

# **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

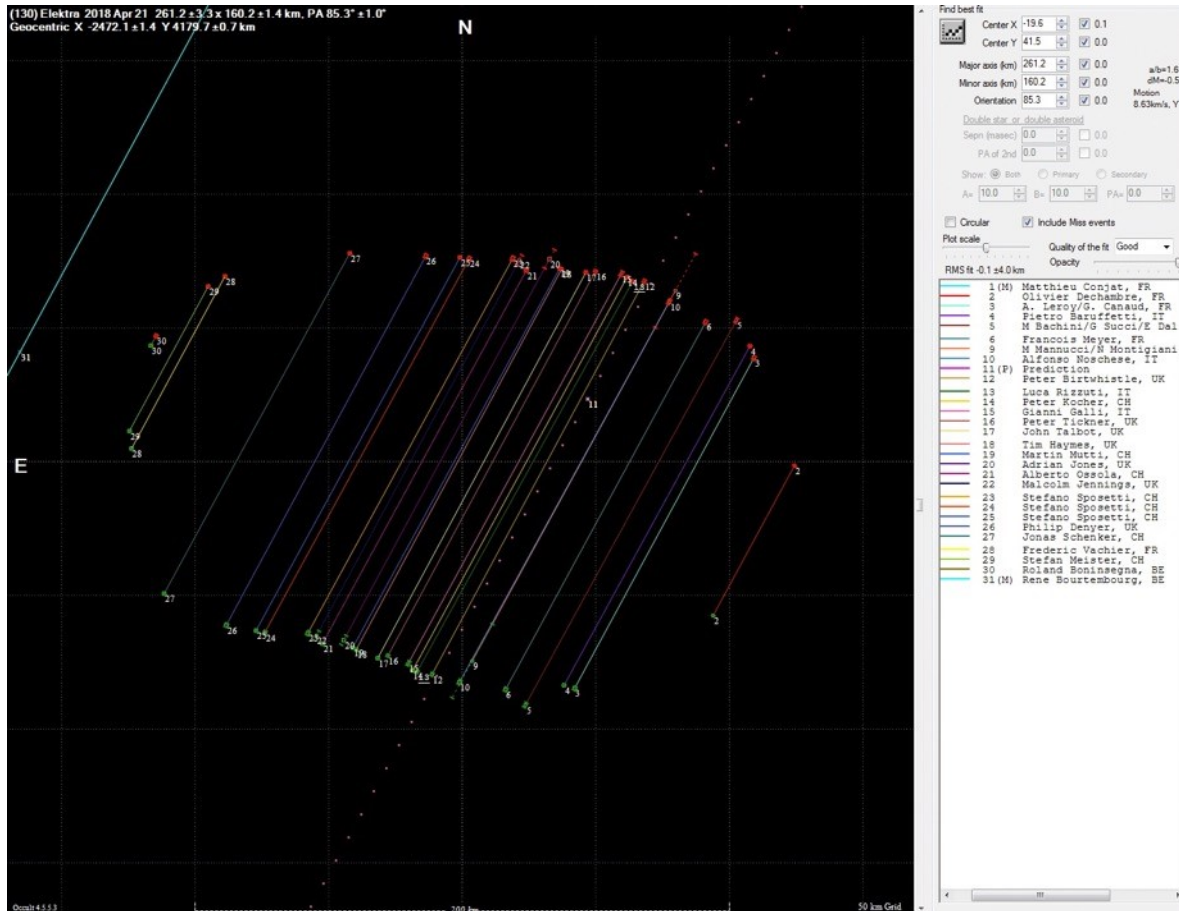


## Stefan Meister

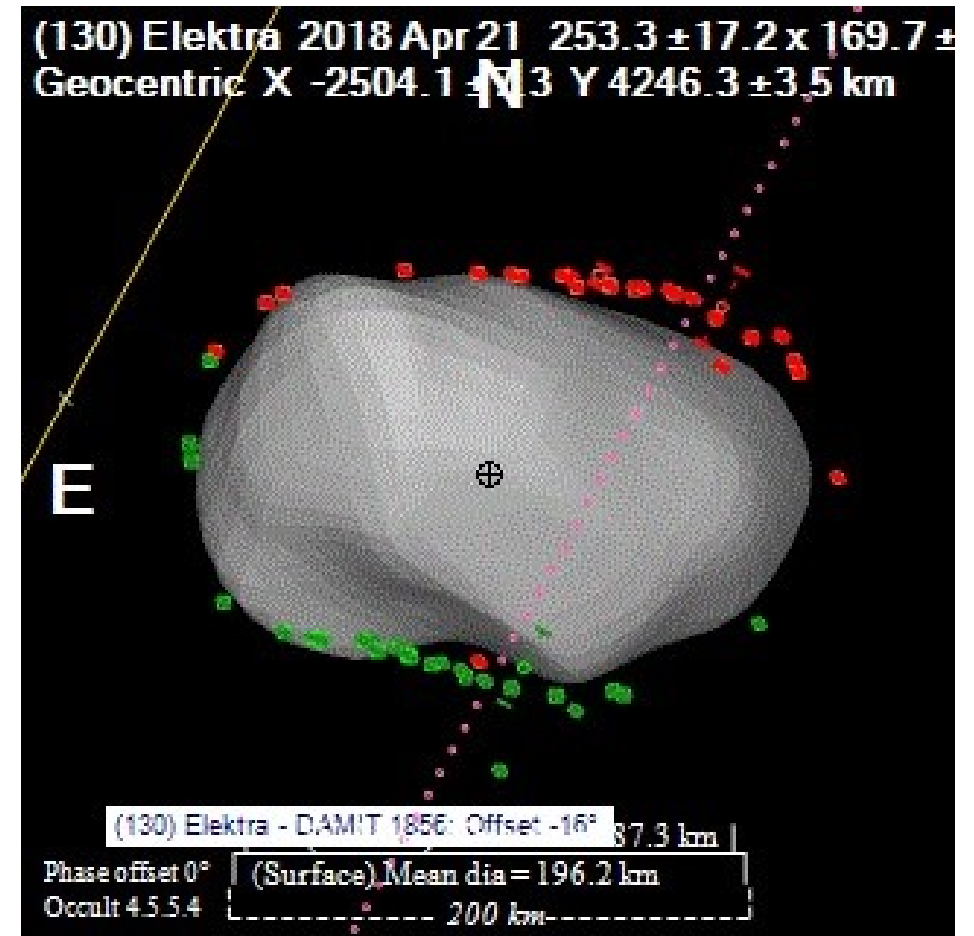
- Working for Mettler-Toledo in Finance & Control
- In the board of the Swiss Astronomical Society (SAG/SAS) and active in various working groups (sun, meteors, exoplanets)
- Other hobbies: cycling, kayaking

