

Development of a new Camera with Digital Video Time Insertion

Andreas Schweizer & Stefan Meister

31.08.2019

Who are we?



Andreas Schweizer

- Software Engineer
- Married since 2013, 1 Girl (3½)
- Astronomy as hobby since ~1993
- Other hobbies: Amateur radio, squash

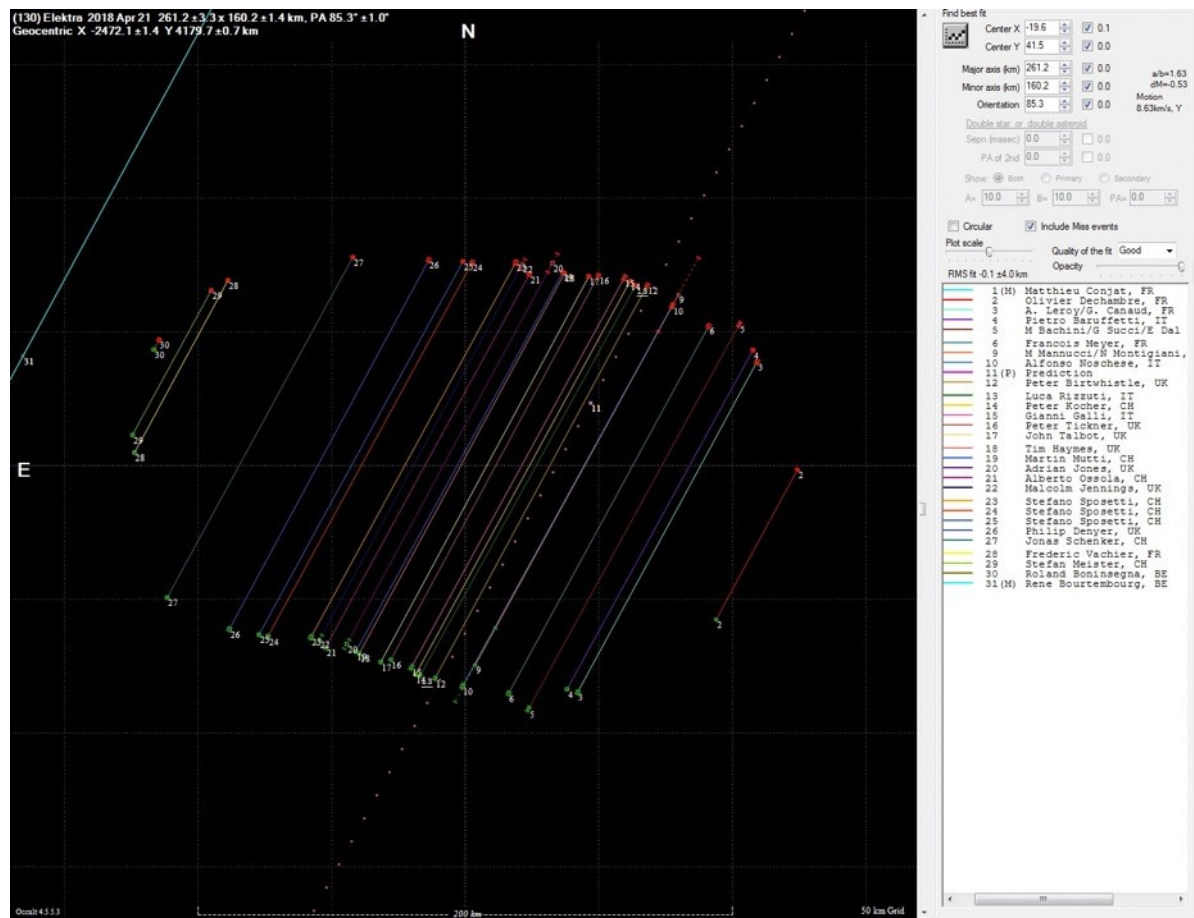


Stefan Meister

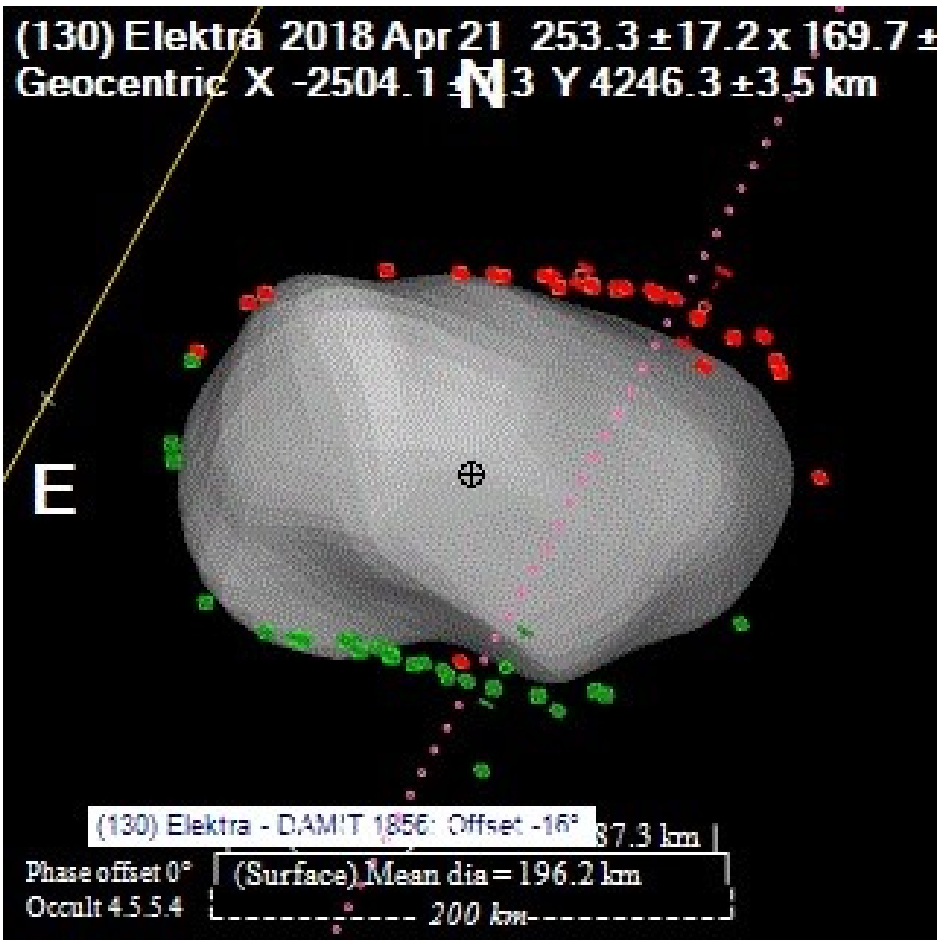
- Working for Mettler-Toledo in Finance & Control
- In the board of the Swiss Astronomical Society (SAG/SAS) and active in various working groups (sun, meteors, exoplanets)
- Other hobbies: cycling, kayaking

