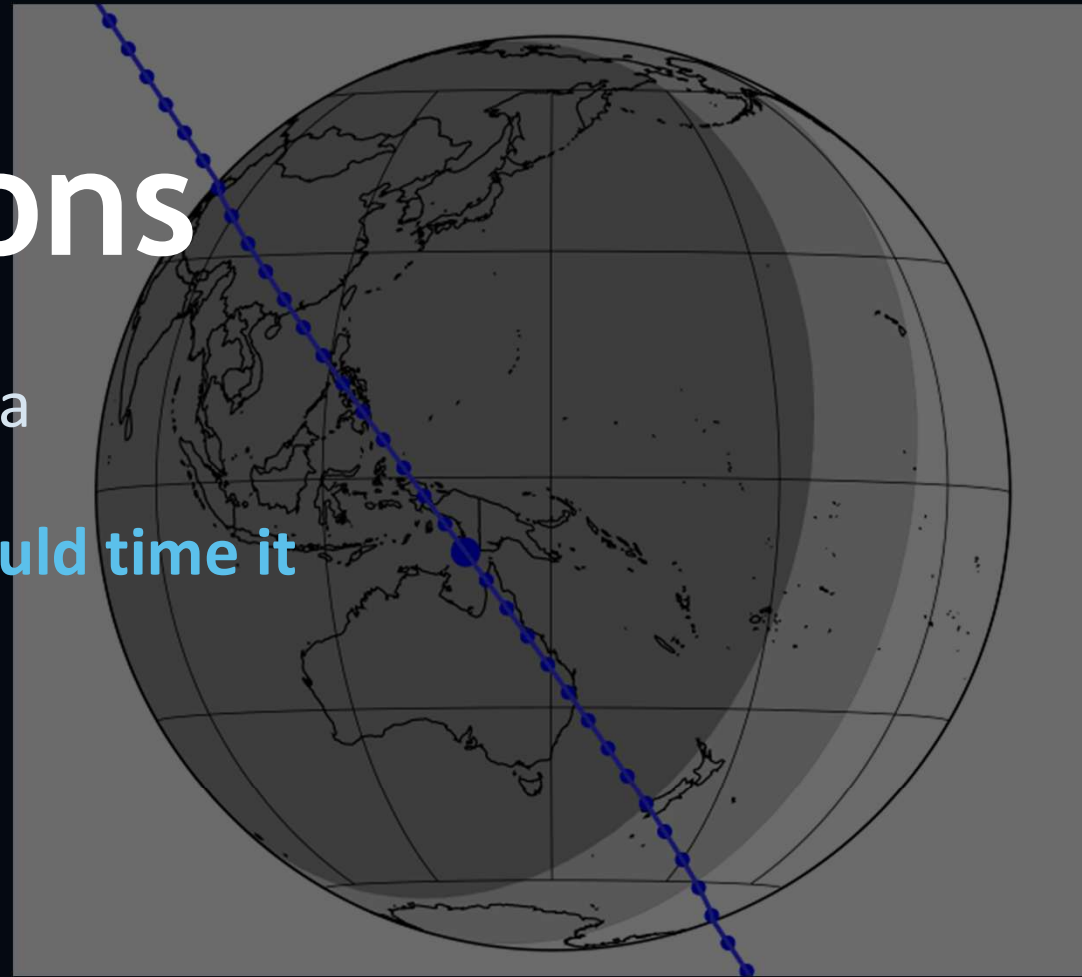


No observations

Not because no one had a camera

Because no one thought they could time it



NTP Timing for Occultations

Michael Camilleri - April 2026

The path for new observers...

Most people researching occultation timing find this:

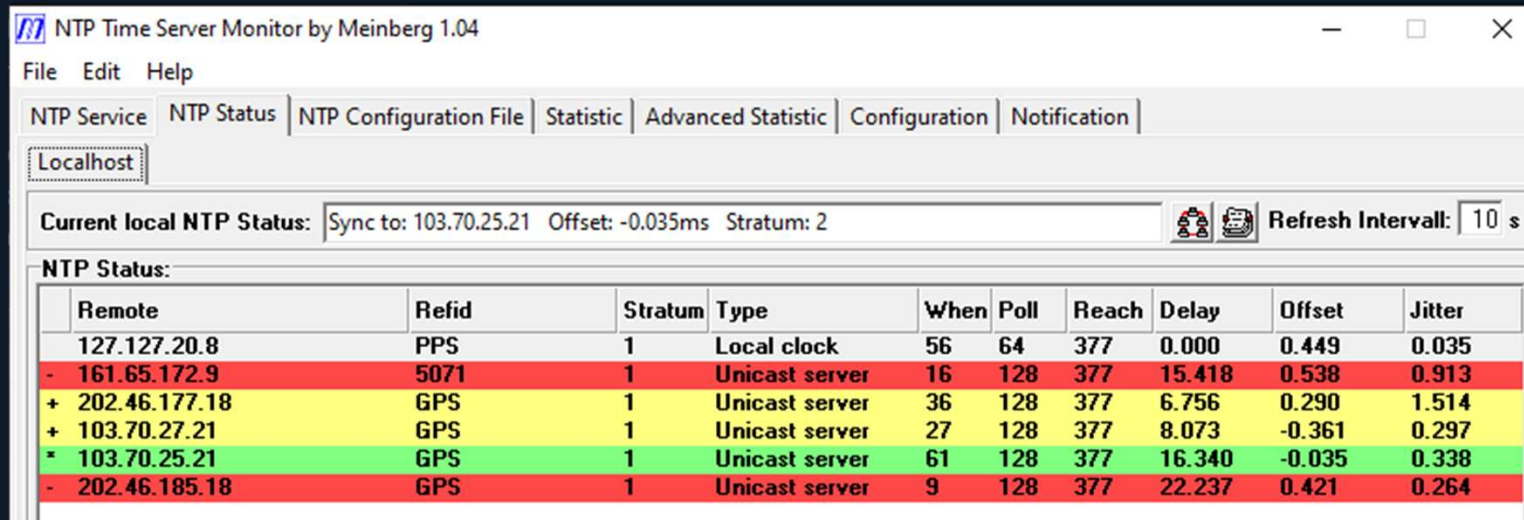
1. "You need a GPS timing device..."
2. "Or an analog camera and VTI..."
3. "Or a dedicated camera..."
4. Hardware cost: **\$500 – \$1,200+ US**