# Motivation

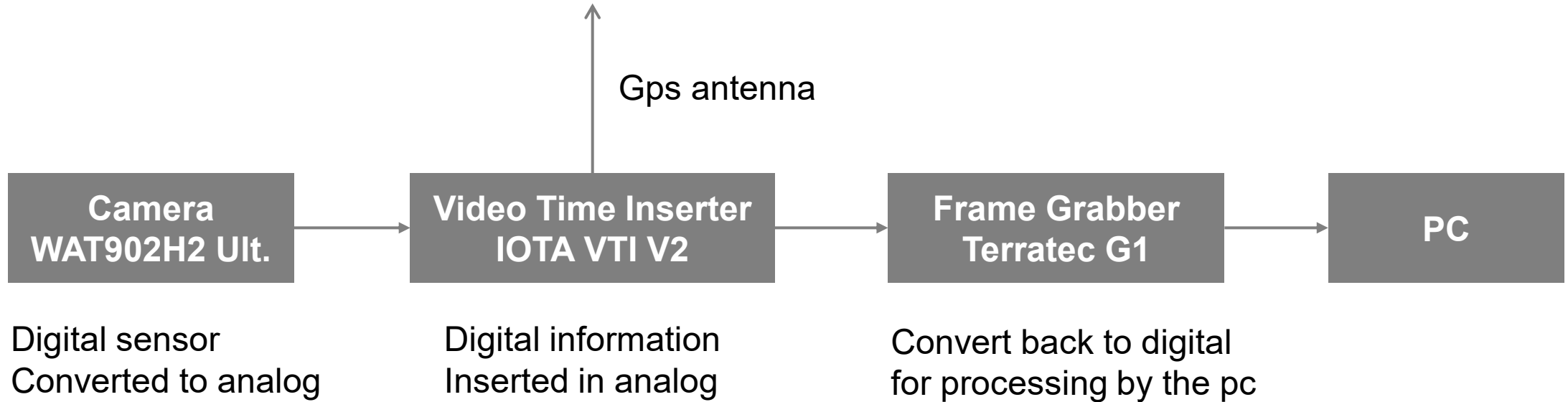
# Motivation



(130) Elektra, 21.04.2018



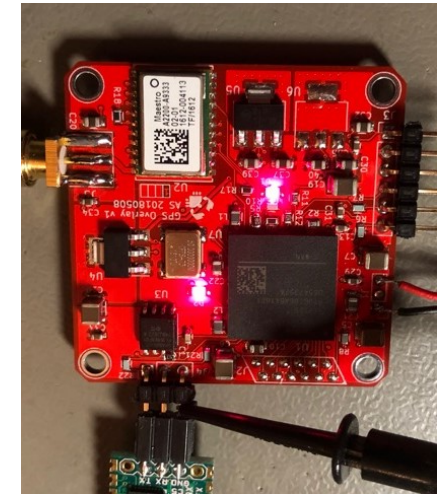
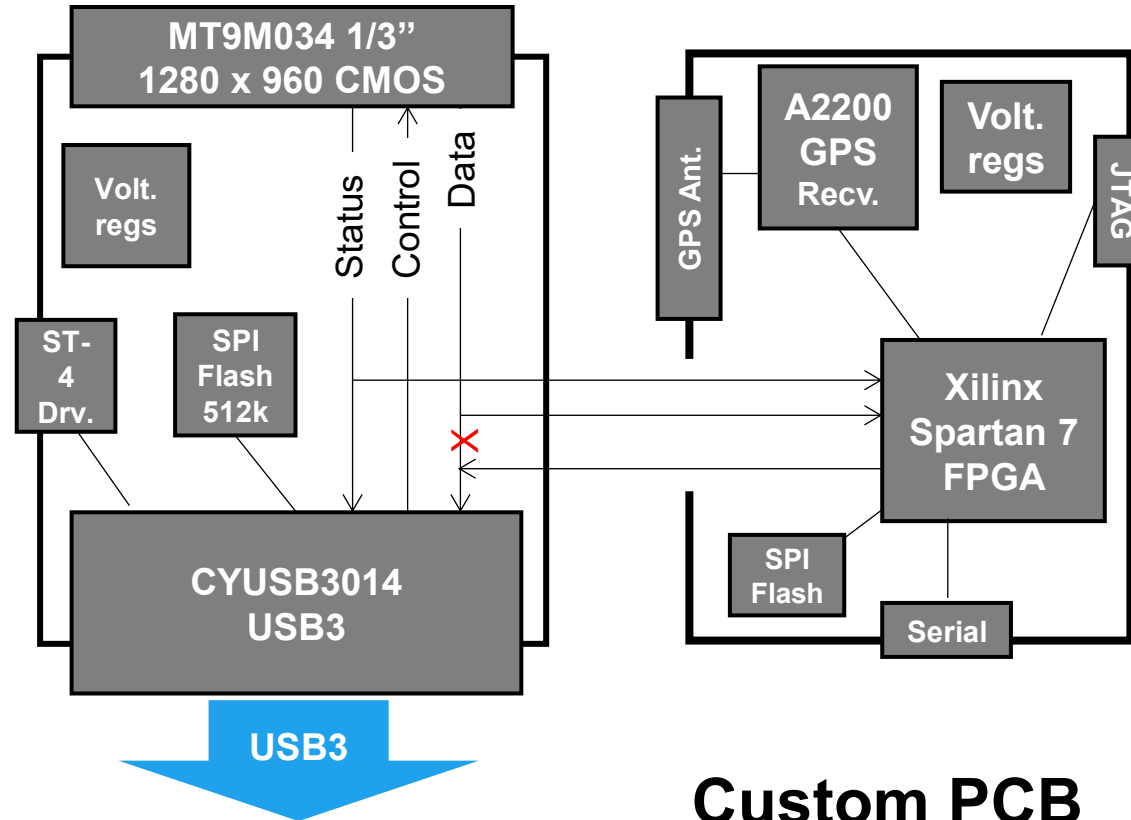
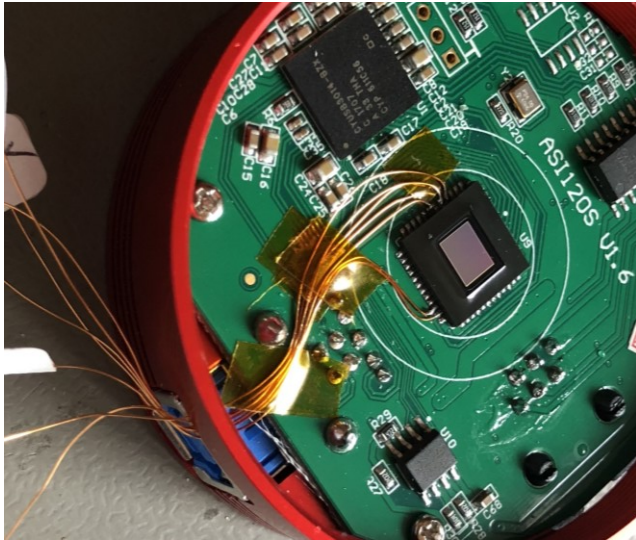
# Motivation



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

# Proof-of-Concept and Prototypes

# Proof-of-Concept



## ASI 120 MM

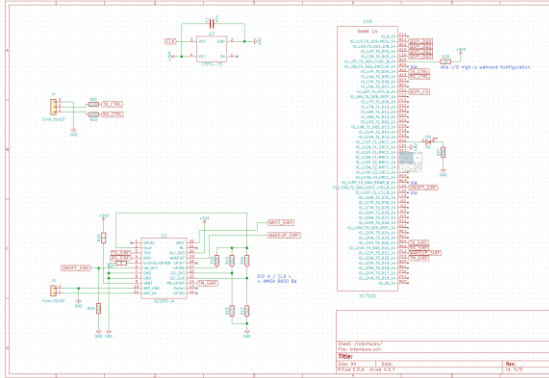
- Cut 2 most significant data lines
- Inject timestamp overlay

