Underwater laser scanning: Integration and testing on a survey vessel

Hydro 2024

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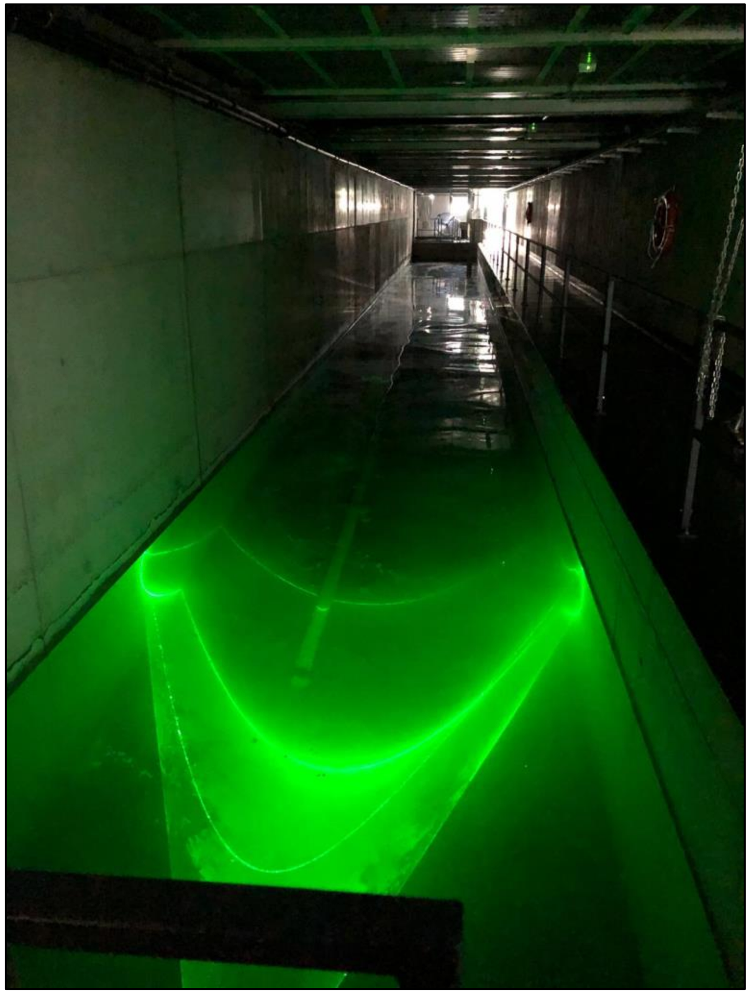
Motivation

Advantages of the new underwater laser scanner

- Higher accuracy and resolution in comparison to acoustic instruments
  - Precision in the range of millimeters
  - Sensor outperforms conventional sonar systems by a factor of 10
  - More accurate and detailed capture of objects
- Usage of ToF
  - Range in turbid waters is three times larger compared to other optical systems
- Delivers a full waveform
  - Derivation of more information compared to a single pulse return
  - Habitat Mapping, detection and analysis of underwater vegetation etc.

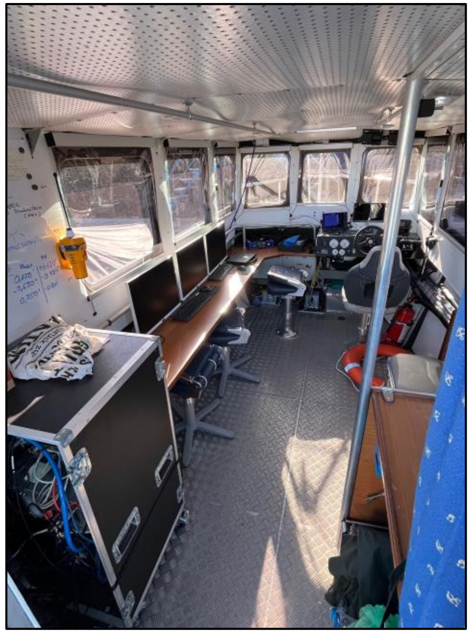
→ Testing the performance in different water bodies (turbidity)

→ Comparison of ULi to acoustic instruments (ULi vs. MBES)

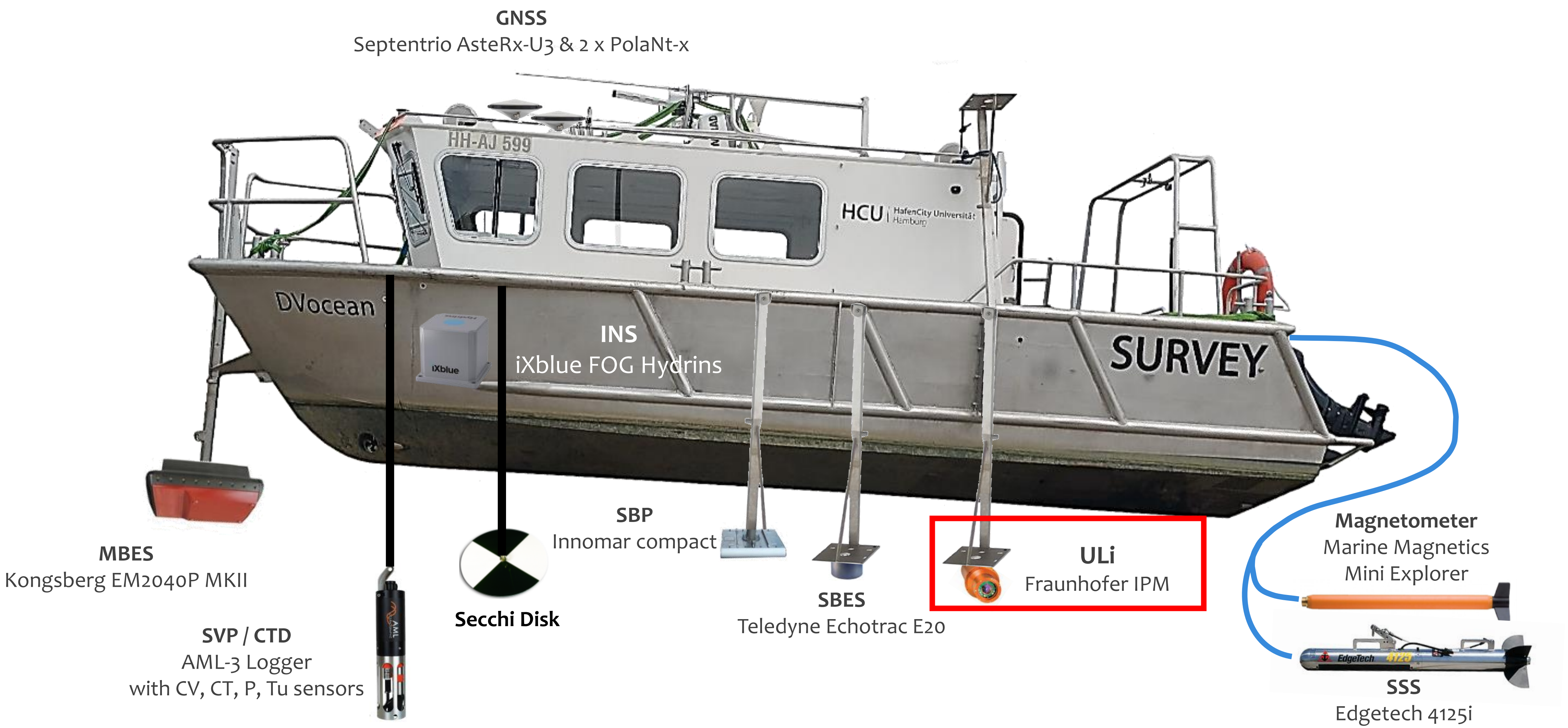


Survey Vessel: DVocean

- Size (L x W x H): 8 m x 2.55 m x 2.8 m (trailerable), max. draught: 0.875 m
- Area of use: Shallow water area (inland waters, coastal areas)
- 3 computer workstations
- 3 poles (holders for underwater instruments)
- Possibility to deploy probes and towed sensors



DVocean: Hydrographic Equipment

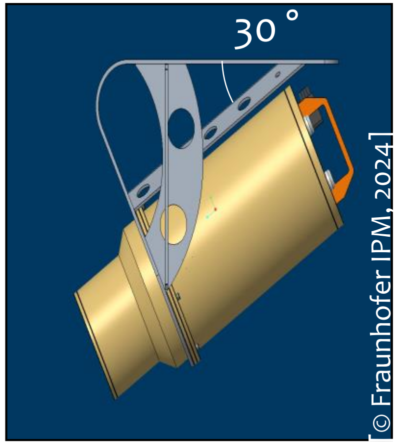


DVocean: Mounting of ULi

Considerations

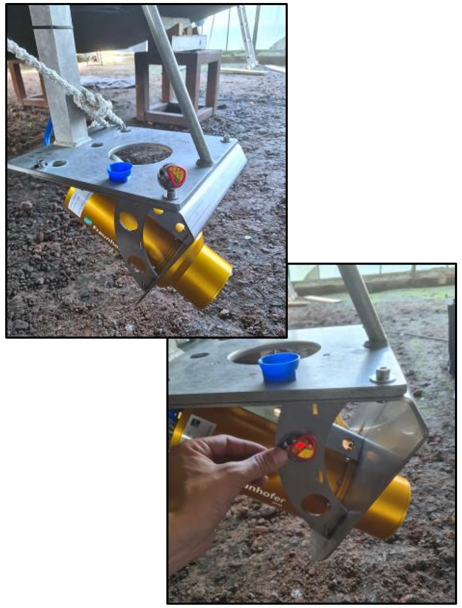
- Lateral mounting on the port side pole to gather reflections from infrastructure elements such as brige foundations or quay walls
- Construction of a stable frame which can be screwed onto the plate of the side pole to allow for a flexible mounting and demounting procedure of ULi
- Quick lowering and raising of ULi into the water by folding down the pole with a leash
- Use of tensioning straps to minimize the movement of the pole in the water due to e.g. currents



DVocean: Calibration of ULi

- Calibration of the ULi by Jannis Gangelhoff from the Fraunhofer IPM
- Determination of the coordinates by using a Leica Absolute lasertracker and spherical mounted reflectors
- Integration into the ship coordinate system using the fixed based adapters on board of the DVocean



