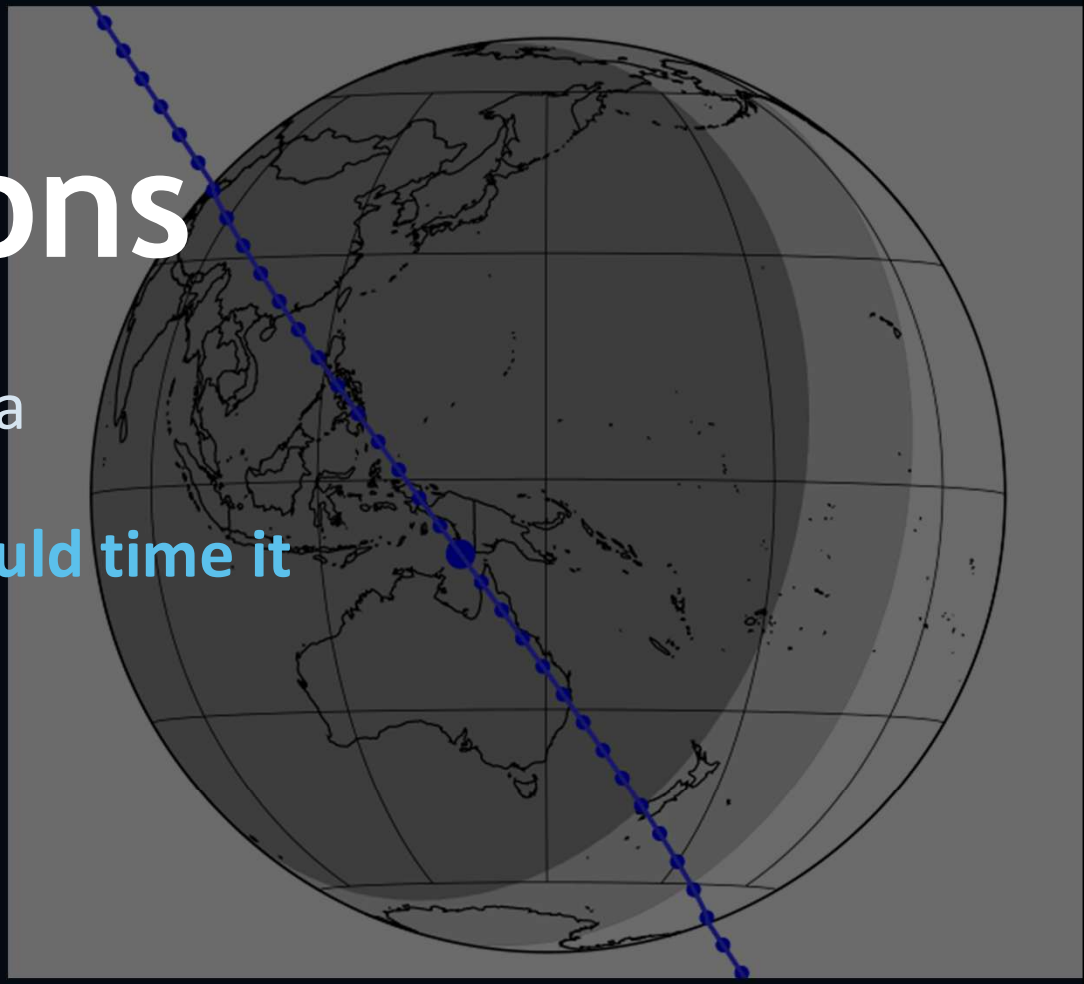
# No observations

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:

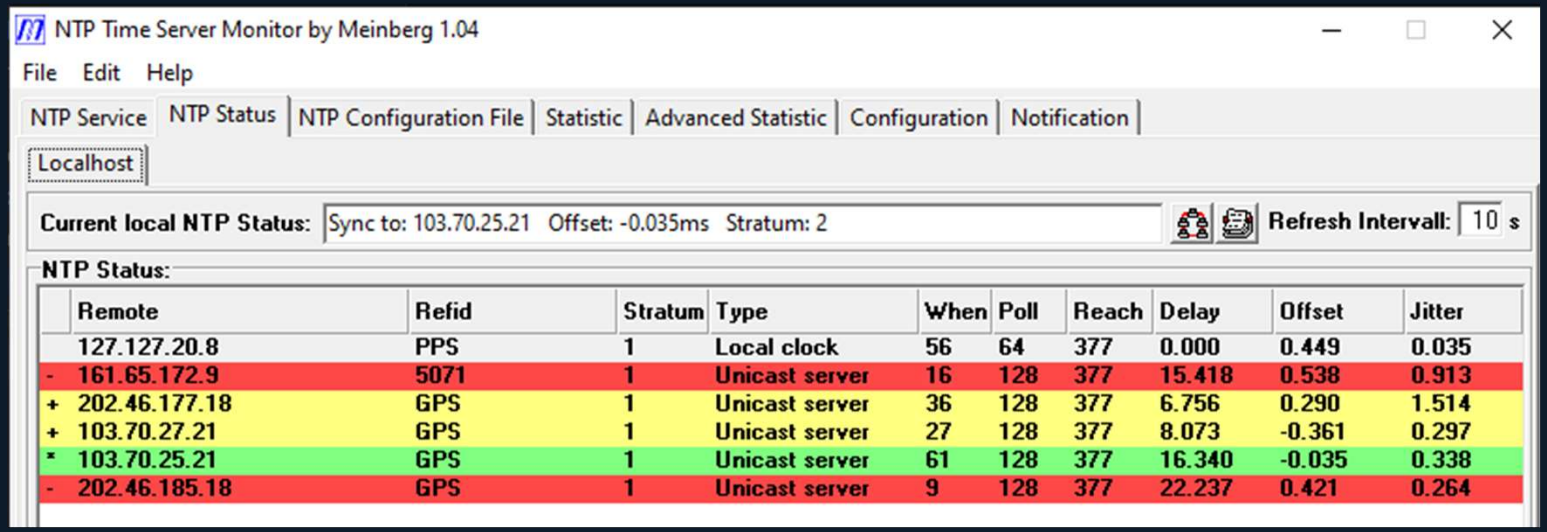
1. “You need a GPS timing device…”
2. “Or an analog camera and VTI…”
3. “Or a dedicated camera…”
4. Hardware cost: **$500 – $1,200+ US**