## Custom PCB

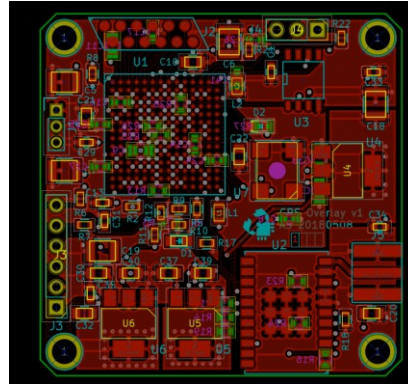
- GPS module, FPGA



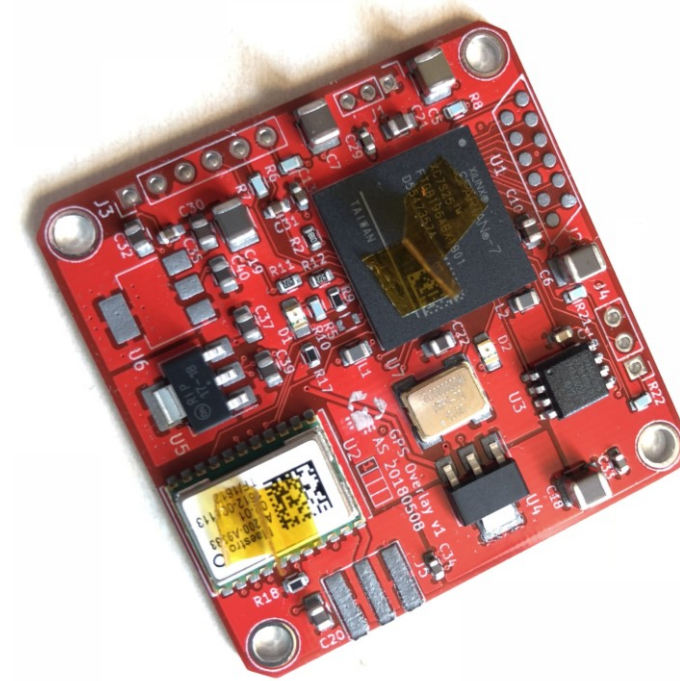
# PoC Development



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):
```

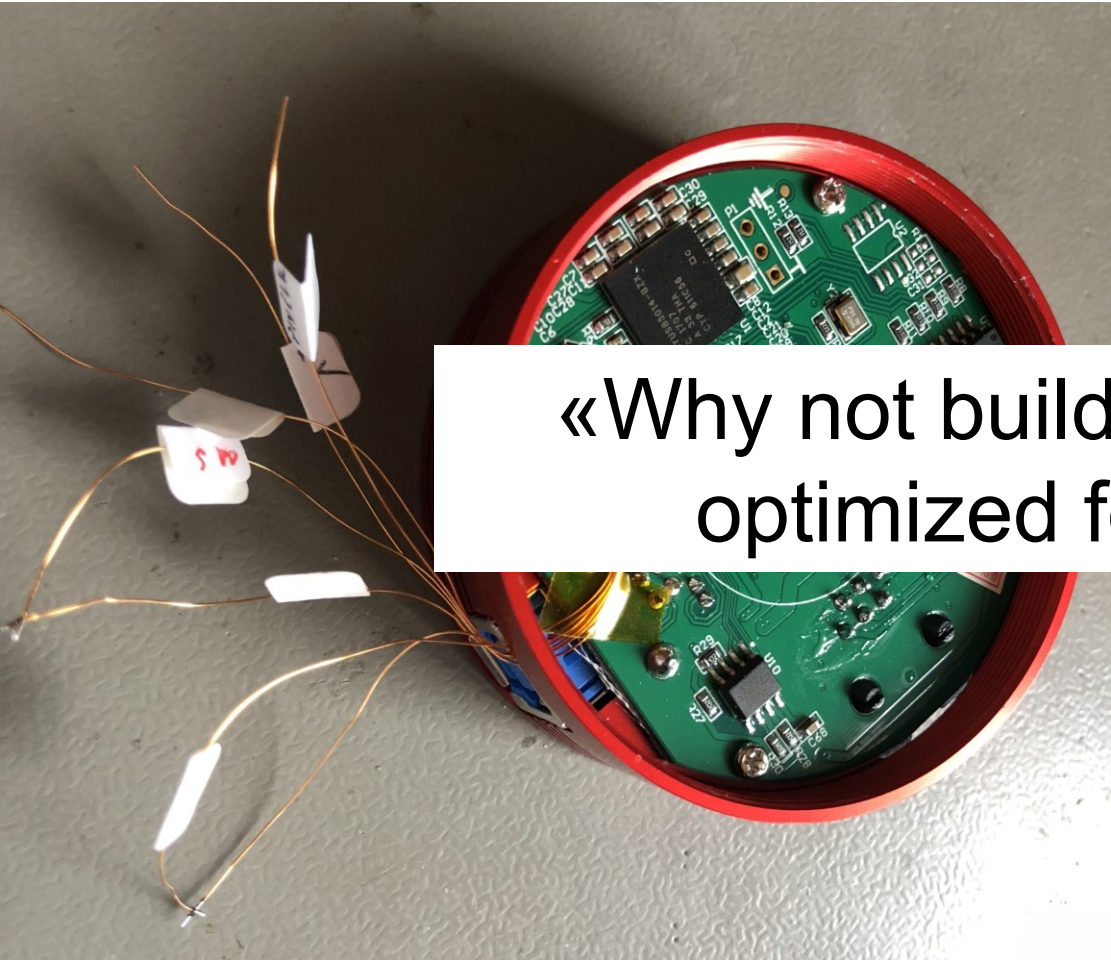
Firmware Code in C

