MEDSI 2023
Beijing
Mechanical Engineering Design of Synchrotron Radiation Equipment and Instrumentation

First Results of a New Hydrostatic Leveling System on Test Procedures at Sirius

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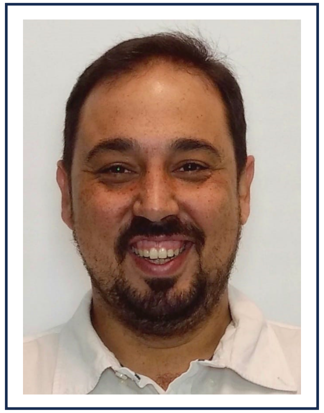
setup LNLS sirius CNPEM

Funded by: FAPESP

Welcome - Nǐ hǎo



William Heinrich (speaker)

Director of Engineering and Entrepreneur at SETUP Automation and Process Control, an engineering company focused on innovation for over 27 years.

At SETUP: Train its engineering team on areas such as computer vision, advanced mechatronics, instrumentation, data acquisition and software engineering.

Background

- Bachelor's degree in **Electrical Engineering with emphasis on telecommunications** and Specialization in **Design Thinking** obtained by the **MIT Sloan Management Executive Education Institute – USA;**
- **14 years of professional experience** in applied research in multiple research and development centers;
- **Almost 10 years as an entrepreneur and 23 years as an researcher** in companies and institutes located in "Brazilian Sylicon Valley" Campinas, Sao Paulo state, including R&D at Samsung in Brazil and a job as applications engineer at Keysight Technologies;
- Author and co-author of at least **4 patented technologies** in various technological disciplines;
- Lead researcher of **two research projects funded by FAPESP and FINEP**, with resources from the state economic subsidy and the federal government in Brazil.

SUMMARY

1. INTRODUCTION
2. HLS-SETUP CONFIGURATION
3. EXPERIMENTAL PROCEDURE
4. RESULTS
5. CONCLUSIONS
6. REFERENCES
7. Q&A SESSION

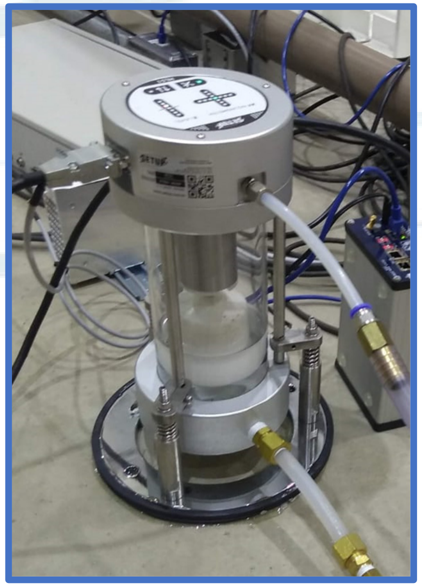
INTRODUCTION

Introduction

Objective:

- Introduce a new Hydrostatic Leveling System (HLS);
  - Pioneering application of the Linear Variable Differential Transformer (LVDT);
  - Detect tidal influences on level variations at the micrometer scale;
  - Resistance to temperature fluctuations and cost-effectiveness;
- Test and structure monitoring at LNLS/CNPEM, from 2020 to 2023.

HLS-Setup



Ref.: https://www.setup.com.br/

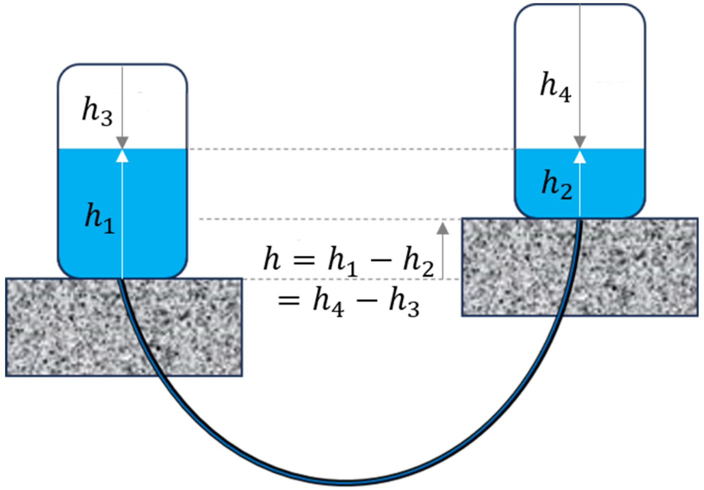
Laboratório Nacional de Luz Síncroton (LNLS/CNPEM) – Campinas, Brazil

Ref.: https://www.lnls.cnpem.br/about/

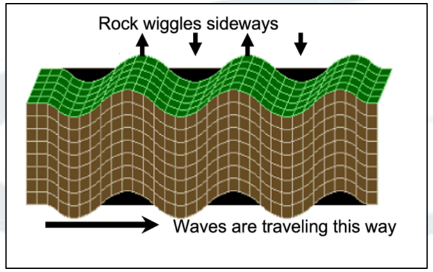
Introduction

Hydrostatic Leveling System (HLS):

Precision measurement and monitoring system designed to detect variations in the levels of structures, typically achieving submicrometric precision and repeatability on the order of microns.