→ **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




**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:
Total error = sqrt(50^2 + 11^2) = **51 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**

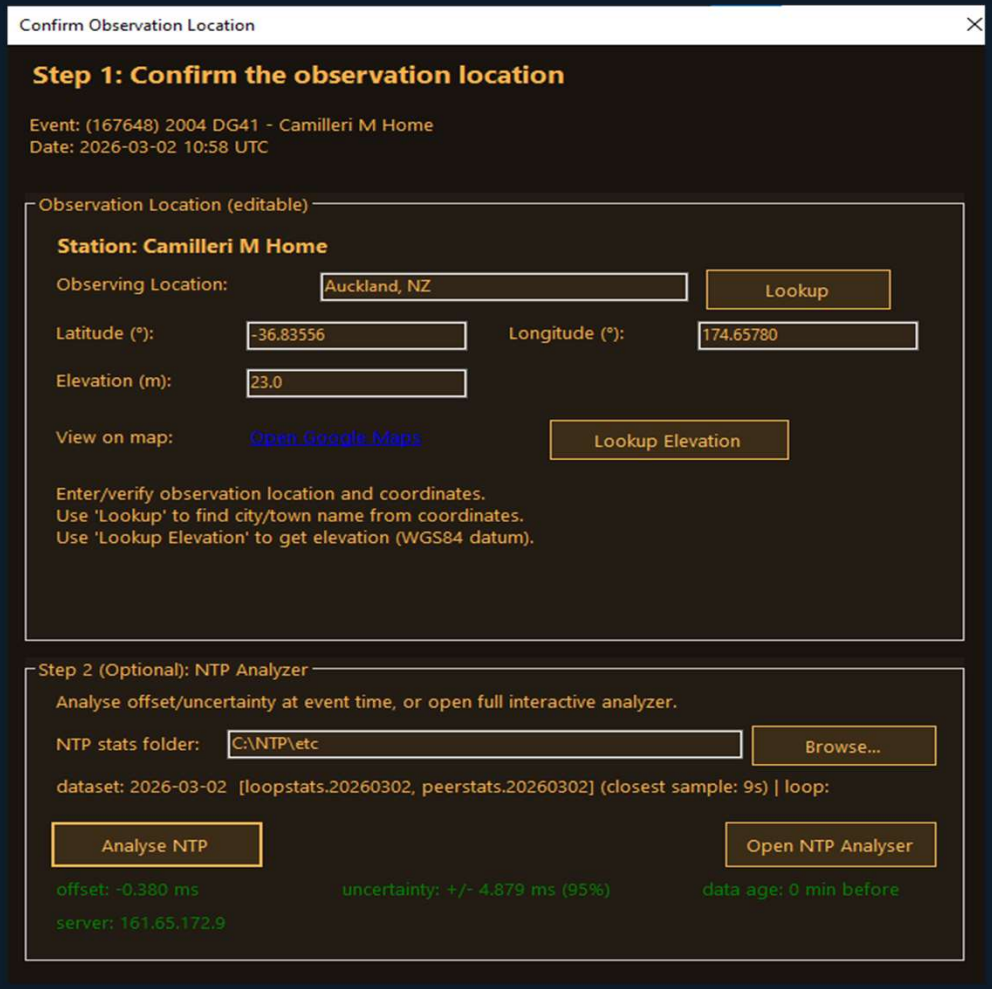
Offset: **−0.38 ms**

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

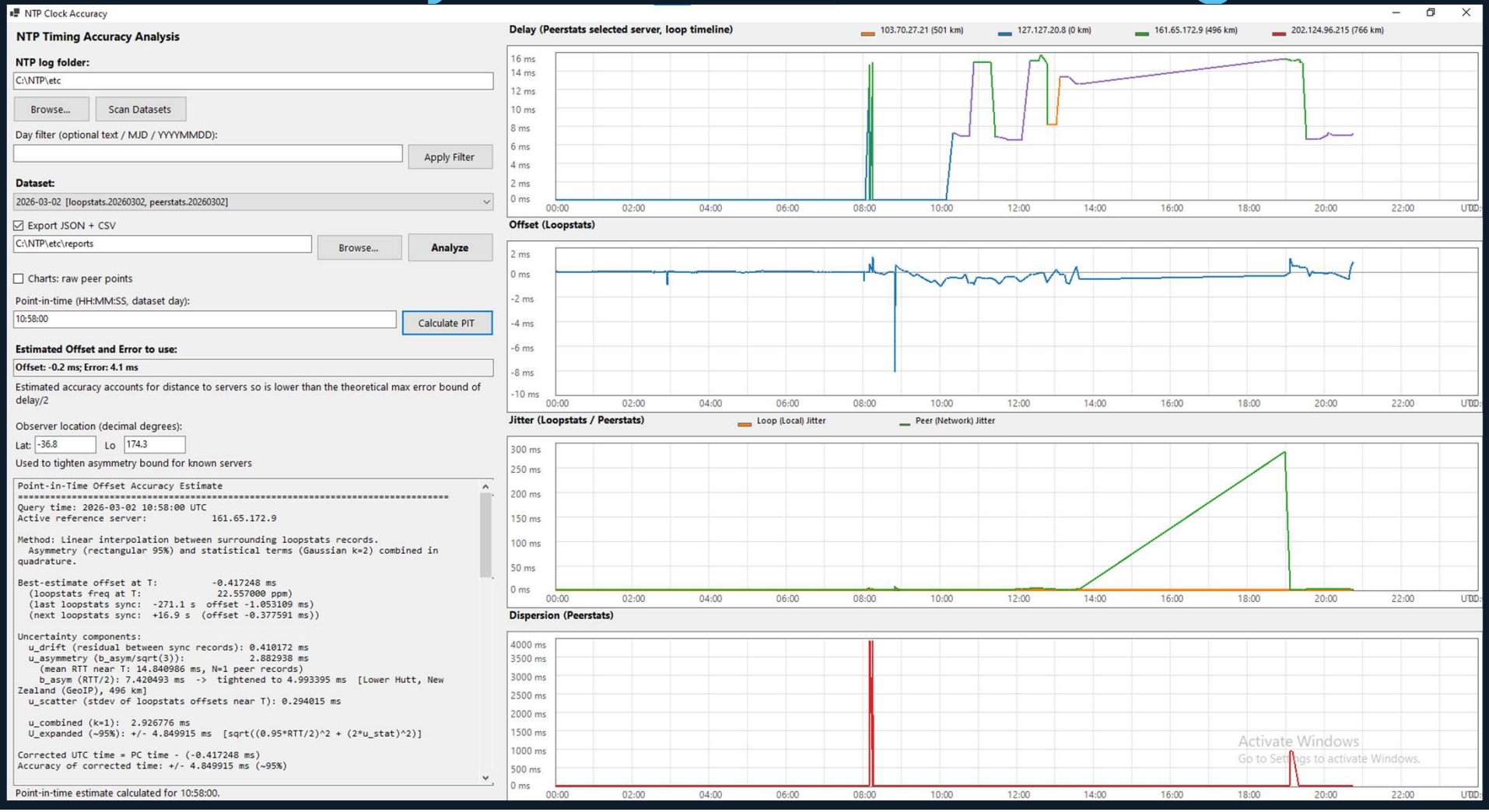
Offset used to adjust timestamps in TANGRA

Uncertainty can go into the observation repo*rt*

*How do you KNOW if your timing is correct?*
*How do you KNOW how accurate it is?*
*NTP can tell you...*