Motivation

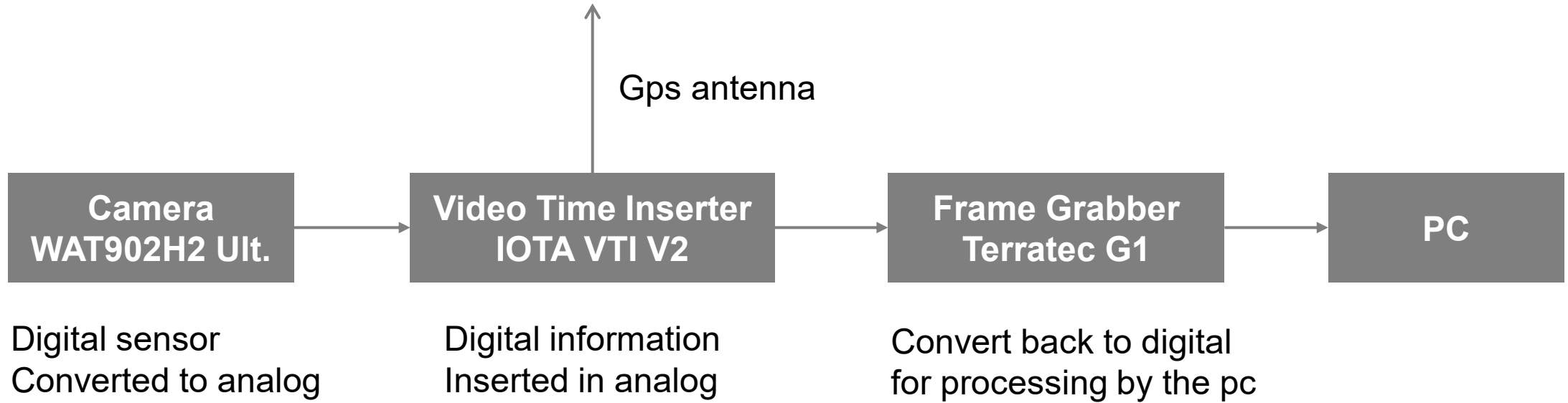
Motivation



(130) Elektra, 21.04.2018



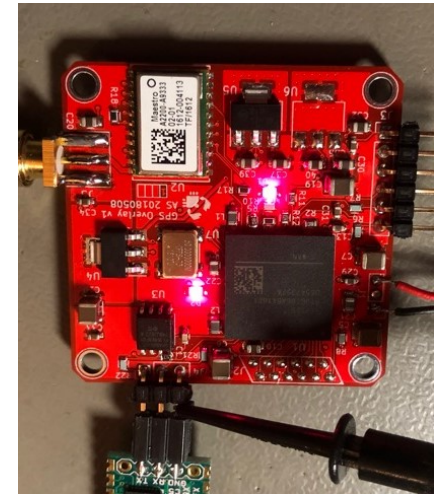
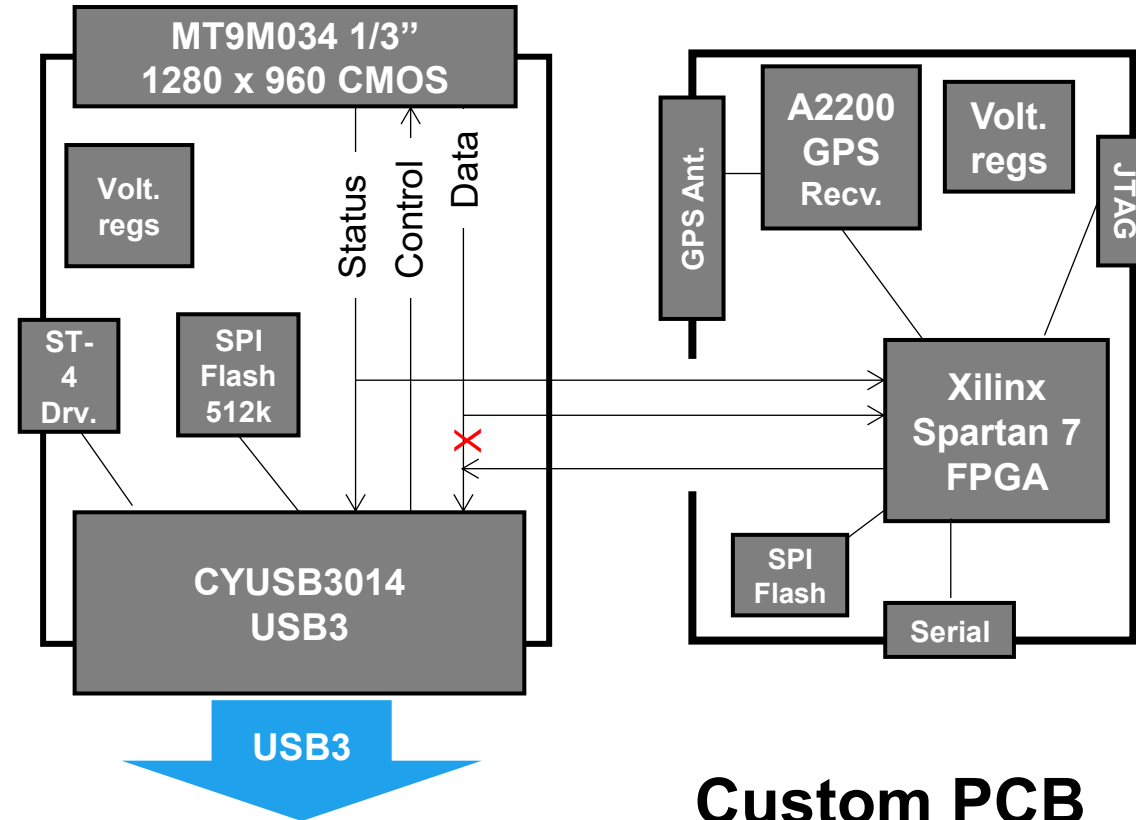
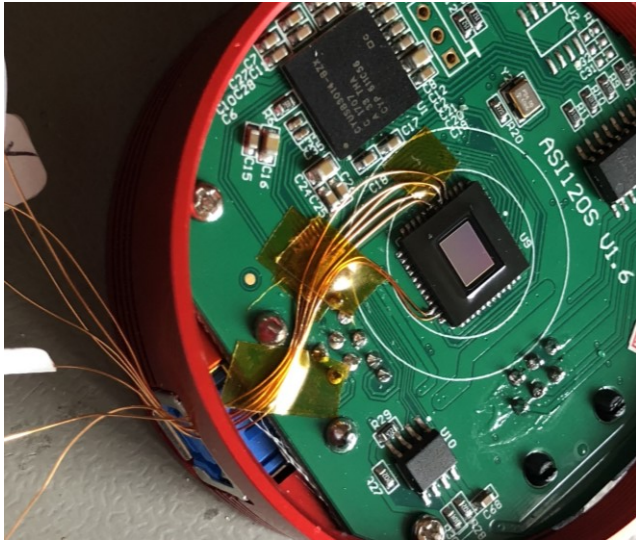
Motivation



«Why not insert the time information directly into the pixel stream?»