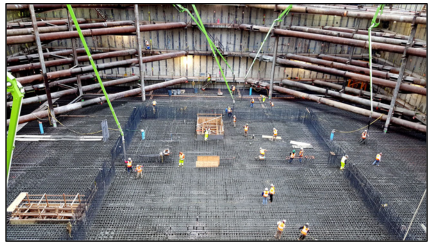


Applications:

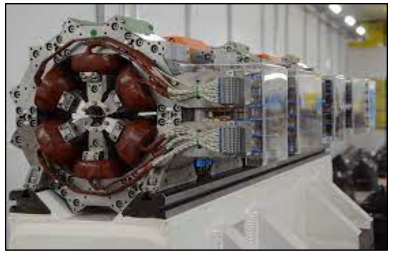


Seismic events

Large resevoirs



Building foundations



Alignment/monitoring of accelerator

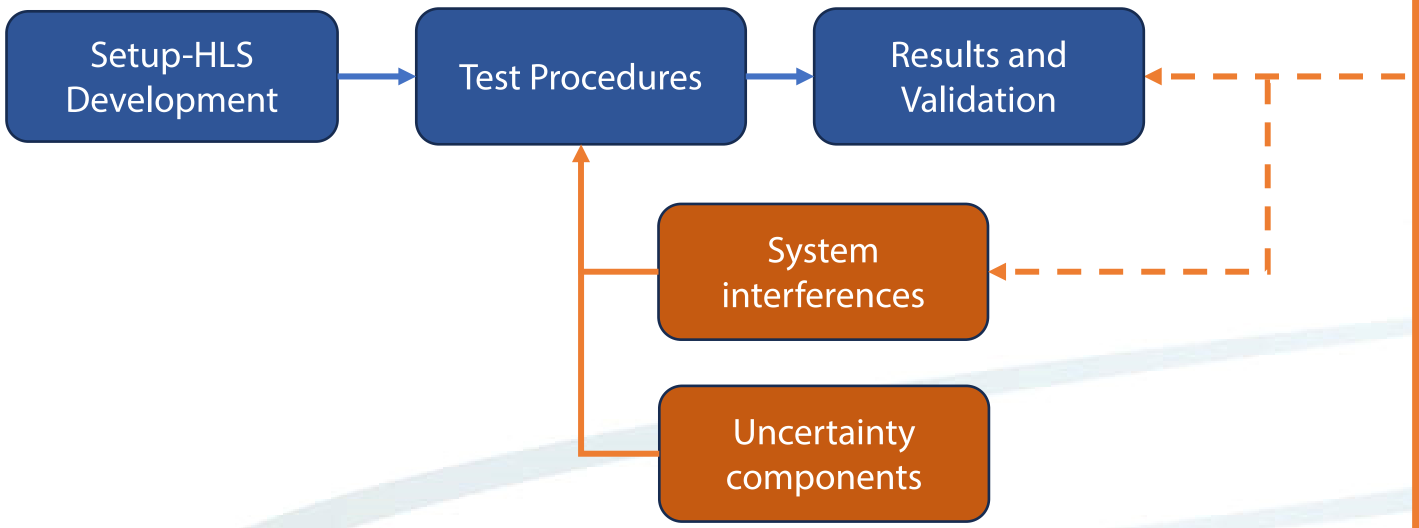
Technique Principles :

- Fiber optic and interferometric methods (F.O.I)
- Ultrasonic technologies (U.T.)
- Capacitance and dielectric measurements (C.D.)
- Mechanical and optical approaches

Features	Main techniques		
	F.O.I.	U.T.	C.D.
Resolution (S.N.)	10^{-12}m	10^{-5}m	10^{-6}m
Fluid dependence	No	Yes	Yes
Temperature influence	Free	+	++
Magnetic field influence	Free	Free	+
Eletric field influence	Free	+	+
Air humidity influence	Free	Free	+
Price (x EUR1000/point)	>160.0	>20.0	>8.0

Introduction

Device Design:



Terrestrial Tidal interferences:

- The semidiurnal of terrestrial tide has a typical amplitude of **approximately 0.55 meters** (Petit and Luzum, 2010);

- Perturbations in particle accelerator systems, on the order of **1 millimeter/minute**, as evidenced by measurements conducted in Geneva at the Large Electron-Positron Collider (LEP) (Arnaudon *et al.*, 1995);

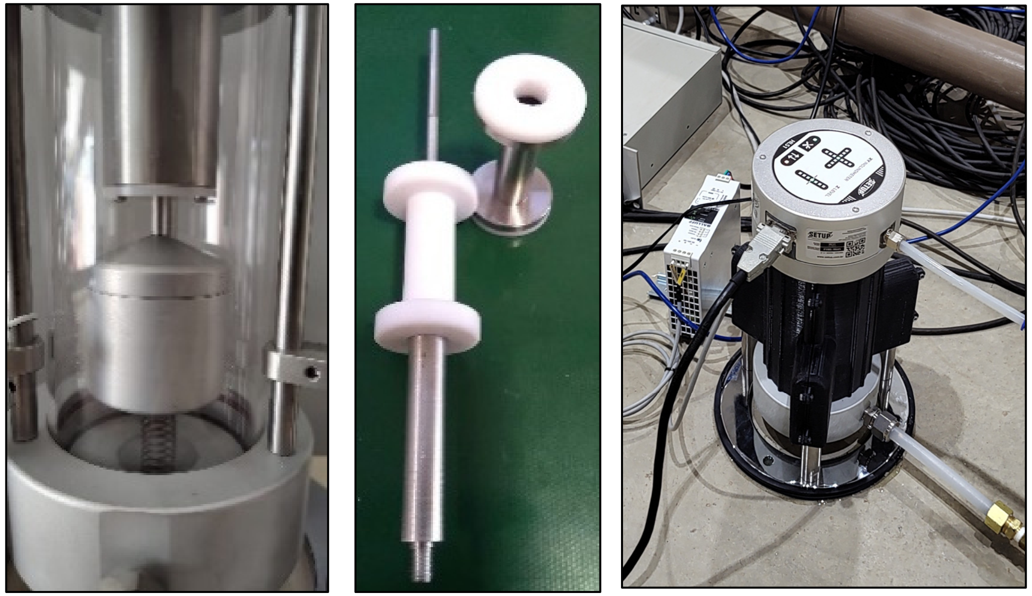
- The standard model of electroweak interactions requires precise knowledge of the LEP beam energy with an accuracy of 20 ppm. However, small fluctuations, induced by tidal effects, resulted in a beam energy variation of **approximately 120 ppm** (Arnaudon *et al.*, 1995).

