

**Development
of a new Camera
with Digital Video Time Insertion
(Update)**

Andreas Schweizer

28.08.2021

Development of a new Camera with Digital Video Time Insertion

- **Project overview**
 - Team
 - Goals
 - Milestones
- **Hardware**
 - Design
 - Sensors
- **Software**
 - Artefacts
 - Control Tool
- **Examples**
- **Next steps**

Project Overview – Team Goals Milestones



Andreas Schweizer

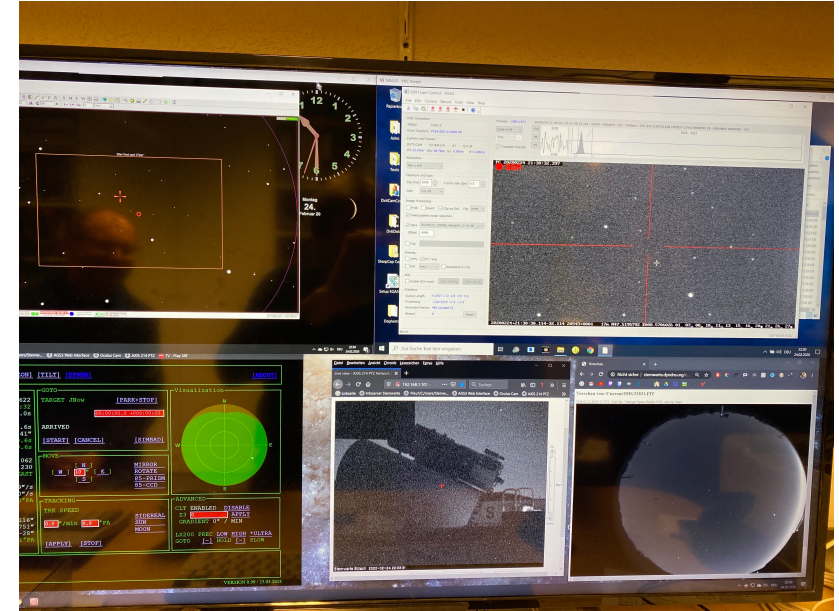
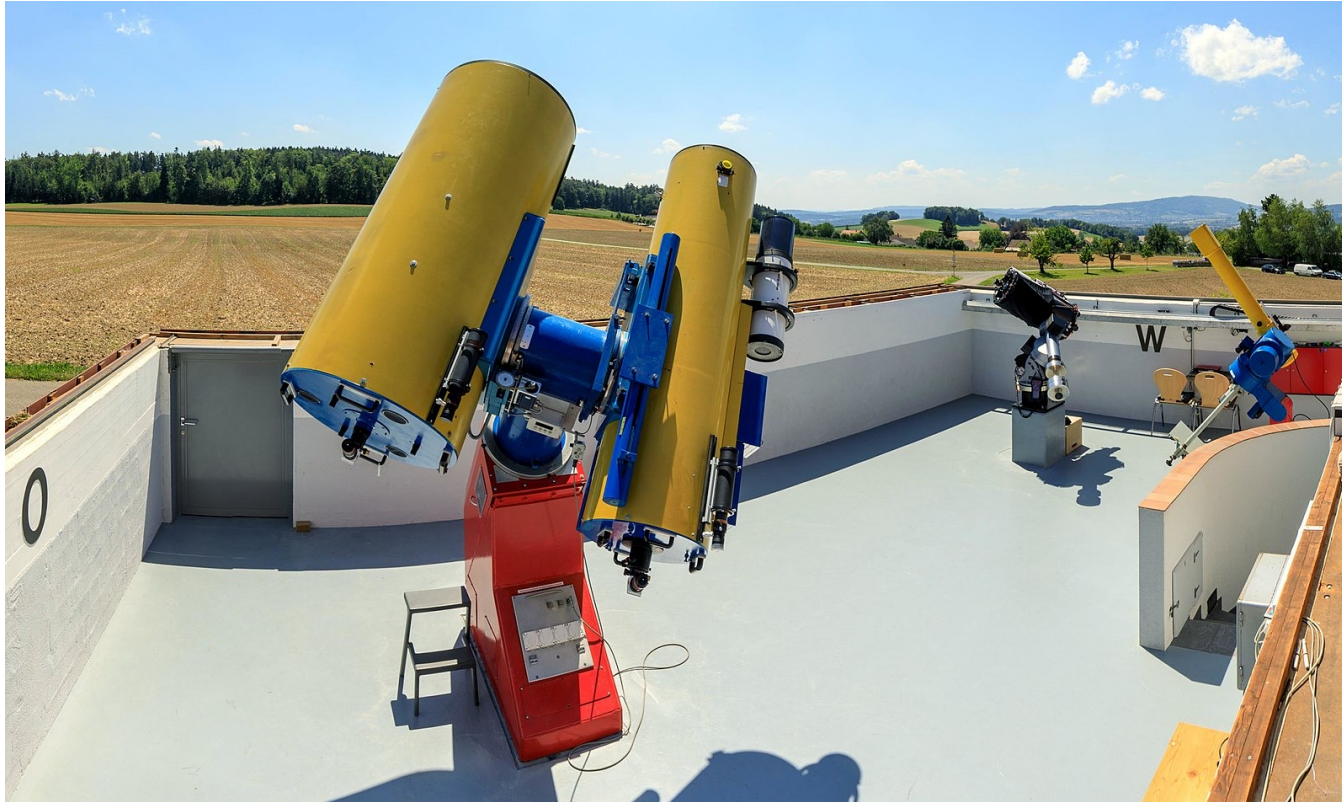
- Embedded Systems and Software Engineer
- AGZU member (association that operates the Sternwarte Bülach)
- Other hobbies: Amateur radio, squash



Stefan Meister

- Working for Mettler-Toledo in Finance & Control
- In the board of the Swiss Astronomical Society (SAG/SAS) and active in various working groups (sun, meteors, exoplanets)
- Other hobbies: Cycling, Kayaking

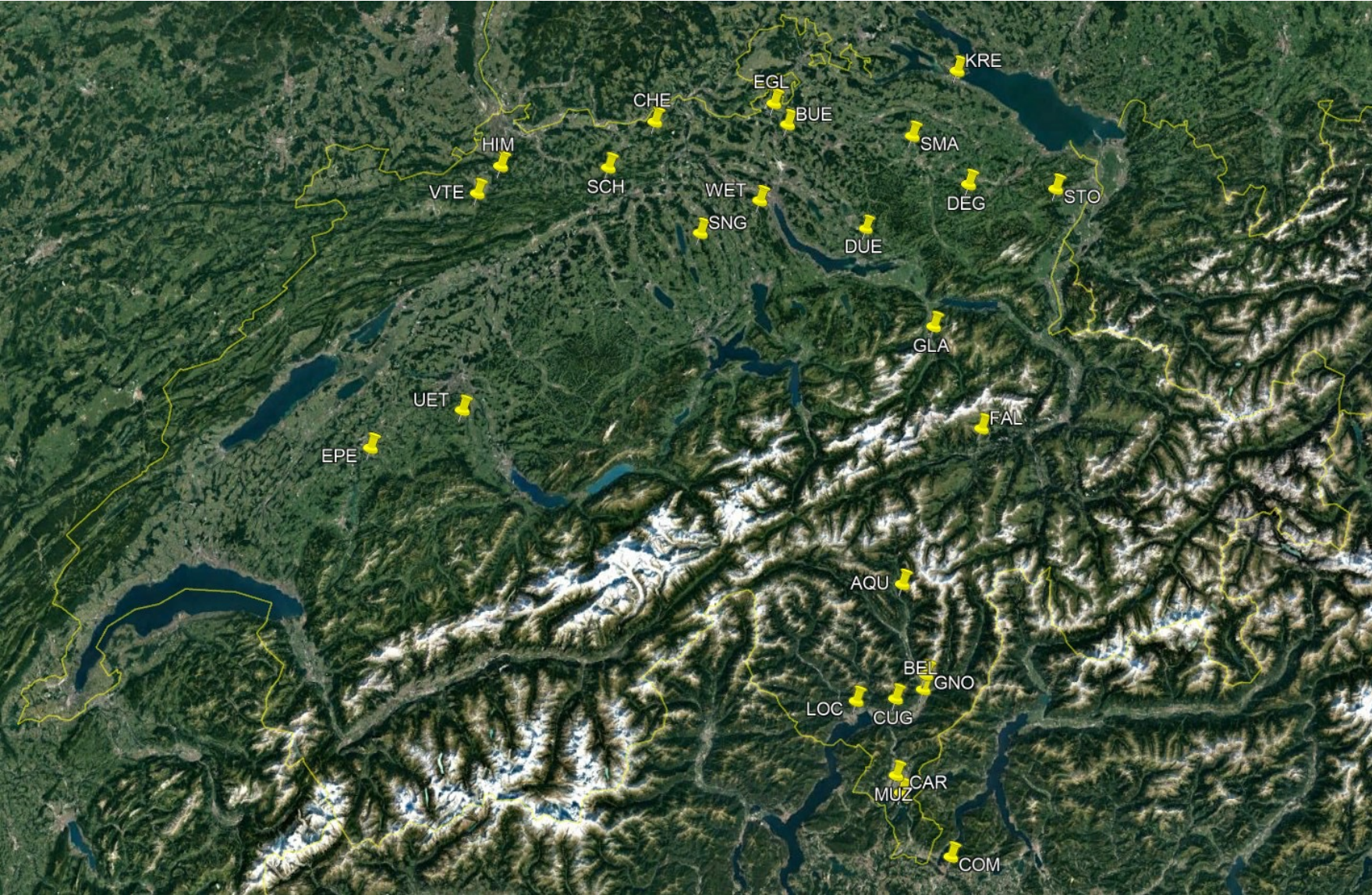
Project Overview – Team Goals Milestones