# 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**

# 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

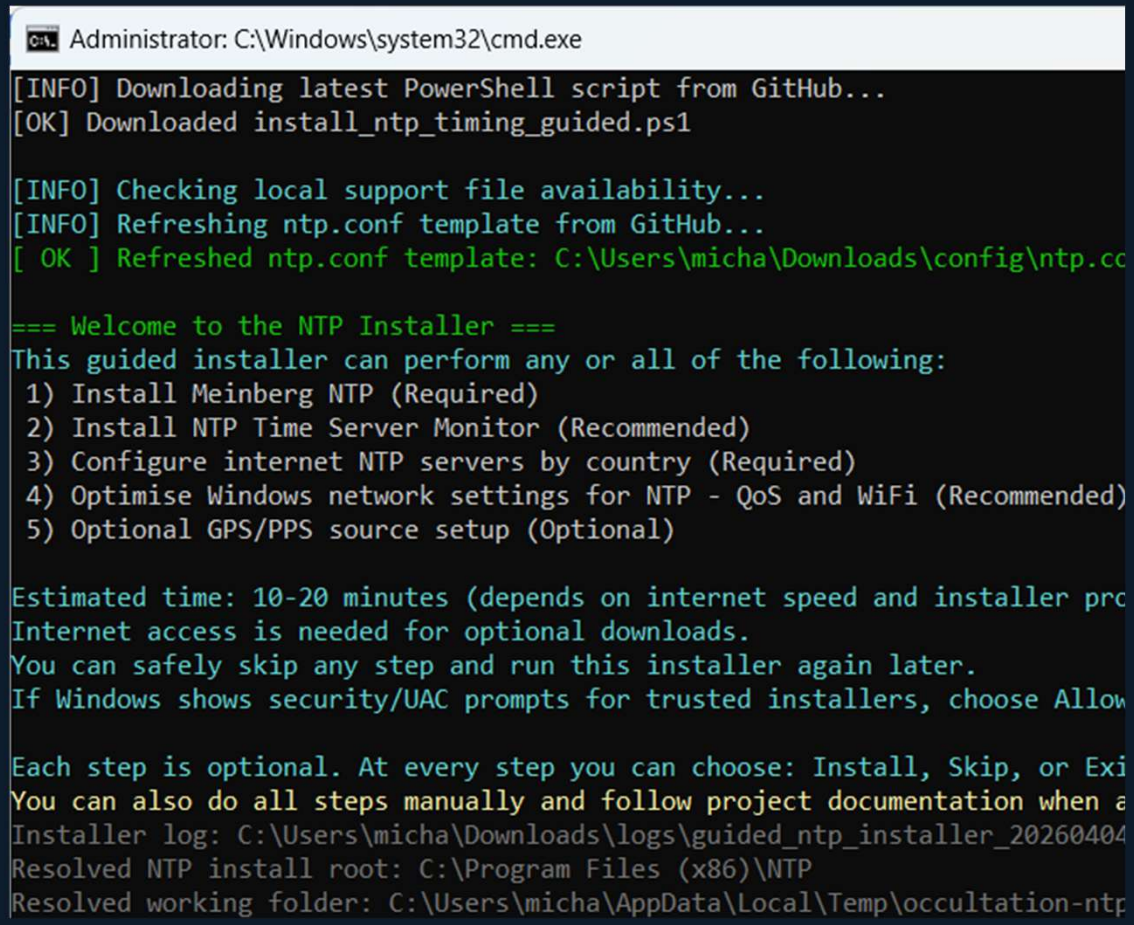
**One run configures everything:**

- 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



# 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' <~5 ms should be OK
- Ethernet best
- Wifi may need tweaks (NTP installer does them)

**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 Servers:**

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

***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, 408×411 ROI, binning ×2 — Per-line: −0.0287 ms | Line delay (Line 0): 13.8 ms*

**per_line_delay = (1 / max_fps) / ROI_height × 1000 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 ≥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**

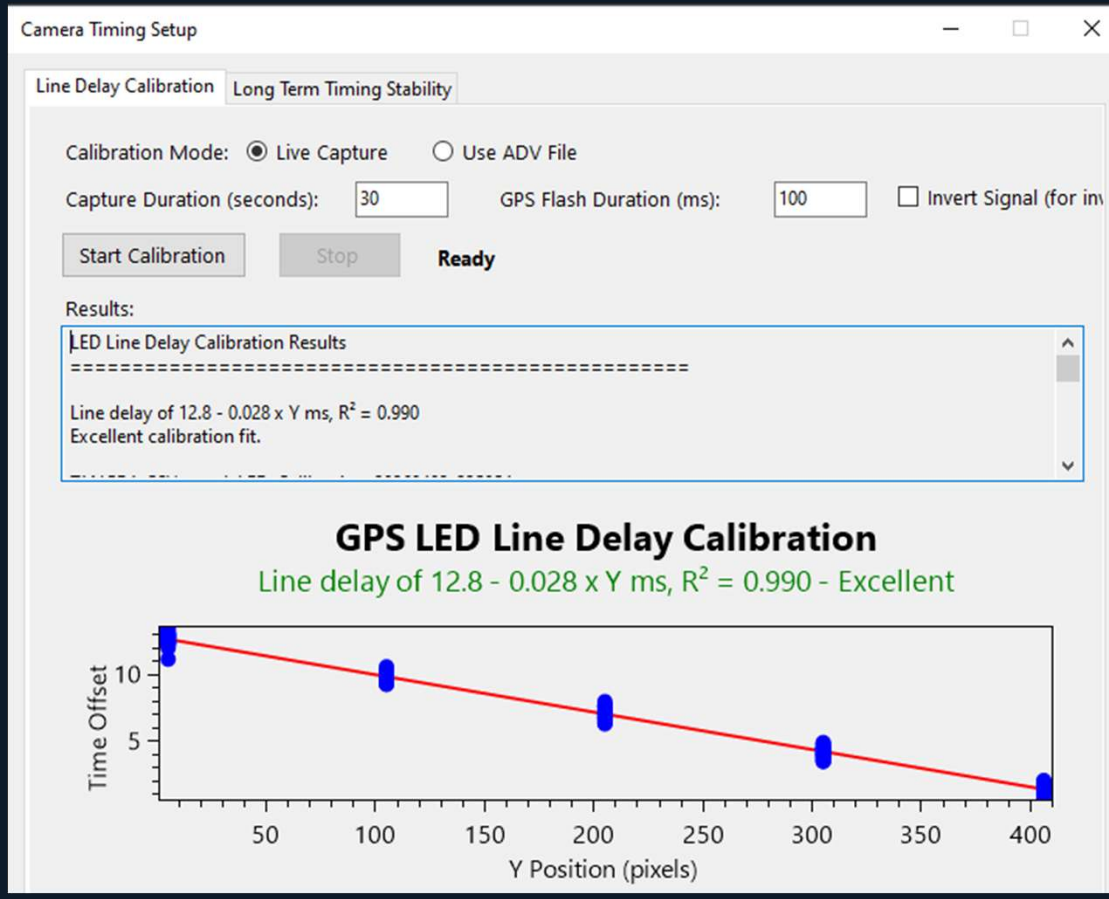
**Built into Occultation Manager**

**Calibration saved for later use**

Result: “Line delay: 12.8 − 0.028 × Y ms”

