IOTA-VTI v3.01
A GPS based video time inserter
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Preamble:-

The IOTA-VTI is a video time inserter intended for astronomical occultation work. It takes a PAL (CCIR) or NTSC (EIA) video feed from a camera presumably attached to a telescope, and overlays the image with GPS-derived time and location information. The output video feed is sent on to some form of video recording system.

The unit is stand-alone, contains its own GPS unit, and does not require a computer to function.

This manual is intended for IOTA-VTIv3, with serial numbers 500 onwards or until further notice.

Enclosure Front and Rear panels:-

The front panel of the enclosure has two slide switches and three indicator LEDs:-

The rear panel has; a socket for Power, a Dark pushbutton, External GPS Antenna, a connector for a FTDI serial dongle, and Video In/Out, and a Reset pushbutton:-

Using the IOTA-VTI:-

The unit requires clean 12-volt dc power. Version 1.1.9 will operate over the input range of 8 to 18 volts, drawing approximately two watts; for version 2.2 and later the operating range is 8 to 28 volts at one watt. The user must provide a video input signal, and some form of video monitor and/or recorder.

A backup battery is used to maintain the memory of the GPS during non-use periods. The condition of the battery is reported by IOTA-VTI systems and for a full description see the Maintaining Battery Backup section.

IOTA-VTI has an internal GPS receiver, with sensitive antenna, and there is provision to connect an external antenna. The GPS will switch automatically to the external antenna when it is connected.

Obtaining a GPS fix:-

 The time to obtain a GPS fix (known as Time To First Fix = TTFF) depends on the condition of the memory backup battery maintained since the IOTA-VTI was last used. TTFF may be brief (30 seconds) if the backup battery is in good condition during the shut down interval, and the GPS reception is excellent, or TTFF may be several minutes if the backup battery is flat or was tampered with, or if the view of the sky is not optimal, or if you have moved large distances since your last use of the unit.

 In general, a fix with three satellites will give geographic information, and a fix with five satellites will provide 1PPS information (including UTC and date).

Analogue Video Cameras:-

 A camera is not necessary for IOTA-VTI to display time and position data and it will output PAL or NTSC formatted video according to the setting of switch-1 on the DIP switch (inside the case). (reset to implement the change to take effect). Of course a camera is required to make astronomical observations.

 IOTA-VTI will accept composite video, either NTSC or PAL from a camera and the (green) Camera LED will light to indicate a good video-in feed, and the video out will carry the camera image as well as overlaid GPS information. ***The unit automatically switches between NTSC and PAL input.***

 For proper operation, the format chosen via DIP position 1 must be the same as the format used by an external camera.