Home Base: Bülach Observatory (MPC 167)

- 50cm Newton/Cassegrain
- 85cm Cassegrain
- Pro RC 360, TEC Refractor, Zeiss/Coudé Refractor

Project Overview – Team Goals Milestones



Project Overview – Team Goals Milestones

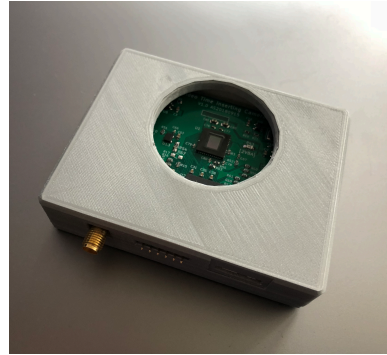
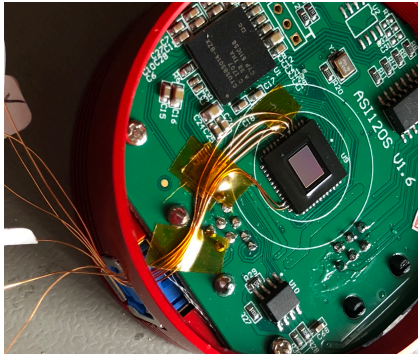
Design a digital video camera with the following aspects:

- **Precise timestamp from integrated GPS module**
- **Sensitive monochrome image sensor**
- **Easy to use**
- **Low price**

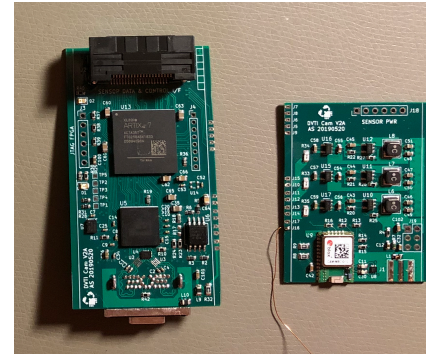
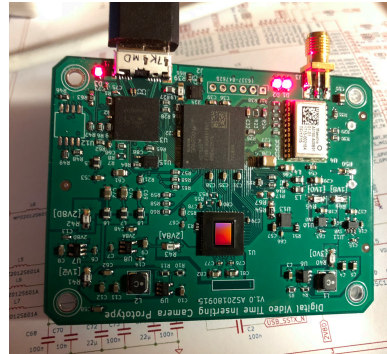
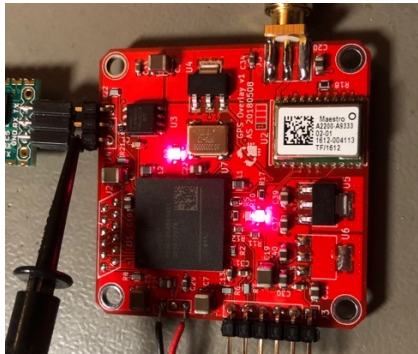
- **Improve hardware and software with feedback from the community**

Project Overview – Team Goals Milestones

http://www.dangl.at/ausruest/dvti/dvti_v2b.htm



Software Version		DvtiCamControl settings				Real Exposure (EXTA)
Camera Firmware	DVTI CamControl	Bit Depth	Resolution	Binning	Exposure set [s]	
0.4.35	4.8.6	16	960x600	2x2	0.001	0.001
0.4.35	4.8.6	16	960x600	2x2	0.002	0.002
0.4.35	4.8.6	16	960x600	2x2	0.005	0.005
0.4.35	4.8.6	16	960x600	2x2	0.010	0.010
0.4.35	4.8.6	16	960x600	2x2	0.020	0.020
0.4.35	4.8.6	16	960x600	2x2	0.030	0.030
0.4.35	4.8.6	16	960x600	2x2	0.033	0.033
0.4.35	4.8.6	16	960x600	2x2	0.040	0.040
0.4.35	4.8.6	16	960x600	2x2	0.050	0.050
0.4.35	4.8.6	16	960x600	2x2	0.080	0.080
0.4.35	4.8.6	16	960x600	2x2	0.100	0.100
0.4.35	4.8.6	16	960x600	2x2	0.160	0.160
0.4.35	4.8.6	16	960x600	2x2	0.200	0.200
0.4.35	4.8.6	16	960x600	2x2	0.250	0.250
0.4.35	4.8.6	16	960x600	2x2	0.320	0.320
0.4.35	4.8.6	16	960x600	2x2	0.500	0.500
0.4.35	4.8.6	16	960x600	2x2	0.640	0.640
0.4.35	4.8.6	16	960x600	2x2	1.000	1.000



Projekte / DVTI-Cam / Board

Backlog

Nur meine Vorgänge Zuletzt aktualisiert Einblicke

STATUS	TITEL	ASSIGN
PROBLEM	Problem wenn Kamera eingesteckt bleibt	CAM-60
PROBLEM	Wechsel von Highspeed Modus zu Normal Modus stretcht Bild vertikal	CAM-151
PROBLEM	USB2 geht wieder nicht mehr	CAM-143
TO DO	Synchronisation PC-time mit GPS-time	CAM-83
TO DO	Telescope Control	CAM-105
TO DO	ADV mit verlustfreier Kompression	CAM-81
TO DO	ADV Files abspielen können	CAM-135
TO DO	Automatische Dark-Auswahl	CAM-125
TO DO	Observation Planner Teil 2	CAM-132
TO DO	Mehr Keywords in den FITS-Header	CAM-101
TO DO	Kalibration der Kamera-Quarzfrequenz anhand 1PPS	CAM-44
TO DO	Farbpunkt der Aufnahme sollte mit Icon übereinstimmen	CAM-148