```
Diagram x top.vhd x
C:/Users/andreas/Projects/gpsoverlay/gpsoverlay.srcs/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);
```

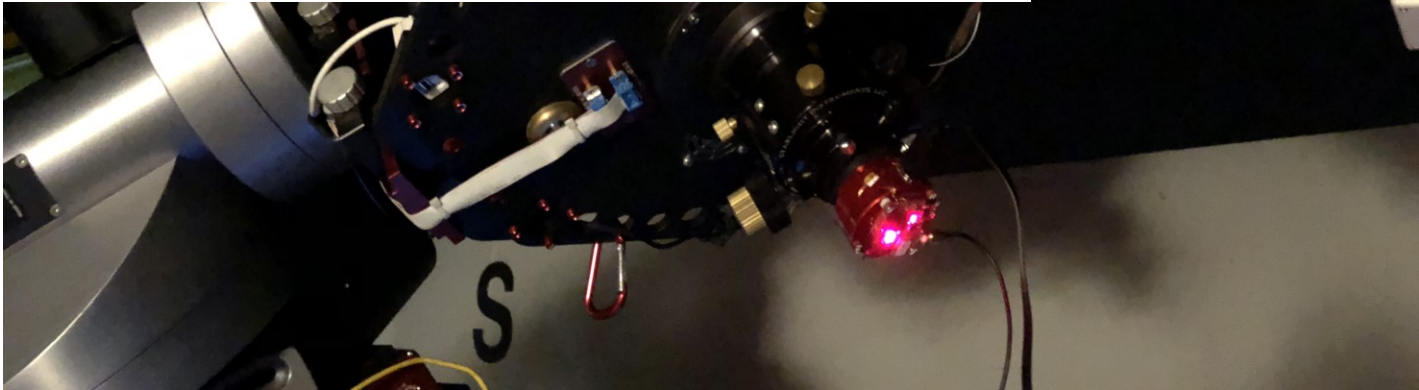
FPGA Design in VHDL



# Proof-of-Concept

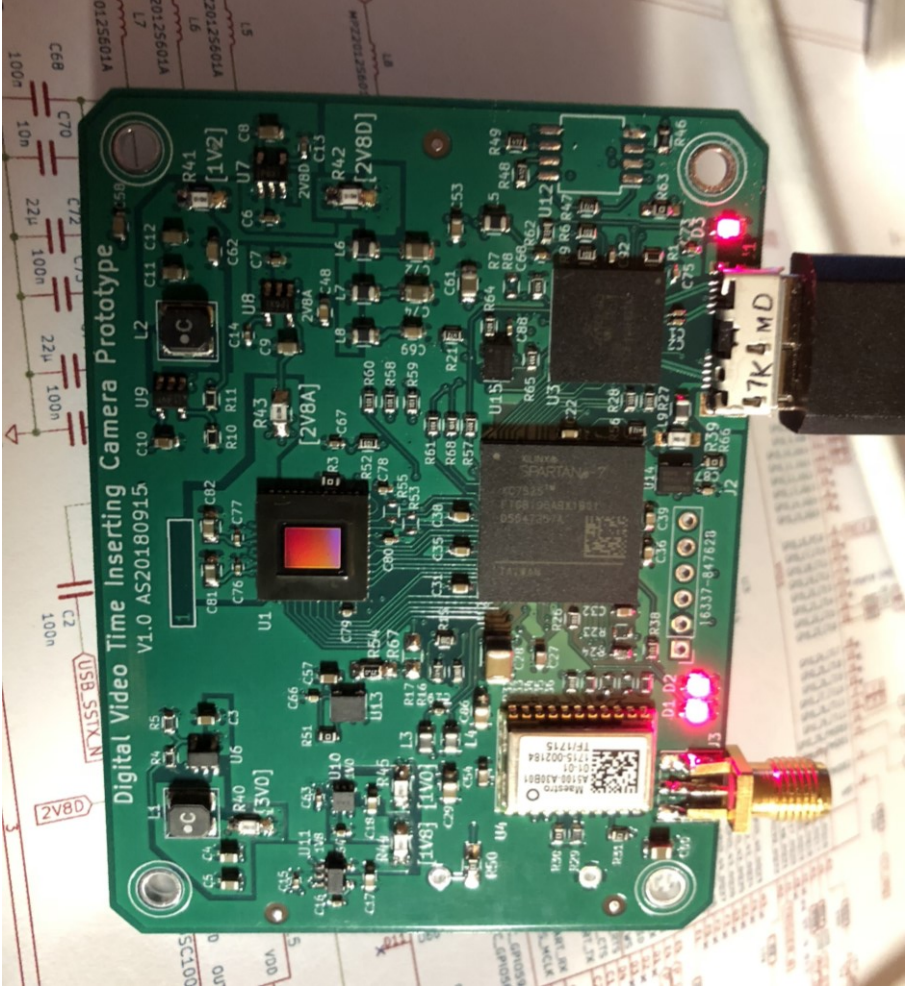


«Why not build a self-contained camera optimized for occultation work?»



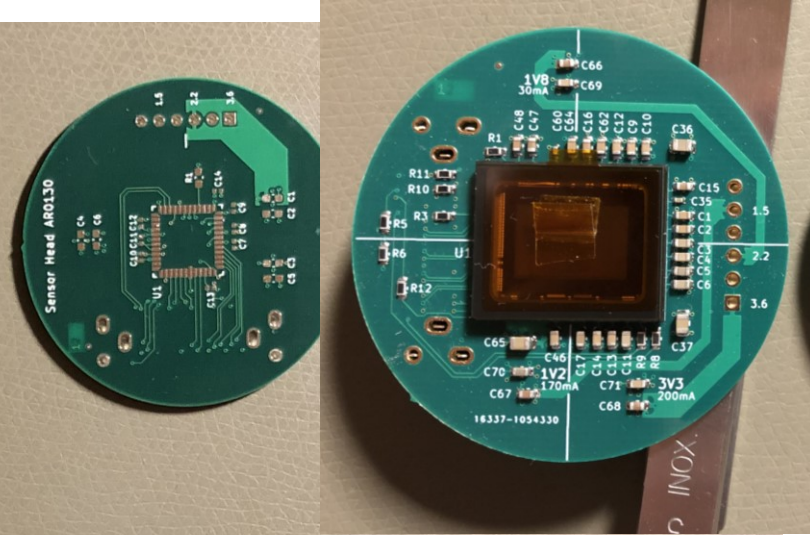


# Prototype V1 (Oct 2018)

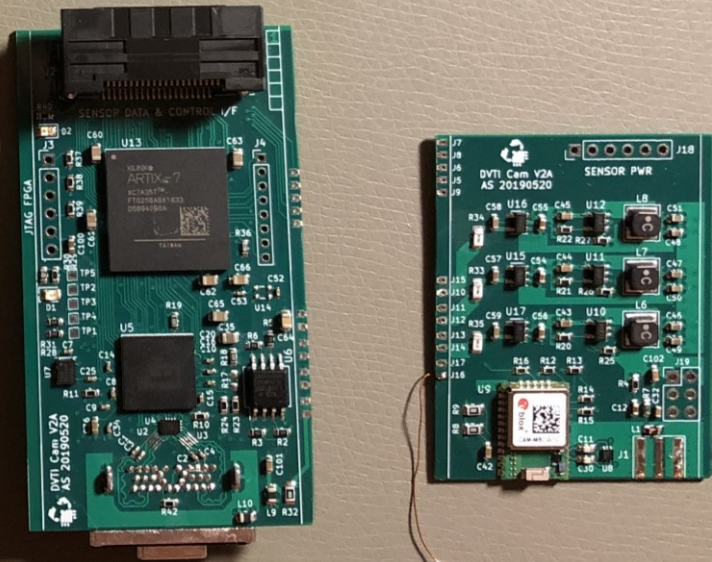




# Prototype V2 (Jun 2019)



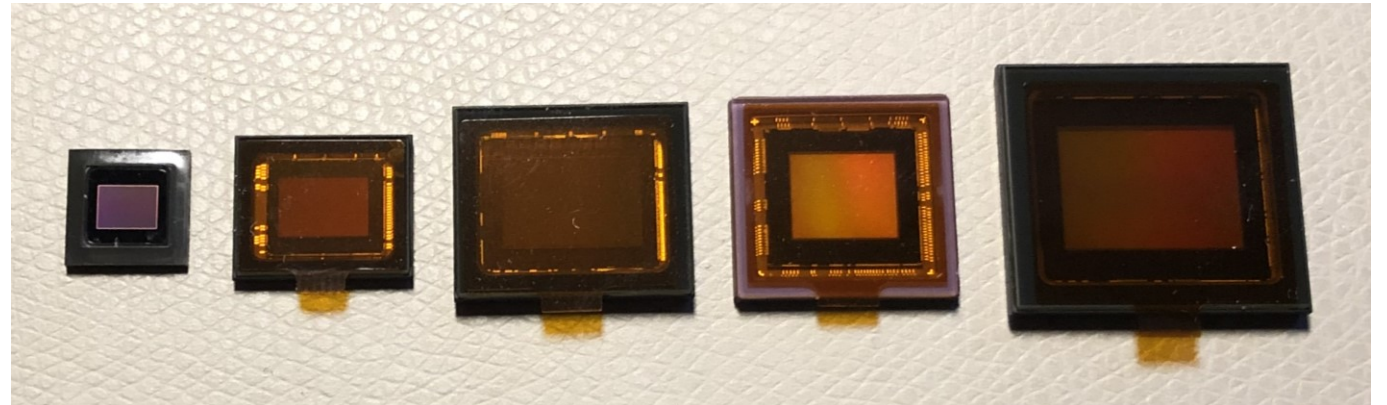
- Sensor plugin module (AR0130, IMX174, ...)
- uBlox GPS module
- Xilinx Artix FPGA
- USB-C connection



# 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

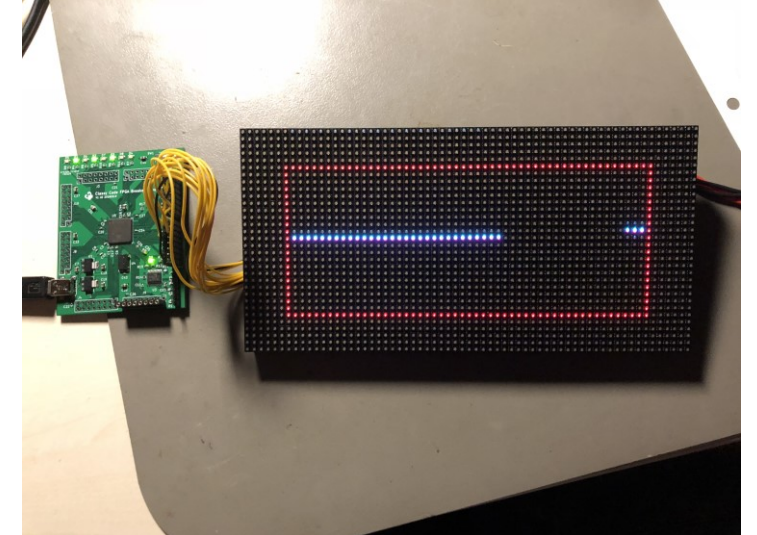
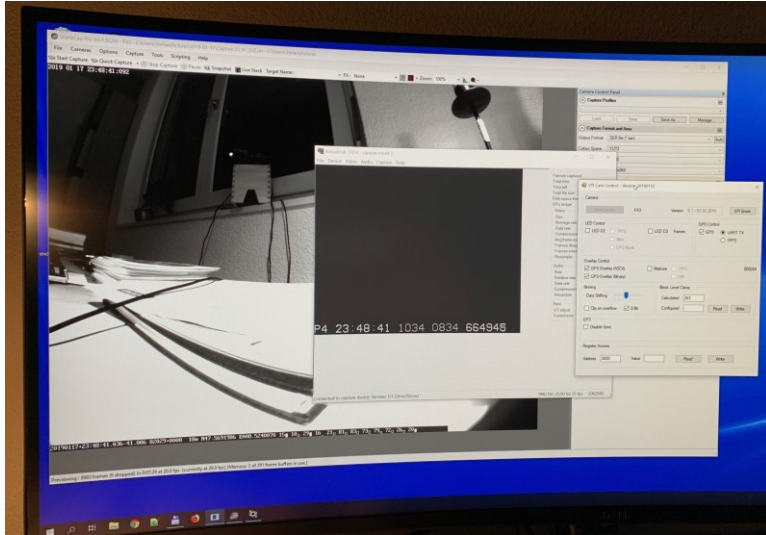
→ Kickstarter Project