Proof-of-Concept and Prototypes

Proof-of-Concept



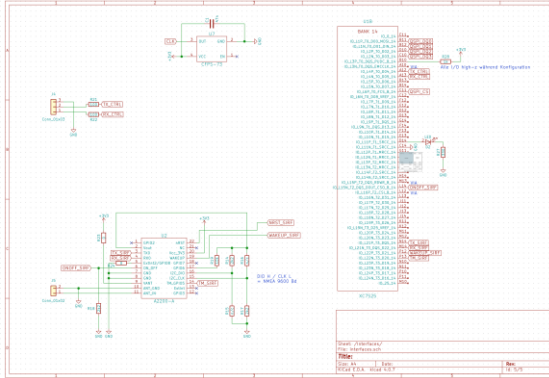
ASI 120 MM

- Cut 2 most significant data lines
- Inject timestamp overlay

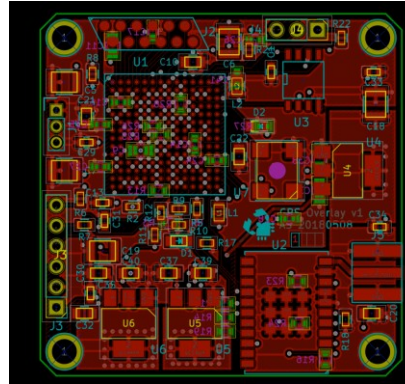
Custom PCB

- GPS module, FPGA

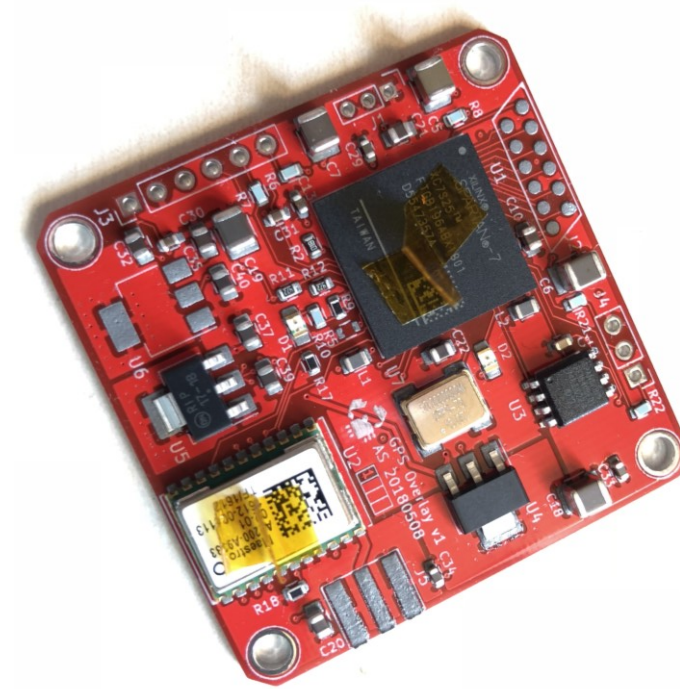
PoC Development



Schematics



→ Layout



```
gpsoverlay.sdk - C/C++ - application/src/main.c - Xilinx SDK
File Edit Navigate Search Project Run Xilinx Window Help
Project Explorer
  application
    Binaries
    Includes
    Debug
    src
      cbuf.c
      cbuf.h
      font.c
      led.c
      led.h
      main.c
      platform_config.h
      platform.c
      platform.h
main.c
  gNofExtIntCalls++;
  uint32_t interruptFlags = REG_INTERRUPTS;
  if (interruptFlags & REG_INTERRUPT_START_OF_FRAME) {
    // REG_SCR &= ~0x00000004; // Test-Output oRsvd3
    REG_SCR |= 0x00000100; // Test-Output oRsvd2

    // REG_FRAME_NR enthält 24 bit binär.
    // Lesen bestätigt den Start-of-Frame Interrupt.
    uint32_t frameNr = REG_FRAME_NR;
    // Lesen in Reihenfolge yymmdd, dann hhmmss, dann ms
    uint32_t yymmdd = REG_GPS_00YYMMDD;
    uint32_t hhmmss = REG_GPS_00HHMMSS;
    uint32_t ms = REG_GPS_MS;

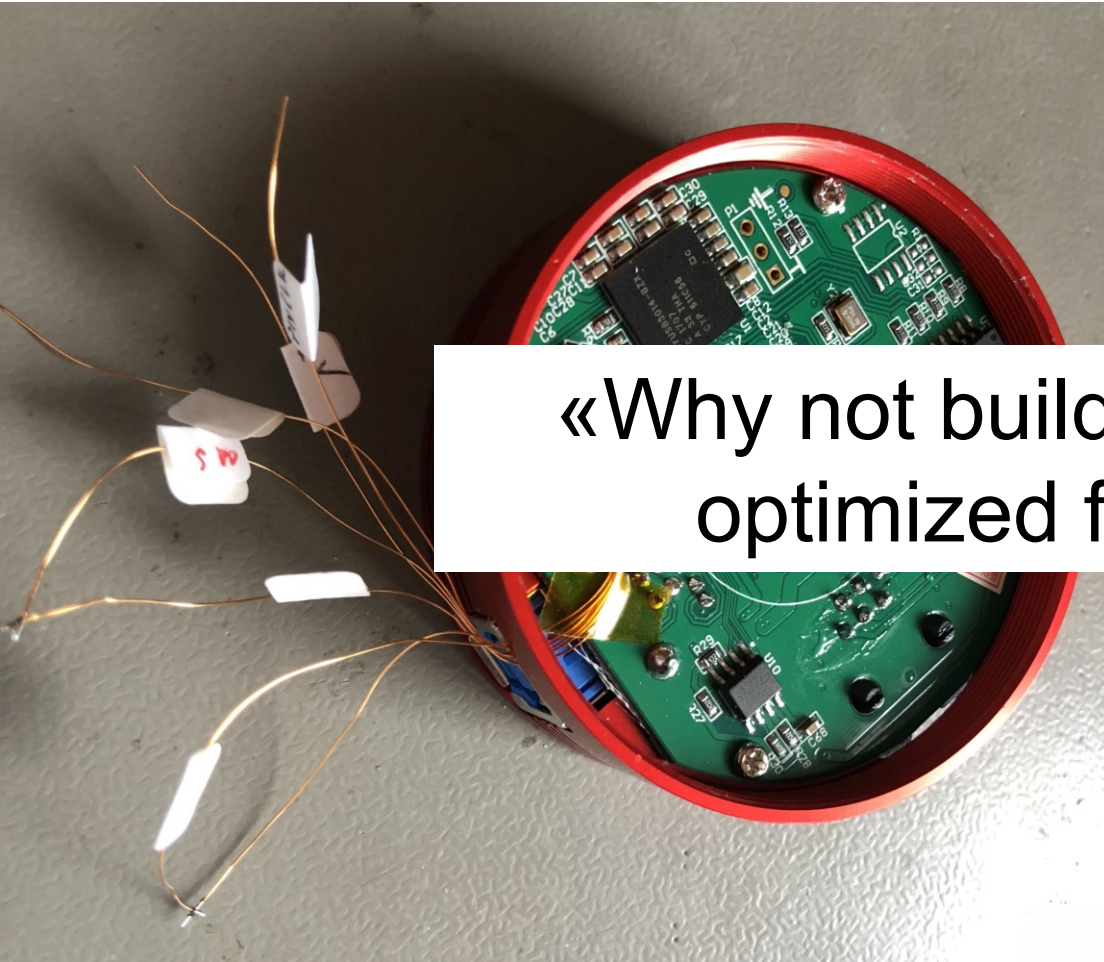
    // Daten sofort ins BlockRAM zum Anzeigen
    // YYMMDD
    write21212/vymmdd. 11):
```