05/2018
Proof-of-Concept
 with ASI120MM

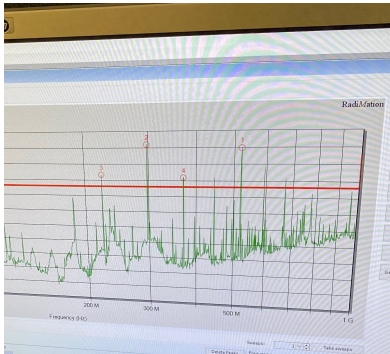
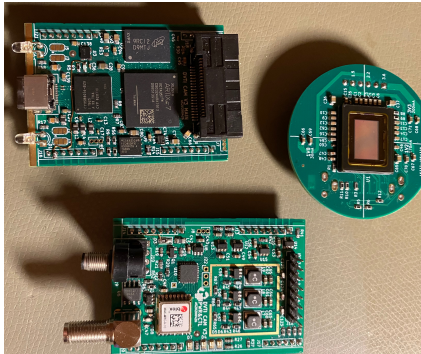
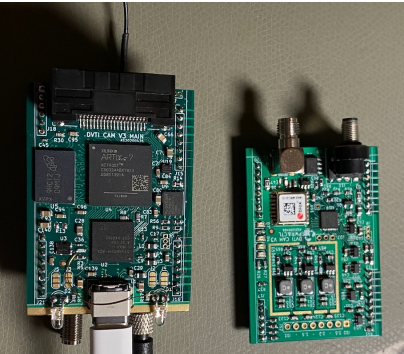
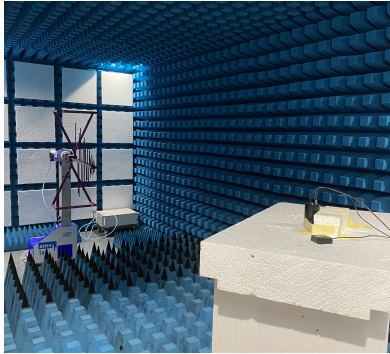
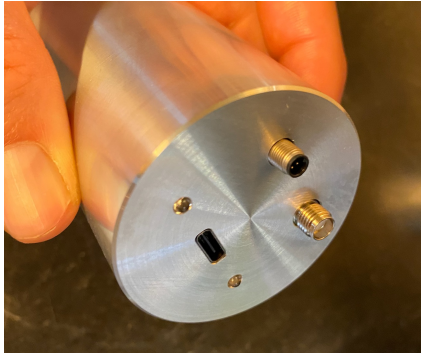
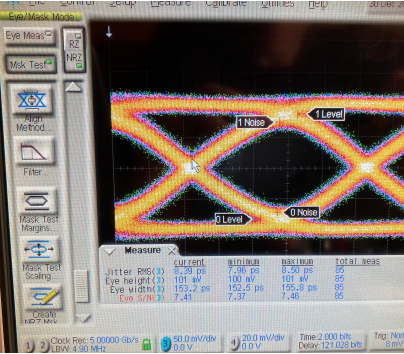
11/2018
Prototype V1
 AR0130

07/2019...
Prototype V2
 AR0130, IMX174,
 IMX178

late 2019 / early 2020
Prototype V2
 Beta testers, EXTA
 test, improvements



Project Overview – Team Goals Milestones



06/2020
Prototype V3A
 IMX174, IMX178,
 IMX432

...08/2020
Prototype V3A
 Milled case

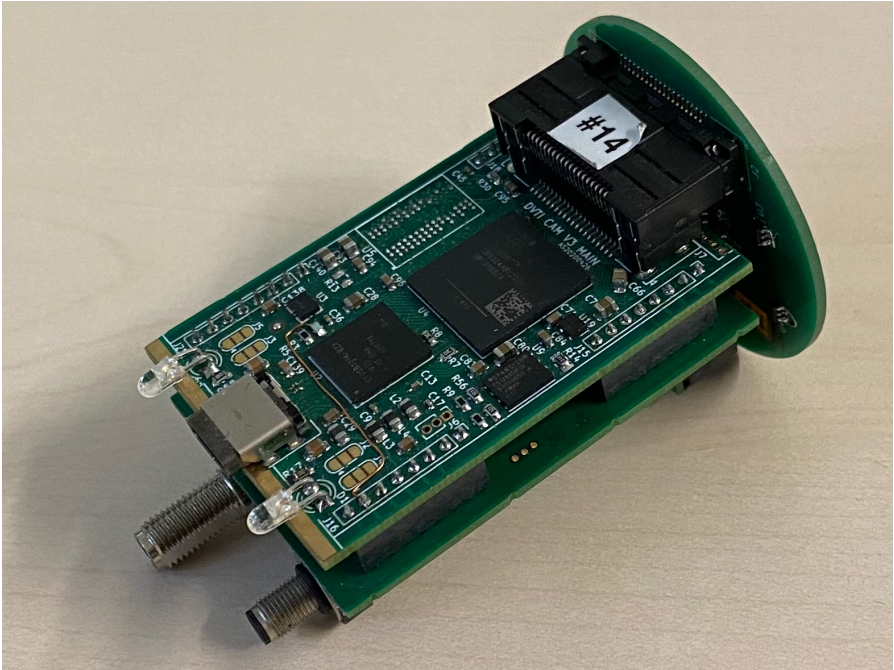
02/2021
Prototype V3B RC1
 EMC testing

05/2021
Prototype V3B RC2
 EMC testing

Project Overview – Team Goals Milestones



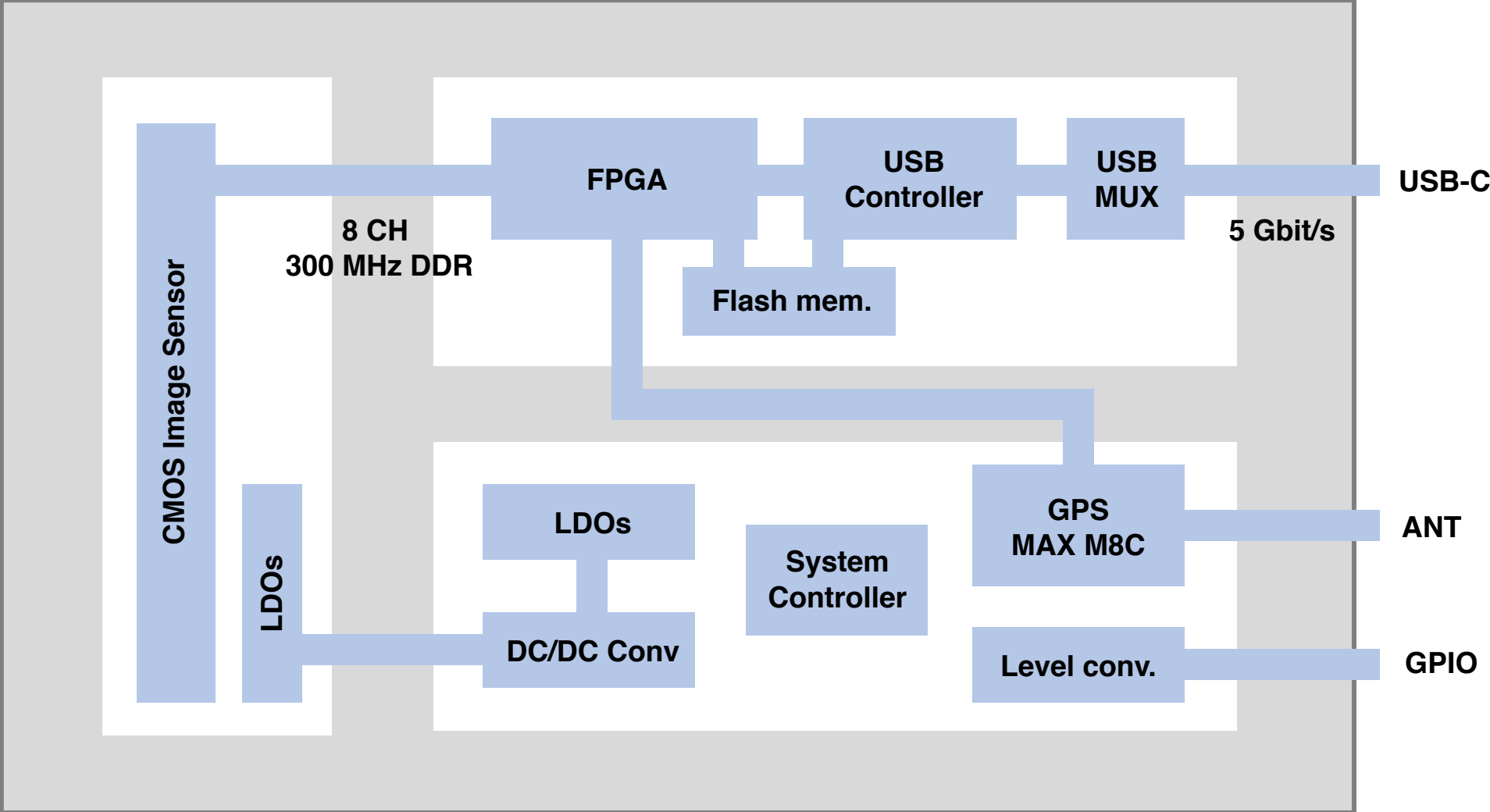
Project Overview – Team Goals Milestones