A $10 GPS USB receiver is all you need

*HiLetgo VK172, Beitian BN-180, or similar*



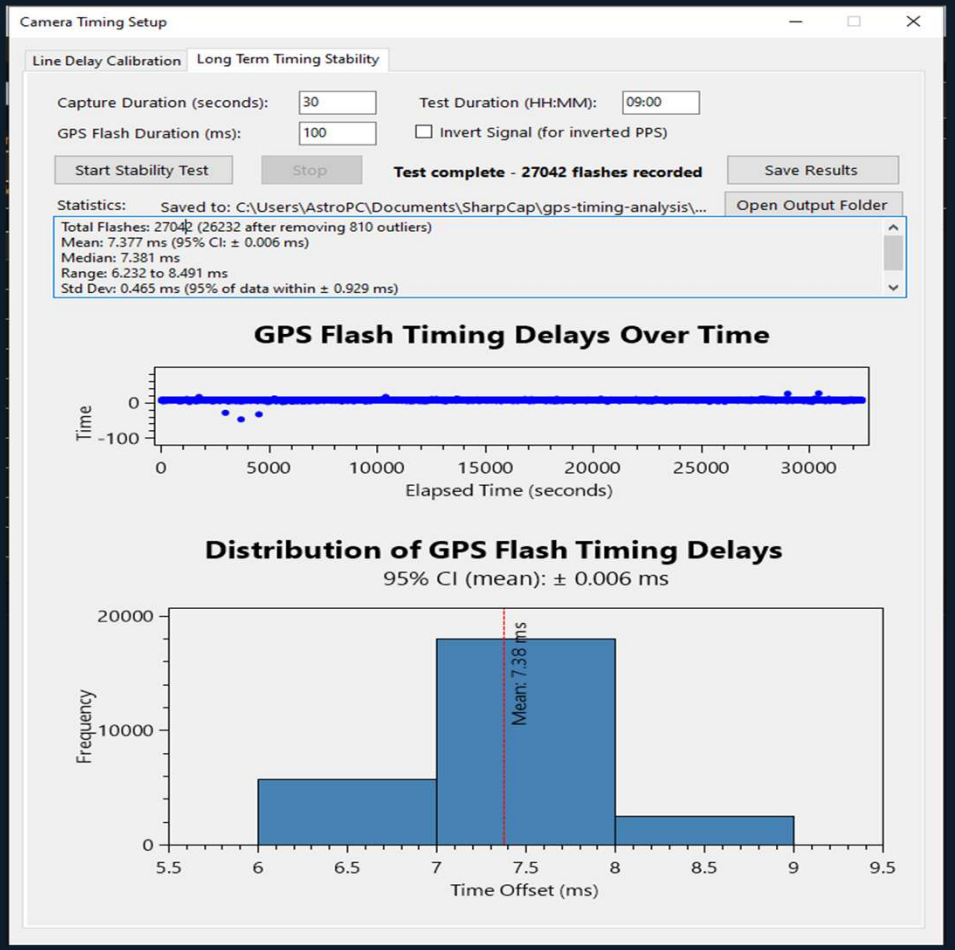
# Camera delay is stable

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 ± 1 ms | + $50–200 |
| 2 — TimeBox / GPS NTP server | < 1 ms | Measured ± 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 Occulation Manager and NTP/GPS tools