Firmware Code in C

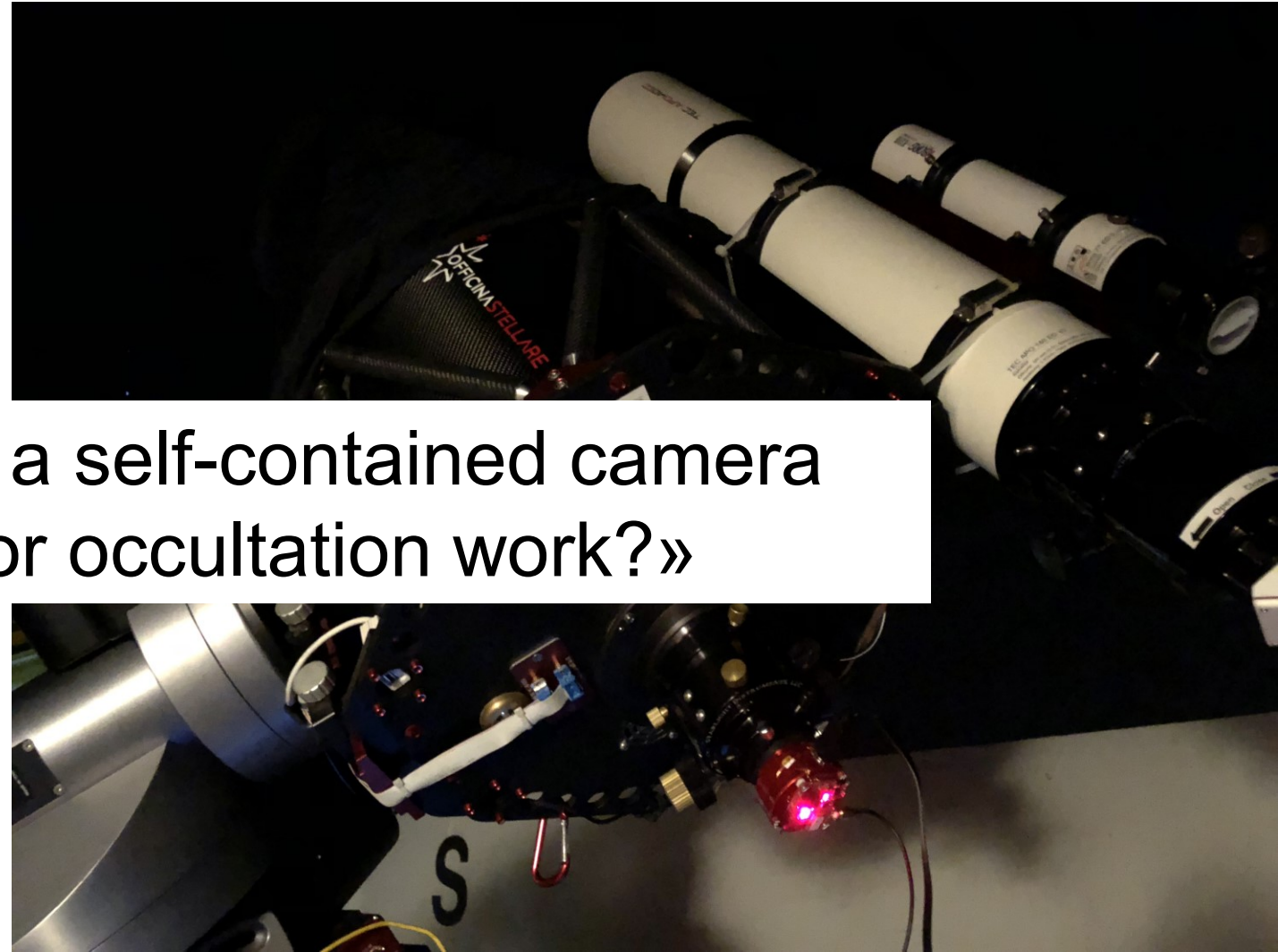
```
Diagram x top.vhd x
C:/Users/andreas/Projects/gpsoverlay/gpsoverlay.srscs/sources_1/imports/Desktop/top.vhd
1 library IEEE;
2 use IEEE.STD_LOGIC_1164.ALL;
3 use IEEE.NUMERIC_STD.ALL;
4
5 library UNISIM;
6 use UNISIM.VComponents.all;
7
8 entity top is
9 Port (
10   clk: in std_logic; -- 50 MHz clock from oscillator
11   o_led: out std_logic;
12   -- i/o
13   i_io_addr_strobe: in std_logic;
14   i_io_address: in std_logic_vector(31 downto 0);
15   i_io_write_strobe: in std_logic;
16   i_io_write_data: in std_logic_vector(31 downto 0);
```