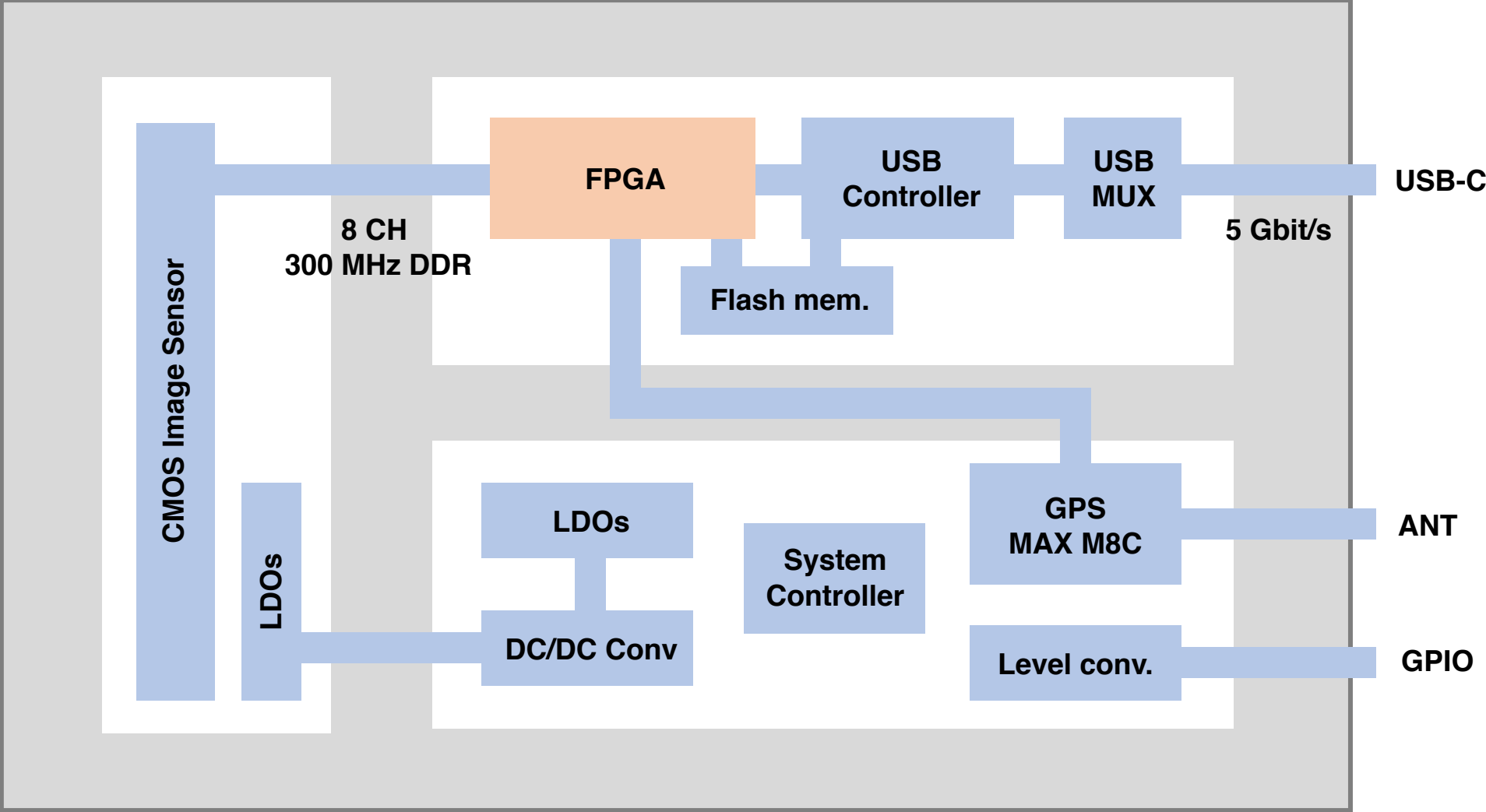
Project Overview – Team Goals Milestones



Hardware – Design Sensors



Hardware – Design Sensors



Hardware – Design Sensors

The FPGA maintains a precise time based on the GPS 1PPS signal.

For each frame, the start and end time (together with other meta information such as frame nr, gain, satellite DOP) are injected into the image stream in the last line:



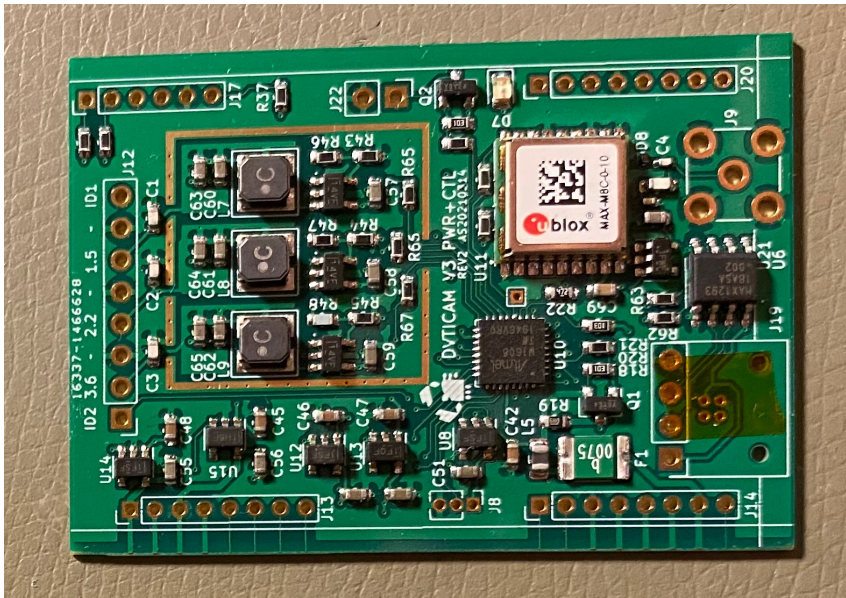
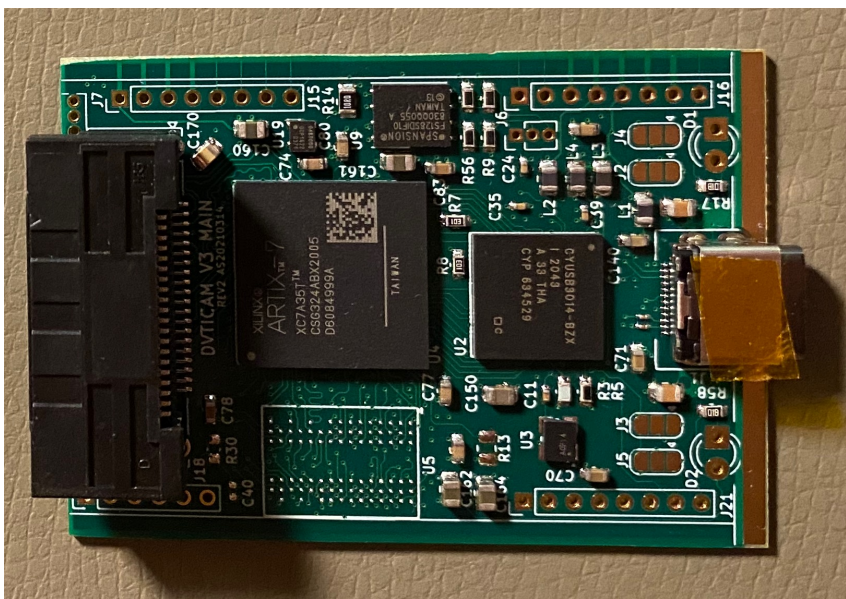
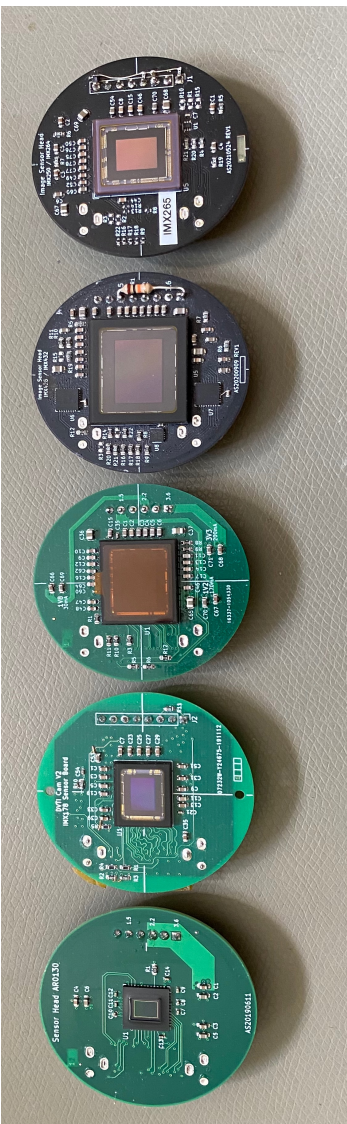
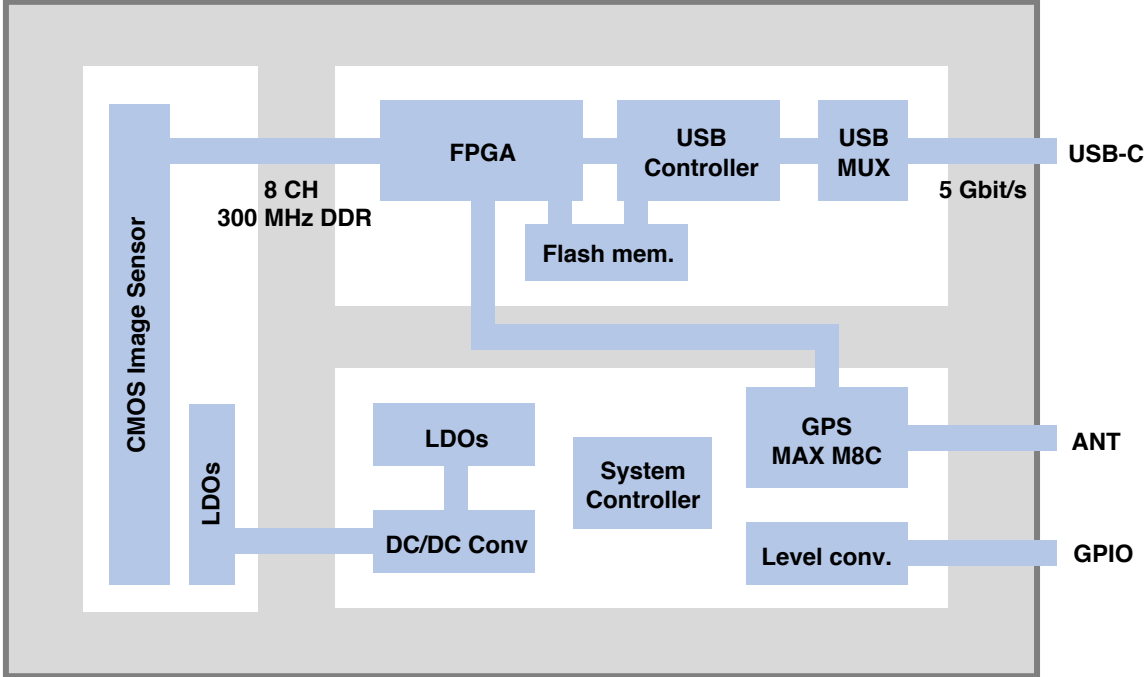
```
20210308+20:26:54.985-55.235 27681+0000 960x600 2x2 250ms 32dB 0100 +2
```