Ref.: https://moon.nasa.gov/resources/444/tides/

HLS-SETUP CONFIGURATION

HLS-Setup Configuration

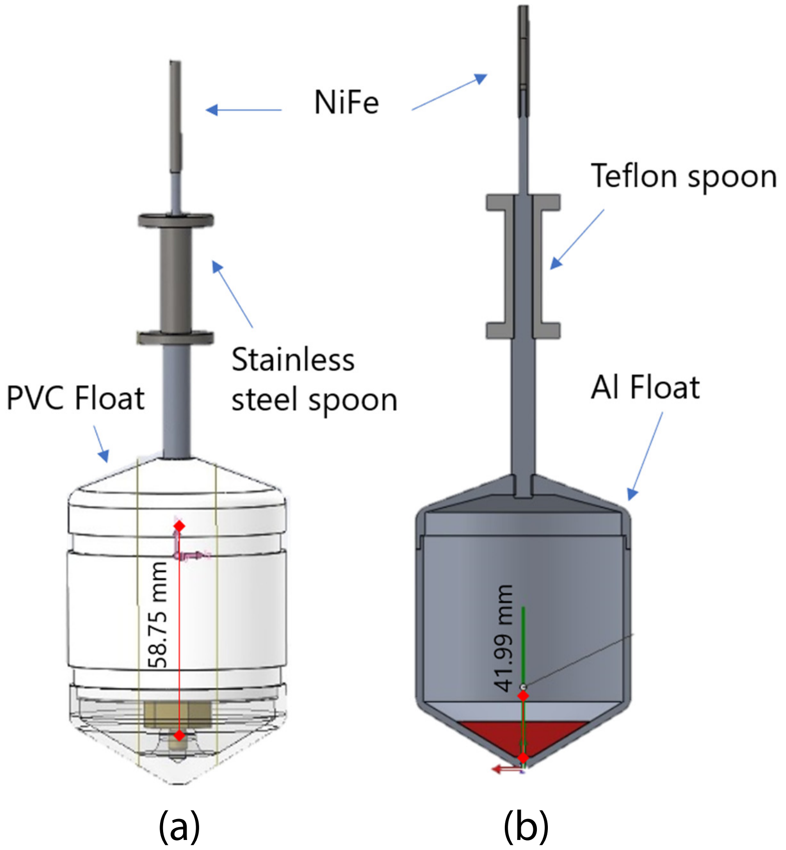
Device Concept:



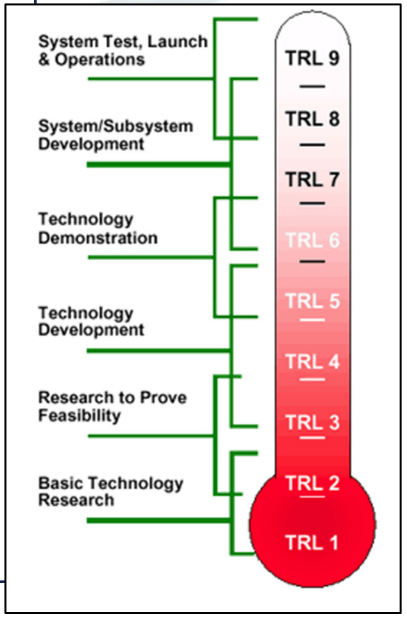
(a) (b) (c)

(a) Setup-HLS without case protection;
(b) PTFE spool and permalloy core;
(c) Device on-site.

Evolution Steps:



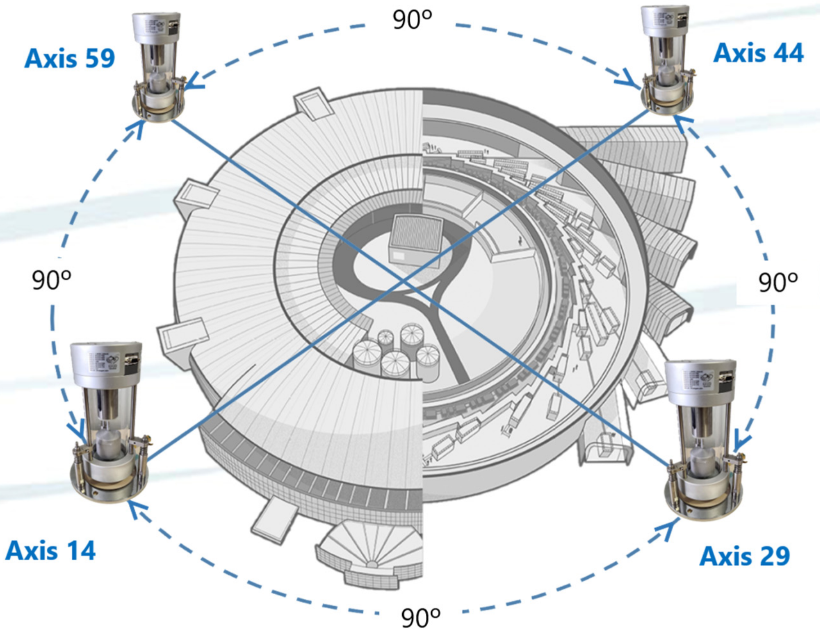
Float modification
from (a) TRL5 to (b) TRL9.