TV safe area:-

 If your output monitor or recorder displays/records only the TV-safe area of video transmission (such as a regular TV monitor or a video recorder) then you should set the front panel switch to TVsafe. This will place all the information within the TV safe area.
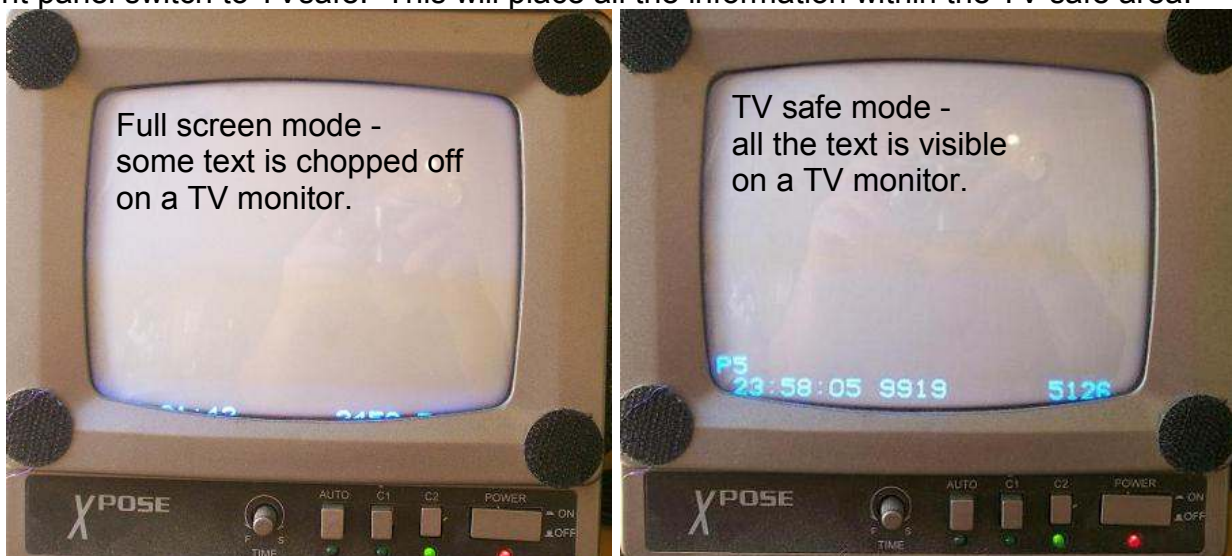
After changing that switch, a reset or power cycle is required for the change to take effect in the software.

Video Screen Types:-
The unit displays a splash screen for a few seconds at startup and is followed by either a Position screen or Time screen, depending on the setting of the Position/Time switch.

Splash | Position | Time
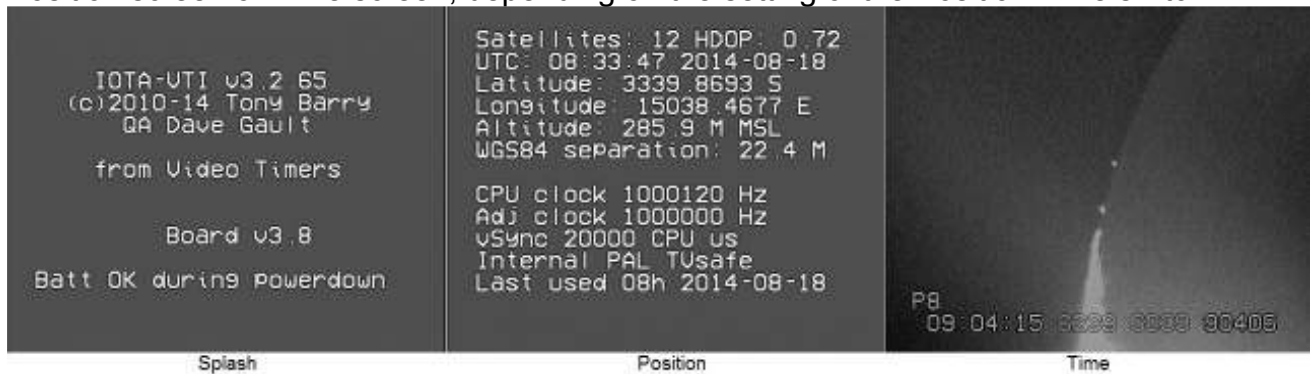
<u>Splash Screen</u>. This gives general credits, the software version (top line), hardware version (near the bottom of the screen), and an indication of the condition of the backup battery will be indicated during the interval the splash screen is displayed.

<u>Position Screen</u>. This gives information about the GPS status, the current date and time (to three second resolution), geographic location, and VTI system information. Latitude and longitude are given in degrees, minutes, and decimal minutes. The date the IOTA-VTI was last used is displayed.

<u>Time screen</u>. This single line display gives GPS fix information, UTC (HH-MM-SS), the number of 100 microsecond intervals since the most recent 1PPS signal, and the number of video fields counted since power was applied or the Reset switch was pressed.