Optionally, the FPGA can overlay a textual timestamp above the binary timestamp.

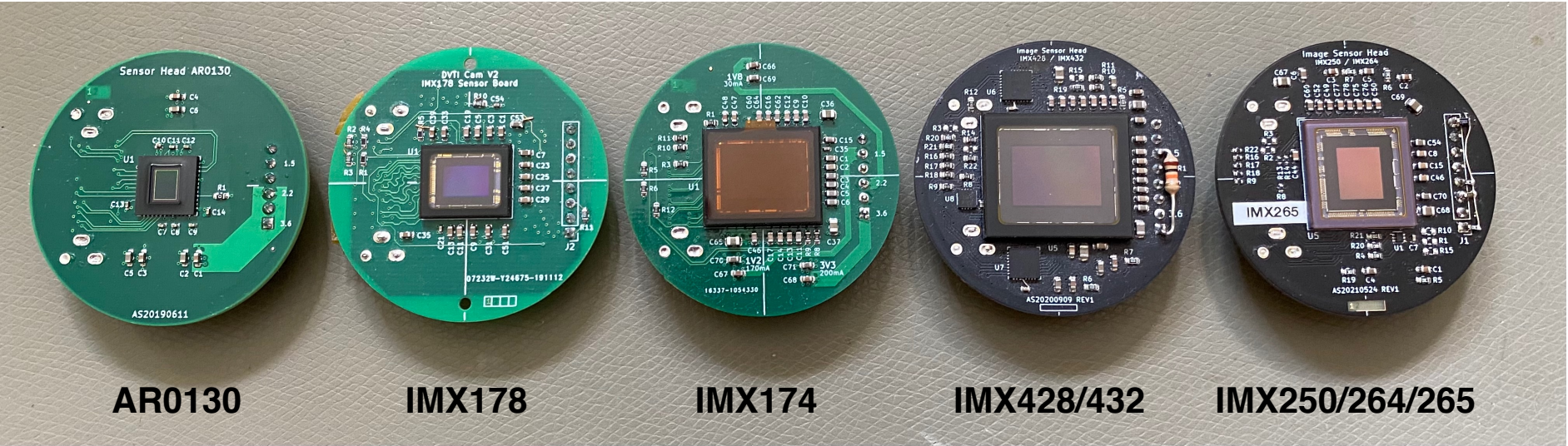
The DVTI control tool extracts the metadata and writes it into the recorded file (ADV, FITS, SER).

More information: <https://groups.io/g/d-vti-cam/wiki/11974>

Hardware – Design Sensors



Hardware – Design Sensors



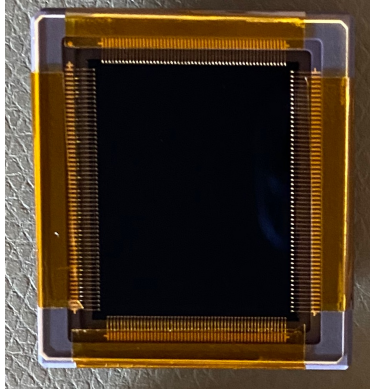
AR0130

IMX178

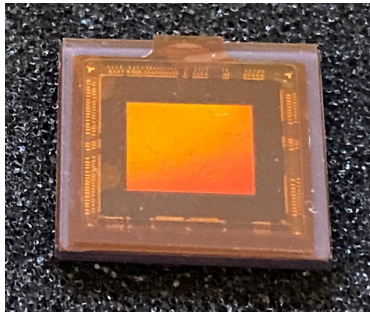
IMX174

IMX428/432

IMX250/264/265



GSENSE4040



IMX250MZR

Software – Artefacts Control Tool

Camera Firmware

- USB Firmware
- FPGA Bitstream

DVTI Control Tool (MS Windows)

Occult Watcher Plugin

- **Download from wiki page**
- **Camera Firmware update option in the control tool**

Software – Artefacts Control Tool

- Control camera settings (resolution, frame rate, gain etc.)
- Preview image
- Histogram
- Record ADV, FITS, SER
- On-the-fly dark subtraction, flat field correction, fixed pattern noise reduction

- Observation planner (Occult + OW integration, open-in-O2A)
- Plate solving
- Telescope control
- Report generation (European format)
- Define Locations / Equipment / Mounts

Examples – 05.07.2021 23:51 UTC – (2978) Roudebush

File Edit Camera Record Tools View Help

85cm Cassegrain 50cm Newton

Camera
DVTI-CAM - P3-IMX174 - #20 - 0.9.77 --°C
Status USB3.0
Error Counters P3780:000 L0:0000 R0