FPGA Design in VHDL

Proof-of-Concept

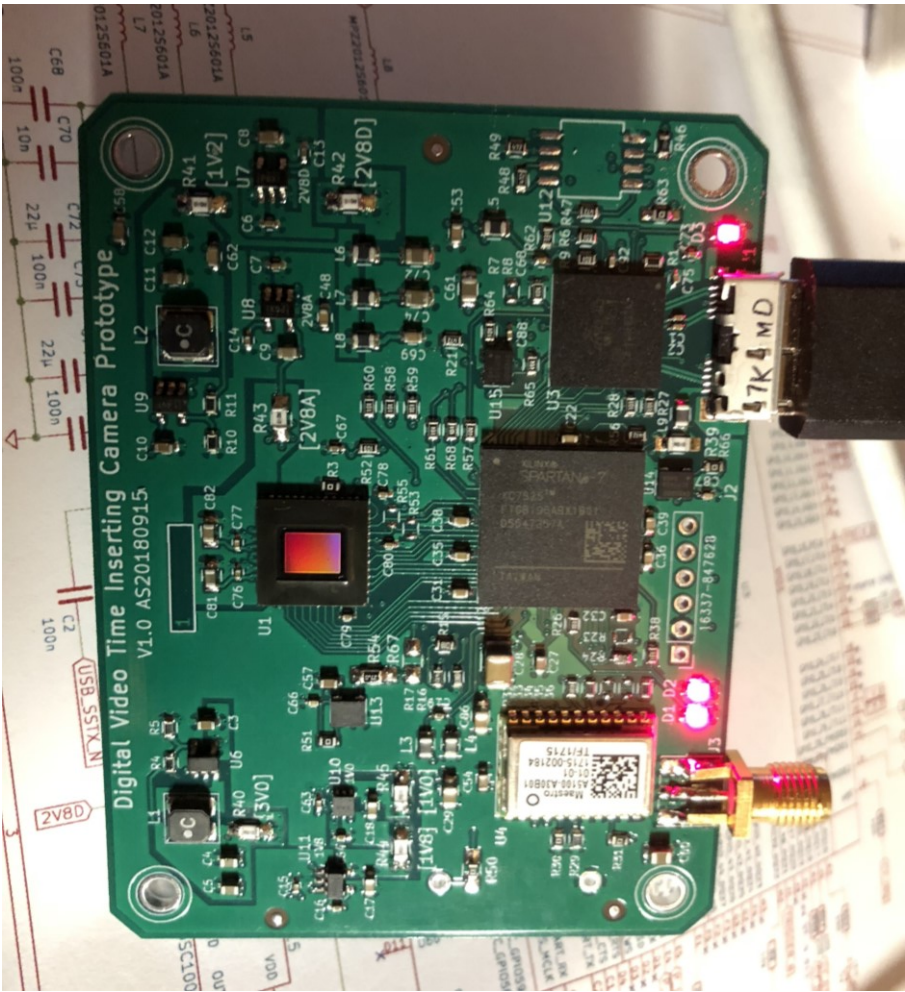


«Why not build a self-contained camera optimized for occultation work?»

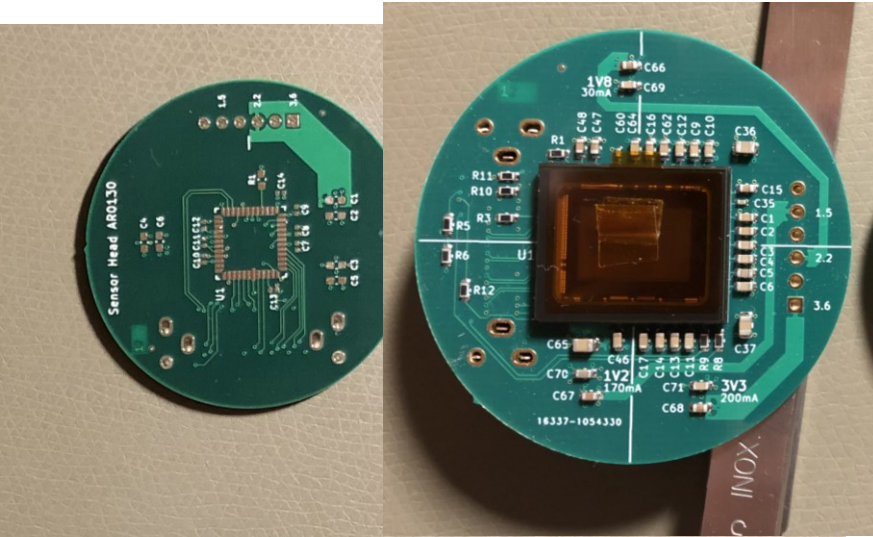


GPS UTC 2018-07-22 18:00:21.967-21.994 101500 - 12m N47.3419138 E008.4730658 01 11 17 18 23 03 09 22 31 14 32 19

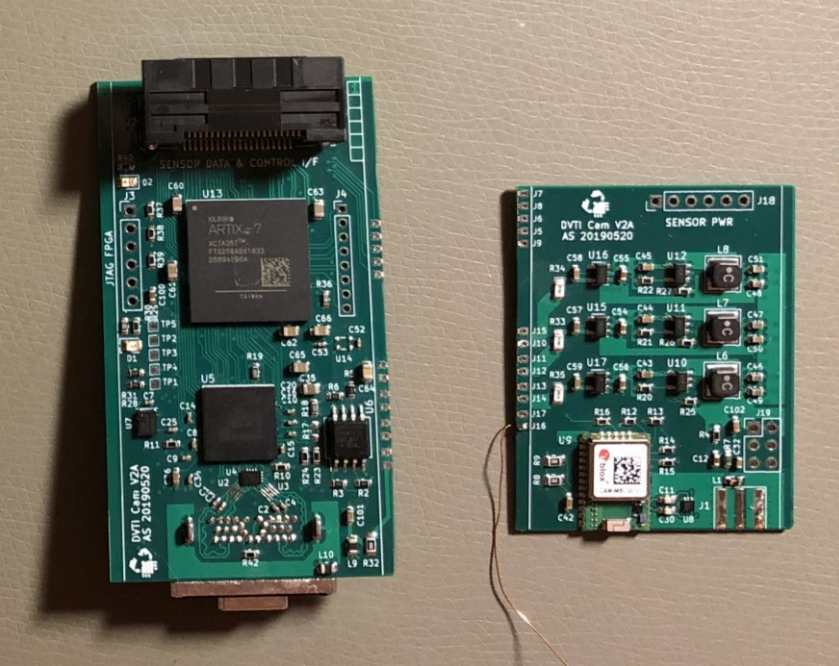
Prototype V1 (Oct 2018)



Prototype V2 (Jun 2019)



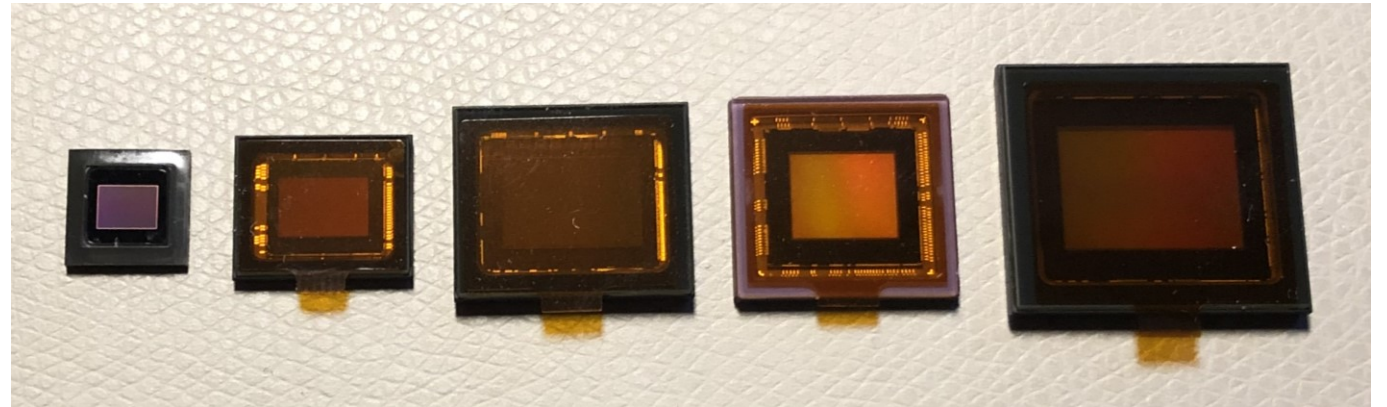
- Sensor plugin module (AR0130, IMX174, ...)
- uBlox GPS module
- Xilinx Artix FPGA
- USB-C connection