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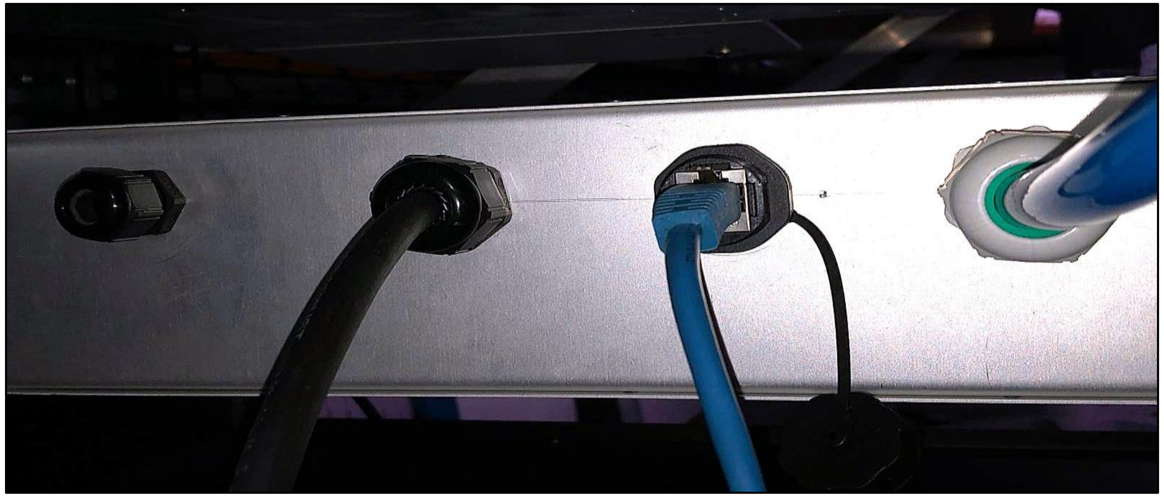
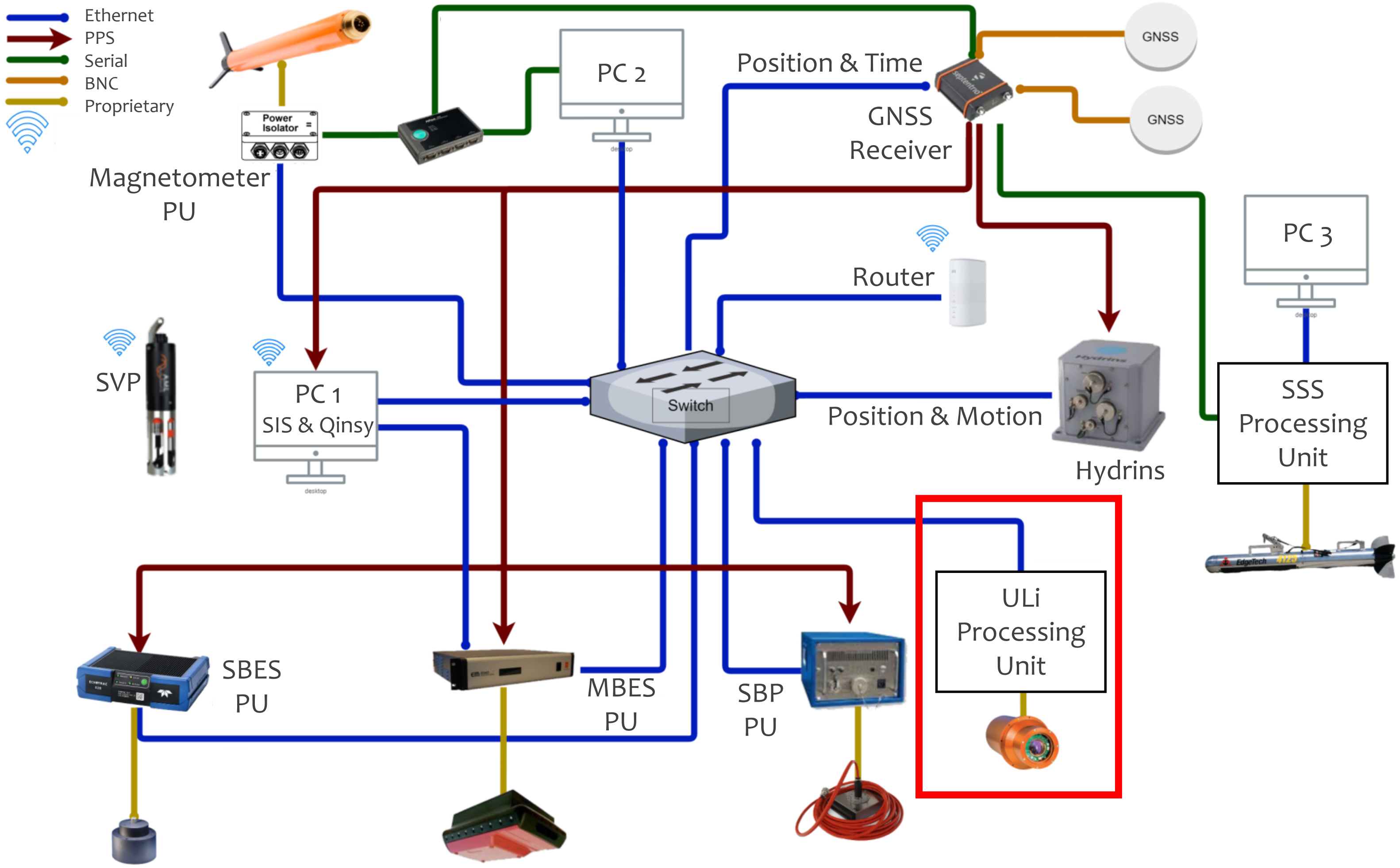
DVocean: Hardware Installation of ULi

- Processing Unit of ULi inside the ship
- Backside with 3 cable connection inputs:
  - 1 x to 24 V power supply
  - 1 x Ethernet to Switch
  - 1 x proprietary blue cable to the sensor for power supply and data transmission
- Frontside with:
  - Pressure switch
  - Lock to start the scanner in 3B mode
  - Laser On Lamp
  - Power OFF / ON switch



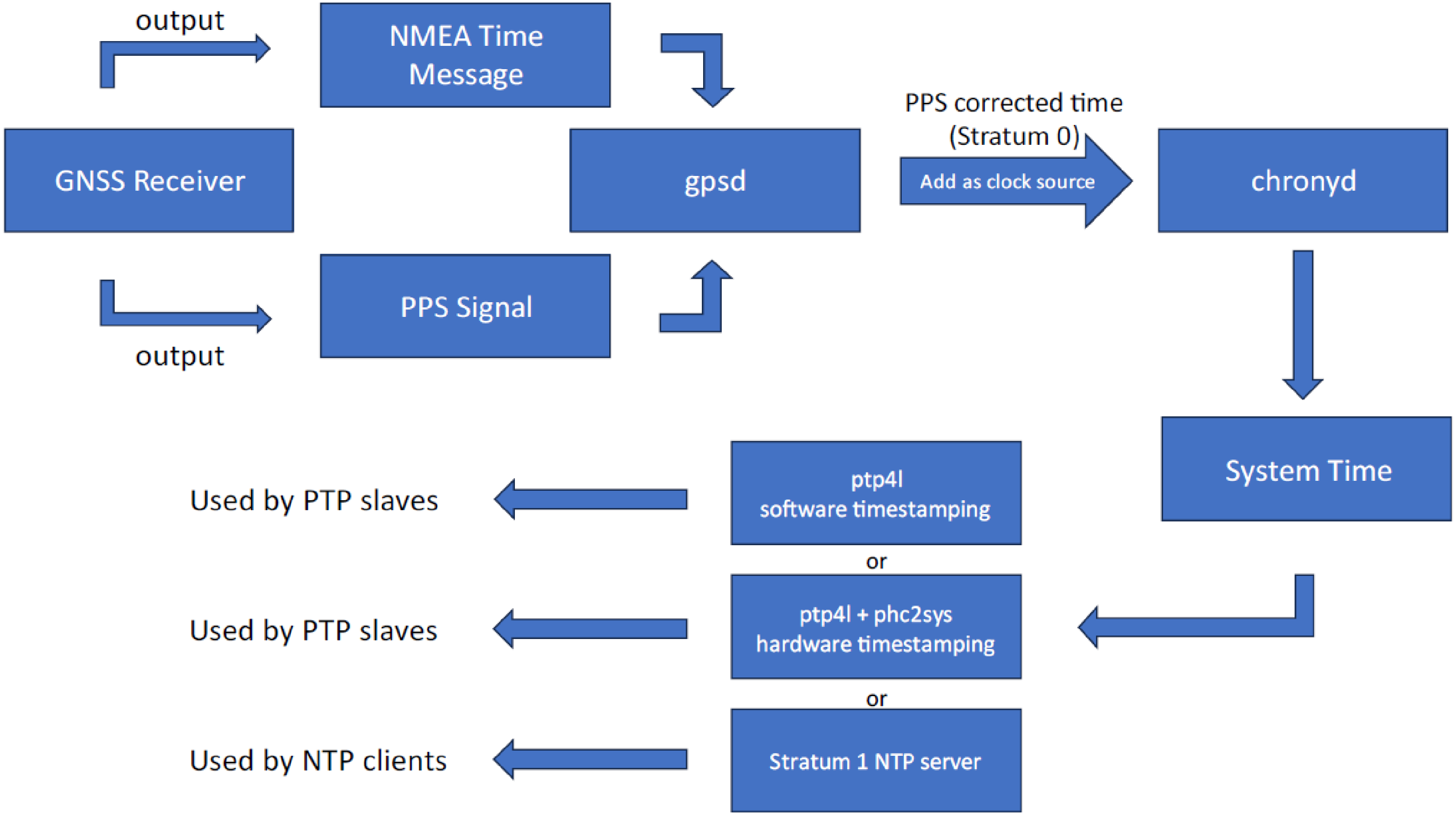
DVocean: Network Integration of ULi



DVocean: Time Synchronisation of ULi

- Objective:
  - Time synchronisation via Precise Time Protocol (PTP) in the local ship network
- Realization:
  - Hardware:
    - Ublox EVK-M8T evaluation kit (GNSS receiver) to provide PPS via an RS232 serial port
    - Raspberry Pi 5 Model B Rev 1.0 to generate a PTP signal
  - Software:
    - Ubuntu Time Server with several software packages including **gpsd, chronyd and linuxptp**