github.com/labstercam/occultation-tools

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Pavlov and Gault. JOA2020_2

# Part Two
# NTP In Practice

*Run through of the recording and analysis processes*

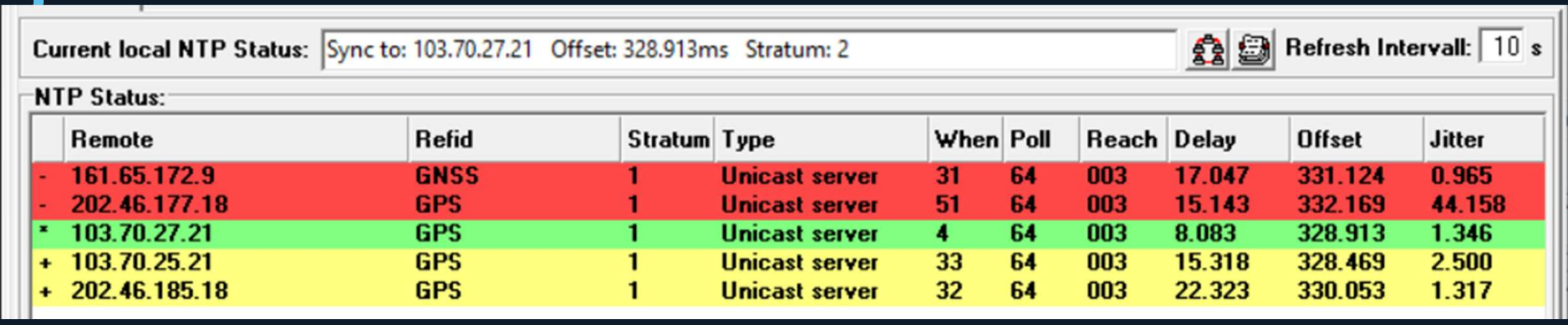
# Setting Up - NTP startup

*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

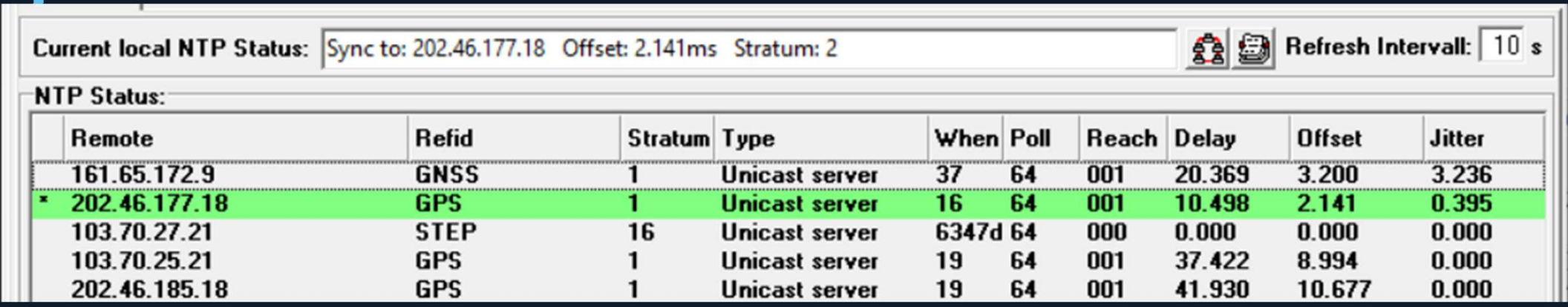
So wait a little while...




| | 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




| | 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 |

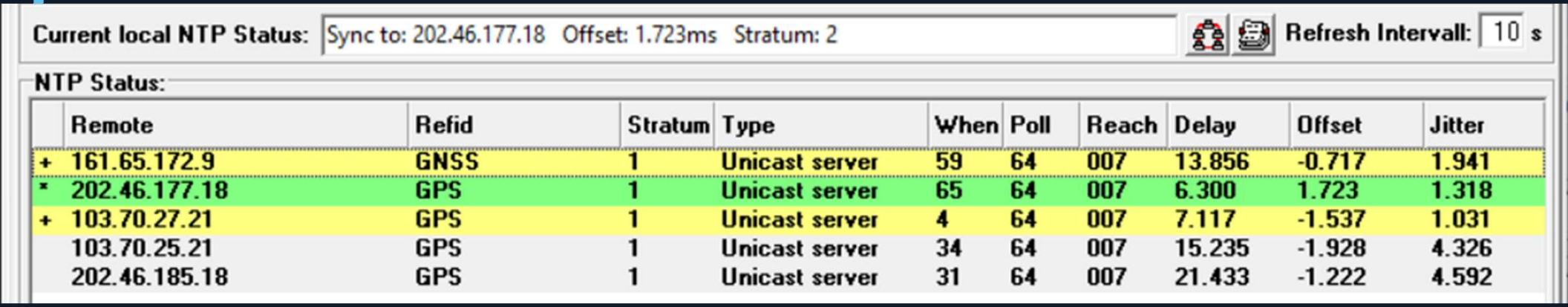
# NTP Settled in 10 minutes from Startup

