 0.32°
Pixel Sampling @ 1000mm focal lengh	1.21"/Px.	0.93"/Px.
Binning Modes	1×, 2×, 4×	1×, 2×, 4×
Cooling	Passive	Passive
Full resolution (unbinned) max. fps without gaps	1920 x 1200: 25ms (40 fps)	1624 x 1240: 25ms (40fps)
(binned 2 × 2)	960 x 600: 20ms (50 fps)	816 x 620: 6ms (166 fps)
High speed mode max. fps without gaps	1920 x 128: 4ms (250 fps)	1240 x 128: 4ms (250 fps)
(binned 2 × 2)	176 x 128: 2ms (500 fps)	176 x 128: 1ms (1000 fps)
Exposure Time Range	1ms to 5s	1ms to 5s
A/D Sample Depth	12-bit monochrome	
Shutter Type	Global shutter	
Time Source	u-blox MAX M8C GNSS module	
Computer Interface	USB3.0, Type C connector, 5 Gb/s	
Other ports	Antenna and GPIO port	
Telescope Interface	2" and M42 × 0.75 thread	
Weight	142 g	
Diameter	50.8 mm (2" cylindrical form)	
Height	Case 79.8mm, antenna plug 10mm	

The following table[13] lists the characterisation of the various binning modes of the DVTI+CAM 430:

Camera @ Gain 24dB	1632 x 1240	816 x 620	408 x 310
Pixel size [µm²]	4.5 × 4.5	9 × 9	18 × 18
Number of Pixels	1	4	16
Readout Noise [units]	133.22	100.76	50.28
Gain [e/unit]	0.011	0.022	0.087
Readout Noise [e]	1.43	2.19	4.38
Dynamic	491.94	650.4	1303.54

[12]The throughput rates refer to firmware 1.2.0 and Tool 5.8 and may be extended at a later date.
[13]Source: Analysis by Martin Gutekunst, Nov. 2023

7.2 Binning and data throughput

The following should be noted as to why the data throughput is not always reduced accordingly when binning.

With the IMX430, the sensor sets the first limit:

- 89.1 fps at full resolution
- 268 fps with 2x2 binning

Higher binnings are not possible directly on the sensor and must always be made on the data stream, which comes from the sensor at max. 268 fps.

The FPGA firmware sets the second limit. This is currently always limiting (see comment in the release notes), but a later version is planned which will improve this limit.

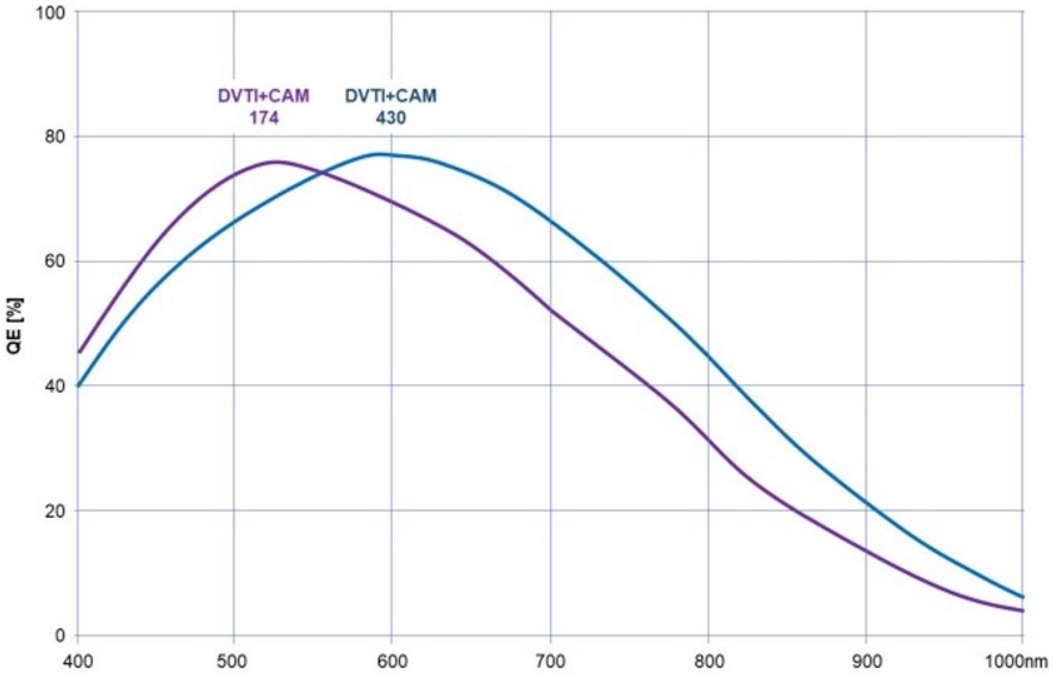
The third limit would theoretically be the USB connection. Technically, 400 megabytes/s would be possible if the transfer is perfect and no other devices are running on the USB host controller. In practice, this value can practically never be achieved, realistically around 300 to 350 MByte/s raw data due to packet overhead, shared bus, retransmissions and others. In addition, the hard disc must be able to store a continuous data stream with this bandwidth, which requires that no other processes access the hard disc during recording.

A frame with full resolution in our camera has about 3 MByte at 12 bit and compact transmission, so about 100 to 120 fps would be possible from the USB bus. After a later revision of the firmware, the following frame rates will probably be available with the DVTI+CAM 430:

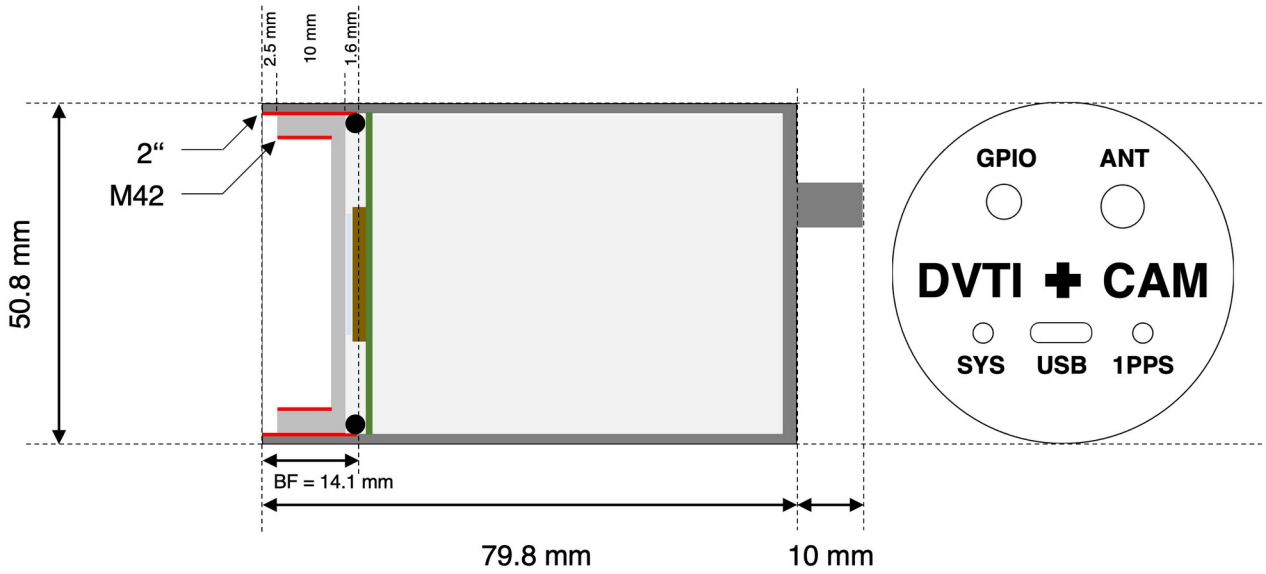
- 12ms (83.3 fps) at full resolution, possibly 13ms (76fps) due to data overhead
- 4ms (250 fps) with binning 2x2 and higher

With the DVTI+CAM 174, unfortunately, no such major improvements are possible, as binning can never be carried out directly on the sensor.

7.3 Spectral sensitivity of the two sensors



7.4 Dimensions of the housing



7.5 Antenna and battery

The Taoglas AA.162 GPS antenna supplied with the camera is an active antenna for the frequency range 1575-1610 MHz and is supplied with 3.3 volts by the camera. Other passive or active antennas that are compatible with this operating voltage can also be used.

The current DVTI+CAM does not contain a backup battery. The GPS module used (u-blox MAX M8C) receives the GLONASS satellites in addition to the GPS satellites. The GLONASS satellites transmit a time already corrected by the leap seconds[14] . If at least one GLONASS satellite is received, which is practically always the case over Europe, the correct time with regard to the leap seconds is immediately available.

It is also possible to download the latest almanac from u-blox via the Internet for the satellite module used and receive an immediate fix[15] . This is not yet integrated at the moment, but may be implemented at a later date.

7.6 Power consumption

The power consumption of the DVTI+CAM 174 is between approx. 500mA and 550mA depending on the configuration, the power consumption of the DVTI+CAM 430 is between approx. 430mA and 570mA. Roughly speaking, the camera consumes around 2.5 watts of power, +/- approx. 15% depending on the configuration.

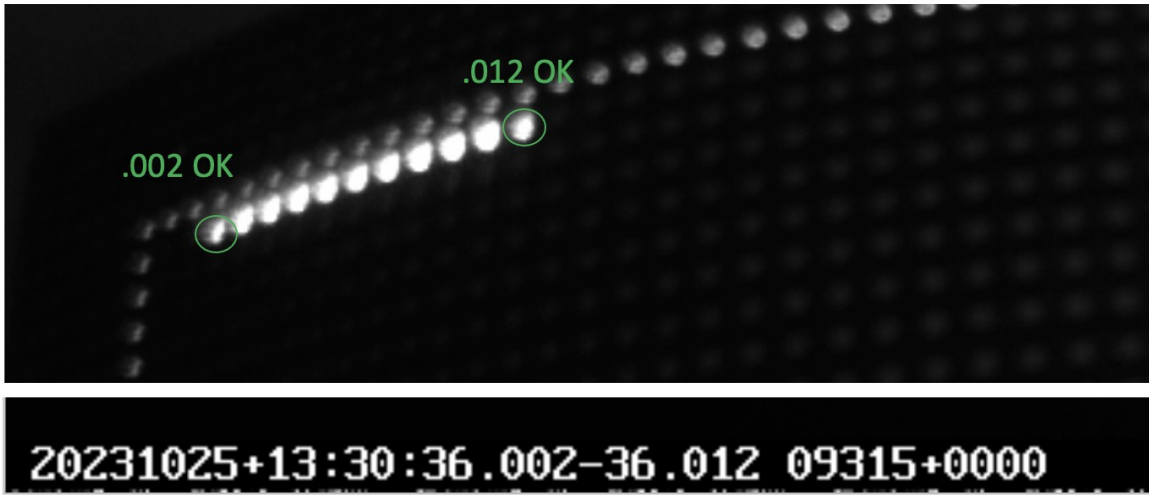
7.7 Accuracy tests

In order to fulfil the high requirements for star occultations with regard to the accuracy of the time stamp of our DVTI camera, several test procedures were carried out. In particular, independent tests were carried out by Gerhard Dangl with his EXTA (EXposure Time Analyser). The test results can be viewed on his website[16] . The basic structure and function of the EXTA is described there under the left-hand menu item "EXPOSURE TIME ANALYZER - EXTA".

We also carried out our own tests with a replica of the EXTA using an industrially available LED panel. The construction plan and functionality of this in-house development is documented in detail in a blog post[17] by Andreas Schweizer.

[14]See https://gssc.esa.int/navipedia/index.php/Time_References_in_GNSS under GLONASS
[15]AssistNow service, see https://www.u-blox.com/en/product/assistnow
[16]At http://www.dangl.at/menue_hh.htm and then in the menu on the left under "DIGITAL VIDEO CAMERA WITH GPS DVTI v2b"
[17]For medium: https://aschweiz.medium.com/creating-an-exta-with-a-32x64-video-wall-led-panel-d72e0088c64f

Before each release, it is ensured that the start and end times are correct to +/- 0.2 ms:



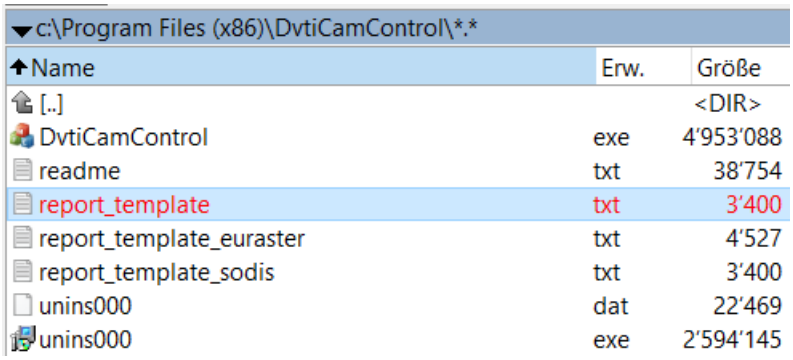
The DVTI Cam Control Tool can also be used to measure the delay of the PC clock to the precise GPS time. To do this, simply press the "PC Time" button (see section 4 in the menu item "Overlay") to display the second time stamp of the PC clock in the top left-hand corner of the window. After a video recording has been made, the time offset of the two time stamps can then be determined for each individual frame.