DVocean: Time Synchronisation of ULi



DVocean: Time Synchronisation of ULi

- Software timestamping resulting in:

PTP	NTP Pi	NTP AsteRx
≈ 80 µs	≈ 347 µs	≈ 15 ms

- Current issues in the integration of the PTP server into the backend of the ULi software leads to the usage of NTP

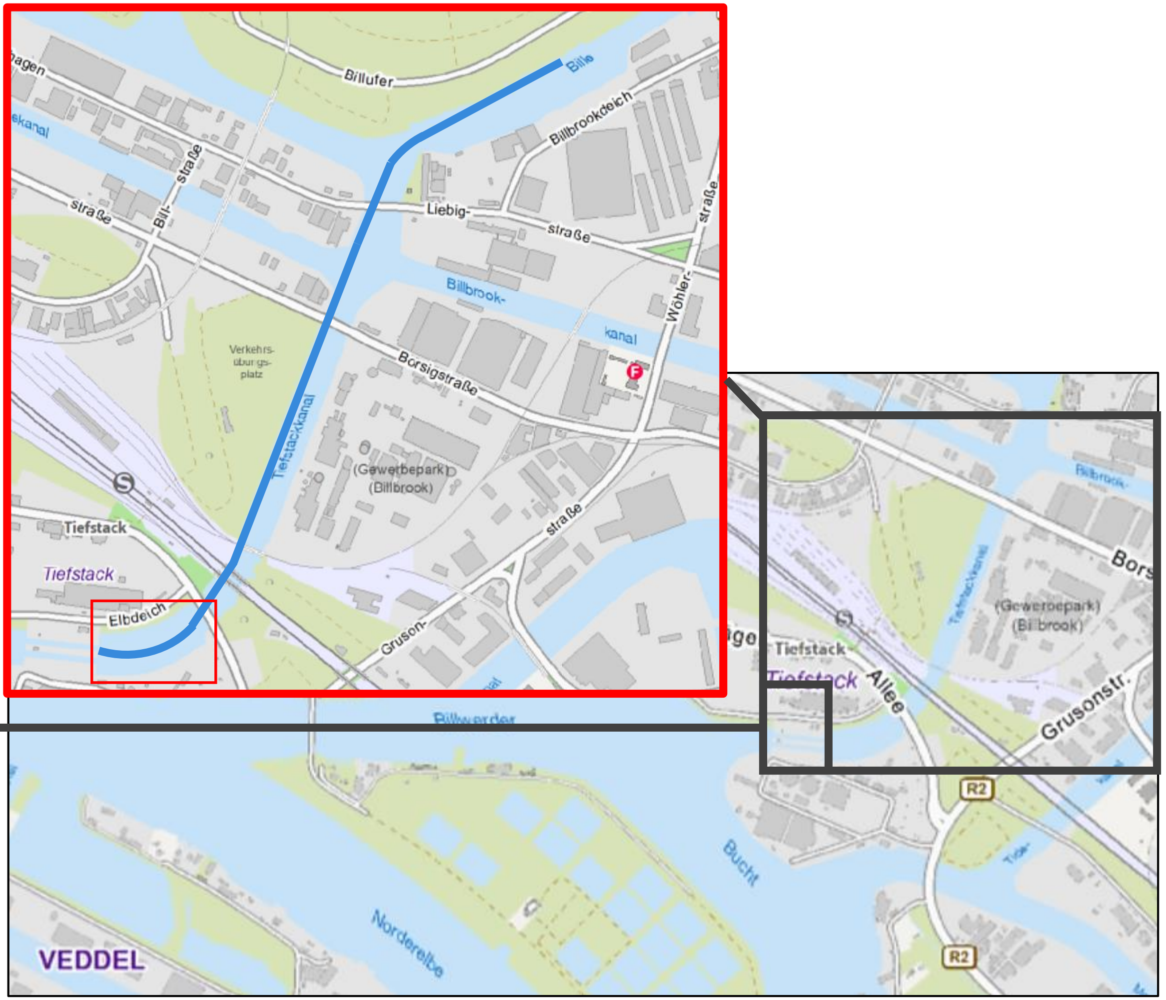
```
Every 0.1s: chronyc sources -v                    ciam-XMG: Fri Oct 25 11:41:15 2024

  .-- Source mode  '^' = server, '=' = peer, '#' = local clock.
 / .- Source state '*' = current best, '+' = combined, '-' = not combined,
| /             'x' = may be in error, '~' = too variable, '?' = unusable.
||                                                 .- xxxx [ yyyy ] +/- zzzz
||      Reachability register (octal) -.           |  xxxx = adjusted offset,
||      Log2(Polling interval) --.      |          |  yyyy = measured offset,
||                                \     |          |  zzzz = estimated error.
||                                 |    |           \
MS Name/IP address         Stratum Poll Reach LastRx Last sample
===============================================================================
#* PTP                           1   2   377     7    +22us[  +27us] +/-   80us
^- prod-ntp-3.ntp1.ps5.cano>     2   6   377    37    -11ms[  -11ms] +/-   27ms
^- prod-ntp-3.ntp1.ps5.cano>     2   7   377   119  -6734us[-6744us] +/-   27ms
^- prod-ntp-4.ntp4.ps5.cano>     2   7   377   119  -8737us[-8746us] +/-   38ms
^- alphyn.canonical.com          2   7   377   119    +36ms[  +36ms] +/-  112ms
^- 64:ff9b::6bbd:c62             3   7   377   121  -7191us[-7192us] +/-   27ms
^- 64:ff9b::b90d:9447            2   7   377   124    -12ms[  -12ms] +/-   22ms
^- 2a01:4f8:121:1061::2          2   7   377   125    +13ms[  +13ms] +/-   53ms
^- dc8wan.de                     2   7   377    59  -9059us[-9105us] +/-   42ms
^? 192.168.0.104                 0   9     0     -    +0ns[   +0ns] +/-    0ns
^- 192.168.36.166                1   7   377    55   -120us[ -131us] +/-  347us
^- 192.168.36.150                1   6   377    48  -3079us[-3117us] +/-   15ms
```

HafenCity Universität Hamburg

DVocean: First test survey of ULi

- Survey on 25.10.2024 in the Tiefstackkanal / Hamburg
  - Lock seperates the area from the main channel of the Elbe
  - Less sediment entry and lower amount of salinity offer the chance for clearer water conditions with less turbidity

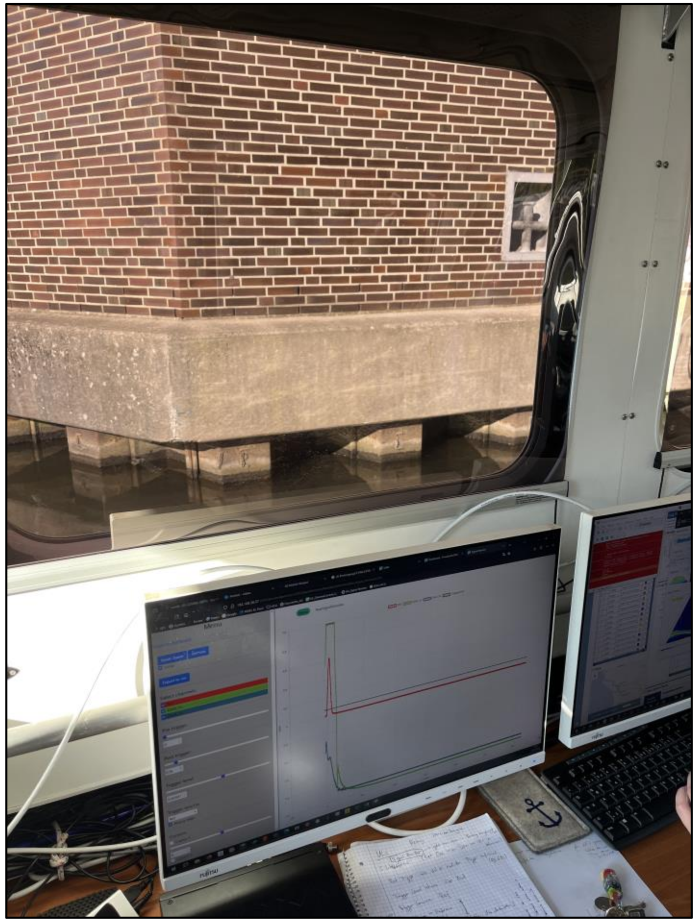


DVocean: First test survey of ULi

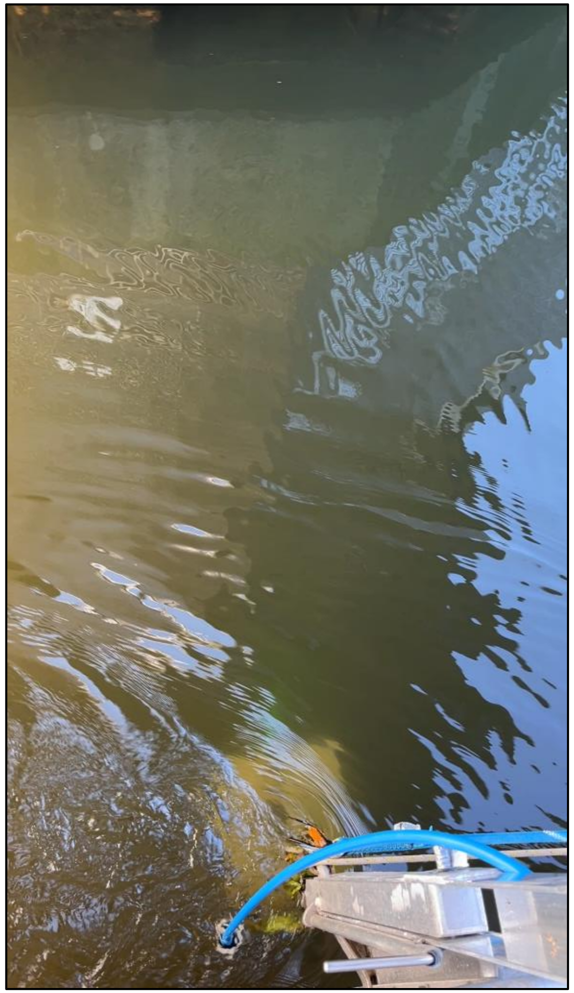
- Measurement of turbidity prior to the survey using the AML-3 Logger and a secchi disk
- Probe results:
  - Ø Turbidity: 6 NTU
  - Secchi Depth: 1.10 m
- Remarks:
  - Higher clearance in comparison to the main channel:
  - Ø Turbidity: 8.6 NTU
  - Secchi Depth: 0.79 m
  - Higher clearance expected in spring