Ref.: https://ntrs.nasa.gov/api/citations/20170005794/downloads/20170005794.pdf

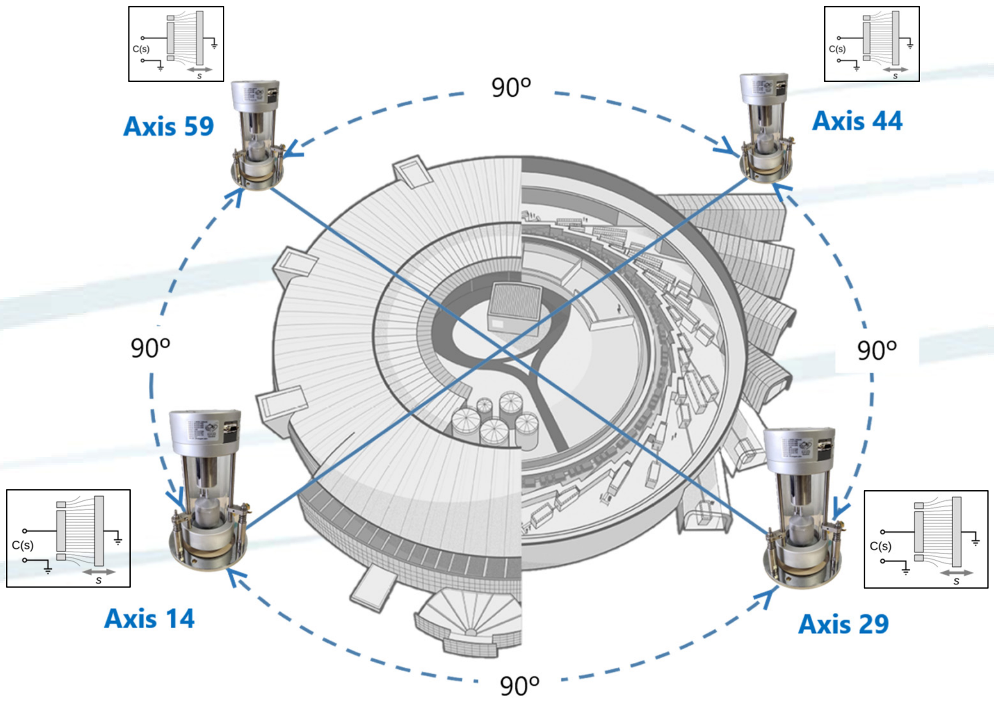
EXPERIMENTAL PROCEDURE

Experimental Procedure



4 HLS-Setup
(765 seconds)
4 capacitance-based
off-the-shelf HLS
(31 seconds)

Experimental Procedure



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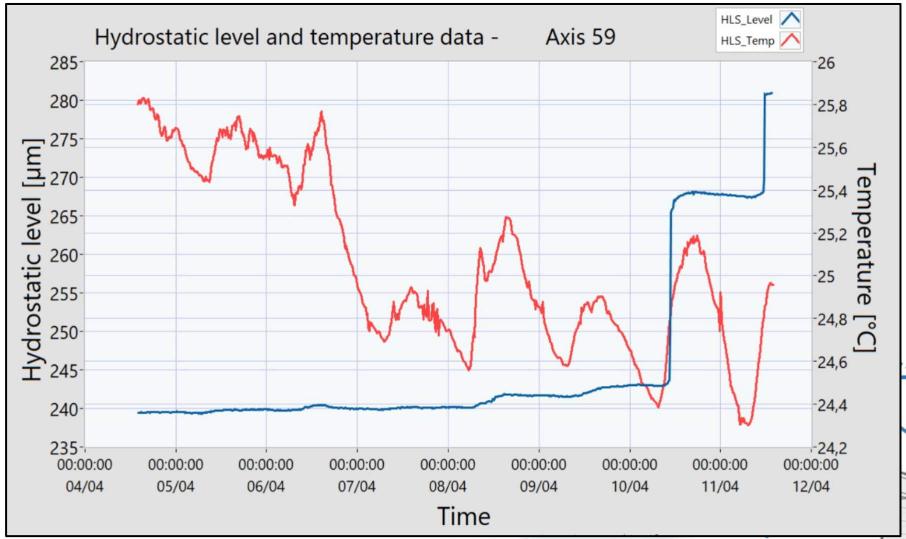