The Splash Screen – <u>In Detail</u>:-
The Splash screen (as shown above) displays useful information during the startup phase;
- The version of the firmware installed in the device.
- The Author and Quality Assurance origin.
- The Manufacturer.
- The version of the board installed.
- A message that reports on the condition of the Backup Battery since the device was last used.

The user should note the type of message displayed. There are three conditions:-
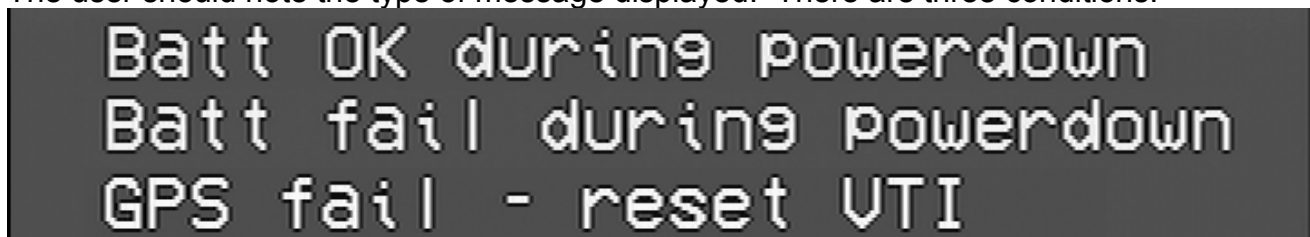
- Battery OK - is the normal startup condition. All is well.
- Battery fail - means the battery has failed or the battery was tampered with during the shut down interval. This will be displayed the first time a new device is used, because a new device is shipped with a battery insulation tag in place, which of course is removed after unpacking.
- GPS fail - indicates the firmware failed to communicate with the GPS for some reason. A Reset or Power on/off/on cycle should restore normal operations.

For more information see the <u>Battery Backup</u> section.

The Position Screen – <u>In Detail</u>:-

The Position screen displays useful geographic location and some system values you may find useful. The screen updates every three seconds.

```
Satellites: 9 HDOP: 0.83
UTC: 03:17:03 2014-12-20
Latitude: 3339.8731 S
Longitude: 15038.4661 E
Altitude: 286.3 M MSL
WGS84 separation: 22.4 M


CPU clock 1000012 Hz
Err Persistent Ext ant
vSync 20000 CPU us
External PAL TVsafe
Last used 03h 2014-12-20
```

- **Satellites**: is the numbers of satellites in the GPS fix. The Position screen may well display more satellites than the time screen can, simply because the time screen has one character to display the satellite count and the Time screen has two characters.
- **HDOP**: (Horizontal Dilution of Precision) is a value output by the GPS and is an indication of the precision of the GPS position information.
  - o <1   = Ideal
  - o 1-2   = Excellent
  - o 2-5   = Good
  - o >5   = Poor (inaccurate as much as 300 metres)
- **UTC**: current Universal Time and Date
- **Latitude and Longitude**: displayed as degrees, minutes, and decimal minutes.
- **Altitude**: is displayed in metres and referenced to MSL (Mean Sea Level)
- **WGS84 separation**: is the offset (m) between the WGS84 geiod and MSL
- **CPU clock**: is the rate of the CPU clock inside the IOTA-VTI's microprocessor compared to 1 pulse per second (1pps) ticks from the GPS. This should be within 30 microseconds of true.
- **Err** ors: displayed as Transient or Persistent as set by the DIP switch on the circuit board.
- **Ext ant/Int ant**: is the confirmation that an external GPS Antenna is connected or not. This message is dependant on the GPS and may not appear with your unit.
- **vSync**: is an indication of how accurate the clock in your camera is.