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*




| | 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*

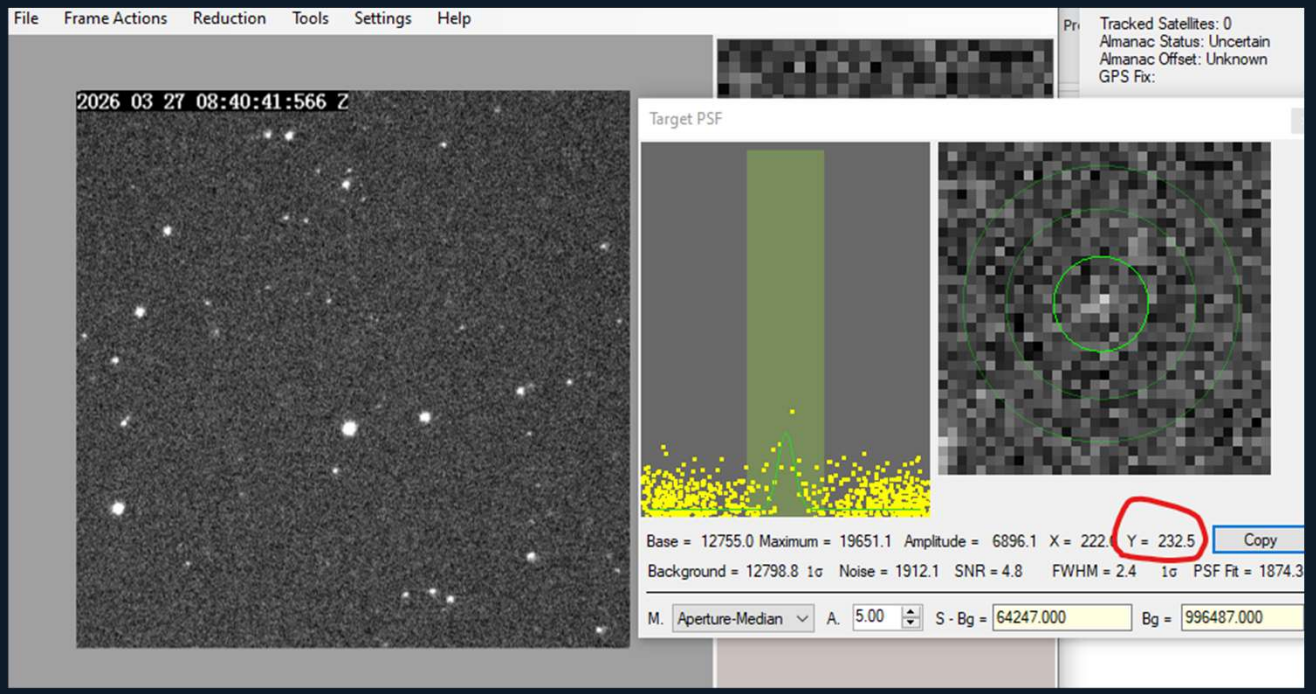
# TANGRA: Find Y line of occulted star

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

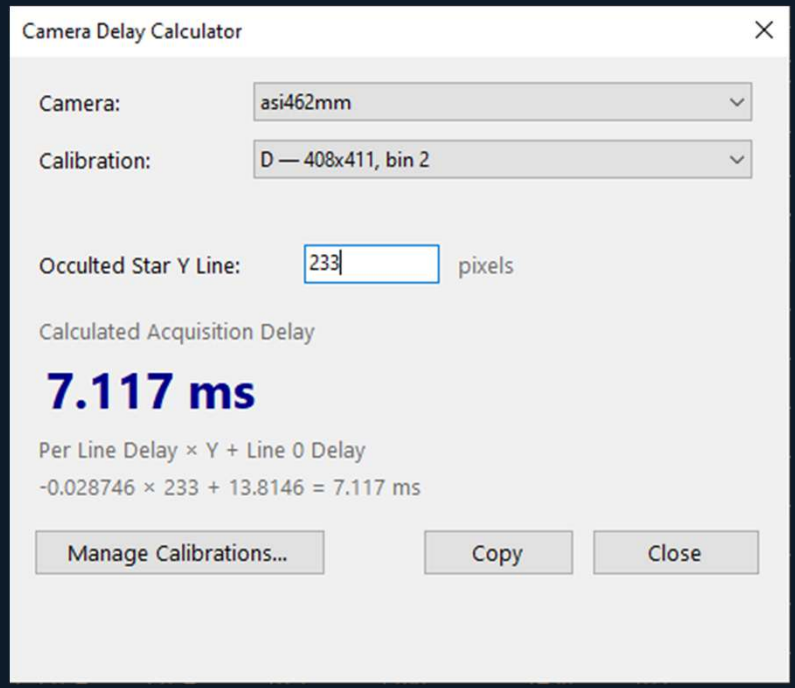