8 Reporting

The SODIS portal has been available for reporting star occultations since 2023. To minimise the reporting effort, reports can be created directly from the tool. To do this, a template file must be stored in the programme directory. The template file contains variables (e.g. name of the asteroid, time, location, etc.) that are automatically filled with data when the report is generated.

8.1 The template file

The template for the report generator of the tool is freely definable. It is a simple text file with the name "report_template.txt" in the programme directory:



It is also possible to generate two different reports with different layouts using a single report template, which can then be used to prevent a name change in the "Program Files" directory (for which admin rights are always required). Several reports can be useful if, for example, one of them is used for uploading to the SODIS database and the second is created in the old EURASTER format (and therefore easier for a reviewer to read) and is to be supplemented with additional data if necessary. The following data is not requested in the SODIS input mask, but the fields are automatically generated by the tool if the event was imported from OccultWatcher and could be useful for archiving purposes in an additional text file:

```
#EXTRA_FIELDS
#Feed: IBEROC Events, #MpcObsCode: -, #Prediction: no, #ProbabilityPercent:
13.3, #PredictedDurationSec: 2.9, #DistanceCentralLineKm: 44.5,
#PathWidthKm: , #StarMag: 15.9, #StarAltDeg: 60, #StarAzDeg: 187,
#StarConstellation: Gemini, #AsteroidMag: 15.0, #AsteroidDiameterKm: 25.0,
#CombinedMag: 14.6, #DeltaMag: 0.4, #Moon: below horizon, #TelescopeType:
Newtonian, #MountModel: equatorial, #MountMotorDrive: yes, #StartObsAccSec:
0.001, #EndObsAccSec: 0.001, #FieldOfView:, #CameraGainDb: +28 dB D,
#CameraBinning: 2x2, #CameraWidthHeight: 812x620, #CameraRecordingFormat:
ADV 16-bit, #ImageSensor: Sony IMX430LLJ-C (1.1" 1624x1240 4.5um CIS),
#TimeSource: Max M8C GNSS module in the camera, #TimeInserter: -,
#FrameGrabber: -, #RecordingSoftware: DVTI Cam Control v5.6.0-14,
#LightcurveExtractionSoftware: , #LightcurveAnalysisSoftware: ,
#ErrorInTime: +/- 4.432 s, #StarMagnitudeInV: , #StarMagnitudeInR: ,
#MaxDuration: 2.9 s, #MagnitudeDrop: 0.4, #MagnitudeDropInR: ,
#EventRank: , #Probability: 13.3.
```

(Extract already filled with sample data)

The "splitting" of the text file into two different reports can either be done manually with a text editor or with a small script. Under Windows, for example, a single-line PowerShell script (*.ps1) with the following content would split a file at line no. 89 into two components:

```
gc .\Report*.txt -Tail 89 | sc .\Report_2.txt
```

On Mac or Linux, splitting a file would be even easier with the "split" command on the command line.

Two standard templates (the old EURASTER format and the new one for SODIS) can be downloaded from the website. The individual keywords and variables are described below. They can be used to compile any report templates.

8.2 Reporting variables

Keyword	Example	Description of the
OBSERVER		Details of the currently selected observer as recorded in the Observer dialogue.
{{OBSERVER_NAME}}	Tony Tester	
{{OBSERVER_NOTES}}		
{{OBSERVER_EMAIL}}	toni@tester.com	
{{OBSERVER_ADDRESS}}	Testroad 1, Testcity	
SITE		Information on the currently selected observation site as entered in the site dialogue. Report variables are available for the coordinates of mobile observations, which contain an averaging of the geographical longitude, latitude and altitude from the GPS during the recording (RECORDING_GPS_AVG...).
{{SITE_NAME}}	Home	
{{SITE_NOTES}}		
{{SITE_NEAREST_CITY}}	Zurich	
{{SITE_STATION}}		
{{SITE_LATITUDE}}	N47 31' 10.402"	
{{SITE_LATITUDE_SODIS}}	+47 31 10.402	
{{SITE_LONGITUDE}}	E08 34' 14.300"	
{{SITE_LONGITUDE_SODIS}}	+008 34 14.300	
{{SITE_ALTITUDE}}	550	
{{SITE_COUNTRY_CODE}}	CH	
MOUNT		Information on the currently selected mount as entered in the Mount dialogue.
{{MOUNT_NAME}}	EQ6	
{{MOUNT_NOTES}}		
{{MOUNT_MODEL}}	SkyWatcher EQ6 Pro	
{{MOUNT_MOTOR_DRIVE}}	yes	
{{MOUNT_ASCOM_DRIVER}}		
INSTRUMENT		Information on the currently selected telescope as entered in the instrument dialogue. The aperture and focal length are entered in mm in the dialogue. Variables are available that contain the values in mm and cm.
{{TELESCOPE_NAME}}	Borg 107FL	
{{TELESCOPE_NOTES}}		
{{TELESCOPE_TYPE}}	Refractor	
{{TELESCOPE_TYPE_SHORT}}	1	
{{TELESCOPE_MAGNIFICATION}}		
{{TELESCOPE_APERTURE}}	107	
{{TELESCOPE_APERTURE_CM}}	10.7	
{{TELESCOPE_FL_RAW}}	600	
{{TELESCOPE_FL_FACTOR}}	1.0	
{{TELESCOPE_FOCAL_LENGTH}}	600	
{{TELESCOPE_FOCAL_LENGTH_CM}}	60.0	
{{TELESCOPE_OBSTRUCTION}}	0	
EVENT		Data on the selected star occultation, as provided by Occult Watcher or Occult or
{{EVENT_PROBABILITY}}	49.1	
{{EVENT_ASTEROID_MAG}}	16.2	
{{EVENT_ASTEROID_NR_NAME}}	(219) Leona	