# Testing, Results



# Testing (accuracy of time stamp)



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

2 Flash Test (Nikon SB-700)  
Water 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)



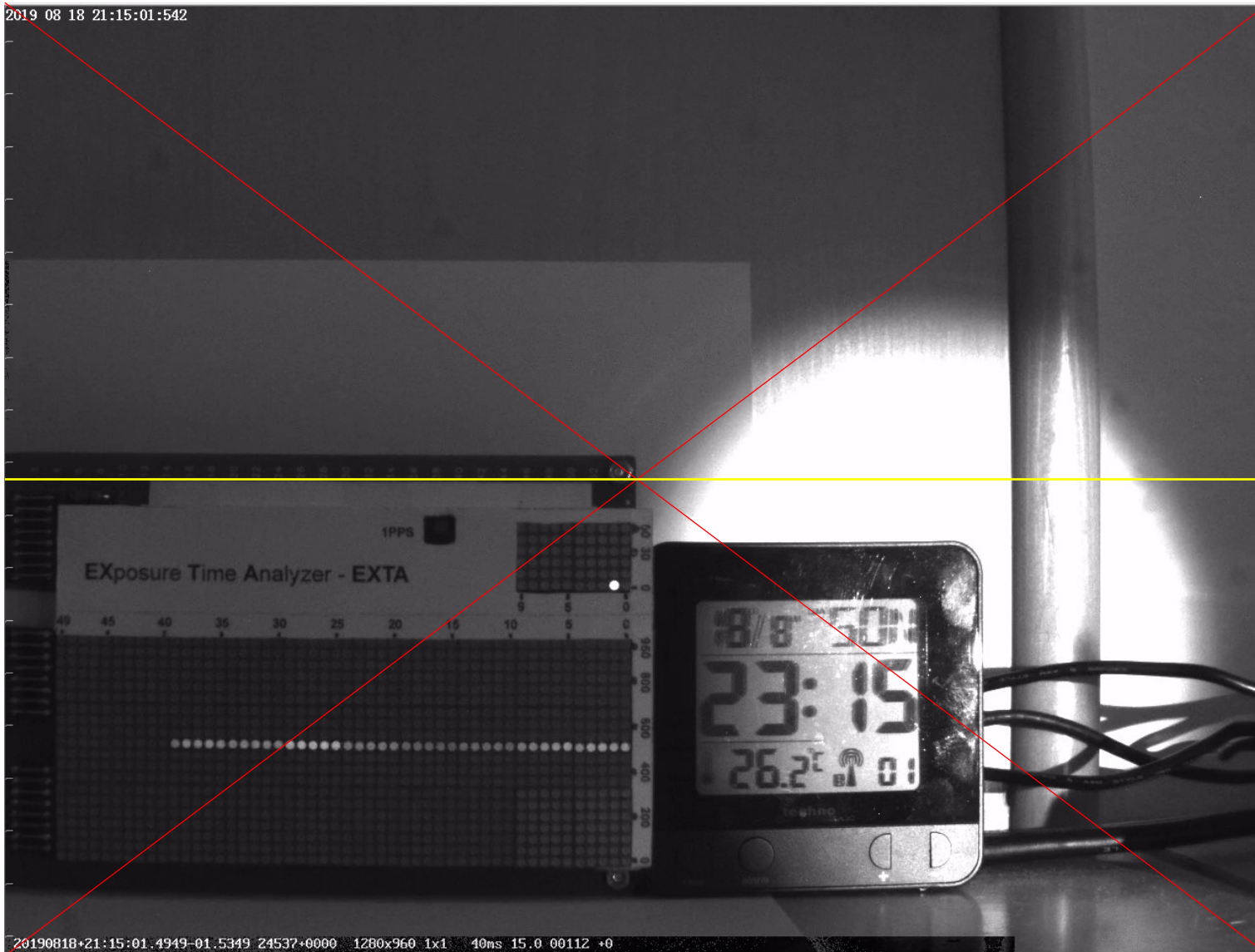
# Results (by Gerhard Dangl)

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	<b>0.002</b>	+/-0.001	
29	2019/08/18	23_17_05	YUY2	Maximum	1280 x 960	1x1	0.010	0.010	0.001	<b>0.012</b>	+/-0.001	
30	2019/08/18	23_17_37	YUY2	Maximum	1280 x 960	1x1	0.005	0.005	0.001	<b>0.017</b>	+/-0.001	
31	2019/08/18	23_18_10	YUY2	Maximum	1280 x 960	1x1	0.002	0.002	0.001	<b>0.020</b>	+/-0.001	
32	2019/08/18	23_18_26	YUY2	Maximum	1280 x 960	1x1	0.001	0.001	0.001	<b>0.021</b>	+/-0.001	