Prototype V3 (planned)

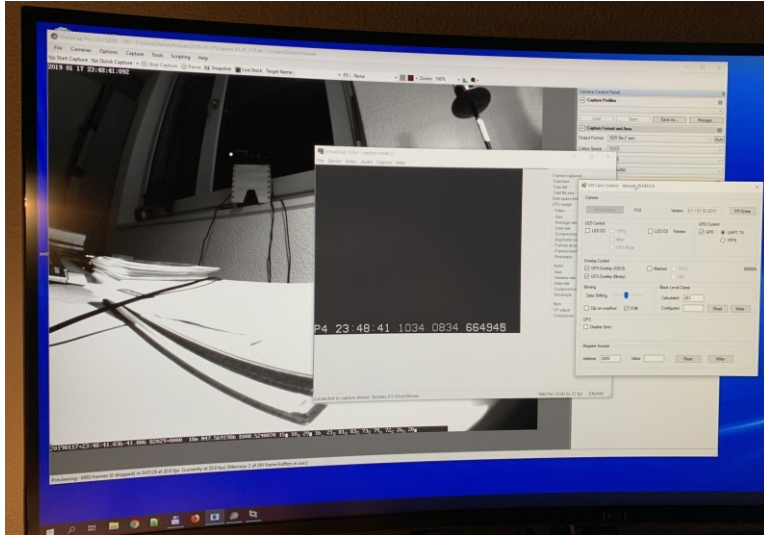
- Sensor plugin modules (AR0130, IMX174, **IMX428**)
- Internal GPS antenna, if possible (?)
- Frame buffer on board (?)
- SD Card slot (?)
- USB-C connector
- 2" cylinder, M42 thread

→ Kickstarter Project



Testing, Results

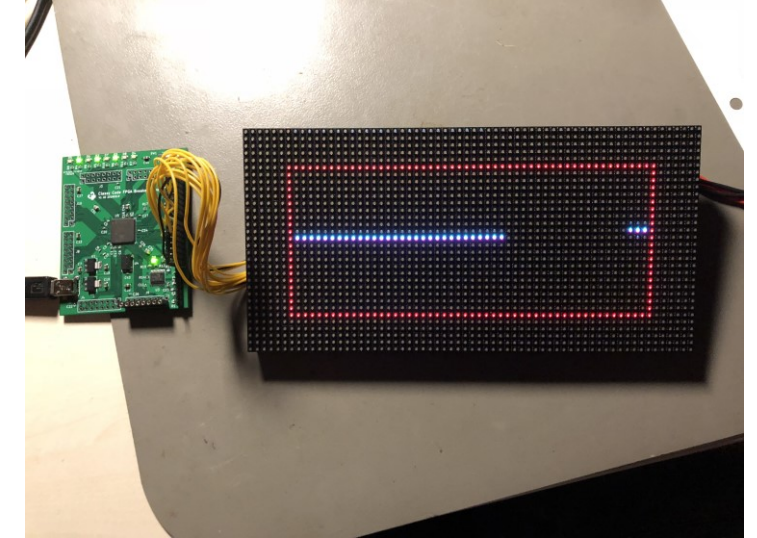
Testing (accuracy of time stamp)



- 1 Simple 1PPS LED Test
Waterc and DVTI Cam
Integrity tests over 40 min.



- 2 Flash Test (Nikon SB-700)
Waterc and DVTI Cam



- 3 Construction of an own EXTA.
Testing of integration time and
time stamp

4

Additional independent timing tests by Gerhard Dangl
(July and Aug. 2019)

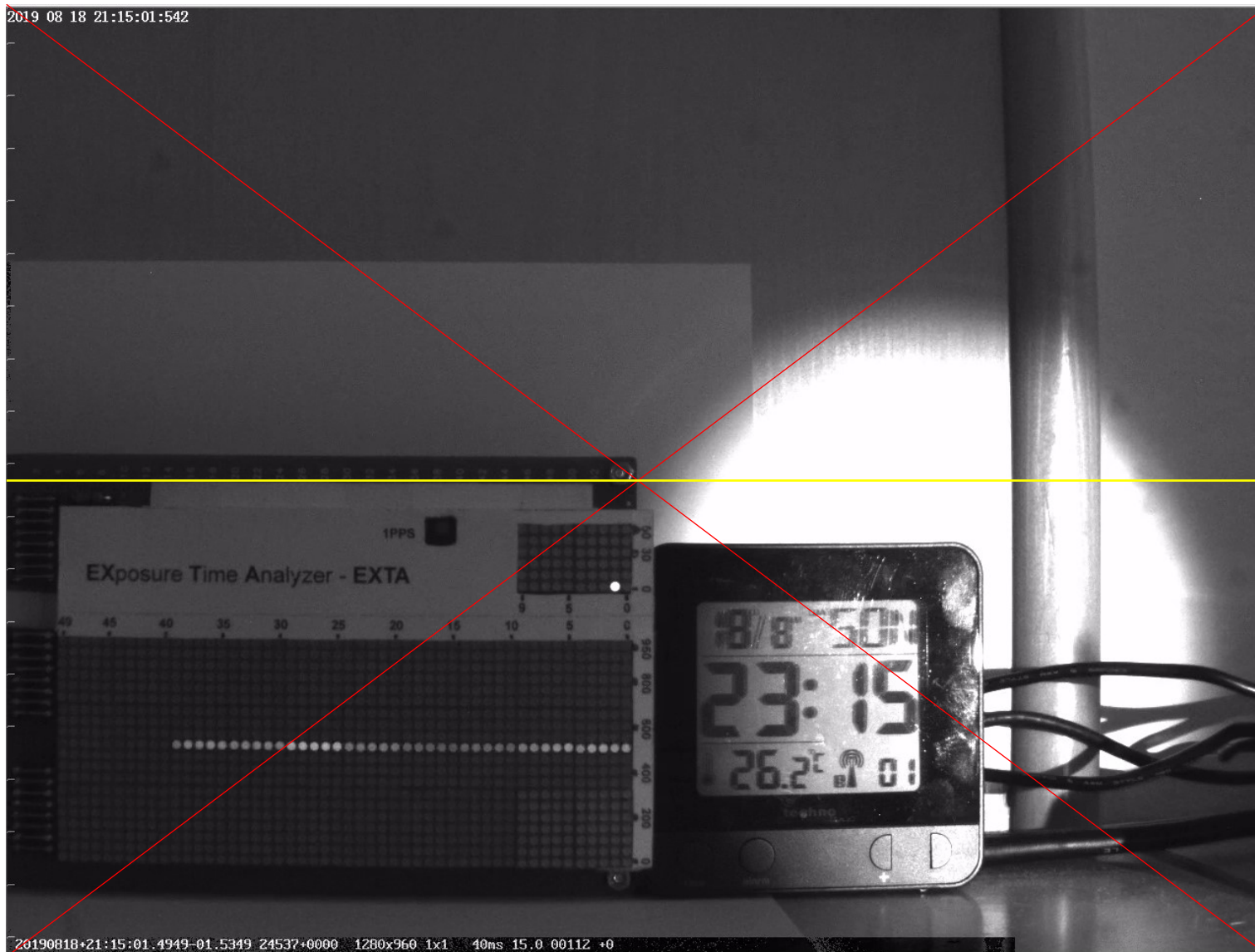
Results (by Gerhard Dangl)