→ **They GIVE UP TRYING.**

There is a Step 0 they were never told about...

What Network Time Protocol (NTP) can do

Home observatory PC — domestic fiber internet. Excellent NTP performance



The screenshot shows the NTP Time Server Monitor interface. The current local NTP status is: Sync to: 103.70.25.21, Offset: -0.035ms, Stratum: 2. The refresh interval is set to 10 seconds. The NTP Status table is as follows:

Remote	Refid	Stratum	Type	When	Poll	Reach	Delay	Offset	Jitter
127.127.20.8	PPS	1	Local clock	56	64	377	0.000	0.449	0.035
- 161.65.172.9	5071	1	Unicast server	16	128	377	15.418	0.538	0.913
+ 202.46.177.18	GPS	1	Unicast server	36	128	377	6.756	0.290	1.514
+ 103.70.27.21	GPS	1	Unicast server	27	128	377	8.073	-0.361	0.297
* 103.70.25.21	GPS	1	Unicast server	61	128	377	16.340	-0.035	0.338
- 202.46.185.18	GPS	1	Unicast server	9	128	377	22.237	0.421	0.264

Offset: **-0.035 ms** Accuracy: **< 0.5 ms vs PPS check**

The “±100 ms” fear = Windows default time service

not properly configured NTP with good servers.

How good is "good enough"?

D/R time errors are ~50 ms for typical main-belt events, mag 12–13 at ~100 ms exposure.

Source	Uncertainty
NTP clock (PIT estimate from logs)	~5-10 ms
Camera line delay (measured)	~1 ms
Camera frame delay (estimated)	~2 ms
NTP/Camera time error	~5-11 ms

Combine ~50 ms D/R error with NTP/Camera error:

$$\text{Total error} = \sqrt{50^2 + 11^2} = 51 \text{ ms}$$

A timing uncertainty of 5-10 ms makes a negligible difference to a typical events D/R error

You can verify NTP accuracy

NTP Clock Accuracy in Occultation Manager
Analyses the NTP logs at the event time
Actual accuracy for the current NTP conditions

Event: 2004 DG41 — 2026-03-02 10:58 UTC

Offset: **-0.38 ms**

Uncertainty: **±4.9 ms (95% - conservative)**

Offset used to adjust timestamps in TANGRA

Uncertainty can go into the observation report

How do you KNOW if your timing is correct?

How do you KNOW how accurate it is?

NTP can tell you...

Confirm Observation Location

Step 1: Confirm the observation location

Event: (167648) 2004 DG41 - Camilleri M Home
Date: 2026-03-02 10:58 UTC

Observation Location (editable)

Station: Camilleri M Home

Observing Location:

Latitude (°): Longitude (°):

Elevation (m):

View on map: [Open Google Maps](#)

Enter/verify observation location and coordinates.
Use 'Lookup' to find city/town name from coordinates.
Use 'Lookup Elevation' to get elevation (WGS84 datum).