33	2019/08/18	23_19_21	YUY2	Maximum	1280 x 960	1x1	0.020	0.020	0.001	<b>0.002</b>	+/-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	<b>0.637 - 0.640 *</b>	0.001	0.000	+/-0.001	
39	2019/08/18	23_26_44	YUY2	Maximum	1280 x 960	1x1	1.280	<b>1.300 - 1.320 *</b>	<b>0.025 *</b>	0.000	+/-0.002	
40	2019/08/18	23_29_06	YUY2	Maximum	1280 x 960	1x1	2.560	<b>2.615 - 2.635 *</b>	<b>-0.01 *</b>	0.000	+/-0.005	
									<b>* different values possible</b>			
<b>Hardware:</b> 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												
<b>Software:</b> 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

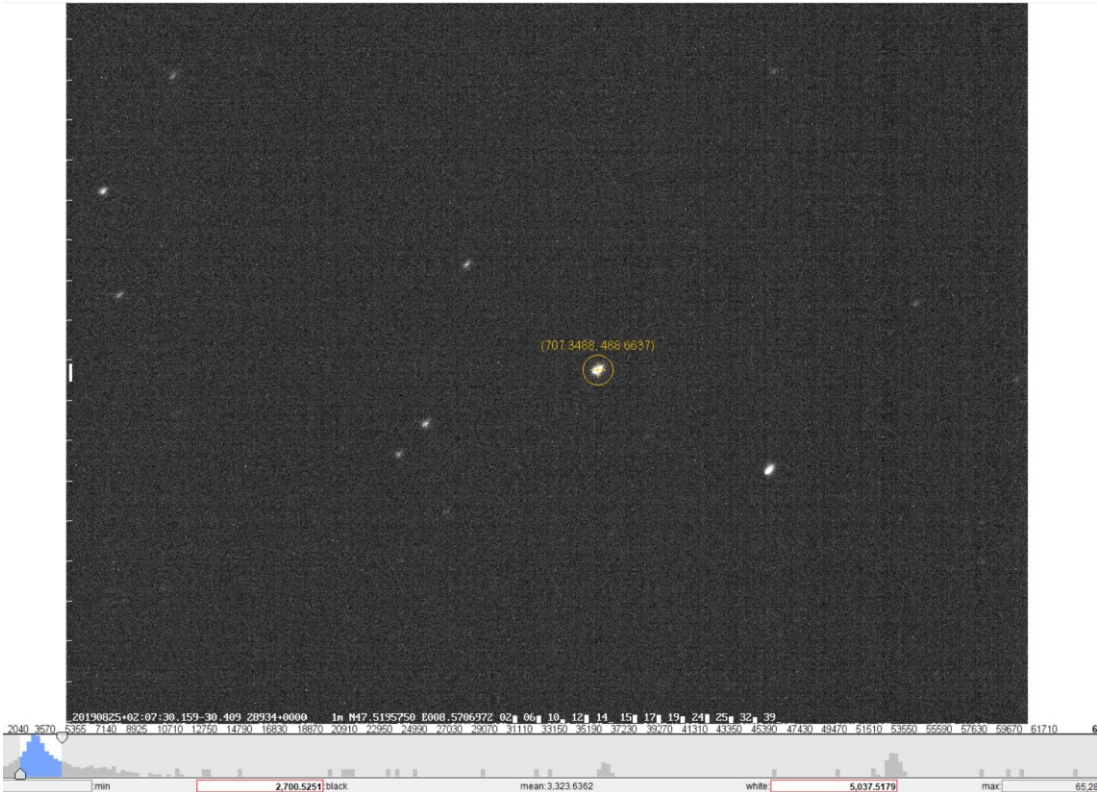


«Home Base» Observatory Bülach, Switzerland (MPC 167)



# 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.

→ 20190825+02:04:59.706-59.746 26607+0000 1m N47.5195