Occultation Manager – Tools menu, Camera Delay Calculator

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

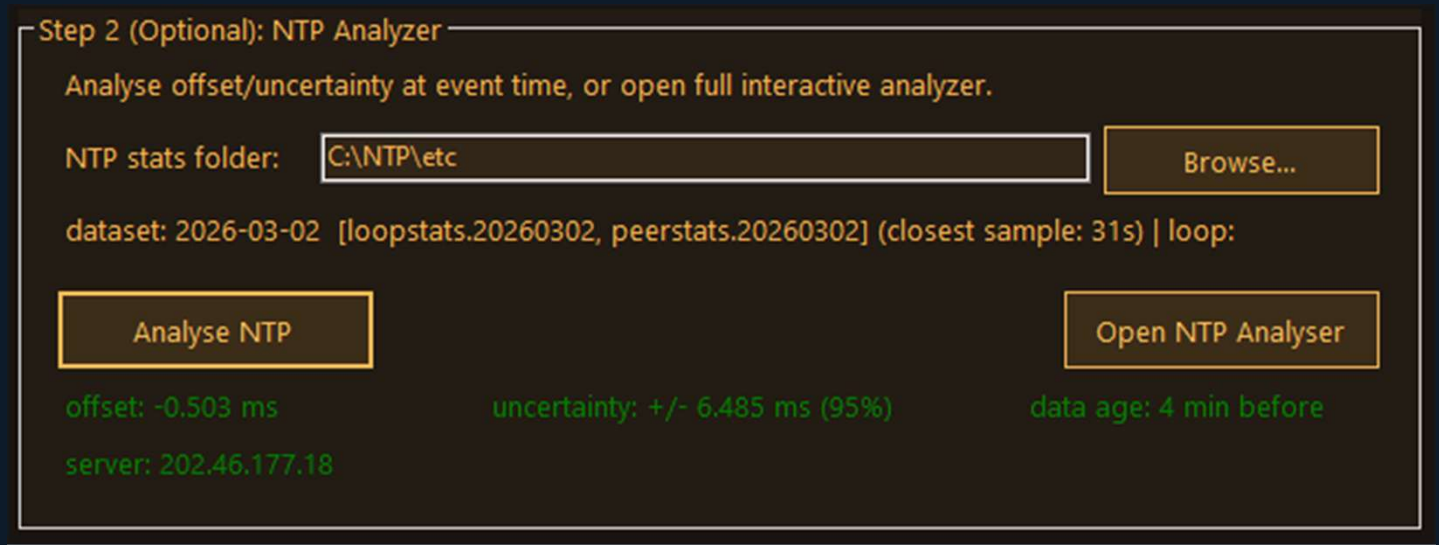


# Calculate NTP offset: Occultation Manager

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)