- **Internal/External**: indicates the source of the V-Sync signals output by IOTA-VTI. Internal V-Sync signals are generated by IOTA-VTI's crystal oscillator. External V-Syncs are generated by a video camera plugged into the Video-IN port. The "Camera" LED on the front panel echoes this setting.
- **PAL/NTSC**: is the video format being time stamped.
- **Fullscreen/TVsafe**: indicated the setting of the DIP switch. See "TV safe area" section above.
- **Last used**: indicated the time the IOTA-VTI was last used. If the time and date are sensible then the backup battery was able to supply sufficient charge to the GPS during the non-powered state, however if the display is "09'd" as shown below then the battery was tampered with during the shut down period or is discharged and should be replaced. See battery maintenance section below.

Last used 09h 2009-09-09

The Time Screen - In Detail:-

The line at the bottom of the Time screen shows you most of the information you need for a valid timestamp.

F6
21:15:28 6170 6370 71095
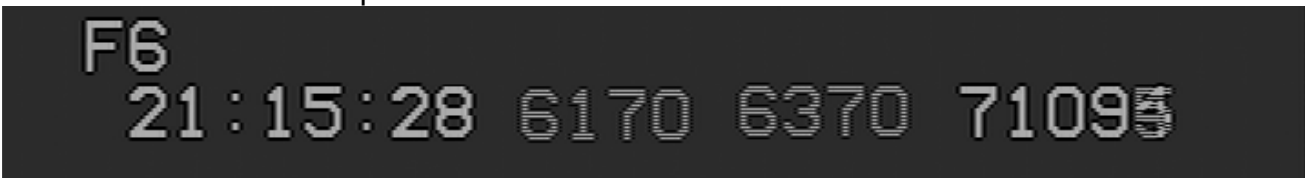
The first character ("F" in this example) represents a grade value for the satellite fix.

Item	Meaning	Details
N	No Fix	No valid GPS info, NMEA sentences may be emitted if previous fix data was reliable
X	Dead Reckoning fix	Based on last real fix. No 1PPS
F	Real (1PPS) Fix	Valid time information (1PPS, GGA), MSL, WGS84

The second character ("6" in this example) represents how many satellites have been acquired. You need at least 5 satellites for a 1PPS timing fix to initiate, and 4 satellites to maintain the 1PPS fix (timing fix). 3 Satellites or less will stop the 1PPS.

The UTC is next ("21:15:28" in this example). It is updated on receipt of a valid 1PPS and a GGA NMEA sentence from the GPS.

The numerals "6170" and "6370" are the times (format SS.ssss second) of the two V-Sync signals that occurred during this video frame.

- the V-Sync of the first video field occurred at 21:15:28.6170 UT
- the V-Sync of the second video field occurred at 21:15:28.6370 UT

Lastly we have the field counter, which in this case shows 71094 and 71095. That is the total number of video fields since power was supplied or the unit was reset. The counter has been tested to 100 million counts (19+ days for NTSC), at which point the least significant digit can no longer fit on the screen. Except for that loss of resolution, the counter will remain valid to 4 billion fields before it overflows to zero.

The Time screen updates every vSync period (20msec PAL, 16.7msec NTSC).

The Time Screen - <u>Hour Glass</u>:-
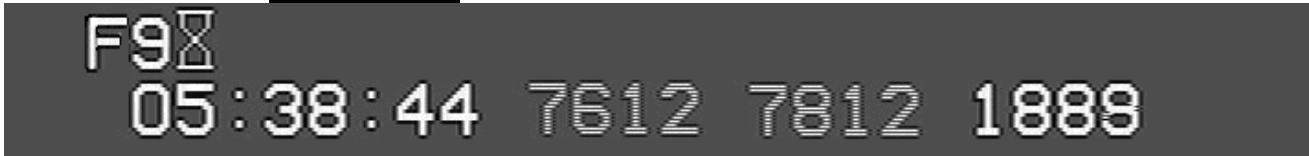
      If the backup battery voltage is not maintained since previous use, due to battery discharge or removal, an hourglass symbol will be displayed next to the satellite number. This is to alert the user that the GPS has lost its backup power and it's almanac has reverted to the default status, thereby perhaps losing the correct offset between GPS-time and Universal Time, therefore time displayed can not be guaranteed.