{{EVENT_ASTEROID_NAME}}	Leona	recorded manually.
{{EVENT_ASTEROID_NR}}	219	
{{EVENT_STAR_MAG}}	12.9	
{{EVENT_STAR_NAME}}	UCAC4 307-126469	
{{EVENT_COMBINED_MAG}}	12.9	
{{EVENT_DELTA_MAG}}	3.3	
{{EVENT_DATE_TIME}}	2023 Apr 17, 21:19 (UTC)	
{{EVENT_DATE_TIME_SODIS}}	17 Apr 2023, 21:19:14	
{{EVENT_DATE_SODIS}}	17 Apr 2023	
{{EVENT_PREDICTED_TIME}}	21 18 56.955	
{{EVENT_PREDICTED_TIME_ACC}}	2.612	
{{EVENT_PREDICTED_YES_NO}}	no	
{{EVENT_PREDICTED_DURATION}}	1.3	
{{EVENT_FEED_NAME}}	Planned Observations	
{{EVENT_ASTEROID_DIAMETER}}	65.3	
{{EVENT_DISTANCE_CENTRAL_LINE}}	5.4	
{{EVENT_MOON_INFO}}	below horizon	
{{EVENT_STAR_ALTITUDE}}	14	
{{EVENT_STAR_AZIMUT}}	183	
{{EVENT_STAR_CONSTELLATION}}	Ophiuchus	
RECORDING		Data for the video recording that was assigned to the event. An assignment requires valid GPS times for the start and end of the recording.
{{RECORDING_START}}	21 18 34.123	
{{RECORDING_START_SODIS}}	21:18:34.123	
{{RECORDING_END}}	21 19 26.555	
{{RECORDING_END_SODIS}}	21:19:26.555	
{{RECORDING_START_ACC}}	0.001	
{{RECORDING_END_ACC}}	0.001	
{{RECORDING_FORMAT}}	ADV 16-bit	
{{RECORDING_GPS_PRECISION_METERS}}	2	
{{RECORDING_GPS_AVG_LAT}}	+47 20 30.800	
{{RECORDING_GPS_AVG_LON}}	+008 17 22.335	
{{RECORDING_GPS_AVG_HEIGHT}}	562	
{{RECORDING_GPS_AVG_NOF_VALUES}}	61	
OCCULTATION		Data on the start and end of the coverage as recorded in the detailed dialogue of the event. Whether the occultation was negative or positive and how long it lasted is calculated automatically from the input.
{{D_TYPE}}	D	
{{D_TIME}}	21 18 57.333	
{{D_TIME_SODIS}}	21:18:57.333	
{{D_ACCURACY_SEC}}	0.050	
{{R_TYPE}}	R	
{{R_TIME}}	21 18 58.444	
{{R_TIME_SODIS}}	21:18:58.444	
{{R_ACCURACY_SEC}}	0.050	
{{OCCULTATION_NEGATIVE_POSITIVE}}	POSITIVE	
{{DURATION_SEC}}	1.111	
CAMERA		Information about the camera and the camera settings during recording. This data is determined automatically.
{{CAMERA_GAIN}}	+36 dB D	
{{CAMERA_MODEL_NAME}}	DVTI+CAM 430	
{{CAMERA_SERIAL_NR}}	17	
{{CAMERA_SENSOR_NAME}}	Sony IMX430LLJ-C (1.1" 1624x1240 4.5um CIS)	
{{CAMERA_EXPOSURE_TIME}}	50	
{{CAMERA_EXPOSURE_TIME_SEC}}	0.050	
{{CAMERA_BINNING}}	1x1	
{{CAMERA_W_H}}	1624x1240	
{{DVTI_SOFTWARE_NAME}}	DVTI Cam Control	
{{DVTI_SOFTWARE_VERSION}}	v5.6.1-15	

Note regarding the location coordinates:

Based on the GPS data, the software calculates the average latitude, longitude and altitude during the recording and saves them in the event data. After recording, the average values are provided in the following report variables:

```
{{RECORDING_GPS_AVG_LAT}}
{{RECORDING_GPS_AVG_LON}}
{{RECORDING_GPS_AVG_HEIGHT}}
{{RECORDING_GPS_AVG_NOF_VALUES}}
```

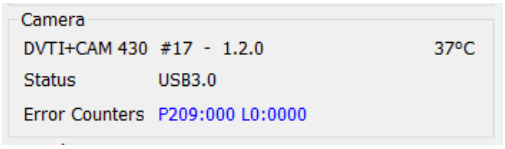
The standard template for SODIS (can be found at https://dvticam.com/support > Report Template SODIS) does not contain these variables. Instead, it uses the fixed location from the location dialogue of the tool under Edit > Observing Sites...:

```
#Latitude: {{SITE_LATITUDE_SODIS}}
#Latitude: {{SITE_LONGITUDE_SODIS}}
#altitude: {{SITE_ALTITUDE}}
```

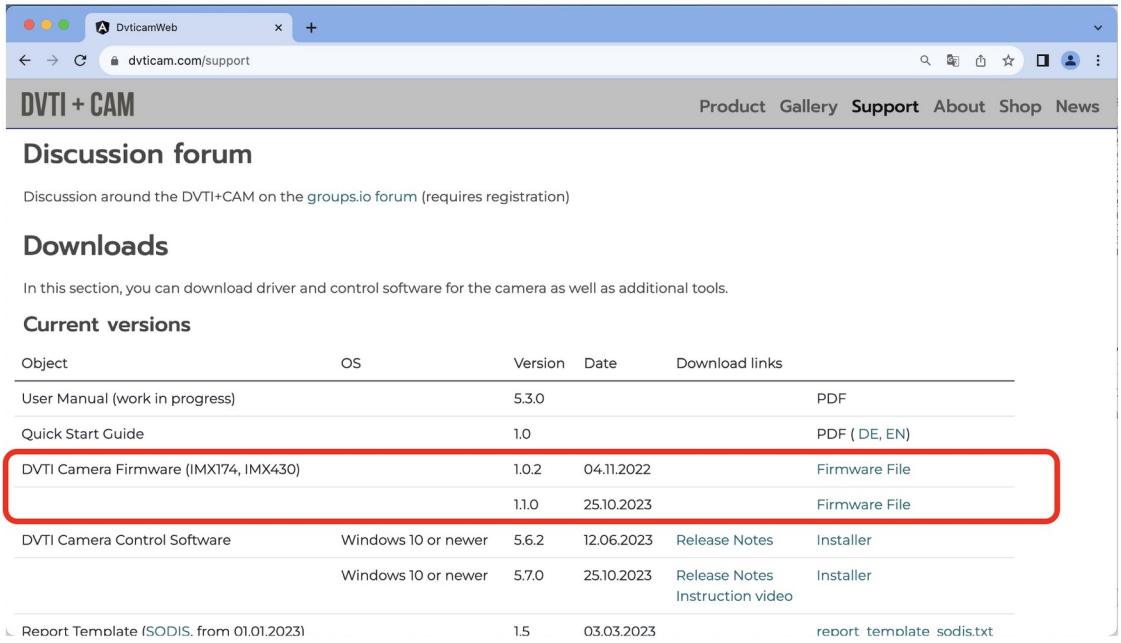
However, it is possible to replace the fixed location with the average location by modifying the SODIS template with the keywords mentioned above. It is also possible to add both and then delete the unnecessary element before submitting the report to SODIS.