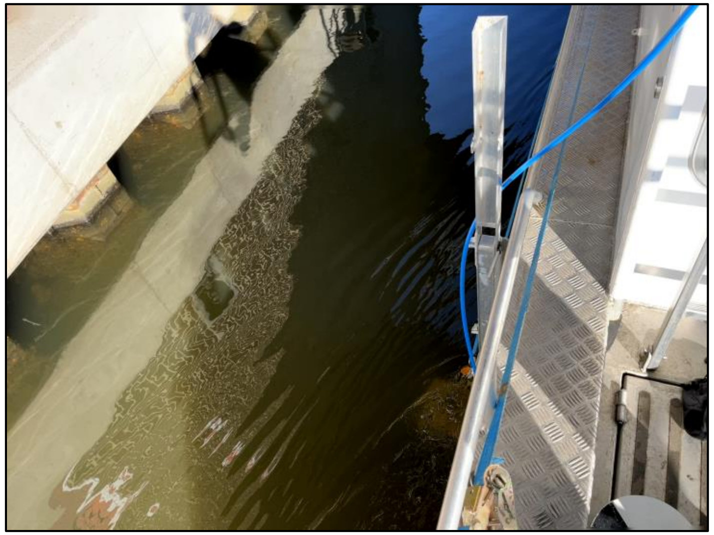
DVocean: First test survey of ULi

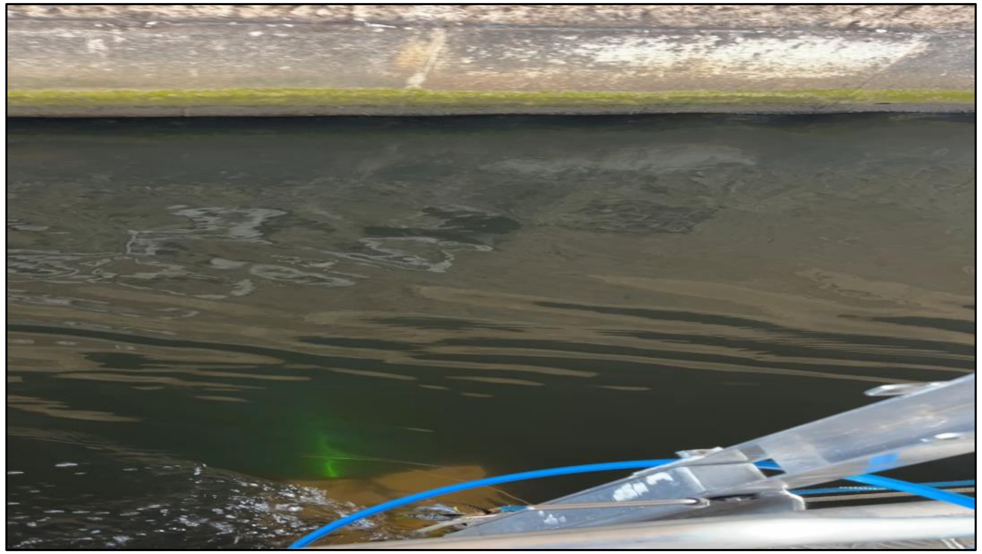
- Survey along mooring dolphins, a laying brage and bridge foundations



DVocean: Impressions from the test survey

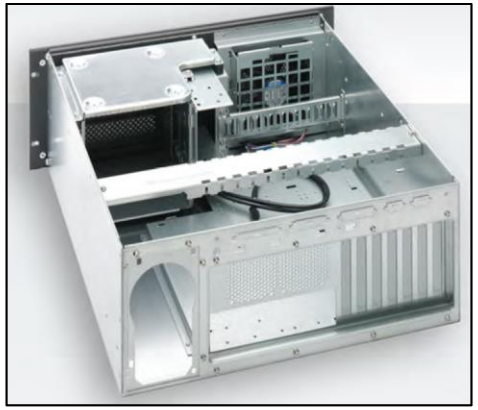






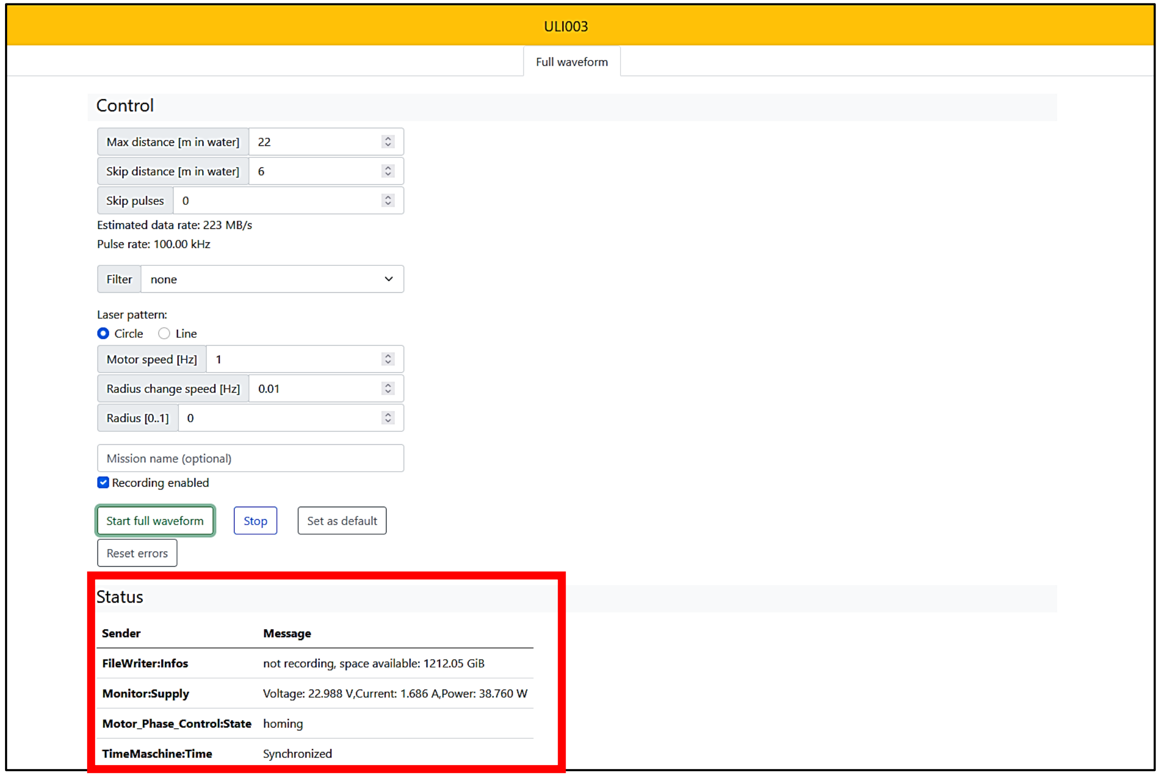
DVocean: Data acquisition with PC

- Input data rate: Up to 100.000 points per second
- Rack PC with:
  - IP54 protection class on the front panel
  - IP20 protection class
  - Vibration dampers for shock protection
  - Cooling Fan 60 mm
  - 64 GB RAM
  - CPU Core i7-14700



DVocean: Data acquisition software of ULi

- Colour Bar indicates the status of the Laser
- Specify certain parameters i.e. max distance
- Select Filter Mode:
  - Adjustment (Laser class 2 M)
  - Medium (Laser class 3 B)
  - None (Laser class 3 B)
- Set the Laser Pattern:
  - Circular
  - Linear
- Start the measurement



DVocean: Data acquisition software of ULi

- Displayed Signals:
  - Red:

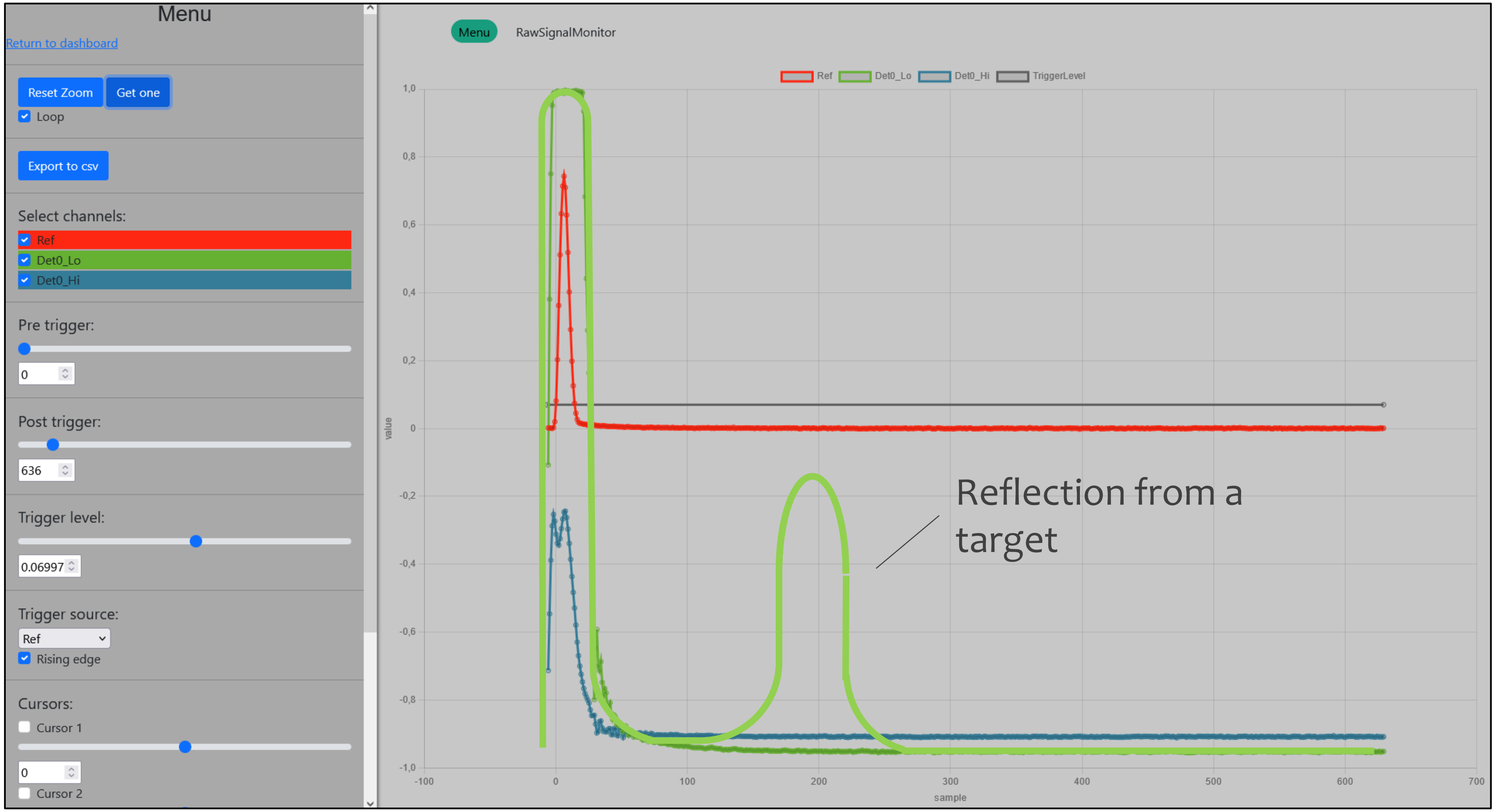
    Internal Reference Signal
  - Blue:

    Less sensitive channel
  - Green:

    Sensitive channel:

    Attenuation of the

    signal by factor 10



DVocean: Data acquisition and processing - Motion

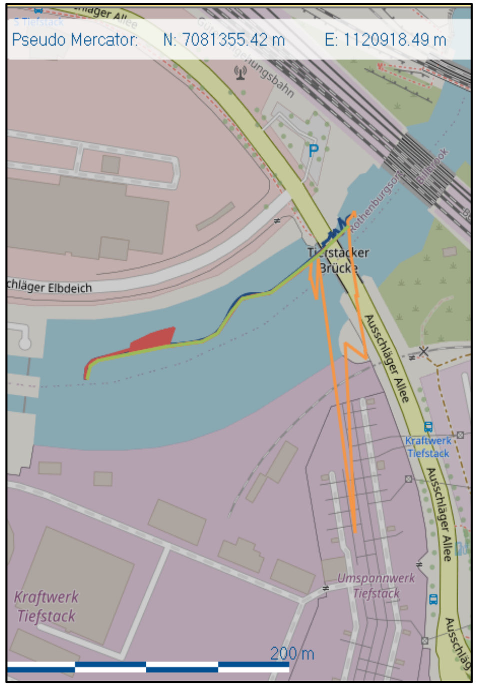
- iXBlue MultiLogger software to record the raw motion data from the motion sensor Hydrins
- Combination of the point cloud from ULi and the respective trajectory from the motion data in the post-processing

Therefore:

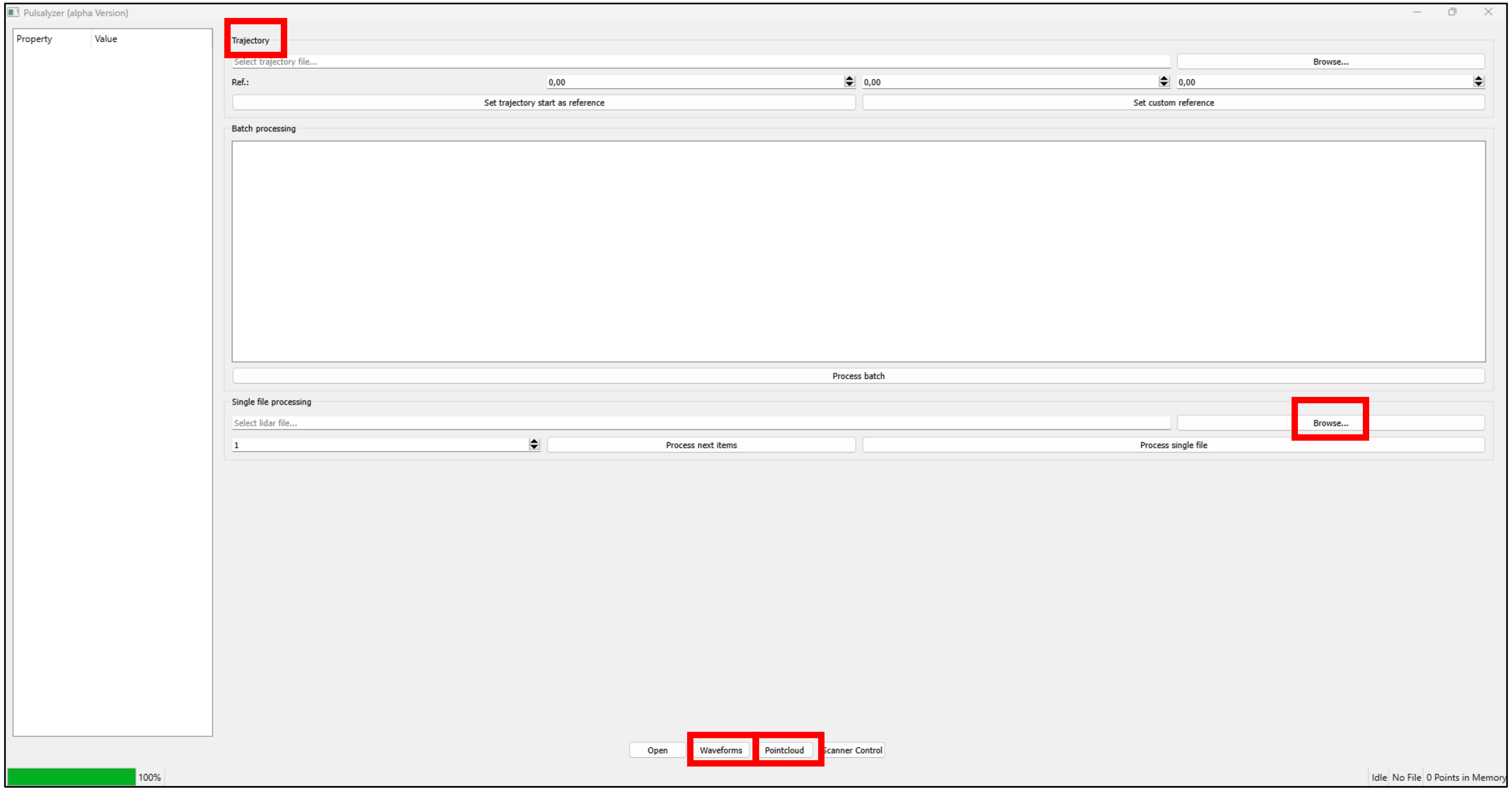
- Smoothing (green) of the trajectories under bridges (blue) using a Kalman Backward (purple) - and Forward (green) Filter using Delph INS
- Export the trajectory to a text-based Ascii file with time, position and orientation
- Ascii file can be imported into the post-processing software of ULi

exail iXMultiLogger
App

Delph INS
App



DVocean: Post-Processing software Pulsalyzer of ULi



DVocean: Post-Processing software Pulsalyzer of ULi

- Replay of the recorded data
- Waveforms:
  - Red:

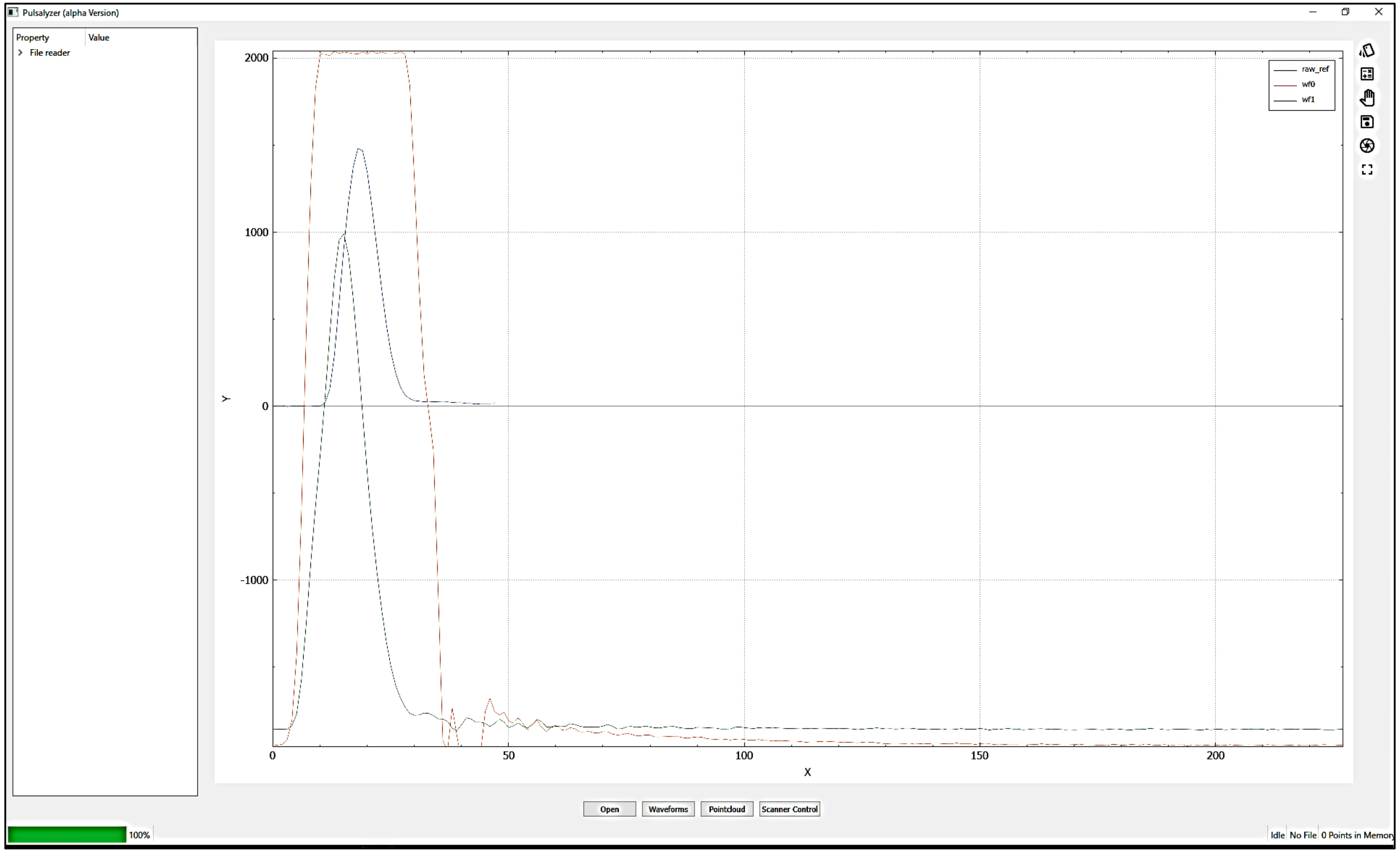
    Internal Reference Signal
  - Blue:

    Less sensitive channel
  - Green:

    Sensitive channel:

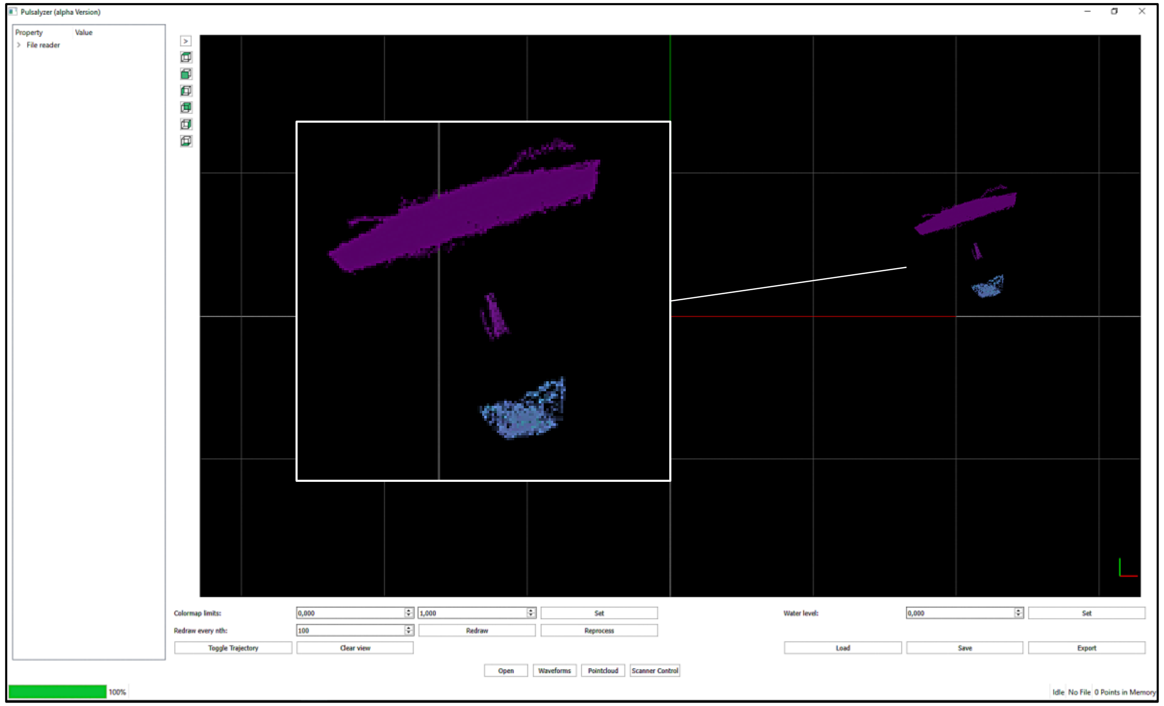
    Attenuation of the

    signal by factor 10

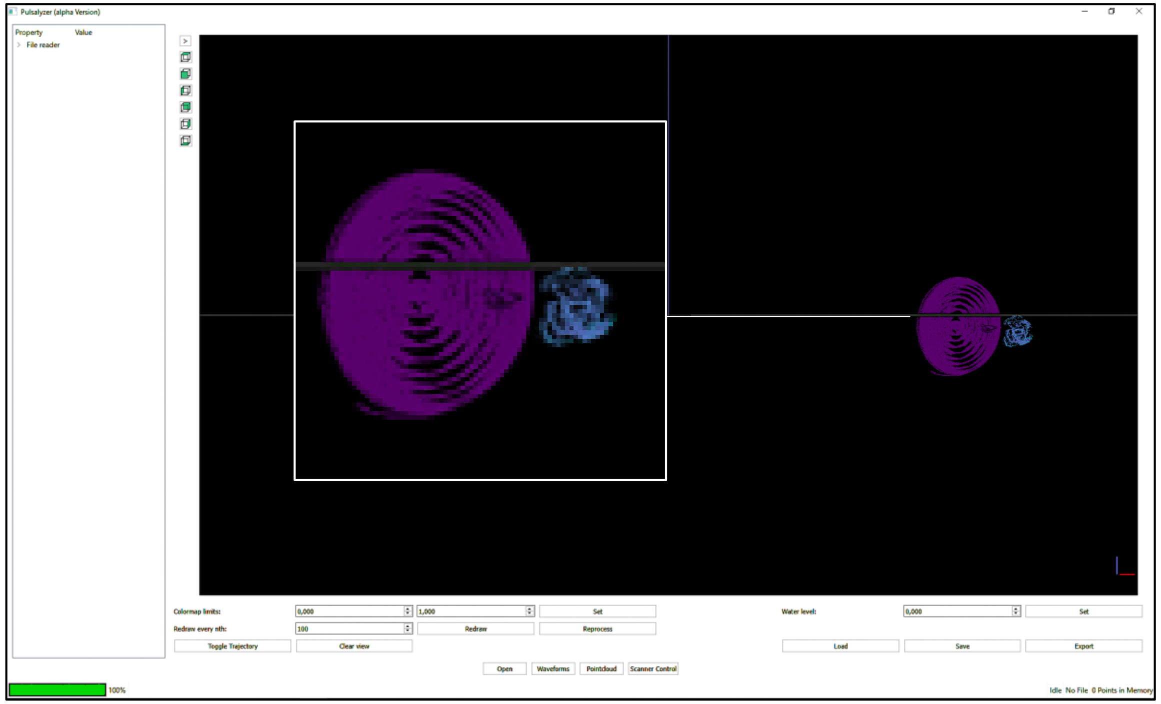


DVocean: Post-Processing software Pulsalyzer of ULi

Top View Circular Scan Pattern

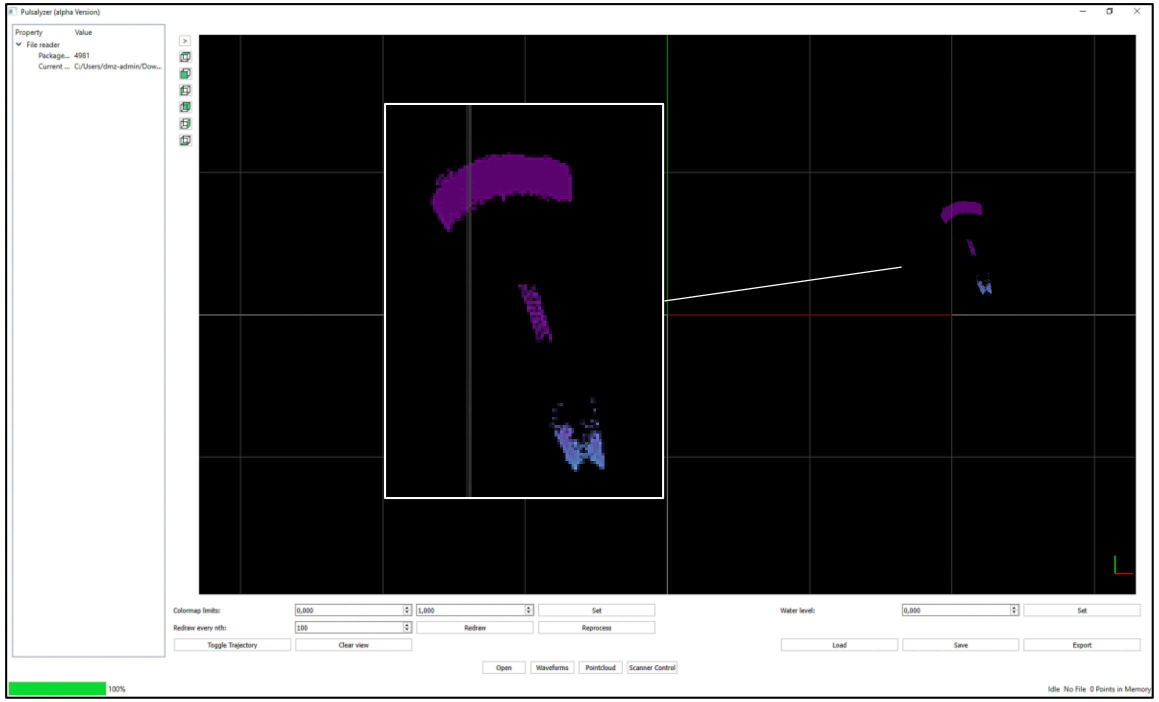


Side View Circular Scan Pattern

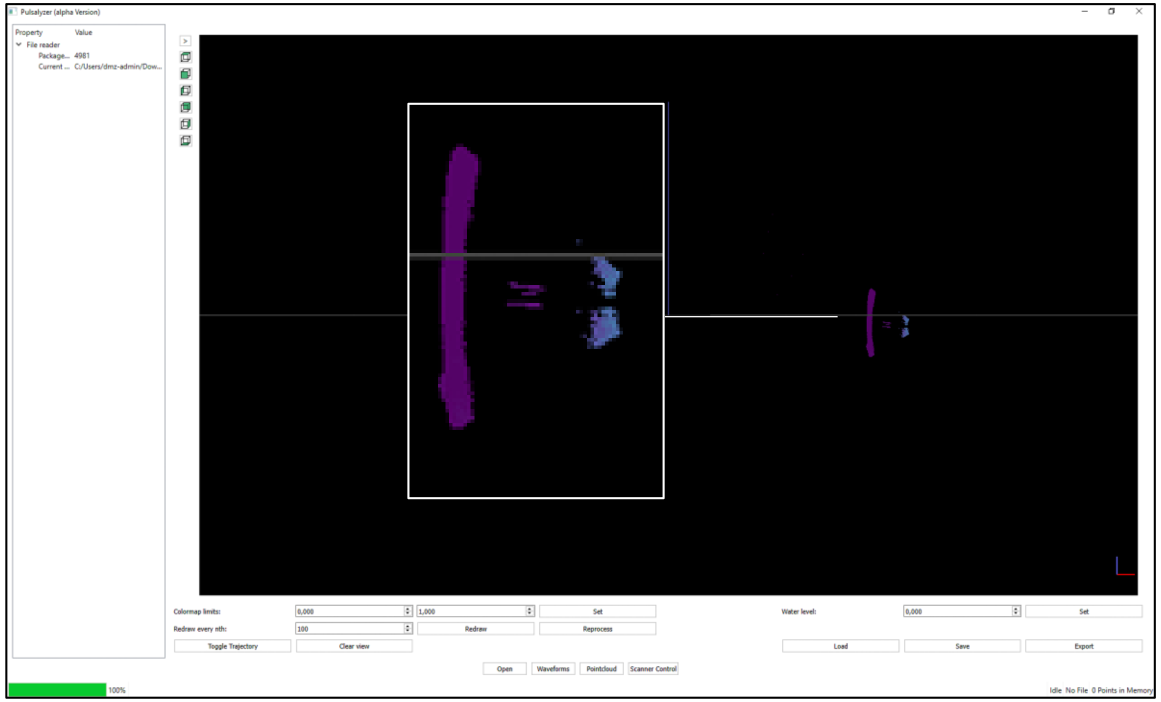


DVocean: Post-Processing software Pulsalyzer of ULi

Top View Line Scan Pattern

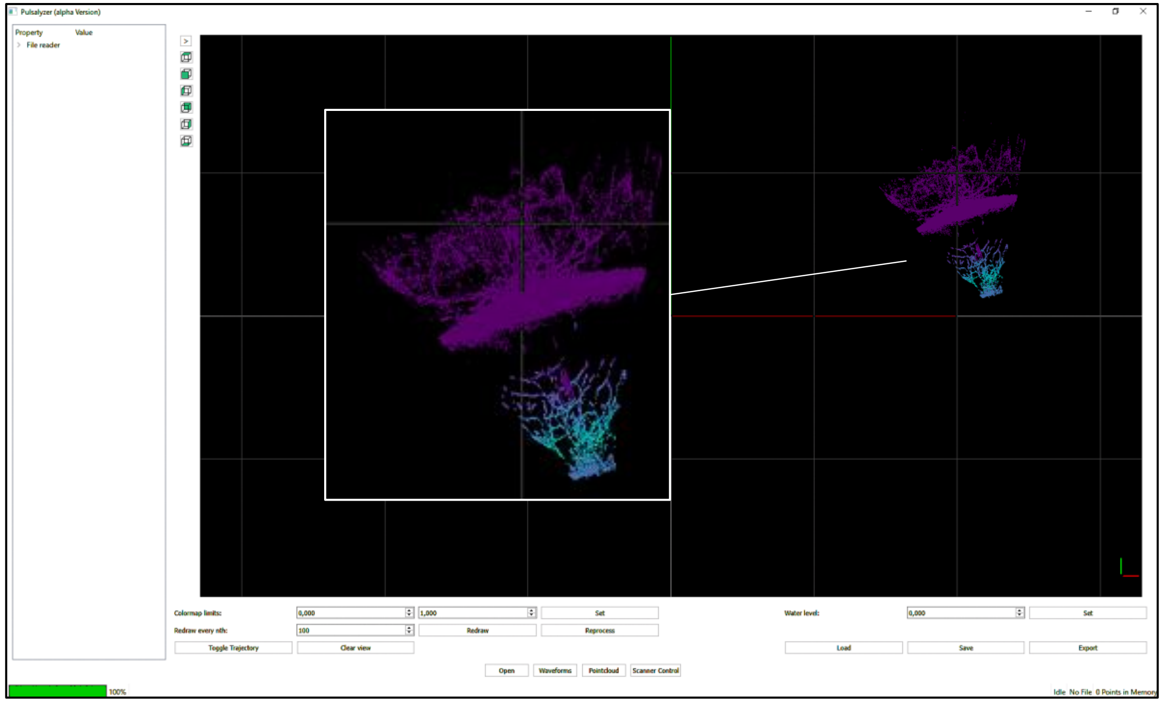


Side View Line Scan Pattern

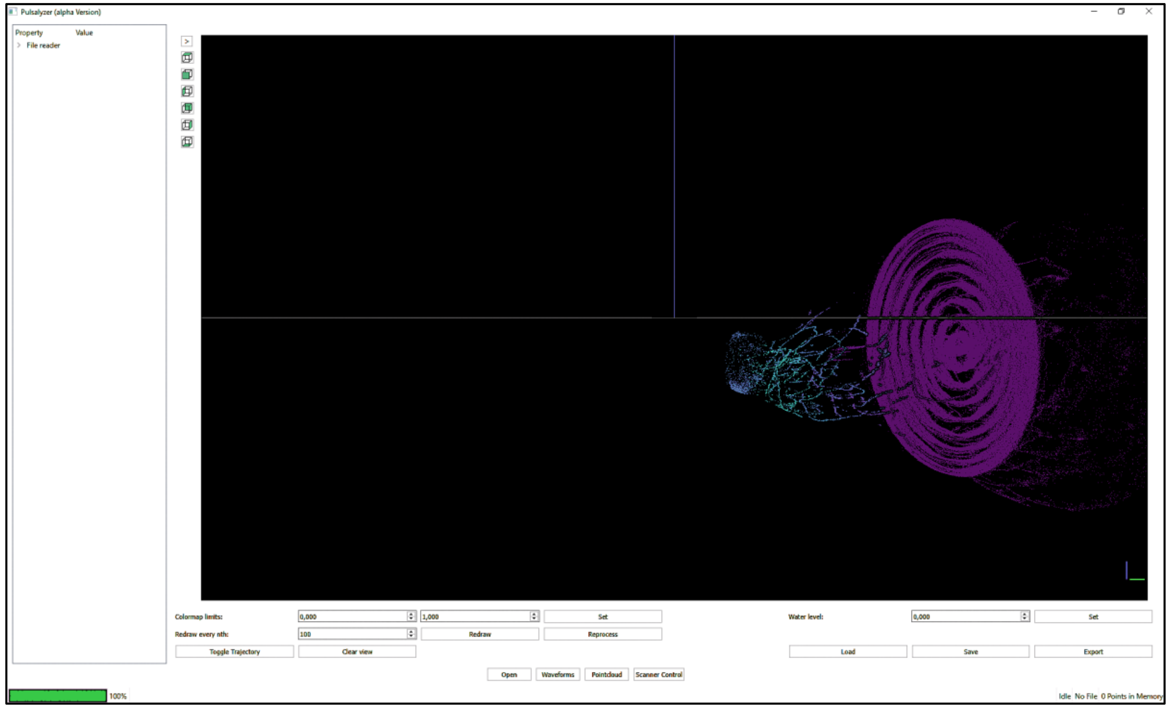


DVocean: Post-Processing software Pulsalyzer of ULi