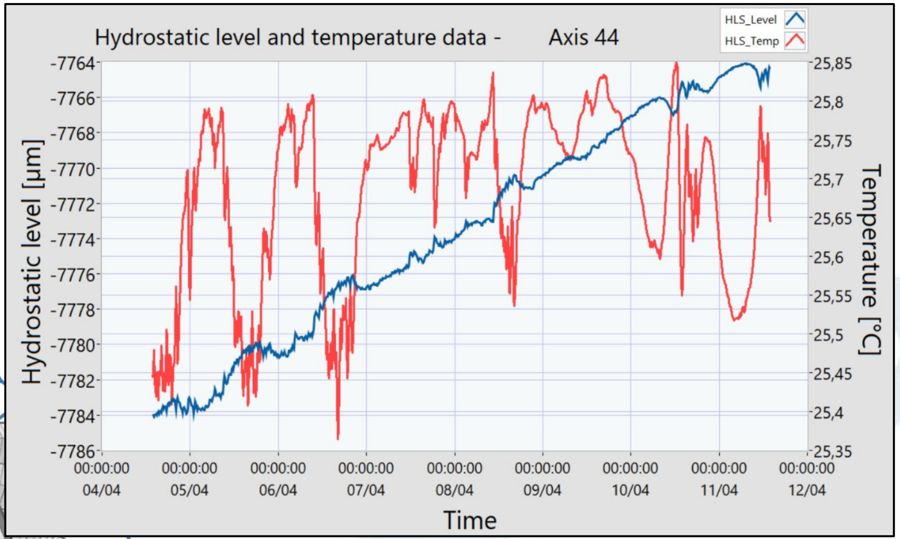

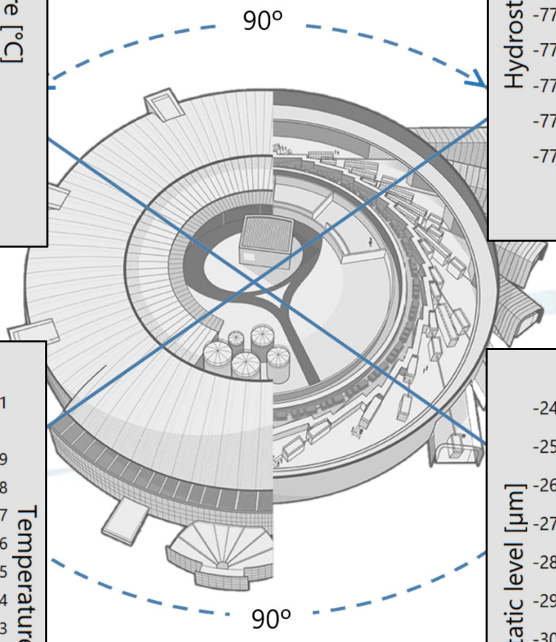

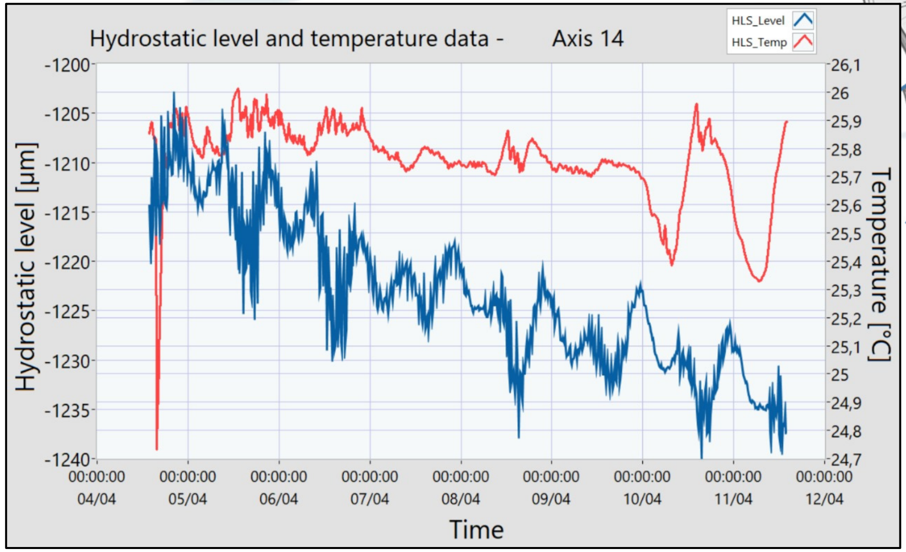

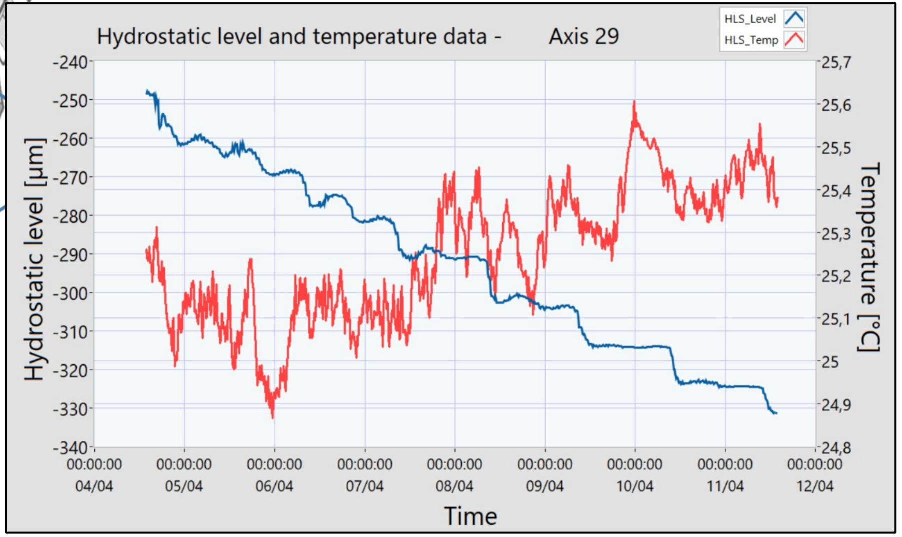

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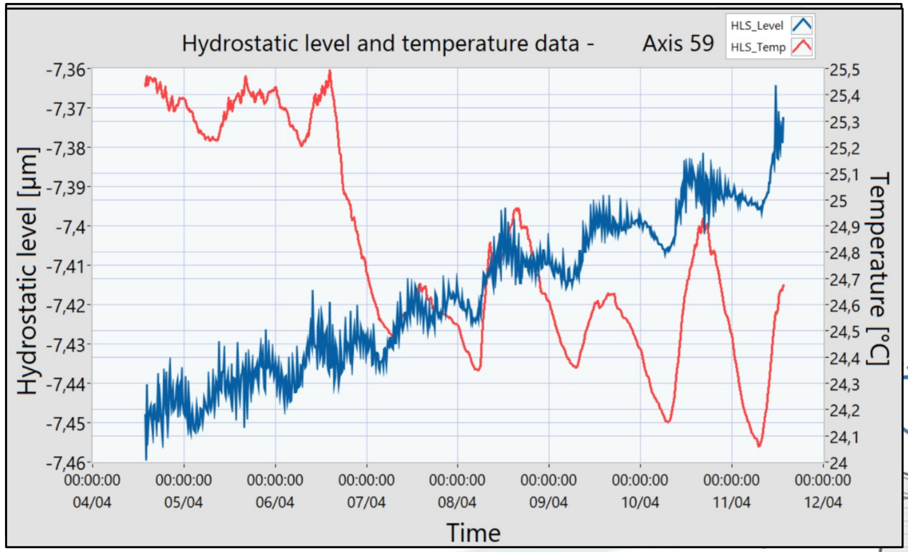