9 Firmware updates

The tool can be used to load new (or old) firmware into the camera's flash memory. The firmware controls all camera functions, generates the timestamp on each frame and is responsible for transferring the data via USB. The firmware currently installed on the camera is displayed in the main window of the tool in the "Camera" area:



The latest firmware files are always available on the camera's support page .[18]



A video showing the update process in detail is also available on the website .[19]

The firmware file must be unpacked after downloading and before importing it into the camera. It can then be selected and imported using the "Firmware Update..." function in the camera menu.

To ensure that the function of the camera is not impaired if a firmware update fails, the camera contains enough flash memory for two complete firmware versions. When uploading, the software automatically selects the area of the flash memory that is not currently active (IMG-1 or IMG-2). The new firmware is only activated and loaded the next time the camera is plugged in or unplugged after the new firmware has been transferred in full and a checksum check has been carried out.

[18] https://dvticam.com/support
[19] https://dvticam.com/static/videos/tutorial1.mp4

10 Notes and troubleshooting

10.1 Assembly

Make sure that the camera is securely locked in place and cannot slip through the focus pull-out. If required, a locking ring is available on request, which can be screwed onto the camera housing.

10.2 Strain relief USB cable

In order to protect the USB socket of the camera, it should be ensured that the cable does not exert any force on the socket. If necessary, a model for a cable holder device published by Martin Gutekunst in the camera forum can be used, which can be produced on a 3D printer or a milling machine.

10.3 Storage location of the settings

If you want to transfer the profile and the settings from the tool as well as the log data with the calendar to another installation or another PC, the files to be copied can be found in two directories under the path C:\Users\[Username]\AppData\Local\DVTI:

The first folder "Equipment" contains four *.xml files with the data on the instruments, the mount, the observers and the observation locations. The other folder "Events" contains a collection of all observed star occultations, provided that the event data was previously imported from OccultWatcher or via an *.xml file. One *.xml file is stored for each event.

To transfer the settings, simply copy the contents of C:\Users\[Username]\AppData\Local\DVTI to the new PC under the same path.

10.4 Preventing dropped frames

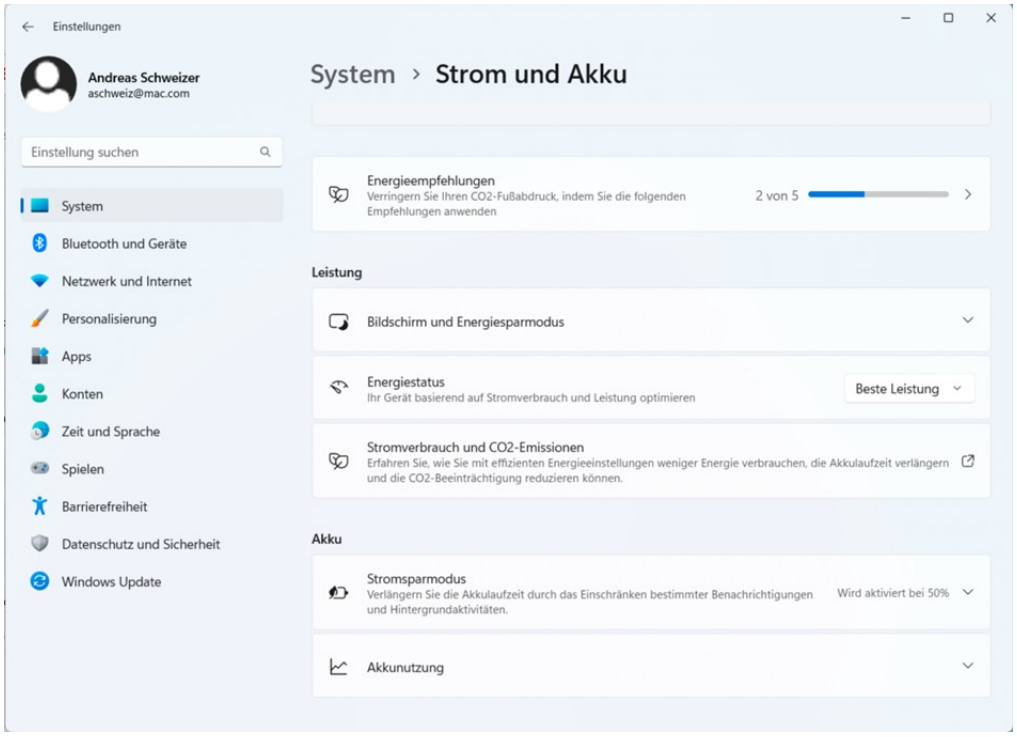
Sometimes there is not enough computing power available on the PC to receive and process all incoming video frames from the camera. In this case, the corresponding frames are dropped, which is of course undesirable for recording star occultations.

This appendix contains some tips and tricks on how to reduce "Dropped Frames".