Step 2 (Optional): NTP Analyzer

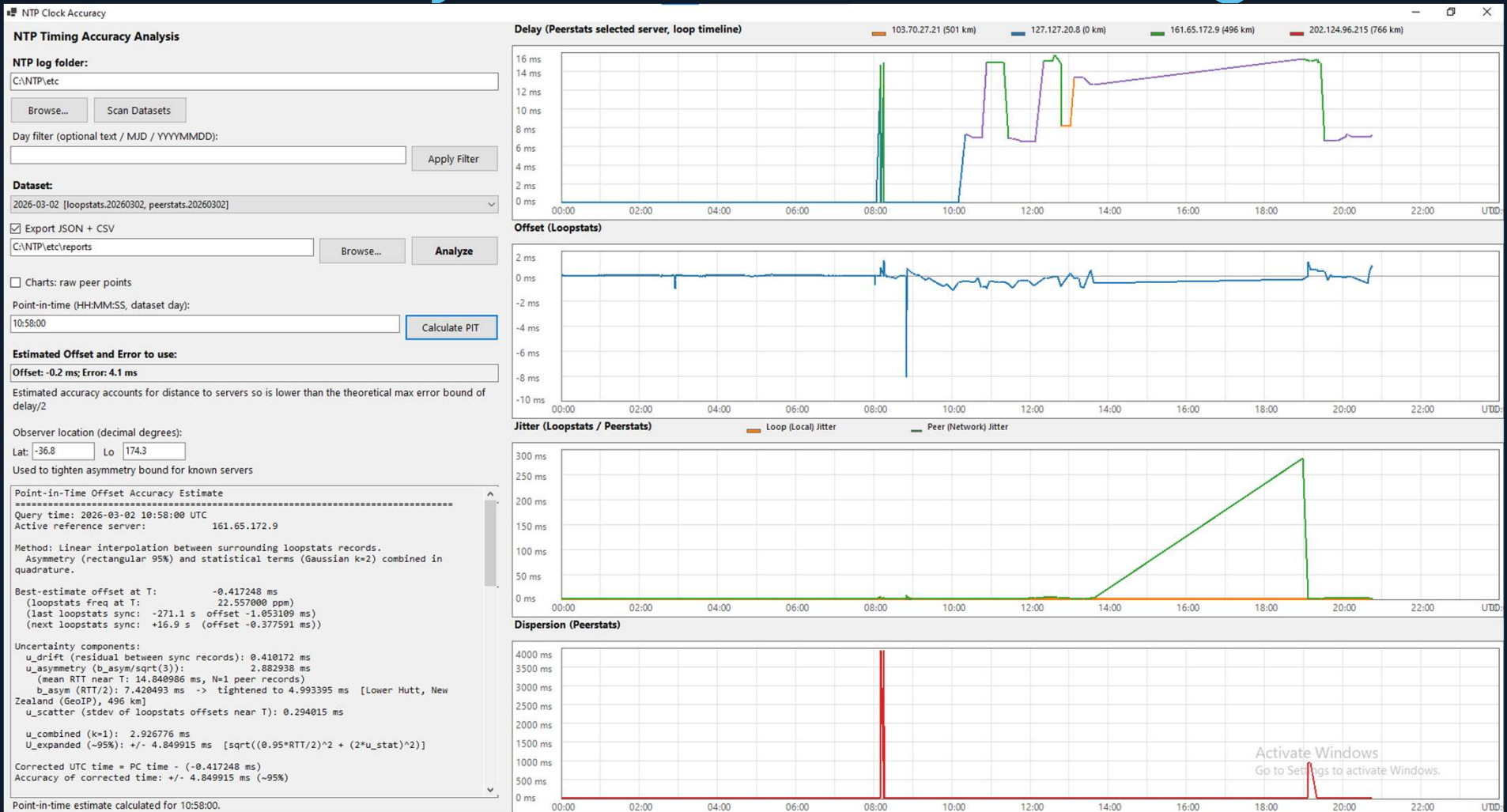
Analyse offset/uncertainty at event time, or open full interactive analyzer.

NTP stats folder:

dataset: 2026-03-02 [loopstats.20260302, peerstats.20260302] (closest sample: 9s) | loop:

offset: -0.380 ms uncertainty: +/- 4.879 ms (95%) data age: 0 min before
server: 161.65.172.9

Full NTP analysis in Occultation Manager



GPS ground-truth verification

GPS vs NTP Testing — 23 hours against GPS PPS reference

Mean UTC error: **0.5 ms**

Range : **-1.3 to +0.5 ms**

The calibration chain back to UTC: UTC ← GPS PPS ← NTP servers ← your PC

Selected Peer UTC Error + Clock Drift

UTC Error (offset - GPS) OLS drift (dashed)



Network Time Protocol (NTP) can give PC times accurate to a few ms

*When set up properly
With good internet*

How can YOU do it?

10-minute install.
Free.

Everything configured automatically

The NTP Installer

One run configures everything:

- Meinberg NTP + Time Server Monitor
- National Standards servers for 35 countries
- Country specific pool servers
- Network and WiFi performance tweaks
- Optional GPS PPS receiver setup

Estimated time: 10–20 minutes

“You can set this up in the time it takes to make a toasted cheese sandwich.”

[NTP Installer](#)

```
Administrator: C:\Windows\system32\cmd.exe
[INFO] Downloading latest PowerShell script from GitHub...
[OK] Downloaded install_ntp_timing_guided.ps1

[INFO] Checking local support file availability...
[INFO] Refreshing ntp.conf template from GitHub...
[ OK ] Refreshed ntp.conf template: C:\Users\micha\Downloads\config\ntp.conf

=== Welcome to the NTP Installer ===
This guided installer can perform any or all of the following:
1) Install Meinberg NTP (Required)
2) Install NTP Time Server Monitor (Recommended)
3) Configure internet NTP servers by country (Required)
4) Optimise Windows network settings for NTP - QoS and WiFi (Recommended)
5) Optional GPS/PPS source setup (Optional)

Estimated time: 10-20 minutes (depends on internet speed and installer progress)
Internet access is needed for optional downloads.
You can safely skip any step and run this installer again later.
If Windows shows security/UAC prompts for trusted installers, choose Allow.

Each step is optional. At every step you can choose: Install, Skip, or Exit.
You can also do all steps manually and follow project documentation when a step is skipped.
Installer log: C:\Users\micha\Downloads\logs\guided_ntp_installer_20260404.log
Resolved NTP install root: C:\Program Files (x86)\NTP
Resolved working folder: C:\Users\micha\AppData\Local\Temp\occultation-ntp
```

What is needed for good NTP time

Internet:

- Fiber connection to local fiber network
- VDSL to nearby fiber cabinet might be OK
- If Speed Test 'Ping' $< \sim 5$ ms should be OK
- Ethernet best
- Wifi may need tweaks (NTP installer does them)

NTP Servers:

- Connect to at least one National Standards server
- Good pool servers with small delays (< 20 ms)
- Servers in nearby cities

PC:

- Low performance Atom CPU PCs may have issues
- Turn power saving features off
- Don't sleep or hibernate the PC
- Minimise load when recording

NTP Installer does most of this for you!