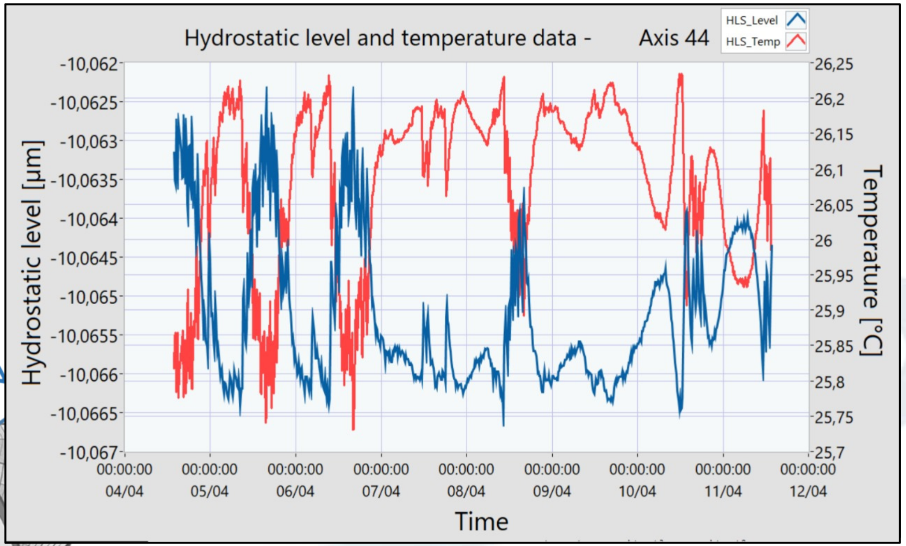

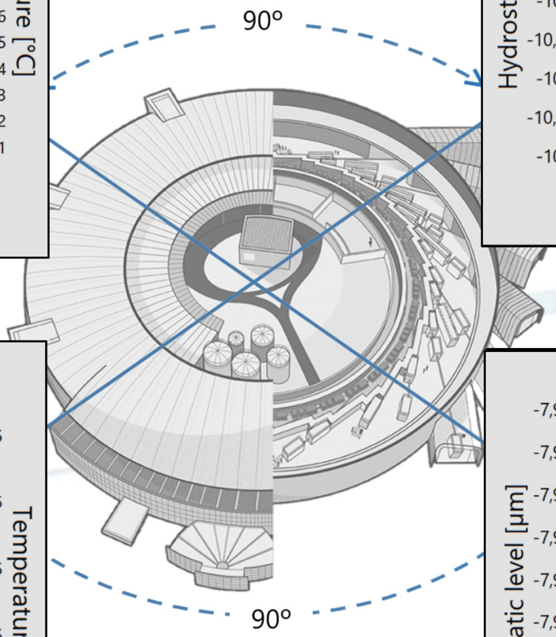

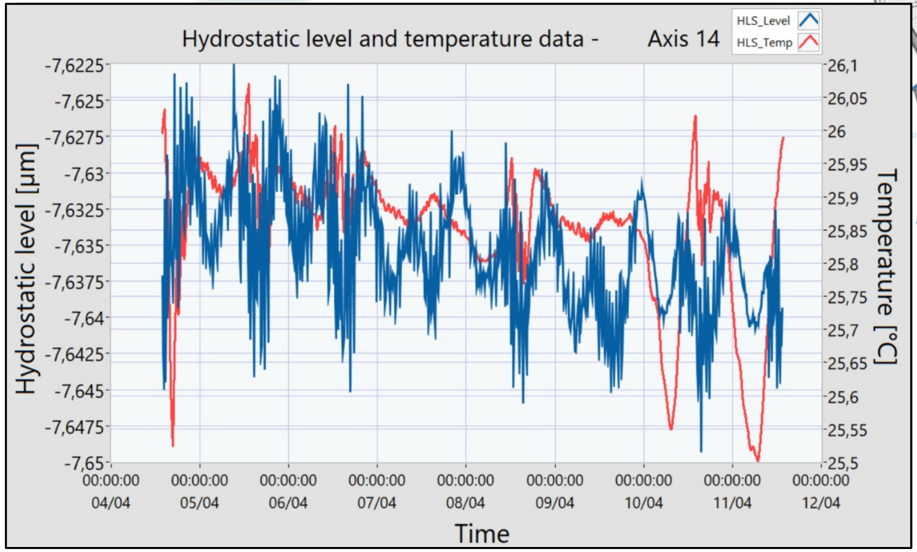

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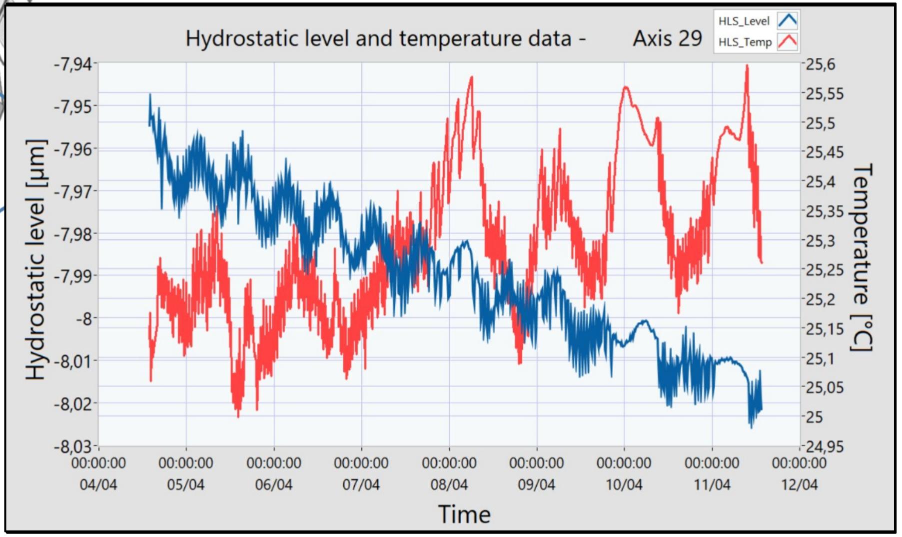