10.4.1 Switch off energy saving options

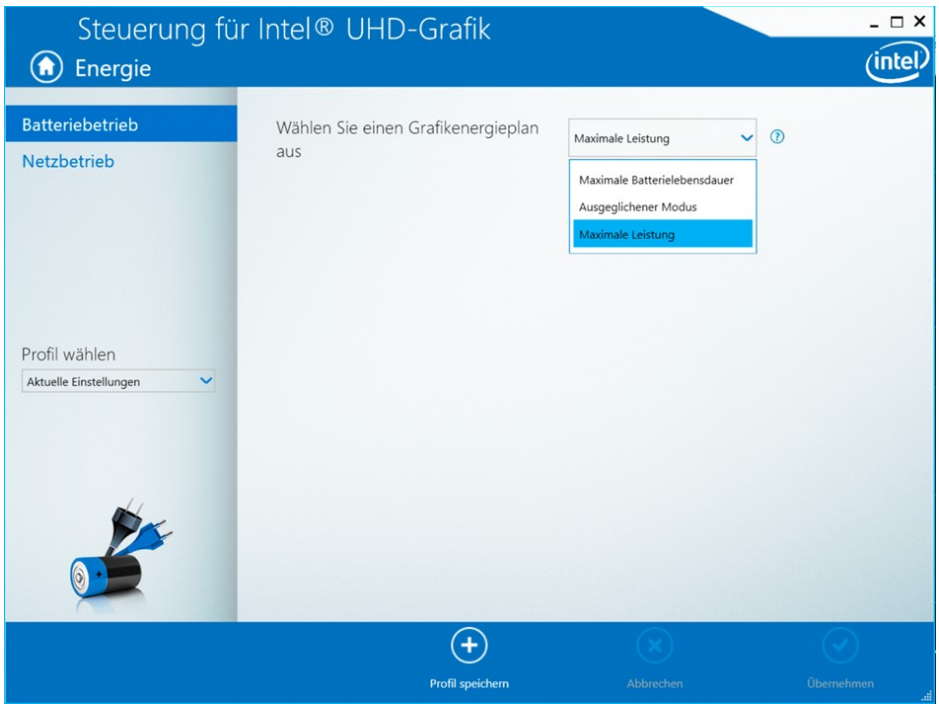
In order to extend the battery life, Windows contains settings for energy saving in various places. Unfortunately, these settings have the effect of reducing the performance of the system, e.g. by downclocking system components. Therefore, the energy saving options should generally be switched off, especially while a recording is running.

The main settings under Windows 11 are as follows:



The energy status should be set to "Best performance".

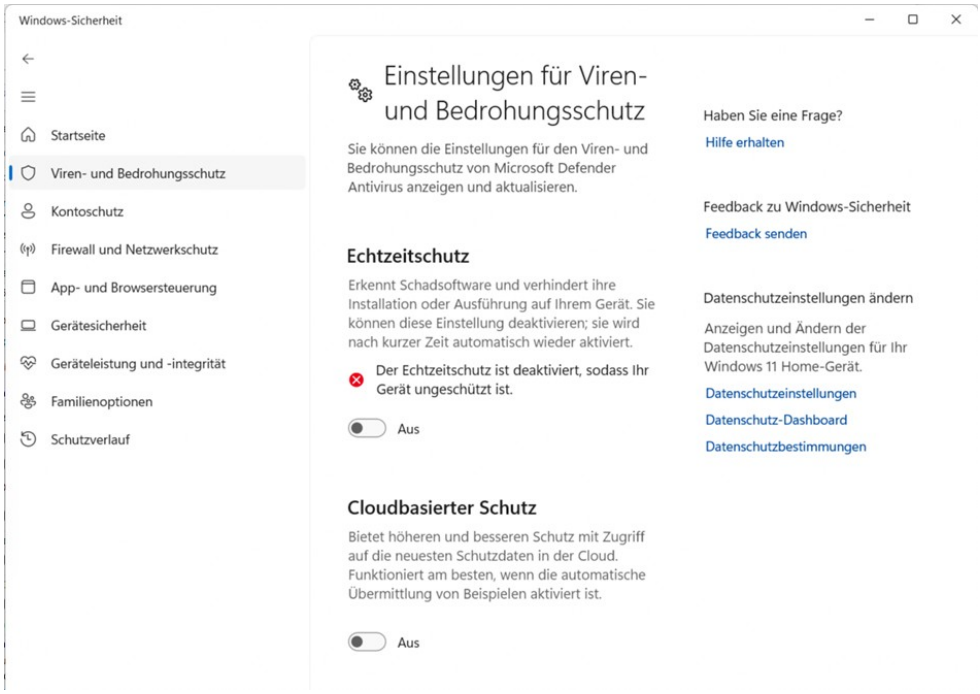
The graphics card typically also contains energy-saving settings, which should also be switched off. Here, for example, for an integrated Intel graphics card:



10.4.2 Restrict virus scanner

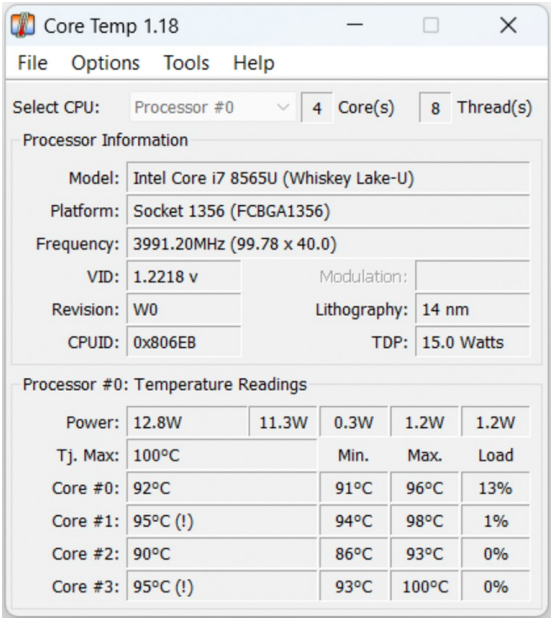
Windows has had a built-in virus scanner for some time now. With the default settings, the scanner continuously scans the files for known virus signatures (so-called "real-time protection"). This

should either be switched off completely or the control software and the directories with the video files should be excluded from the scan.



10.4.3 Temperature-dependent power reduction

If the temperature of the device rises, the processor performance is automatically reduced. This can happen in a warm environment, for example, or if the laptop is installed in a box. A helpful tool to detect this problem is the "Core Temp" software.

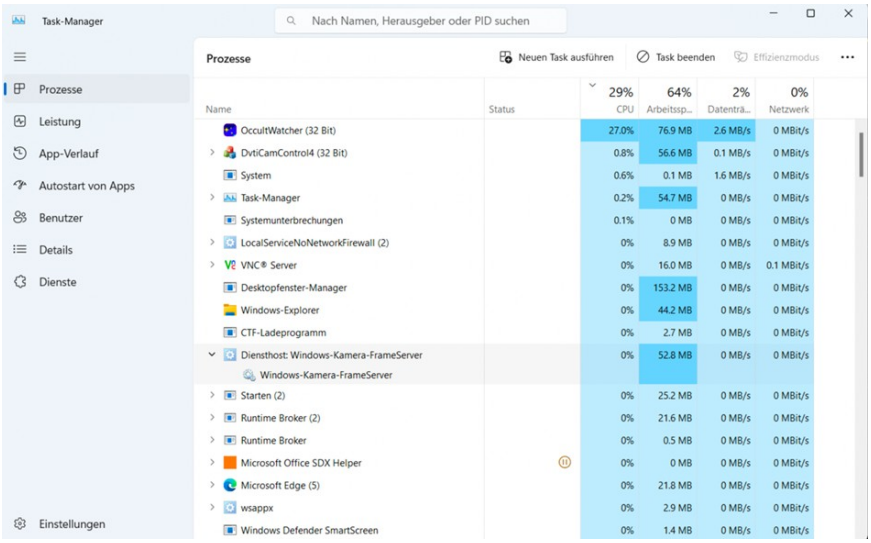


10.4.4 Other processes and programmes

Windows distributes the available computing power and memory among all services and programmes running on the computer. This means that the more programmes are active, the less

computing power and memory is available for the camera and the more likely it is that frames will be lost.