Camera Delays

Camera delays – estimate without a flasher

Line delay can be accurately measured using the Max frame rate

Occultation Manager does this and saves the calibration for later use

Date/Time (UTC)	Label	Camera Name	Camera	Binning	Tilt	Pan	Colour	File	Exposure	Gain	Per Line (ms)	Line 0 (ms)
2026-04-04T01:59:59Z	D	ZWO ASI462MM	408x411	2	68	280	MONO16	ADV files...	60.0	300	-0.02874600...	13.814612

ZWO ASI462MM, 408x411 ROI, binning x2 — Per-line: -0.0287 ms | Line delay (Line 0): 13.8 ms

$\text{per_line_delay} = (1 / \text{max_fps}) / \text{ROI_height} \times 1000 \text{ ms}$ — Occultation Manager calculates this automatically

Frame delay cannot be measured without a GPS flasher. Must estimate.

For small sensors, small ROI: typically **1-2 ms**

- Use community-shared calibrations for your camera
- Not suitable: USB 2.0 cameras; sensors $\geq 4/3''$ using large ROI
- Use the smallest ROI that is workable for the observations

Camera delays – measured with a GPS flasher

Camera Timing Setup – Line Delay Calibration

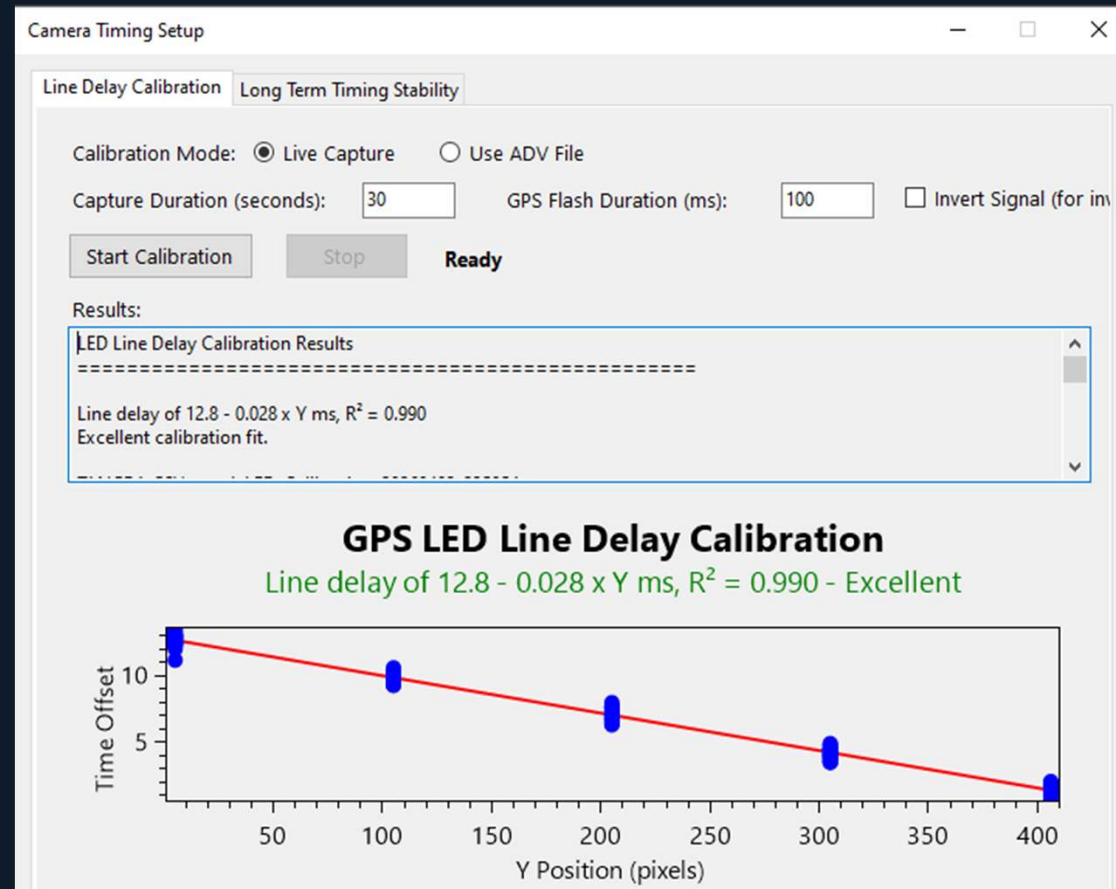
Built into Occultation Manager

Calibration saved for later use

Result: “Line delay: $12.8 - 0.028 \times Y$ ms”