RESULTS

Results

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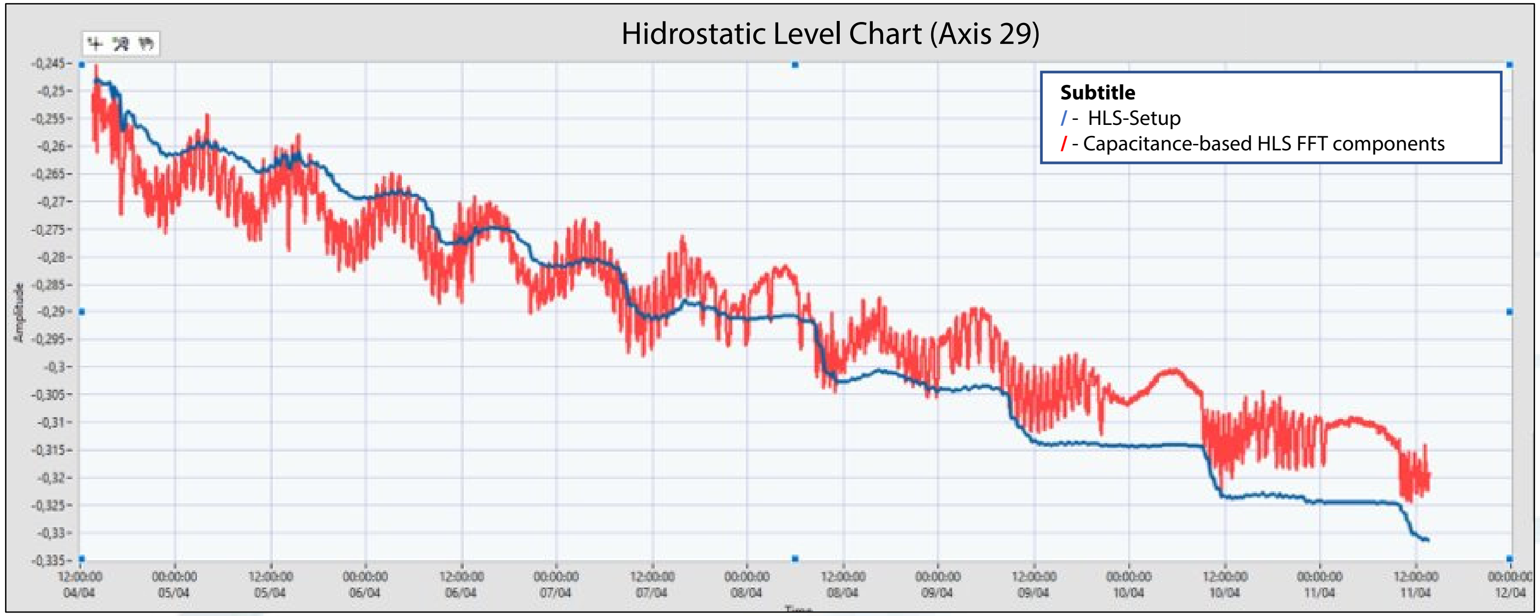
Device Concept:



Results

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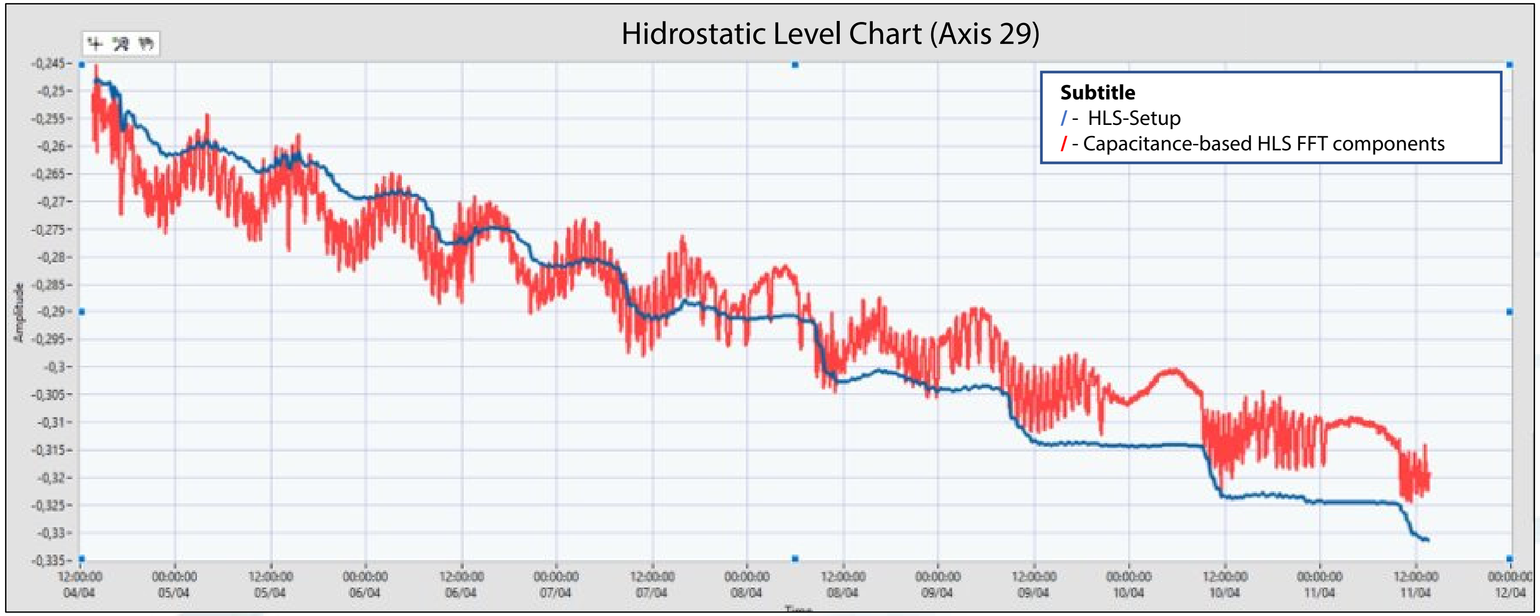
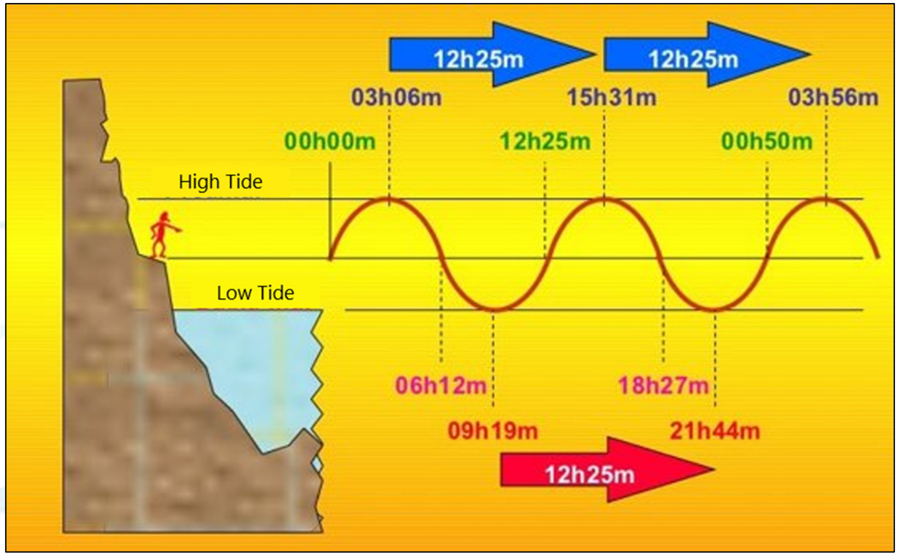