A good tool to see what is currently running on the computer is the "Task Manager" built into Windows. In the following example, the "Occult Watcher" software is currently carrying out a synchronisation. To prevent this from happening during a star occultation and losing frames as a result, all non-essential programmes should be closed at this time.



10.4.5 Connection to the USB root hub

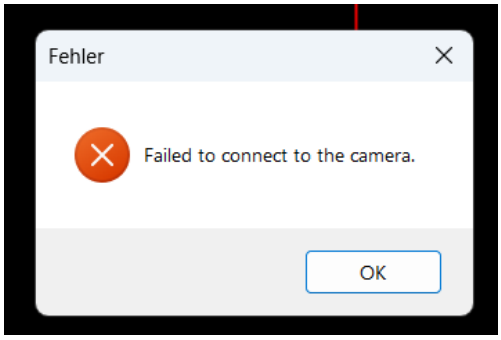
Another way to find the cause of dropped frames is to analyse the traffic on the USB bus. The "USB Device Tree Viewer" programme[20] can be used, for example, to check whether there are other devices on the root hub to which the camera is connected.

Ideally, the camera should be the only device on the root hub. Below is a "bad" example of a development computer in a virtual machine where a mouse is connected to the same root hub as the camera:

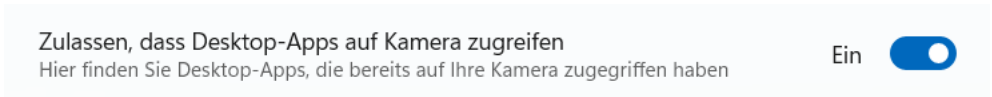
[20]https://www.uwe-sieber.de/usbtreeview_e.html

10.5 Enabling access to the camera

Under restrictive Windows security settings, access to the camera may not be permitted by the DVTI tool. This is indicated by the following error message appearing after connecting via the green cable symbol (the camera is recognised correctly):



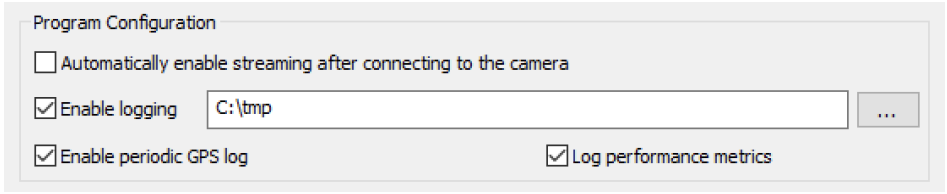
The restriction can be adjusted in the Windows settings under ‘Privacy’ > ‘Camera’ (a little further down under App permissions). There, a switch can be used to allow desktop apps to access the camera:



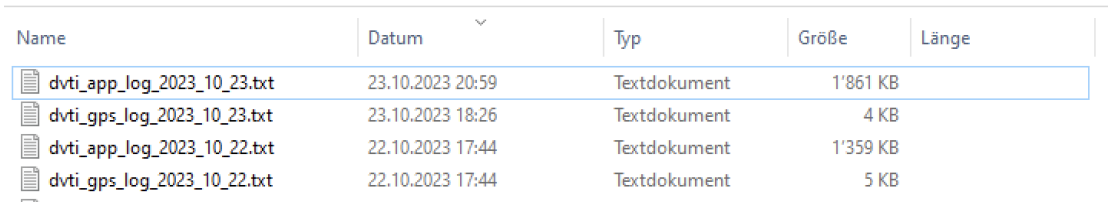
10.6 Logging

Note: Logging requires some computing power and data throughput to the hard drive and should therefore only be switched on if it is really necessary, e.g. for troubleshooting or for logging GPS information.

Various logging functions can be activated via the settings (Edit > Settings...) under "Programme Configuration".



Logging is switched on via the "Enable logging" checkbox, whereby a valid directory must be specified in the field next to the checkbox where the log files can be saved.



10.6.1 Logging for troubleshooting

If logging is active, status information about the camera and the system is stored in a log file. There is a single log file per day, with the file name corresponding to the following format (YYYY=year, MM=month, DD=day):

```
dvti_app_log_YYYYY_MM_DD.txt
```

If the "Log performance metrics" checkbox is also selected, entries on the execution time of the individual image processing steps are made in the log file at regular intervals.

Example:

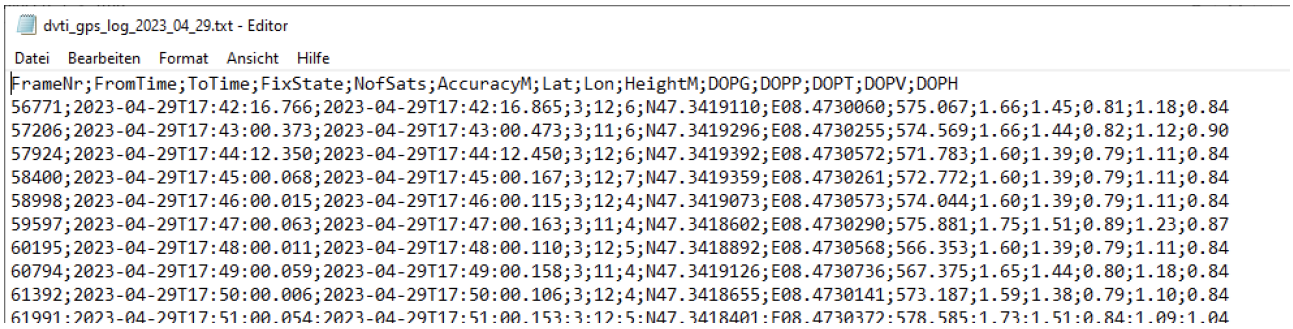
```
2023-10-07 10:08:44.463  I PERF 15.6  0.0  5.4  0.0  0.0  0.0  5.8
2023-10-07 10:08:54.464  I PERF 15.5  0.0  5.1  0.0  0.0  0.0  5.7
2023-10-07 10:09:04.483  I PERF 15.0  0.0  5.0  0.0  0.0  0.0  5.7
2023-10-07 10:09:14.479  I PERF 14.6  0.0  5.0  0.0  0.0  0.0  5.5
2023-10-07 10:09:24.497  I PERF 14.8  0.0  5.0  0.0  0.0  0.0  5.7
```