The absence of the hourglass symbol in the third character position means that the time displayed is correct to Universal Time.

For information on Almanac Updates and Battery Maintenance, see sections below.

The Time Screen - <u>Loss of GPS fix</u>:-
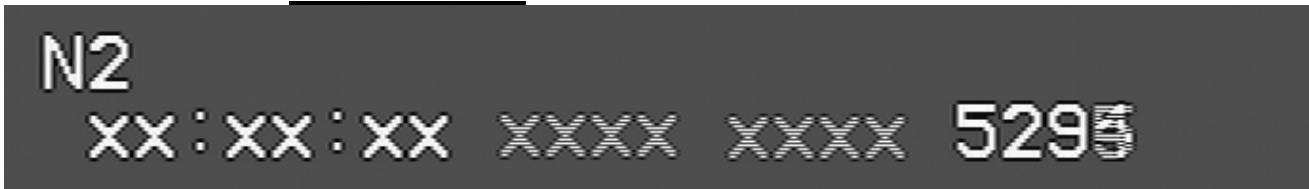
In normal circumstances, once started IOTA-VTI's sensitive GPS should keep good reception to the GPS constellation of satellites. However, if the number of satellites in the GPS fix falls to 3 or less, the GPS will stop outputting 1pps signals, and so IOTA-VTI will stop displaying time and will display 'x' shown above.

IOTA-VTI will display plenty of warning that loss of fix might be imminent by;
- the F, X and N code (see above)
- the reduction of the satellite count

Should loss of fix appear likely, and an event is imminent, the user should make a brief recording of the time screen display, thereby calibrating the field counter to UT, then the event timing can be salvaged by use of the field counter, which will keep working at all times the device has power.

Note-1: this condition is unlikely in <u>normal</u> circumstances because, once the GPS has started, it is very difficult to prevent the GPS from receiving signals. During testing the IOTA-VTI had to be wrapped in aluminium foil AND placed in a metal toolbox to prevent GPS reception.
Note-2: If IOTA-VTI is to be used in difficult conditions, e.g. in an observatory with a metal dome, then the purchase and use of an external antenna that is sited outside the metal dome is recommended. See External GPS Antenna section for more information.

The Time Screen – <u>Error Messages</u> :-

IOTA will display on-screen an error message to alert the user that an event occurred that may affect the time displayed. The message will appear within one second of the event occurring and will advise of the error type and time of the error event.

The philosophy of IOTA-VTI error reporting is to <u>squawk loudly on error</u>, meaning the user is advised within one second of an event that may effect the quality of the timestamp.

The error type and the time of the event are reported at the top of the Time screen and displays 1 error per line. The meaning of the error is as follows.

	Error Name	Details
1	UTnotSeq	A 1PPS was detected, as well ad GGA information that described it, but the description was not what was expected.
2	NoPPS	A One Pulse Per Second (1PPS) was not received.
3	NoGPSmsg	No useful NMEA Sentence was received
4	LoopTooLong	The main loop took too long to write the Time message properly on screen. This is set at 15 msec (PAL) and 12.5msec (NTSC).
6	PPStooQuick	may occur while the unit is re-stabilising after a Loss Of Signal.
7	NoGGA	GGA sentence was delayed. This error will shut down the UT display for five seconds until the unit has recovered. If it occurs frequently, reposition the antenna away from sources of RFI.
8	twoGGA	Two GGA sentences were received. This will occur in tandem with and just after a NoGGA error.
9	antAdvis	The unit received an unexpected antenna advisory message while in Time mode

These errors usually represent problems in communication between the GPS unit and the microcontroller or are induced by an electrically noisy environment.

Note: Error 5 is retired.

Error messages may be set as Persistent or Transient via the setting of the DIP switch.
- Transient means that error messages remain on screen for 5 seconds then are automatically erased when timing returns.
- Persistent means the error message remains on-screen until cleared by the operator, by changing to the position screen and back, or by reset.