Resolution
960 x 600

Exposure and Gain
Exp (ms) 50 Frame rate (fps) 20.0
Gain +24 dB High Gain Mode

Image Processing
 8-bit Invert Clip on Ovf. Flip none
 FPN reduction Shift

Dark D20210705_960_24dB_0050ms.fits
Offset 4000

Flat

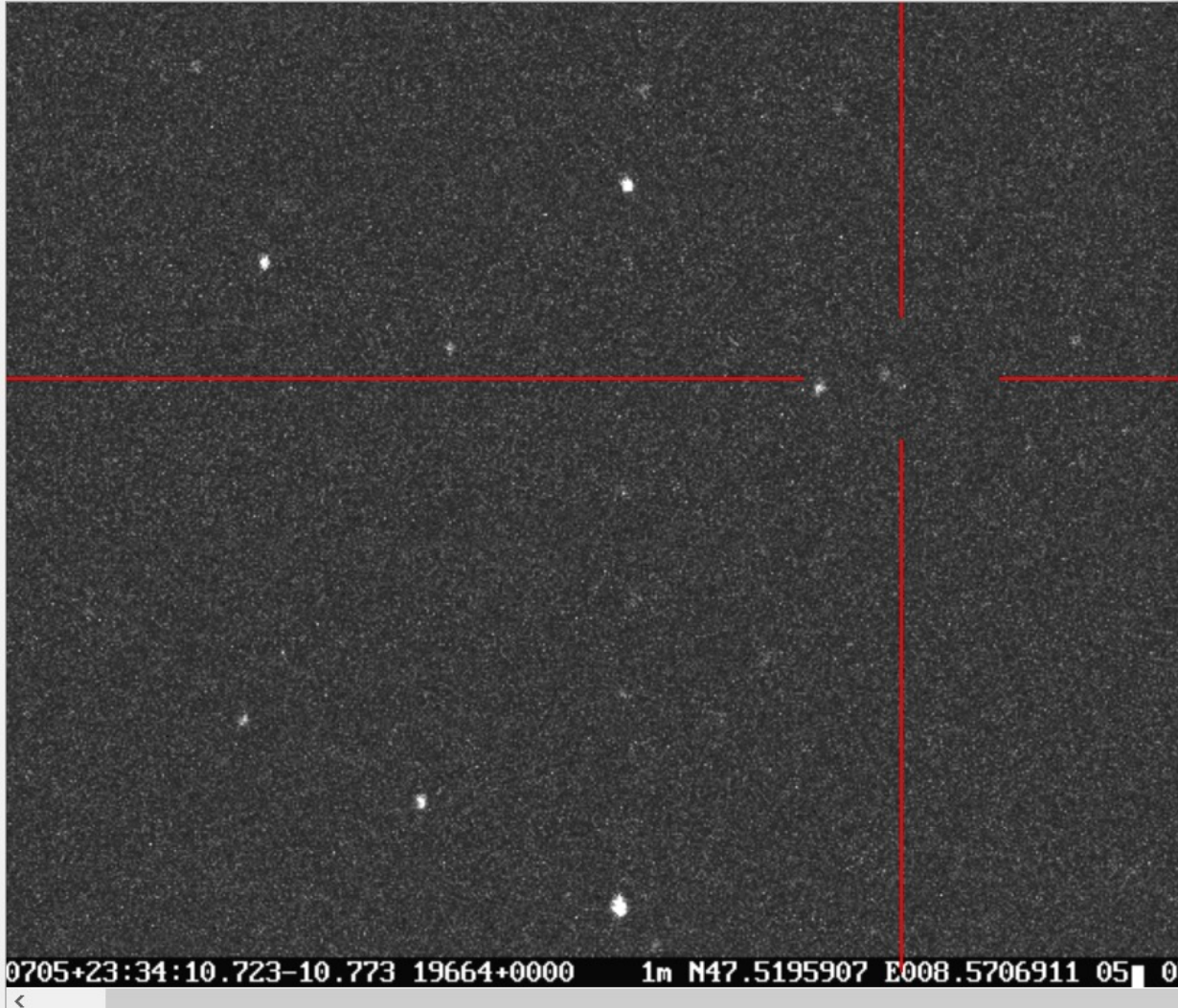
Overlay
 1PPS PC Time
 ISR ascii Resolution 0.1ms

ROI
 Enable ROI mode Start Editing Clear Zones
Only supported for recording ADV video

Statistics
Queue Length 0:18692 1:0 2:0 3:0 F:0
Processing <3/4:18691 <1:0 >1:0
Recorded frames 127 (missed 0) 63 s
Missed 0 Reset

Aspect Scale 150%

Crosshair Overlay
 Platesolving Result



0705+23:34:10.723-10.773 19664+0000 1m N47.5195907 E008.5706911 05 07 13 14 15 18 20 24 30 66 6

Occultation Events

< 05.07.2021 > Today + xml

Date	Time	Offset	Action
05.07.2021	20:39:42UT ±6.5s	-2h 54m	🗑️
(83830) 2001 UM22 - G172900.7-205840 D=0.8s P=8.2% mc=13.9 dm=4.5			
05.07.2021	21:42:52UT ±6.9s	-1h 51m	🗑️
(10248) Fichtelgebirge - UCAC4 331-128675 D=0.7s P=5.5% mc=14.6 dm=3.4			
05.07.2021	22:10:37UT ±2.7s	-1h 23m	🗑️
(5965) 1990 SV15 - UCAC4 352-102041 D=0.8s P=43.8% mc=13.8 dm=3.4			
05.07.2021	23:08:21UT ±4.1s	-25m 49s	🗑️
(569) Misa - UCAC4 331-092136 D=6.0s P=37.6% mc=14.3 dm=0.6			
05.07.2021	23:51:50UT ±1.8s	17m 39s	🗑️
(2978) Roudebush - UCAC4 324-138657 D=1.7s P=83.7% mc=12.6 dm=3.7			
06.07.2021	00:05:35UT ±7.9s	31m 25s	🗑️
(3451) Mentor - UCAC4 486-093972 D=8.2s P=20.7% mc=15.0 dm=0.4			