Recorded file			SharpCapVersion 3.2.5986.0 + VtiCamControl_20190529 settings					EXTA measurement results (V)			
Number	Date	AVI file	Colour Space	Frame Rate Limit	Capture Area	Binning	Exposure set	Real Exposure	Time stamp error	Gap in sequence	Measurement tolerance = EXTA resolution
27	2019/08/18	23_15_01	YUY2	Maximum	1280 x 960	1x1	0.040	0.040	0.001	0.000	+/-0.001
28	2019/08/18	23_16_35	YUY2	Maximum	1280 x 960	1x1	0.020	0.020	0.001	0.002	+/-0.001
29	2019/08/18	23_17_05	YUY2	Maximum	1280 x 960	1x1	0.010	0.010	0.001	0.012	+/-0.001
30	2019/08/18	23_17_37	YUY2	Maximum	1280 x 960	1x1	0.005	0.005	0.001	0.017	+/-0.001
31	2019/08/18	23_18_10	YUY2	Maximum	1280 x 960	1x1	0.002	0.002	0.001	0.020	+/-0.001
32	2019/08/18	23_18_26	YUY2	Maximum	1280 x 960	1x1	0.001	0.001	0.001	0.021	+/-0.001
33	2019/08/18	23_19_21	YUY2	Maximum	1280 x 960	1x1	0.020	0.020	0.001	0.002	+/-0.001
34	2019/08/18	23_20_08	YUY2	Maximum	1280 x 960	1x1	0.040	0.040	0.001	0.000	+/-0.001
35	2019/08/18	23_20_56	YUY2	Maximum	1280 x 960	1x1	0.080	0.080	0.001	0.000	+/-0.001
36	2019/08/18	23_23_00	YUY2	Maximum	1280 x 960	1x1	0.160	0.160	0.001	0.000	+/-0.001
37	2019/08/18	23_24_30	YUY2	Maximum	1280 x 960	1x1	0.320	0.320	0.001	0.000	+/-0.001
38	2019/08/18	23_25_11	YUY2	Maximum	1280 x 960	1x1	0.640	0.637 - 0.640 *	0.001	0.000	+/-0.001
39	2019/08/18	23_26_44	YUY2	Maximum	1280 x 960	1x1	1.280	1.300 - 1.320 *	0.025 *	0.000	+/-0.002
40	2019/08/18	23_29_06	YUY2	Maximum	1280 x 960	1x1	2.560	2.615 - 2.635 *	-0.01 *	0.000	+/-0.005
									* different values possible		
Hardware: HP ProBook 6570b with Intel core i5 2.6GHz CPU, 8GB RAM, Samsung SSD, EVO 840, 500GB, 512MB Cache, SATA III Camera DVTI_v1_Prototype connected via USB3.0; no additional external Power supply											
Software: W7P/64 (all updates) + SharpCapVersion 3.2.5986.0 + VtiCamControl_20190529 Disk write speed test made by SharpCap showed 348 MB/s and 297 fps with format 1280x960											

- High absolute accuracy in all exposure modes <1s: 1 ms or better
- Some issues with inconsistent exp. times >1s
- Exp. times below 22.2ms (>45 fps) in full frame videos produce gaps between frames (time stamp is still accurate)

Example of one Test Case

5 ticks below center line:
Recording happened 5ms after creation of time stamp



Rolling Shutter

*1/10'000s accuracy used
to avoid rounding differences*

Start Time

Time stamp: 01.4949s
- EXTA: 01.500 s
+ RS corr.: 00.005 s
Deviation: -

End Time

Time stamp: 01.5349s
- EXTA: 01.540 s
+ RS corr.: 00.005 s
Deviation: -

Results of actual Occultations

Camera Model	Time period	Pos	Neg	Total
mod. ASI120MM	Oct-Nov 2018	1	2	3
Prototype 1	Jan-Jul 2019	4	35	39
Prototype 2	Jul-Aug 2019	1	12	13
		6	49	55

(34339) 2000 QH218 occults the 3.4 mag star Rasalas in Leo on 5th Feb. 2019.
Mobile station Hulftegg, 950 m altitude, Switzerland.



«Home Base» Observatory Bülach, Switzerland (MPC 167)

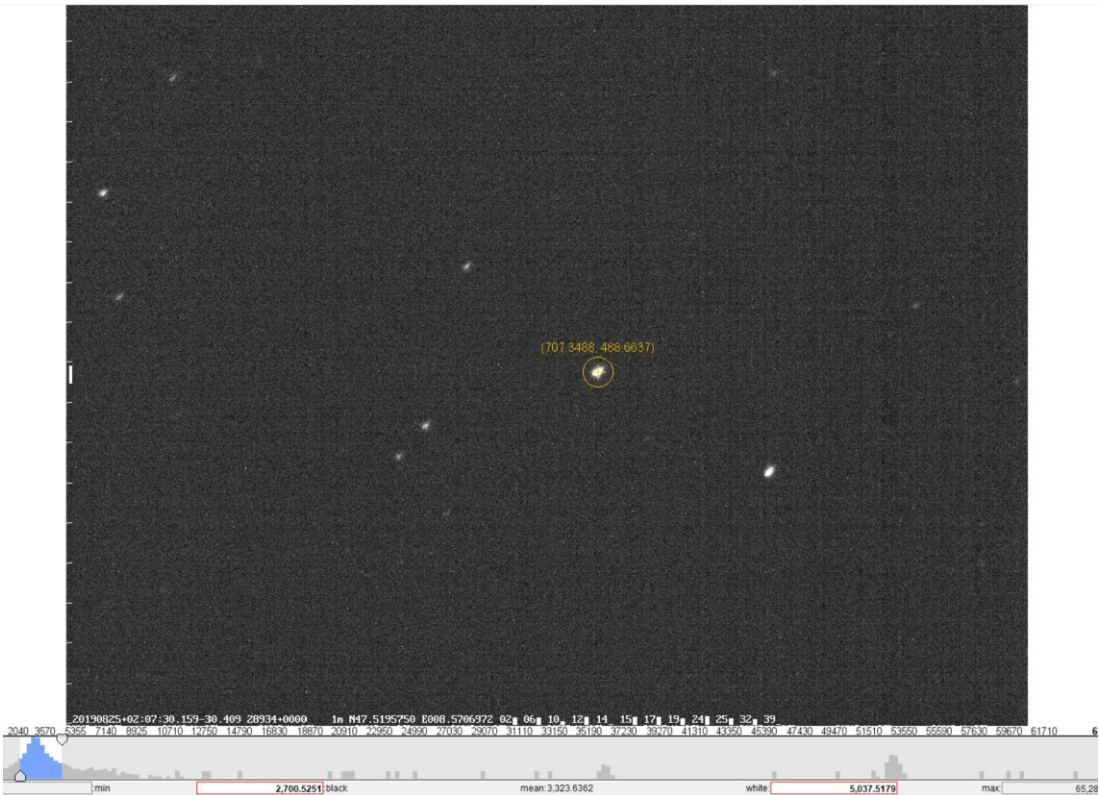
Example of this week...