Time Screen - <u>Almanac Updates</u>:-

If the backup battery supply to the GPS fails or the battery was tampered with during the shut down period the GPS's almanac will revert to the default status. The offset between GPS-time and universal time may be incorrect depending on whether leap seconds have been added after the GPS manufacture date.

This condition is reported on the Time screen by the presence of the Hour Glass.

The GPS may take a maximum of 12 min 30 sec of continuous 'F' fix for the almanac to be fully downloaded from the satellites. When download is complete, the UTC may change by an unexpected number of seconds. The update indicates that UTC has changed from the logical progression begun at initial acquisition, and is now correct. If this occurs, information is provided so you can apply an adjustment to UTC to give you the correct time "before" the update.

If after fifteen full minutes of F fix, the hourglass disappears without an almanac update shown above, then the default almanac of the GPS was current.

Backup Battery:-

The GPS Real Time Clock and Almanac settings are maintained by a backup battery, shown in image at right.

The battery is a CR2032 and should maintain the backup power for years.

On delivery of a new IOTA-VTI, there will be insulation tag fitted to prevent battery use during shipment.

Simply pull on the tag to activate the backup battery.

The battery condition is advised via the splash screen during start up or reboot. See the Splash Screen – In Detail section for more information.

If a battery fail message is observed on the Splash Screen and is not a result of activation of a battery, or known tampering of the battery by yourself or others, then the battery is flat and needs replacing.

To replace the battery;
- remove IOTA-VTI cover
- remove the old battery and replace it with the new battery.
- replace the cover.

Run IOTA-VTI for at least an hour at a site with good reception (5 or more satellites) to ensure the GPS has downloaded the current almanac. You may receive an Almanac Updated message.

Video Frame, Field Type and Frame Central Timing
The video stream has codes to identify an even field type from an odd field type, and IOTA-VTI can read the field type code and action the 10th millisecond display to put the timing for the Even field on the Left and Odd field on the Right.

However it is not consistent how video camcorders, video grabbers and DVRs sequence the field order when assembling video frames. It appears that the sequencing method;
   a) (even+odd), (even+odd), is the most common
   b) (odd+even), (odd+even), is somewhat less common
   c) some will even assemble a pseudo frame from (even+even), (even+even) fields, and actually ignore the odd fields, (or vice versa).   Obviously this method is not desirable because ½ the data the camera sees is tossed away by the recording equipment.
IOTA-VTI has the means to demonstrate and identify field type.
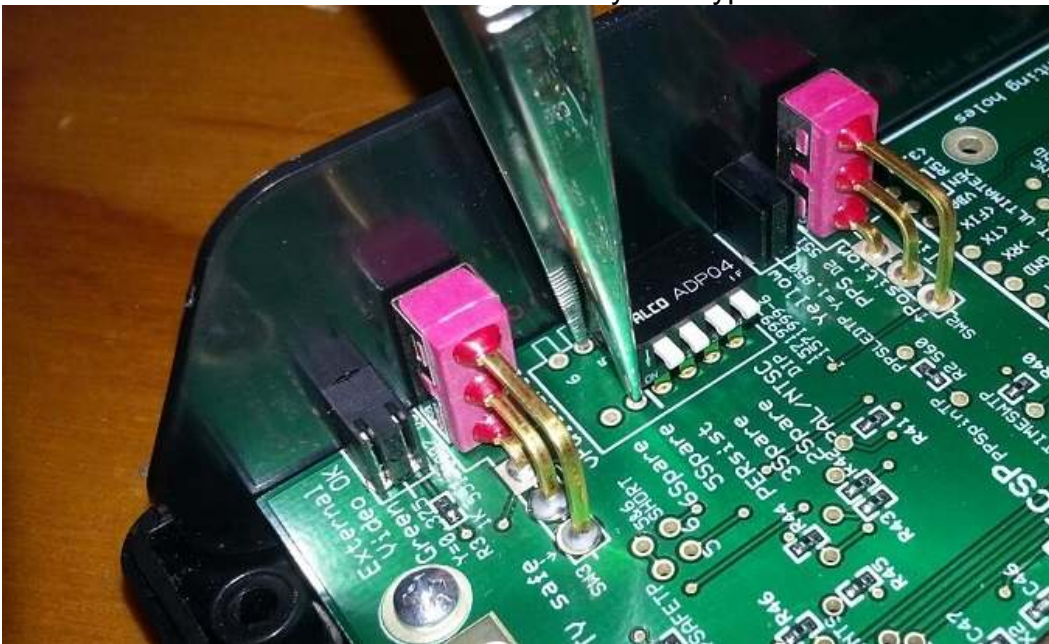
This is the method;
   -   Start IOTA-VTI and display the time screen on a video monitor or similar.
   -   Remove the cover to reveal the PCB. Next to the DIP switches you will find two sites marked 5Spare and 6Spare.
   -   Using a metal probe e.g. tweezers, as shown in photo above, either the even or odd fields can be temporarily nulled.
   -   Probe 5Spare will null odd fields and you will see the right 10th millisecond display disappear.
   -   Probe 6Spare will null even fields and you will see the left 10th millisecond display disappear.
   -   If during this test you can see only one 10th millisecond display and when probing either 5Spare or 6Spare, it disappears with one probe, and nothing happens when probing the other, then you know your recording equipment is of the type c) above and is doing you an injustice by throwing away ½ your data.