A \$10 GPS USB receiver is all you need

HiLetgo VK172, Beitian BN-180, or similar



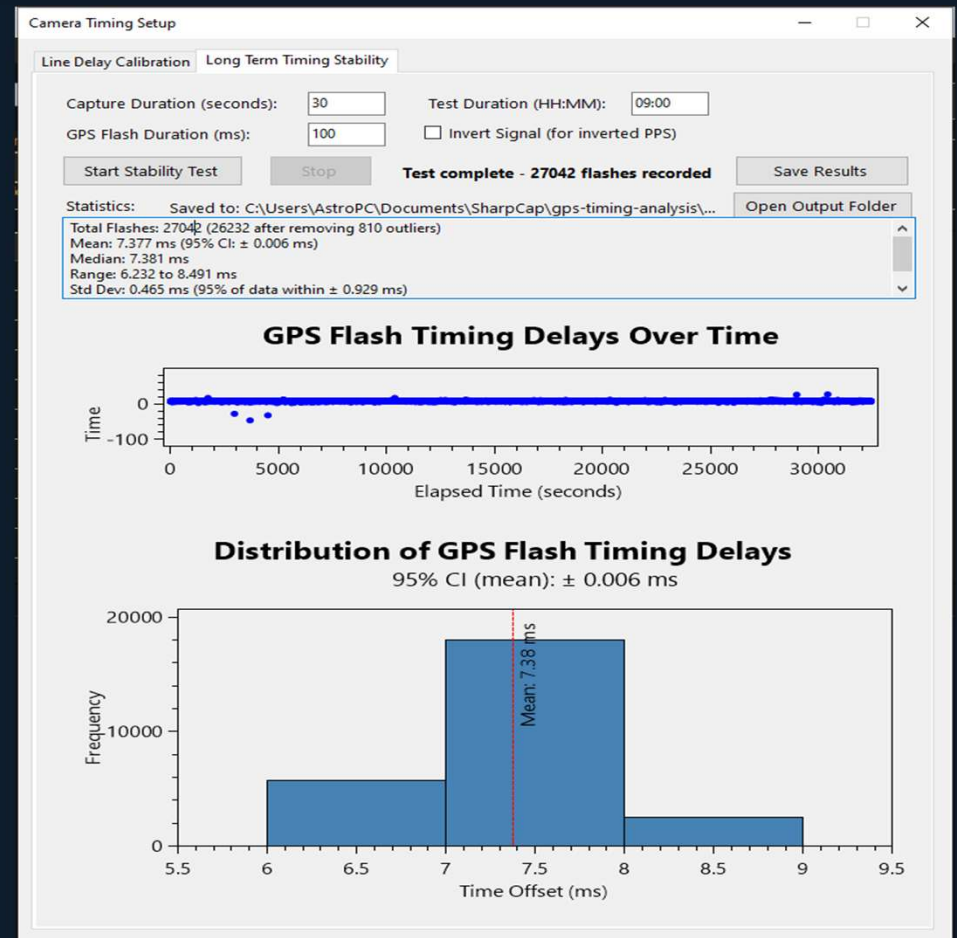
Camera delay is stable

27,042 GPS flashes — 9 continuous hours

Stat	Value
Mean	7.377 ms
Std Dev	0.465 ms
Range	6.2 – 8.5 ms

“How do you know the camera delay doesn’t drift?”

27,000 measurements over 9 hours say: it didn’t for this test.



Costs

What it costs

Component	What	Cost
Windows PC	Already own	\$0
USB3 camera	Already own or ToupTek G3M662M the cheapest	\$0 or ~\$US 179
SharpCap Pro	Capture software	~\$US 20/yr
Meinberg NTP	Clock discipline	Free
NTP Installer	All-in-one setup	Free
Occultation Manager	Events, sequences, reports	Free
Total new cost		~\$US 20

Optional upgrades:

Item	Via	Approx.	Benefit
GPS PPS receiver + flasher	DIY	~\$50–80 AUD	Sub-ms clock + measured delays
Dedicated flash timer	Aarts Timers, StampOfApproval	~\$80–200 AUD	PC clock not needed

The upgrade path

Start today. Upgrade when you're ready.

Level	Clock	Camera delays	Typical cost
0 — NTP only	~5 ms	Estimated from max FPS	~\$20
1 — GPS PPS + flasher	< 1 ms	Measured \pm 1 ms	+ \$50–200
2 — TimeBox / GPS NTP server	< 1 ms	Measured \pm 1 ms	+ \$150–350
3 — Dedicated camera	Built-in GPS	Built-in	\$700–1,200+

NTP is fine for the **majority of events**. Levels 1-3 are the *destination*, not the entry requirement.

*“Start with NTP Only and learn how to do occultations.
Upgrade later when you need to.”*

Start tonight

New observers

Download and run the installer.
Check NTP status in the morning

If the numbers look good — you
can do occultations

Costs nothing to find out

Established observers & clubs

Gear up additional rigs/stations
for multi-station deployments
and campaigns

Enlist casual observers

Help your friends and club
members start — every new
observer adds chords to every
campaign

Observatories

Equip your scopes to do
occultations at zero cost

No additional hardware, no
messing around with your setup

Get involved with TNO and other
important science observations

*NTP timing should be the recommended starting point for new observers
It is time for the occultation community to grow*

Links

NTP Installer

github.com/labstercam/occultation-ntp-installer

Tools & docs

SharpCap Occultation Manager and NTP/GPS tools

github.com/labstercam/occultation-tools

[NTP and GPS Timing Documentation](#)

Using the Windows Clock with Network Time Protocol (NTP) for Occultation Timing.

Pavlov and Gault. [JOA2020 2](#)

Part Two

NTP In Practice

Run through of the recording and analysis processes

Setting Up - NTP startup

Check NTP has started and stabilised

NTP Status During Startup

Check NTP status whilst setting up before observing

Ensure have internet connection

Ensure NTP servers have connected (Reach > 0)

Initial offset likely out by hundreds of ms and not stable yet

Jitter likely high

So wait a little while...

