Exploiting the Potential of the Hydrostatic Leveling System (HLS) at the Swiss Light Source (SLS)

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New Software for HLS at SLS

- Old HLS Software
  - Online graphs of 1 selected sector
  - 1 hour averages of all data were stored
  - Output in Excel

- New HLS Software
  - Data Output in EPICS Control System
  - All important data are visible on one screen
  - Online data analysis -> red / green light
  - Rawdata, Pitch, Roll, Heave is selectable
  - All data are stored
  - Data playback selectable: ASCII, Excel
Girder Layout, total 48 Girders, 192 HLS Sensors

Zelenika et al. 2001

ca. 36 mm to watersurface

G: +/- 0.002 mm grinded support

HLS (horizontal levelling system)

HPS (horizontal positioning system)

V IN

GND

V OUT
Overview Screen: HEAVE

Heave [mm] since 2005
Overview Screen: PITCH & ROLL
Signal Monitoring Conditions

Sector 12

- **Time Interval 1**: 1 h
- **Max. Deviation 1**: 0.13 mm
- **Time Interval 2**: 24 h
- **Max. Deviation 2**: 1 mm
- **Time Interval 3**: 7200 s
- **Min. Deviation 3**: > 0.0005 mm

### Measured Deviation

<table>
<thead>
<tr>
<th>Sensor Name</th>
<th>Deviation 1</th>
<th>Deviation 2</th>
<th>Deviation 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARIAL-HLS1-12G1</td>
<td>0.0029 mm</td>
<td>0.011 mm</td>
<td>0.0029 mm</td>
</tr>
<tr>
<td>ARIAL-HLS2-12G1</td>
<td>0.0021 mm</td>
<td>0.011 mm</td>
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<tr>
<td>ARIAL-HLS3-12G1</td>
<td>0.0021 mm</td>
<td>0.0088 mm</td>
<td>0.0022 mm</td>
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<tr>
<td>ARIAL-HLS4-12G1</td>
<td>0.0022 mm</td>
<td>0.0085 mm</td>
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<tr>
<td>ARIAL-HLS1-12G2</td>
<td>0.0031 mm</td>
<td>0.011 mm</td>
<td>0.0031 mm</td>
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<tr>
<td>ARIAL-HLS2-12G2</td>
<td>0.0033 mm</td>
<td>0.0098 mm</td>
<td>0.0037 mm</td>
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<tr>
<td>ARIAL-HLS3-12G2</td>
<td>0.0034 mm</td>
<td>0.025 mm</td>
<td>0.0034 mm</td>
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<tr>
<td>ARIAL-HLS4-12G2</td>
<td>0.0035 mm</td>
<td>0.013 mm</td>
<td>0.0035 mm</td>
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<tr>
<td>ARIAL-HLS1-12G3</td>
<td>0.0036 mm</td>
<td>0.067 mm</td>
<td>0.0036 mm</td>
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<tr>
<td>ARIAL-HLS2-12G3</td>
<td>0.0034 mm</td>
<td>0.057 mm</td>
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<td>ARIAL-HLS3-12G3</td>
<td>0.0035 mm</td>
<td>0.18 mm</td>
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<tr>
<td>ARIAL-HLS4-12G3</td>
<td>0.0037 mm</td>
<td>0.21 mm</td>
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<tr>
<td>ARIAL-HLS1-12G4</td>
<td>0.0038 mm</td>
<td>5.7 mm</td>
<td>0.0045 mm</td>
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<tr>
<td>ARIAL-HLS2-12G4</td>
<td>0.0038 mm</td>
<td>1.3 mm</td>
<td>0.0044 mm</td>
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<tr>
<td>ARIAL-HLS3-12G4</td>
<td>0.0043 mm</td>
<td>0.2 mm</td>
<td>0.0056 mm</td>
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<tr>
<td>ARIAL-HLS4-12G4</td>
<td>0.0039 mm</td>
<td>0.37 mm</td>
<td>0.0039 mm</td>
</tr>
</tbody>
</table>
System Calibration with Filling Station

![Diagram of calibration software interface]

**Safety:**
- Ack Error
- Low Level
- High Flow
- Signal Difference High
- No Flow

**Control:**
- State: Idle
- Water Tank: Value Valid
- Water Level Setpoint: 0 mm
- Valve State: Closed

**Water Level Control Settings:**
- Stabilisation Time: 30 s
- Max Valve Open Time: 60 s
- Level Tolerance: 0.05 mm
- Suppress Water Error: On
- Water Error: Off

**Calibration Settings:**
- Level Ramp Size: 3
- Water Level Ramp: 4 mm
- Number of Cycles: 2
- Wait after Step: 5 s
- Average Intervall: 10 s

**Calibration Control:**
- Current Cycle: 0
- Current Step: 0
- Water Level: 36 mm
- Valve State: Closed
- Water Level Control State: Idle

**Calibration Measurement File:** [File Path]
Online Data «Oscilloscope view»

Rawdata [V]

Absolute [mm]

Relative [mm]
Data output to EPICS and data storage

- All the data are permanently available in EPICS

- History data

- Earthquake in Italy, 24.8.16

- Average of selectable interval, e.g. 1h

- Output format in ASCII or Excel

Amplitude at SLS: 0.016 [mm]
20 urad steps performed on the last girder

- Selection of the corresponding HLS sensors in the «History Data» window
- Generation of a data output in ASCII format of the selected channels
Calculated from motor encoders

Pitch.val [mrad]
Heave.val [mm]
Roll.val [mrad]

Pitch & Roll [mrad]
Heave [mm]

08/23/2016 09:56 + time [sec]
Comparing motor encoders and HLS

Pitch most important

HLS -3%: 19.53 urad
Encoders: 20.13 urad

tau = 22 ++ 1 sec

08/23/2016 09:56 + time [sec]
Time constant, present Digitizer 16-bit

Heave [mm]

08/23/2016 09:56 + time [sec]

Heave.hls [mm]

 Tau = 22 +/- 1 sec

Heave [mm]

280 300 320 340 360 380 400 420 440

0.0005

0.001

0.0015

0.002
HLS Resolution: Earthtides and Atlantic waves

Mont Terri
Rocklaboratory:

24 bit Seismic
Dataacquisition
System „Quanterra“

Short term signals: Atlantic waves

8 seconds
0.2 microns

Long term signals: Earthtides

12 hours
Neighbor signals explain the heave error
Conclusions

• The new software opened our eyes for future applications
• We learned more about the systematic effects, liquid transport etc. in the HLS tubes
• The HLS system is well integrated with the SLS control system