Finally make a brief recording and examine the 10th millisecond display.
   -   If the earlier time is on the left then your recorder is of the type a) above.
   -   If the earlier time is on the right then your recorder is of the type b) above.

Leap Seconds:-

At the time of writing, the performance of the GPS receiver during the insertion of a leap-second is not known.

However it is imperative that IOTA-VTI be operated for an hour after the insertion of a leap second, to ensure the GPS has updated it's almanac correctly, and to ensure that the correct time is displayed.

External GPS Antenna:-

The usefulness of an external antenna will be in those situations where the IOTA-VTI v3 must operate at a site that offers poor GPS reception. The external antenna, with it's 5 metres of cable will allow flexibility to site the antenna to achieve better reception.

Simply screw the antenna socket onto the Antenna port on the rear panel. The GPS will auto switch between internal and external antennas

Camera latency:-

Not all video cameras are created equal. Some will send video information just as it happens. Some will store a complete frame (2 fields) and then send the picture information down the video line. And some will accumulate several frames before updating the video image.

Your IOTA-VTI does not timestamp the optical image. It timestamps the video transmission from the camera, and is tested to be correct at the Video In plug on the VTI. You must determine how much delay (latency) there is between a known optical event and the appearance of that event on the video stream.

The way to tell what your camera does is to point it at the 1PPS LED on the GPS-VTI and watch the resultant video recording. The LED flashes within 7 microseconds of the 1PPS signal from the GPS, and that's a worst-case scenario; in most cases the LED will illuminate within 3 microseconds of 1PPS. You want to see just when that flash gets to the Video In plug. The delay is measured by the subsecond counter on the IOTA-VTI timestamp.

In the two images below, a GStar-EX PAL camera (an accumulating camera) is viewing the 1PPS LED of a pre-production IOTA-VTI. The camera is set for "no accumulation." On the left-hand image, the timestamp is at 14:22:00.053, and the 1PPS LED is still dark. On the right-hand image, the timestamp has advanced to 14:22:00.073, and the 1PPS LED is now lit. We can safely say that the camera, although set to not accumulate, still has a one-frame (two field) delay between optical event and video timestamp. This does not mean the camera is useless! It simply means that there is latency in the system, and any UTC times reported must include the known camera latency. Thus, if you determine an event occurred at UTC 01:23:45.500 according to the end image timestamp on the video, then for this camera, the actual end image time is 01:23:45.460 UTC.