# Demo



Software interface showing a table of data. The table has columns for 'Menge', 'Preis', 'Werk', 'Kategorie', 'Status', and 'Anzahl'. The data is organized into several rows, with some cells containing numerical values and others containing text or symbols.

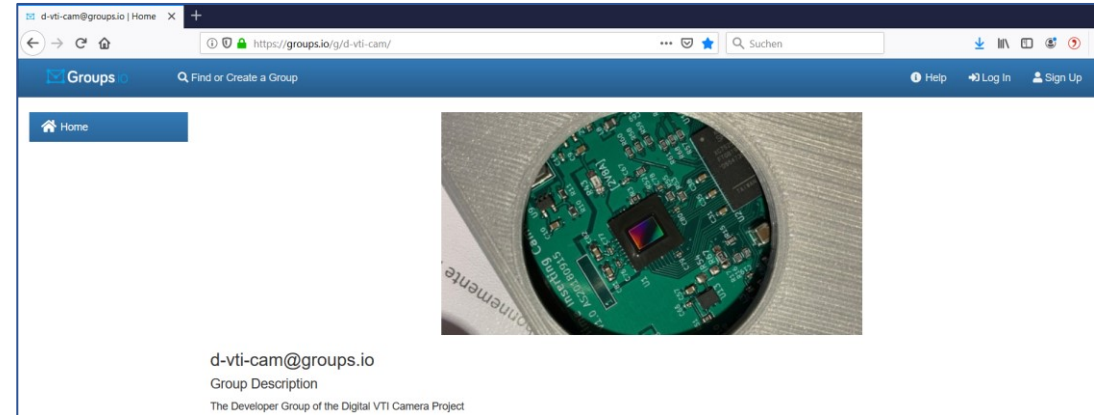
Menge	Preis	Werk	Kategorie	Status	Anzahl
10	100	100	100	100	100
20	200	200	200	200	200
30	300	300	300	300	300
40	400	400	400	400	400
50	500	500	500	500	500
60	600	600	600	600	600
70	700	700	700	700	700
80	800	800	800	800	800
90	900	900	900	900	900
100	1000	1000	1000	1000	1000

# Thank you!

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Stellar Occultation Timing  
Association Switzerland (SOTAS)  
[www.occultations.ch](http://www.occultations.ch)



The DVTI Cam Project Website:  
[groups.io/g/d-vti-cam](https://groups.io/g/d-vti-cam)