DATE: 2019 Aug 25, 02:05 (UTC)

STAR: UCAC4 561-26842 mv: 10.9 mag

ASTEROID: (1010) Marlene mv: 16.3 mag (diam. 47 km)

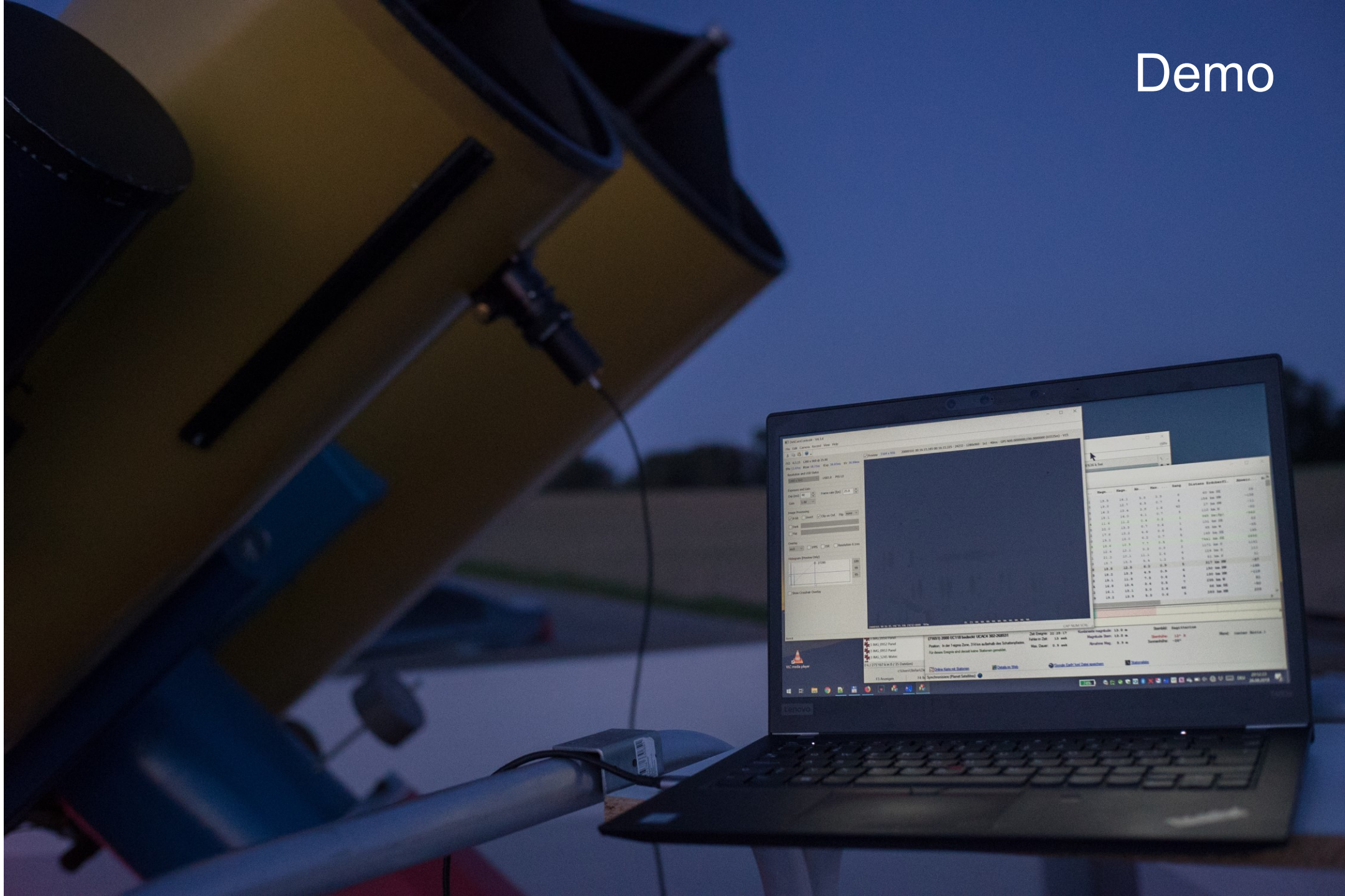
delta-magnitude: mv: 5.4 mag



Video recorded in SER format including all metadata.
Visual timestamp only used as a «backup» to the binary.



Demo

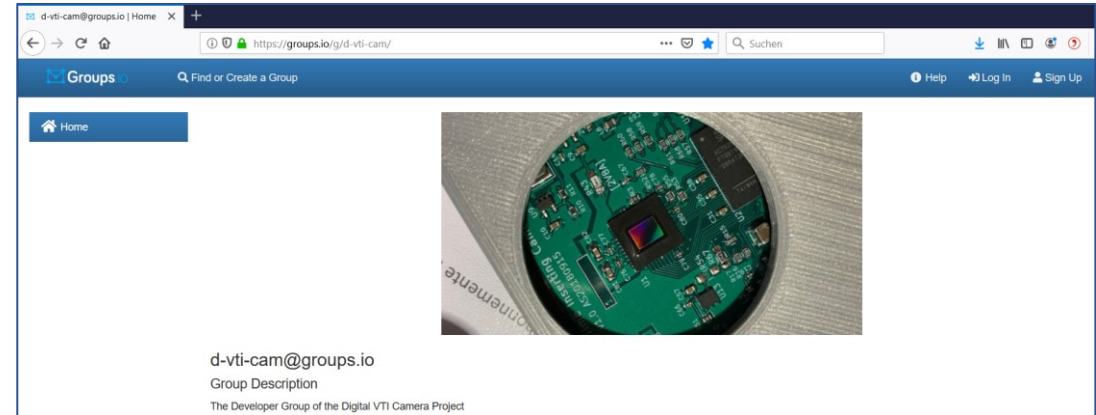


Thank you!

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Association Switzerland (SOTAS)
www.occultations.ch



The DVTI Cam Project Website:
groups.io/g/d-vti-cam