Current local NTP Status: Sync to: 103.70.27.21 Offset: 328.913ms Stratum: 2



Refresh Interval: 10 s

NTP Status:

	Remote	Refid	Stratum	Type	When	Poll	Reach	Delay	Offset	Jitter
-	161.65.172.9	GNSS	1	Unicast server	31	64	003	17.047	331.124	0.965
-	202.46.177.18	GPS	1	Unicast server	51	64	003	15.143	332.169	44.158
*	103.70.27.21	GPS	1	Unicast server	4	64	003	8.083	328.913	1.346
+	103.70.25.21	GPS	1	Unicast server	33	64	003	15.318	328.469	2.500
+	202.46.185.18	GPS	1	Unicast server	32	64	003	22.323	330.053	1.317

NTP Status During Settling

NTP will do a STEP correction if the offset is > 128 ms out
Brings offset back to near zero very quickly
All NTP servers will reset during STEP

Current local NTP Status: Sync to: 202.46.177.18 Offset: 2.141ms Stratum: 2



Refresh Interval: 10 s

NTP Status:

Remote	Refid	Stratum	Type	When	Poll	Reach	Delay	Offset	Jitter
161.65.172.9	GNSS	1	Unicast server	37	64	001	20.369	3.200	3.236
* 202.46.177.18	GPS	1	Unicast server	16	64	001	10.498	2.141	0.395
103.70.27.21	STEP	16	Unicast server	6347d	64	000	0.000	0.000	0.000
103.70.25.21	GPS	1	Unicast server	19	64	001	37.422	8.994	0.000
202.46.185.18	GPS	1	Unicast server	19	64	001	41.930	10.677	0.000

NTP Settled in 10 minutes from Startup

Checks:

Offset is low and stable

Delays normal for your server connections

Jitter low – a few ms

Ideally wait until all servers have Reach = 377 which should be ~ 10 minutes after start or STEP

The BETTER your NTP performance the FASTER it will startup and stabilise

Current local NTP Status: Sync to: 202.46.177.18 Offset: 1.723ms Stratum: 2



Refresh Interval: 10 s

NTP Status:

Remote	Refid	Stratum	Type	When	Poll	Reach	Delay	Offset	Jitter
+ 161.65.172.9	GNSS	1	Unicast server	59	64	007	13.856	-0.717	1.941
* 202.46.177.18	GPS	1	Unicast server	65	64	007	6.300	1.723	1.318
+ 103.70.27.21	GPS	1	Unicast server	4	64	007	7.117	-1.537	1.031
103.70.25.21	GPS	1	Unicast server	34	64	007	15.235	-1.928	4.326
202.46.185.18	GPS	1	Unicast server	31	64	007	21.433	-1.222	4.592

Event Recording

*Record using SharpCap – ADV or SER format
Occultation Manager add-in can streamline or automate*