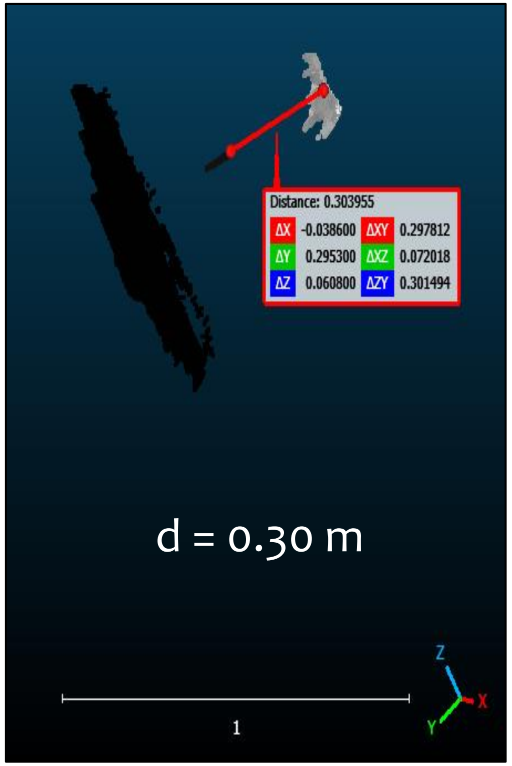
Top View Circular Scan Pattern

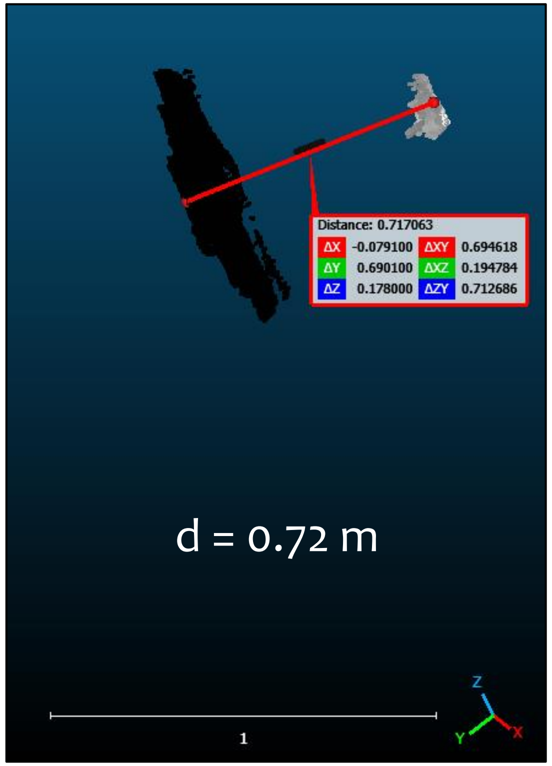


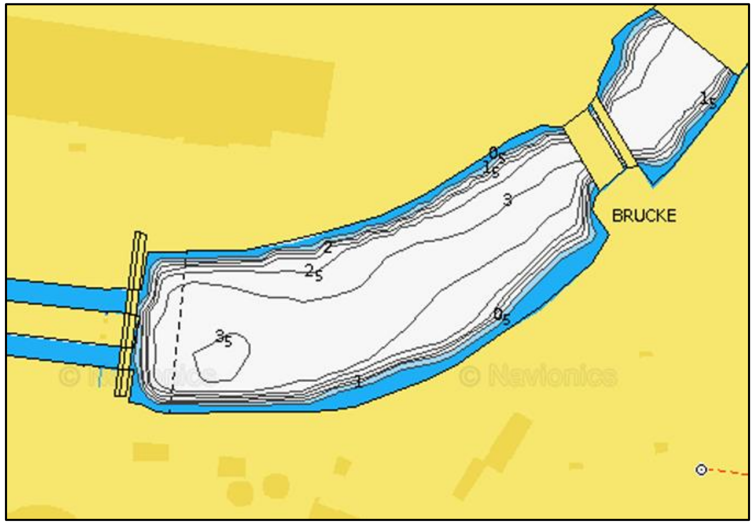
Side View Circular Scan Pattern

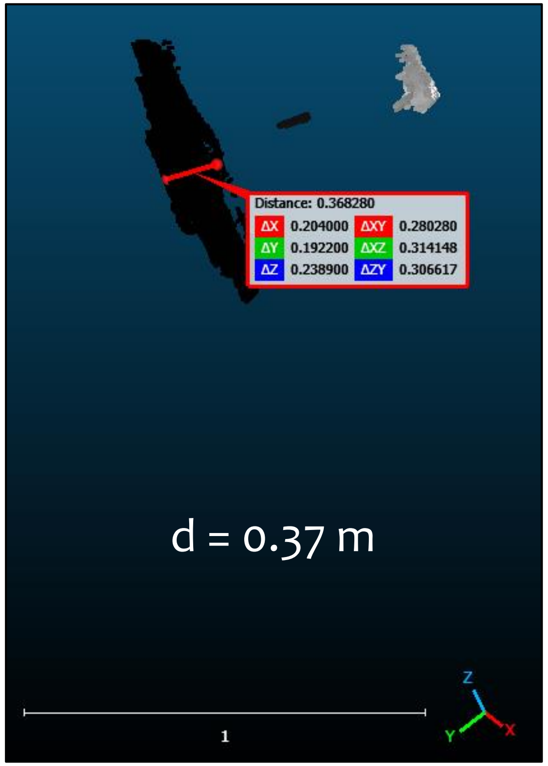


DVocean: Point Cloud of ULi in CloudCompare



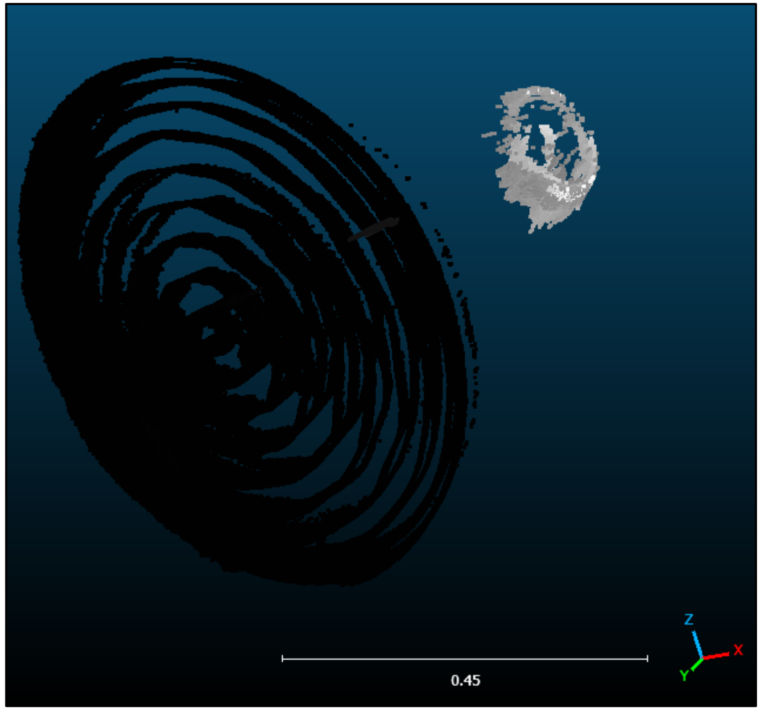


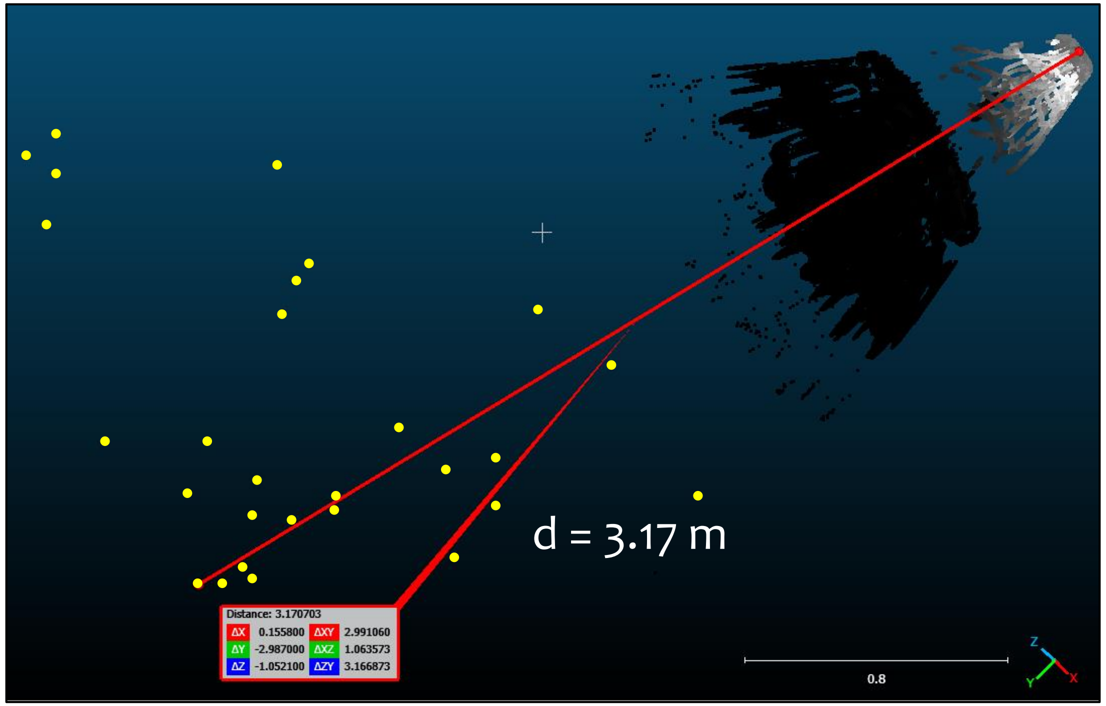




- DVocean passed the objects of interested with a distance of min. 1 m – 2 m
- Average depth between 2.5 m - 3.5 m
- Scattering of the point cloud: varying distance

DVocean: Point Cloud of ULi in CloudCompare





- Single reflections in a distance of 3.17 m