Event Data

Date / 05.07.2021 23:51:50
Max. Duration 1.7 s
Probability 83.7 %

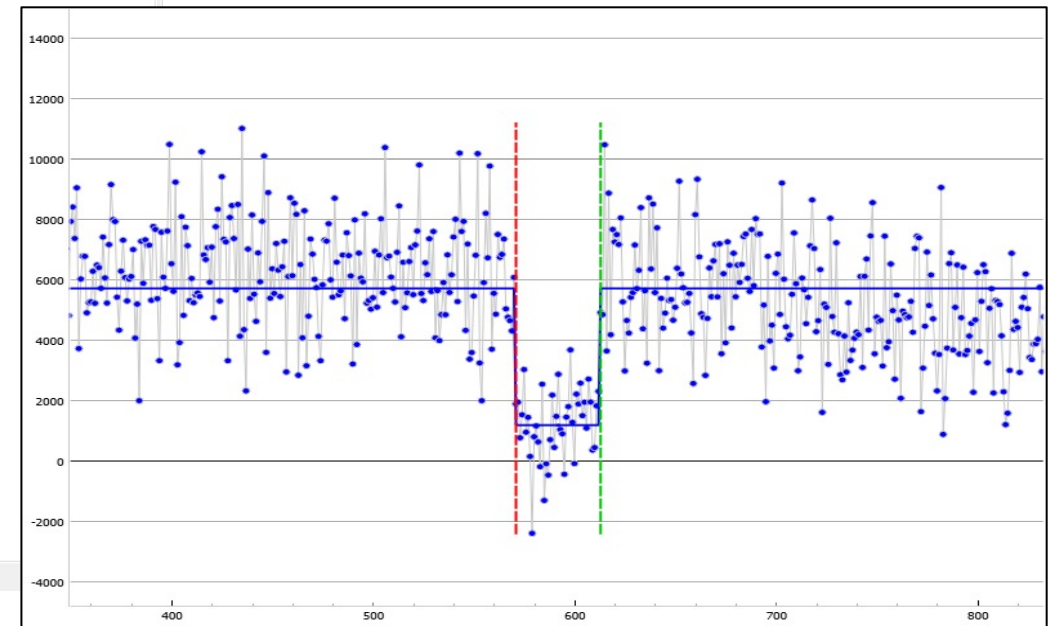
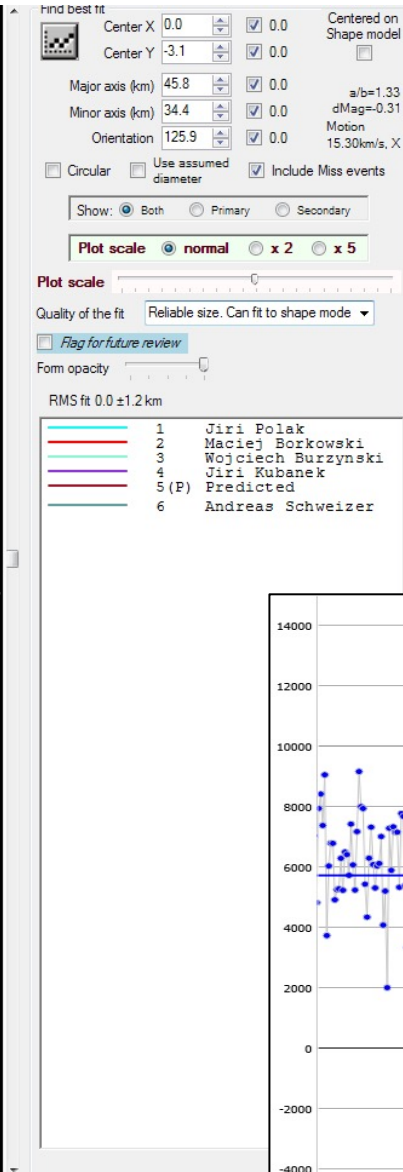
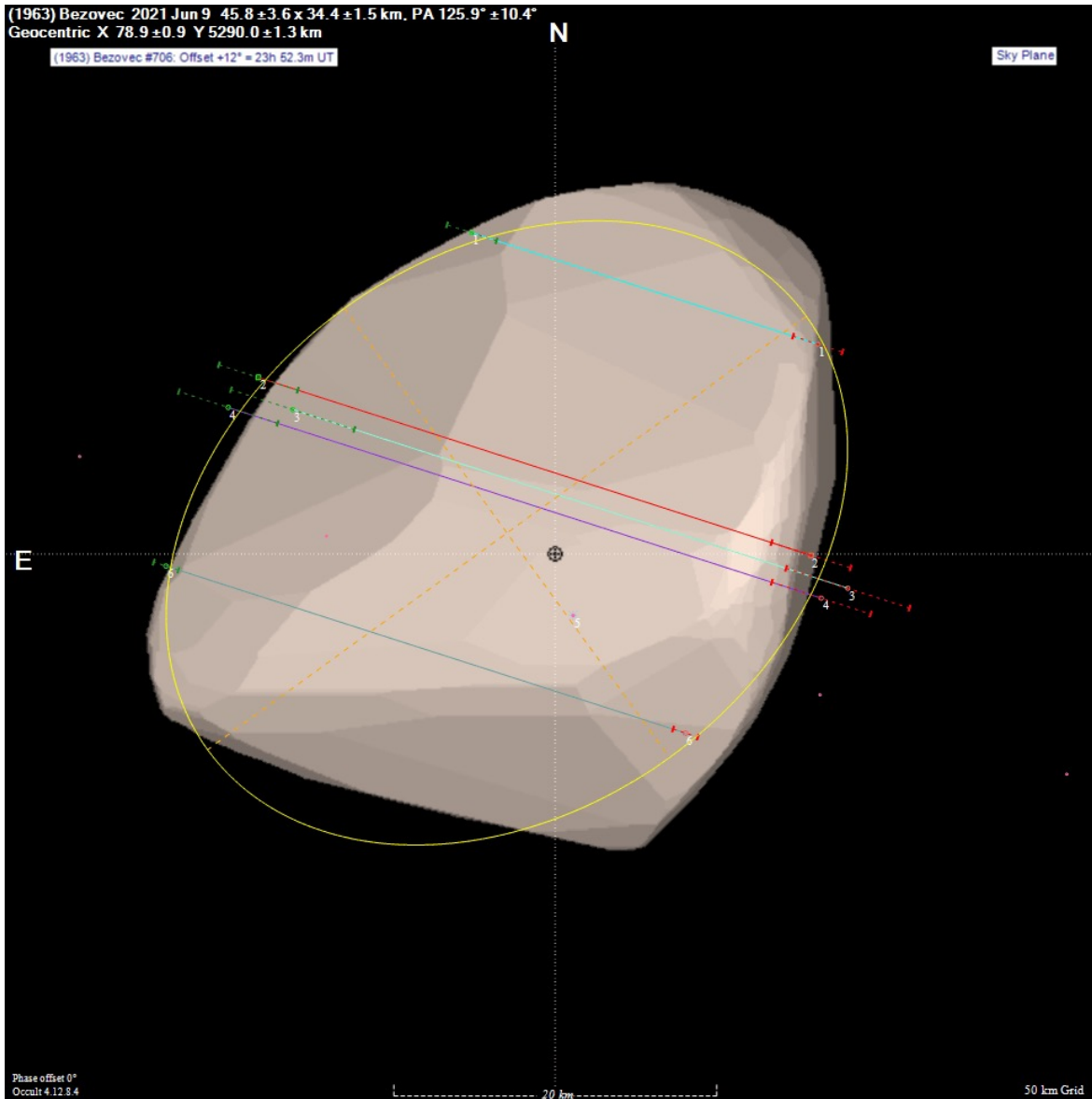
Objects

Asteroid (2978) Roudebush
Star UCAC4 324-138657
Combined
Position 18h 14m 10.1s
Distance -

Report

Recording -
[Create Report...](#)

Examples – 09.06.2021 23:16 UTC – (1963) Bezovec



Examples – 09.06.2021 23:16 UTC – (1963) Bezovec

File Edit Camera Record Tools View Help



Site, Observer and Equipment

Sternwarte Andreas SCHWEIZER

85cm Cassegrain 50cm Newton

Camera
DVTI-CAM - P3-IMX174 - #20 - 0.9.76 --°C
Status USB3.0
Error Counters P14400:000 L0:0000 R0