Analysis

Analyse with TANGRA

Use Occultation Manager to calculate offset and camera delays

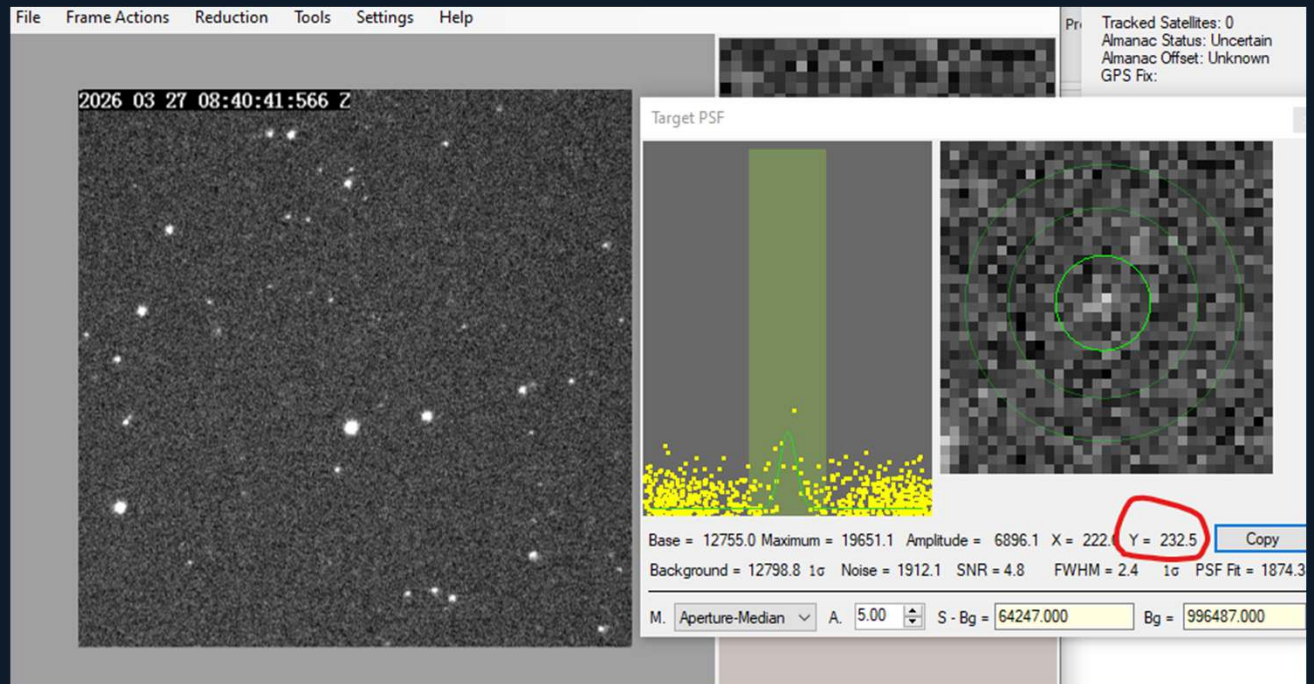
TANGRA: Find Y line of occulted star

Open recording in TANGRA and manually scan to the time of the event

Open menu Tools: PSF Viewer

Click on the occulted star

Y line is 232.5



Calculate camera delay: Occultation Manager

Occultation Manager – Tools menu, Camera Delay Calculator

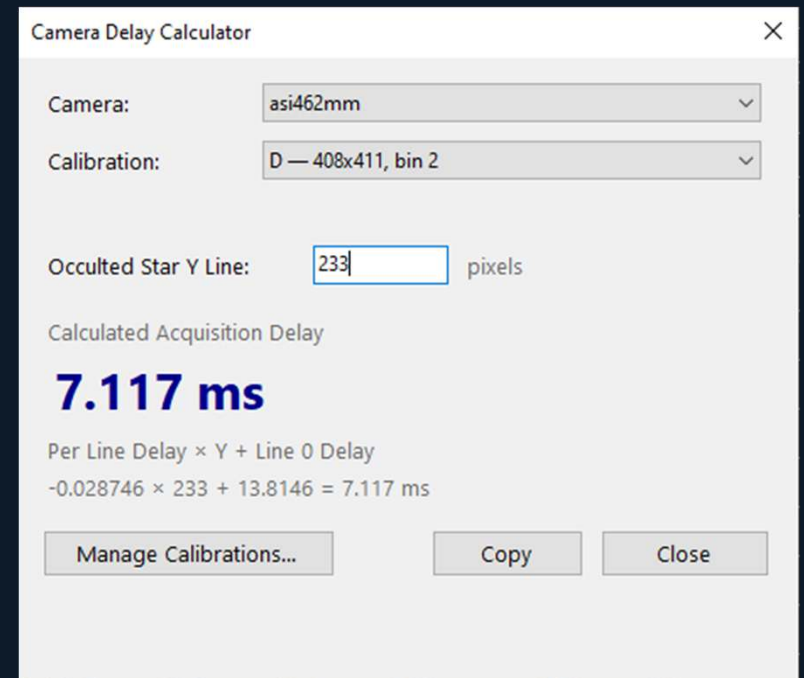
Select the Camera and Calibration for the settings used

Enter the Y line from TANGRA

Delay of 7.1 ms

Alternative:

Excel spreadsheet from my GPS flash timing methods



Camera Delay Calculator

Camera: asi462mm

Calibration: D — 408x411, bin 2

Occulted Star Y Line: 233 pixels

Calculated Acquisition Delay

7.117 ms

Per Line Delay × Y + Line 0 Delay
 $-0.028746 \times 233 + 13.8146 = 7.117 \text{ ms}$

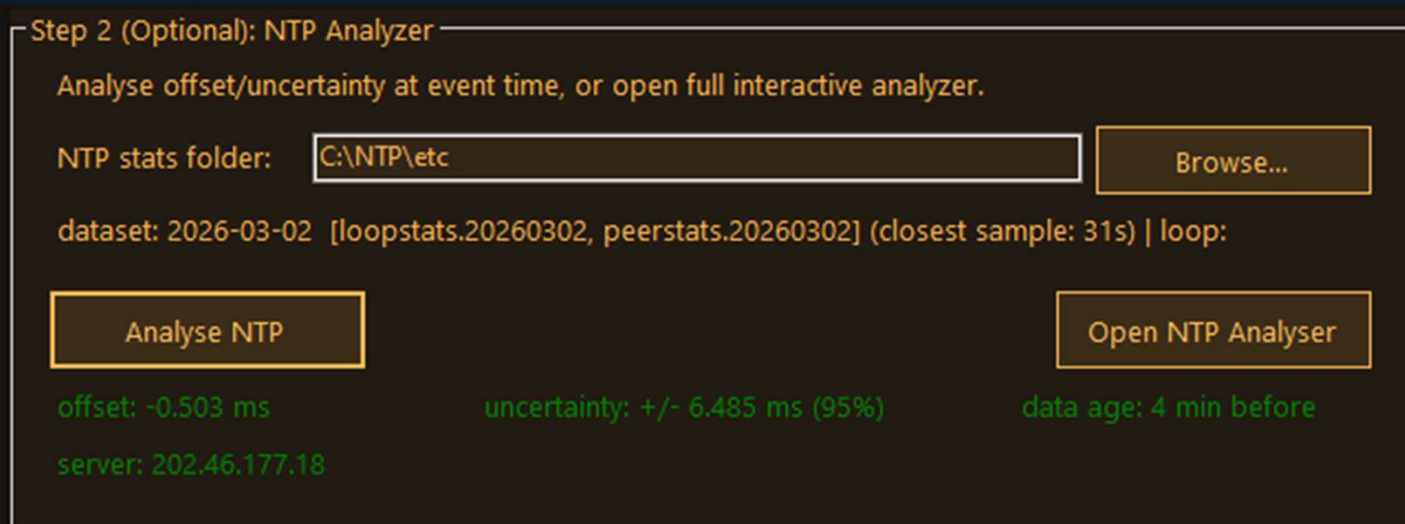
Manage Calibrations... Copy Close

Calculate NTP offset: Occultation Manager

Occultation Manager – Generate Report for your event:

Step 2 – press Analyse NTP to read NTP logs at the expected time and calculate offset.
Accounts for any drift in the offset, and compensates for the distance to the NTP servers
Or Open NTP Analyser to do custom analysis for the exact event time

Offset of -0.5 ms, uncertainty +/- 6.5 ms (conservative)



Step 2 (Optional): NTP Analyzer

Analyse offset/uncertainty at event time, or open full interactive analyzer.