# TANGRA Analysis – Apply Offset and Delay

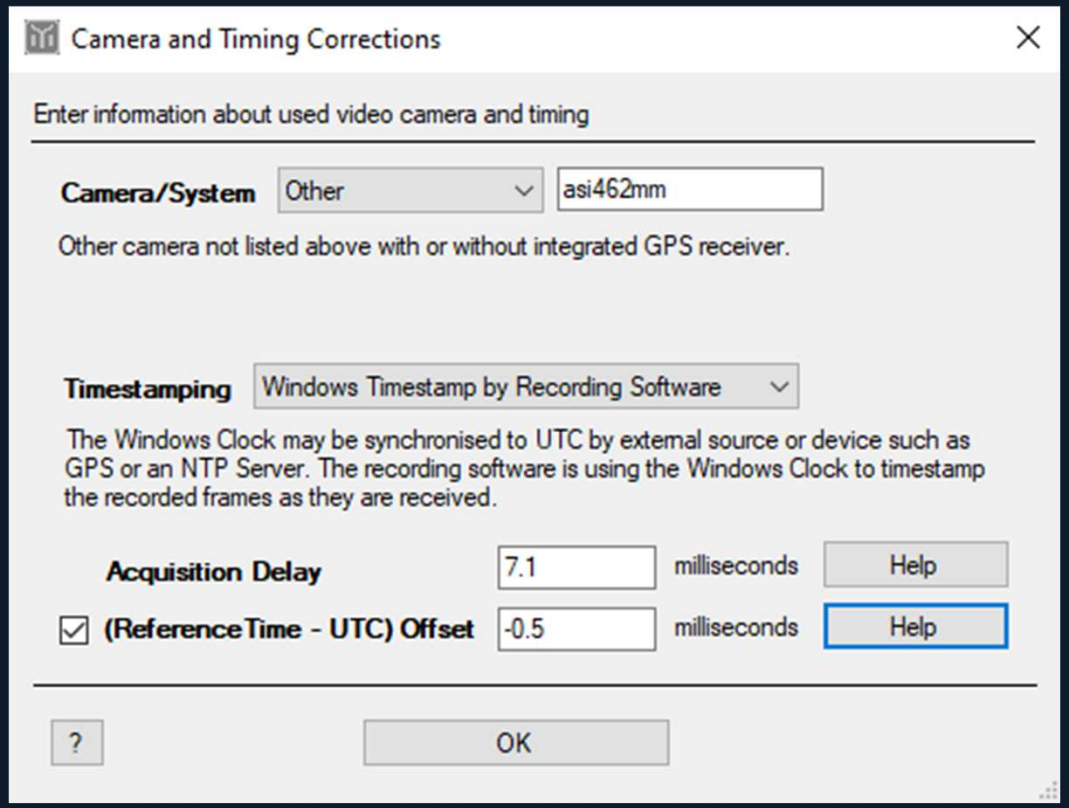
Do the TANGRA analysis as normal.

- 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...



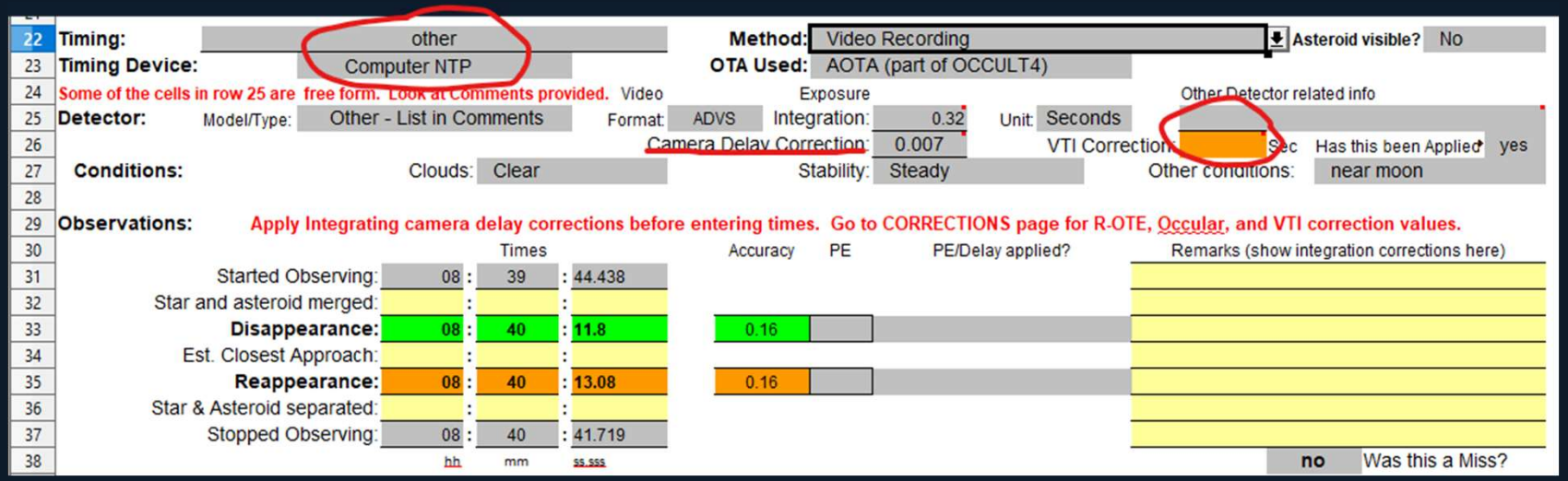
# Reporting

*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



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It is good enough for most events

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