Resolution
960 x 600

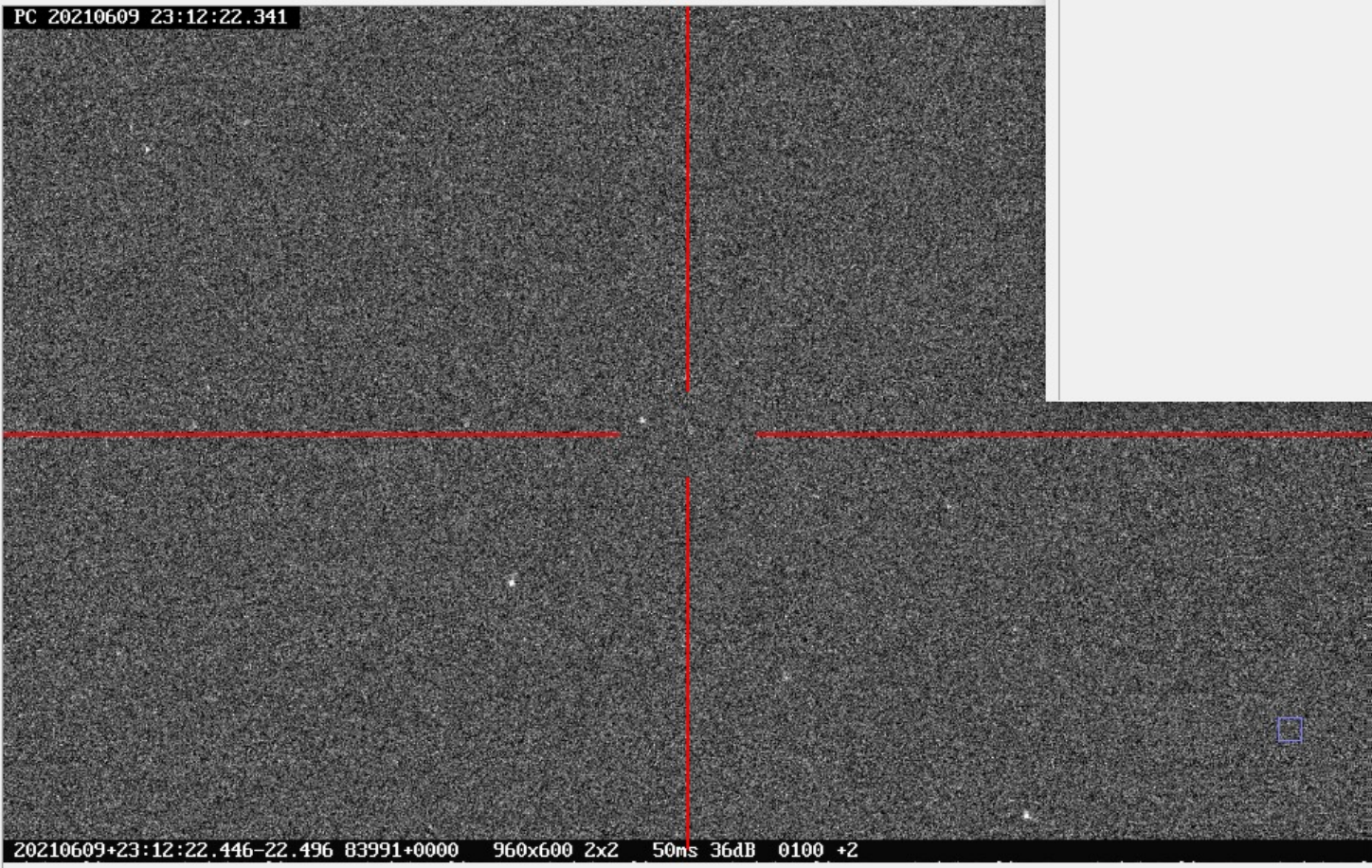
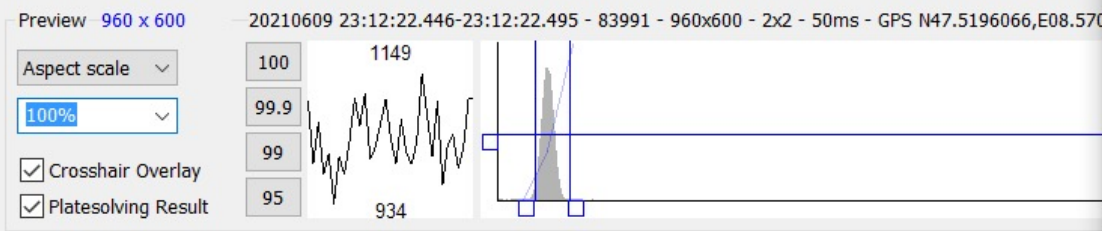
Exposure and Gain
Exp (ms) 50 Frame rate (fps) 20.0
Gain +36 dB D High Gain Mode
Black Level 100

Image Processing
 8-bit Invert Clip on Ovf. Flip none
 FPN reduction Shift
 Dark D20210609_960_36dB_D_0100ms.fits
Offset 4096
 Flat

Overlay
 1PPS PC Time
 ISR ascii Resolution 0.1ms

ROI
 Enable ROI mode Start Editing Clear Zones
Only supported for recording ADV video

Statistics
Queue Length 0:42298 1:0 2:0 3:0 E:0



20210609+23:12:22.446-22.496 83991+0000 960x600 2x2 50ms 36dB 0100 +2

Occultation Events

< Today > 09.06.2021 + xml

- 09.06.2021 22:12:24UT ±2.4s -59m 57s
(2426) Simonov - UCAC4 369-123203
D=2.8s P=48.5% mc=14.0 dm=1.4
- 09.06.2021 23:17:04UT ±1.2s **04m 42s**
(1963) Bezovec - UCAC4 422-070463
D=2.5s P=83.8% mc=13.2 dm=2.1

Event Data

Date /	09.06.2021 23:17:04
Max. Duration	2.5 s
Probability	83.8 %

Objects

Asteroid	(1963) Bezovec
Star	UCAC4 422-070463
Combined	
Position	17h 31m 32.166s,
Distance	-

Report

Recording -

[Create Report...](#)

Examples – 09.06.2021 23:16 UTC – (1963) Bezovec

ASTEROIDAL OCCULTATION – REPORT FORM

EAON EUROPEAN ASTEROIDAL OCCULTATION NETWORK	IOTA/ES INTERNATIONAL OCCULTATION TIMING ASSOCIATION EUROPEAN SECTION
--	--

1 DATE: 2021 Jun 09, 23:17 (UTC)

STAR: UCAC4 422-070463 mv: 13.4 mag
ASTEROID: (1963) Bezovec mv: 15.3 mag (diam. 39.0 km)
combined magnitude: mv: 13.2 mag
delta-magnitude: mv: 2.1 mag

2 OBSERVER:
Name: Andreas SCHWEIZER
E-mail: aschweiz@mac.com
Address: Strumbergächerstr. 3A, 8907 Wettswil, Switzerland

3 OBSERVING STATION:
Nearest city: Bülach
Station: Sternwarte Bülach
Latitude: N47 31' 10.402" (WGS84)
Longitude: E08 34' 14.300" (WGS84)
Altitude: 550 m (MSL) (WGS84)

Predicted observation: yes (Distance 5.2 km from C.L.)
Probability: 83.8 percent

Single station: yes

4 TIMING OF EVENT:

OCCULTATION RECORDED: POSITIVE

Type of event:

S = Start observation I = Interrupt-start D = Disappearance
B = Blink F = Flash E = End observation
I = Interrupt-end R = Reappearance
M = Mid-event P = Predicted time

Event Code	Time (UTC) HH MM SS.sss	Acc. S.sss	Comments
S	23 16 34.765	+/- 0.001 s	: Start observation (UTC)
D	23 17 03.435	+/- *1) s	: Disappearance (UTC)
R	23 17 05.540	+/- *2) s	: Reappearance (UTC)
E	23 17 34.912	+/- 0.001 s	: End observation (UTC)
Duration:	2.105	+/- *3) s	: (predicted: max. 2.5 s)
P	23 17 04.380	+/- 1.212 s	: Predicted time (UTC)

*1)

D time: [23:17:03.4350]
D: 0.6800 confidence intervals: {+/- 0.0199} seconds
D: 0.9500 confidence intervals: {+/- 0.0548} seconds
D: 0.9973 confidence intervals: {+/- 0.1306} seconds

*2)

R time: [23:17:05.5400]
R: 0.6800 confidence intervals: {+/- 0.0199} seconds
R: 0.9500 confidence intervals: {+/- 0.0548} seconds
R: 0.9973 confidence intervals: {+/- 0.1306} seconds

*3)

Duration (R - D): 2.1050 seconds
Duration: 0.6800 confidence intervals: {+/- 0.0291} seconds
Duration: 0.9500 confidence intervals: {+/- 0.0705} seconds
Duration: 0.9973 confidence intervals: {+/- 0.1516} seconds

5 TELESCOPE:

Type: Newton Reflector f/5
Aperture: 500 mm
Focal length: 2500 mm
Magnification: focal (resulting field of view: 15.5' in x-axis)
Mount: equatorial
Motor drive: yes

6 TIMING & RECORDING:

Time source: GPS
Quality of signal: Accuracy 2m
Camera/Sensor: Digital Camera with integrated GPS-VTI (DVTI CAM Prototype V3 RC2, serial #20)
Image Sensor Sony IMX174LLJ-C (1/1.2" 1920x1200 5.86um CIS)
Website of the project: <https://groups.io/g/d-vti-cam/>
Settings: 960x600, Exposure time 50 ms, Gain +36 dB D, Binning 2x2, Format ADV 16-bit
Time insertion: Digital GNSS timestamp into image sensor data stream

7 OBSERVING CONDITIONS:

Atmospheric transp.: good
Moon: below horizon
Wind: no
Star image stability: good
Altitude of star: 36 deg
Azimut of star: 170 deg in Ophiuchus

8 ADDITIONAL COMMENTS:

Feed: Planned Observations
Video recording software: DVTI Cam Control v4.12.0
Light measurement tool: PyMovie 2.9.7, PyOTE 3.7.4
Remarks:

Published by e-mail to planoccult@ls.vvs.be (Planoccult mailing list)

Next Steps

- **First batch of 25 cameras fabricated and tested**
- **Re-test of the timing precision by Gerhard Dangl**
- **Bureaucratic + Legal aspects**
- **Software and firmware improvements**
- **Other sensors**
- **More cameras**

More information: <https://groups.io/g/d-vti-cam/>

Thank you!