NTP stats folder:

dataset: 2026-03-02 [loopstats.20260302, peerstats.20260302] (closest sample: 31s) | loop:

offset: -0.503 ms uncertainty: +/- 6.485 ms (95%) data age: 4 min before

server: 202.46.177.18

TANGRA Analysis - Apply Offset and Delay

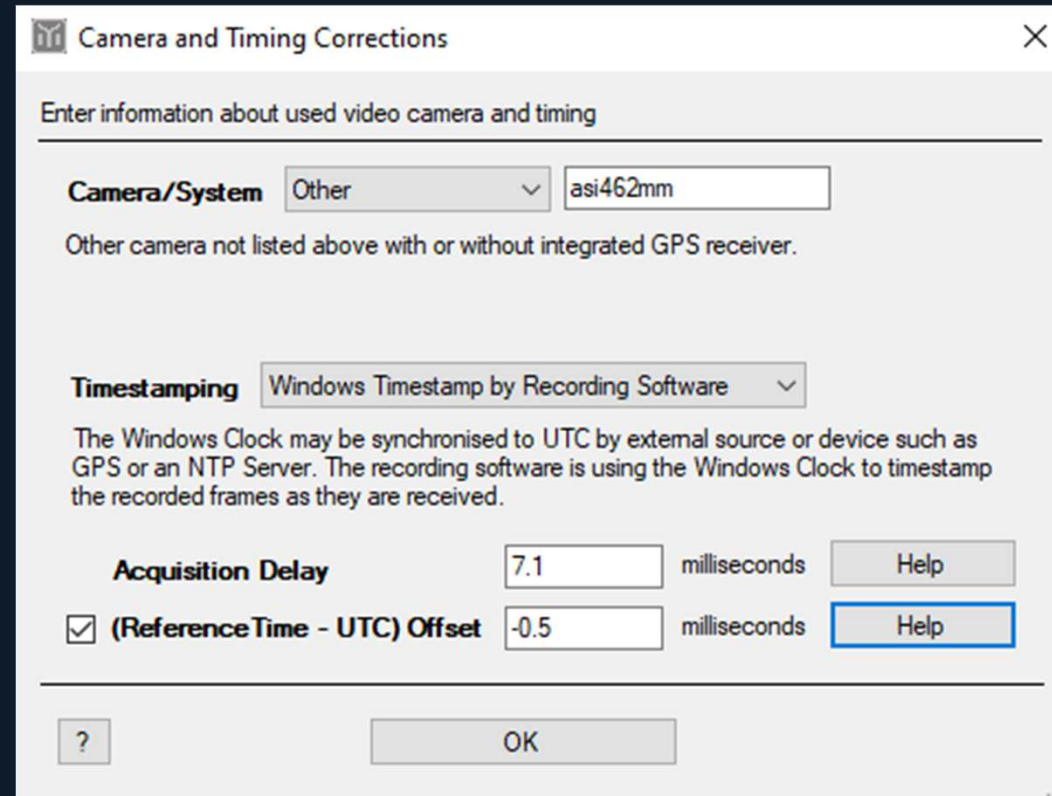
Do the TANGRA analysis as normal.

- Enter the Camera Acquisition Delay as 7.1 ms
- Enter the Offset as - 0.5 ms

Be careful with + and – signs!

The light curve will have the corrected times.

What to do about the NTP offset uncertainty?
Still TBD...



The screenshot shows a dialog box titled "Camera and Timing Corrections" with a close button (X) in the top right corner. The dialog contains the following fields and options:

- Camera/System:** A dropdown menu set to "Other" and a text input field containing "asi462mm". Below this is the text: "Other camera not listed above with or without integrated GPS receiver."
- Timestamping:** A dropdown menu set to "Windows Timestamp by Recording Software". Below this is the text: "The Windows Clock may be synchronised to UTC by external source or device such as GPS or an NTP Server. The recording software is using the Windows Clock to timestamp the recorded frames as they are received."
- Acquisition Delay:** A text input field containing "7.1" followed by the label "milliseconds" and a "Help" button.
- (Reference Time - UTC) Offset:** A checked checkbox, a text input field containing "-0.5" followed by the label "milliseconds" and a "Help" button.

At the bottom of the dialog, there is a question mark icon on the left and an "OK" button on the right.

Reporting

*Use Occultation Manager to Generate Report
Or your normal process*

Reporting

Occultation Manager

- `Manage Cameras` handles the NTP timing method
- Camera delays automatically taken from TANGRA .csv

TBD- where to put the NTP offset and uncertainty

22	Timing:	other	Method:	Video Recording	Asteroid visible?	No
23	Timing Device:	Computer NTP	OTA Used:	AOTA (part of OCCULT4)		
24	Some of the cells in row 25 are free form. Look at Comments provided.					
25	Detector:	Model/Type: Other - List in Comments	Format: ADVS	Exposure Integration: 0.32	Unit: Seconds	Other Detector related info
26			Camera Delay Correction: 0.007	VTI Correction: [redacted]	Sec	Has this been Applied? yes
27	Conditions:	Clouds: Clear	Stability: Steady	Other conditions:	near moon	
28						
29	Observations:	Apply Integrating camera delay corrections before entering times. Go to CORRECTIONS page for R-OTE, <u>Occular</u> , and VTI correction values.				
30		Times	Accuracy	PE	PE/Delay applied?	Remarks (show integration corrections here)
31	Started Observing:	08 : 39 : 44.438				
32	Star and asteroid merged:					
33	Disappearance:	08 : 40 : 11.8	0.16			
34	Est. Closest Approach:					
35	Reappearance:	08 : 40 : 13.08	0.16			
36	Star & Asteroid separated:					
37	Stopped Observing:	08 : 40 : 41.719				
38		hh mm ss.SSS				no Was this a Miss?

**Network Time Protocol (NTP) can
give PC times accurate to a few ms**

It is good enough for most events

Links

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