10.6.2 Logging of GPS information

A data record with information on satellite reception can be logged periodically once a minute. The "Enable periodic GPS logging" checkbox is selected for this purpose. The log is stored daily in a file with the following file name format:

```
dvti_gps_log_YYYYY_MM_DD.txt
```

Example:



11 Support and further links

11.1 Website and forum

Information, news and software for the camera can be found on the following websites:

- Official DVTI+CAM website: https://dvticam.com/product and downloads at https://dvticam.com/support
- DVTI project page with forum and wiki: https://groups.io/g/d-vti-cam/
- Some information on the history of the DVTI camera project with older presentations (at the bottom of the page): http://occultations.ch/equipment.html

A discussion forum with a mailing list is available on the Internet for DVTI+CAM users, where topics relating to the camera can be discussed (second link from above). We recommend that all users register for the forum.

For questions and suggestions that are not of general interest, please contact us by e-mail: info@dvticam.com

We are active amateur astronomers ourselves and have already observed hundreds of star occultations with this camera and have continuously incorporated our experience into the further development of the hardware and software. However, the whole project also depends on the suggestions of all users. If you have any ideas on how the software can be improved, please let us know!

Official DVTI+CAM page

11.2 Further links

Observation preparation and planning:

- C2A Planetarium Software. Proven software in connection with star occultations. Existing interfaces of OccultWatcher: http://www.astrosurf.com/c2a/english/
- Notes on integrating the UCAC4 catalogue into C2A (a little further down under "Star Catalogues"): http://www.astrosurf.com/c2a/english/information.htm
- OccultWatcher (OW). Software for planning visible star occultations. Data can be imported into our tool via an add-in: https://www.occultwatcher.net/
- OccultWatcher Cloud (OWC). Further development of OW, but currently does not yet calculate location-based data, which means that OW is still required in parallel: https://cloud.occultwatcher.net/
- List of major stellar occultations Steve Preston: https://asteroidoccultation.com/asteroid.htm
- Lucky Star Preditions: https://lesia.obspm.fr/lucky-star/predictions.php
- CORA by Mike Kretlow: https://astro.kretlow.de/?CORA
- The Minor Planet Centre (MPC) of the International Astronomical Union for querying orbital elements and ephemerides: https://minorplanetcenter.net//iau/MPEph/MPEph.html

Recording and evaluation tools:

- Alternative recording software: oaCapture https://www.openastroproject.org/oacapture/ or SharpCap https://www.sharpcap.co.uk/
- PyMovie for analysing the recordings and creating light curves. Is a Python script and can therefore run on all common operating systems: https://pypi.org/project/pymovie/ and guidelines at https://occultations.org/observing/software/pymovie/
- PyOTE for measuring light curves. Optimised in combination with PyMovie: https://pypi.org/project/pyote/
- Tangra for measuring the recordings and creating light curves: http://www.hristopavlov.net/Tangra3/
- AOTA for analysing light curves (part of Occult): http://www.lunar-occultations.com/iota/occult4.htm
- Documentation on the ADV format: https://ui.adsabs.harvard.edu/abs/2020JOA....10c...8P/abstract
- ADV Player for macOS: https://groups.io/g/d-vti-cam/files
- SER videos can be played with the freely available SER Player: https://github.com/cgarry/ser-player
- Documentation on the SER format: http://www.grischa-hahn.homepage.t-online.de/astro/ser/

Community:

- IOTA and IOTA-ES (European Section). https://occultations.org/ and https://iota-es.de/
- Journal for Occultation Astronomy" published by IOTA (free download): https://iota-es.de/joafree.html
- Forum of IOTA: https://groups.io/g/IOTAoccultations/topics
- Planoccult mailing list for European observers (registration required): https://lists.vvs.be/postorius/lists/planoccult.ls.vvs.be/
- SOTAS, Stellar Occultation Timing Association Switzerland (corresponding specialist group of the Swiss Astronomical Society): http://occultations.ch/index.html
- SODIS. New IOTA-ES reporting portal for European stellar occultations from 2023. https://sodis.iota-es.de/ and the SODIS forum at https://forum.iota-es.de/

An almost 100-page documentation can be found in the forum under "SODIS" (note necessary).

12 Legal information

12.1 FCC conformity

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:
(1) This device may not cause harmful interference and (2) this device must accept any interference received. This includes interference that may cause undesired functions.

12.2 EU conformity

Schweizer Technik Manufaktur GmbH hereby declares that this device is in compliance with Directive 2014/53/EU. A copy of the EU Declaration of Conformity can be downloaded from the website at www.dvticam.com/compliance.

12.3 Frequency bands

This device contains a satellite receiver module for GPS, GLONASS, Galileo and BeiDou satellites. It receives radio radiation in the frequency range from 1561.098 MHz to 1609.3125 MHz.

12.4 Notes on disposal and recycling

The symbol shown on the left indicates that this product must be disposed of separately from household waste. When disposing of this product, ensure that you comply with environmental regulations.

If you wish to dispose of the product, you can send it back to us. We will cover the costs for the return shipment. Please contact us at info@dvticam.com.

12.5 Software licence agreement

By using this device, you declare your agreement with the software licence conditions of Schweizer Technik Manufaktur GmbH and third-party providers. You can find these terms and conditions at www.dvticam.com/sla.

13 Change Log

Revisions to these instructions or what has happened so far:

13.01.2025	Minor fixes.
29.07.2024	Added chapter 10.5, Enabling access to the camera.
30.05.2024	Translation and first release of the EN Manual.
10.05.2024	Revision of "Record with Options" / Edit > Instruments with new screenshot (Reducer) / Adjustment to "Obstruction", where % specifications are now also possible / Import of D & R Times (new screenshot) with drag & drop option (all in chap. 3) / FITS Dark/Flat: Time delay of 10s as an option in chap. 5.5 / New chap. 7.2 regarding three limitations of the data stream during binning / 2 new keywords FL_RAW and FL_FACTOR in chap. 8.2.
19.04.2024	First release of the German version for tool version 5.8