DVocean: Point Cloud of ULi from Surface Vehicle

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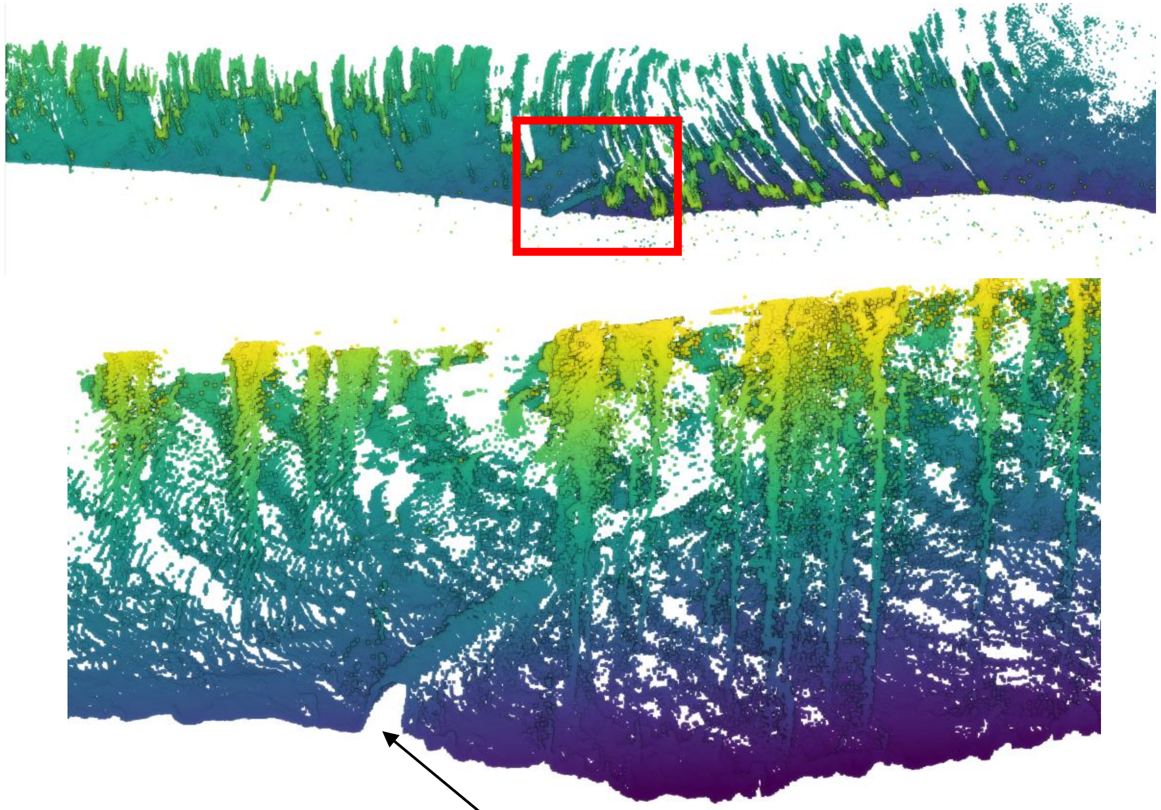

Approx. 5 cm diameter

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Outlook

- Varying water bodies (turbidity)
- Detection of objects with different surface properties
- Combination with other sensors
- Fusion with data from other sensors to gain maximum insights
- Operation on unmanned vehicles to get close to objects and to capture the land water transition zone
- Development of a field calibration method

Thank you very much!

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