If you see the LED illuminate within one field of UTC change, then your camera sends video as it happens. If the LED illuminates two fields or more after UTC change, then the camera is an accumulating camera. YOU NEED TO KNOW how many fields the camera accumulates before sending the image.

NMEA sentence output:-

It is possible to listen in to the NMEA-GGA sentences from the GPS. This will require use of the USB Dongle, which in turn requires installation of FTDI drivers and software like HyperTerminal or similar.
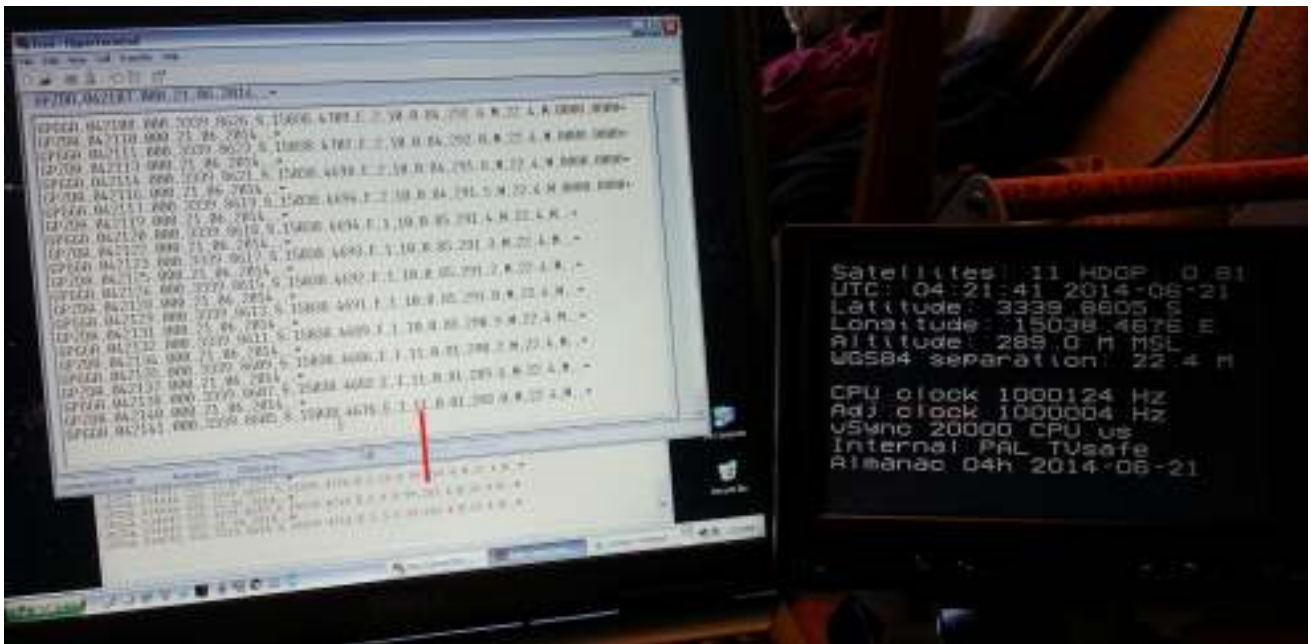
Dark Frame:-

On the IOTA-VTI's Rear Panel, a switch marked Dark can be found. This is to allow dark frames to be made, for subtraction of darks from the recordings. Pressing the switch simply nulls the OSD and can only be activated while switched to the Position Screen. The dark switch will not work while the Time screen is activated.

Conclusion:-

IOTA-VTI will provide you with good, accurate timestamps if you take the time to set your system up beforehand, and measure your camera latency at the accumulation settings you use on the night.

Clear skies!

<div align="center">

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Walter Morgan and Sandy Bumgarner - Video Timers

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