Time interval between tides:



Ref.: https://www.slideshare.net/ifuspescola/mares-7093902?smtNoRedir=1

Results

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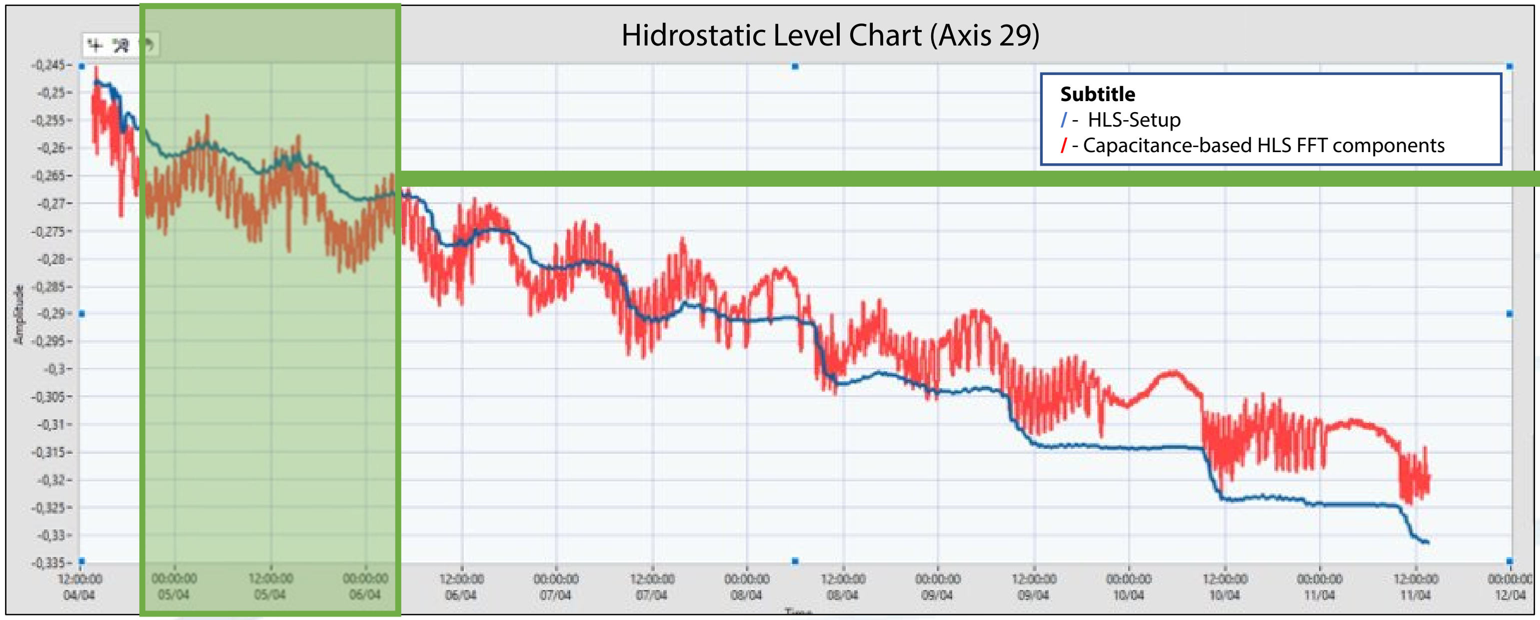
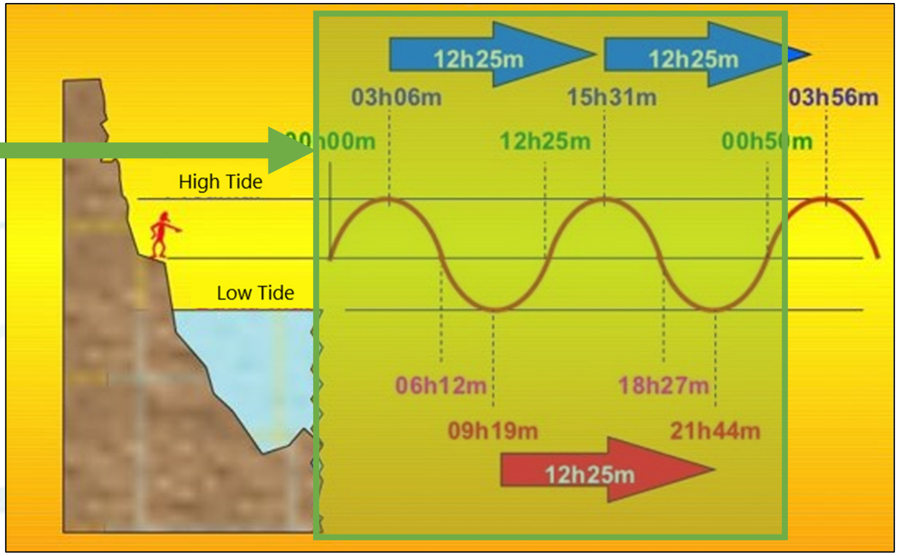


Time interval between tides:



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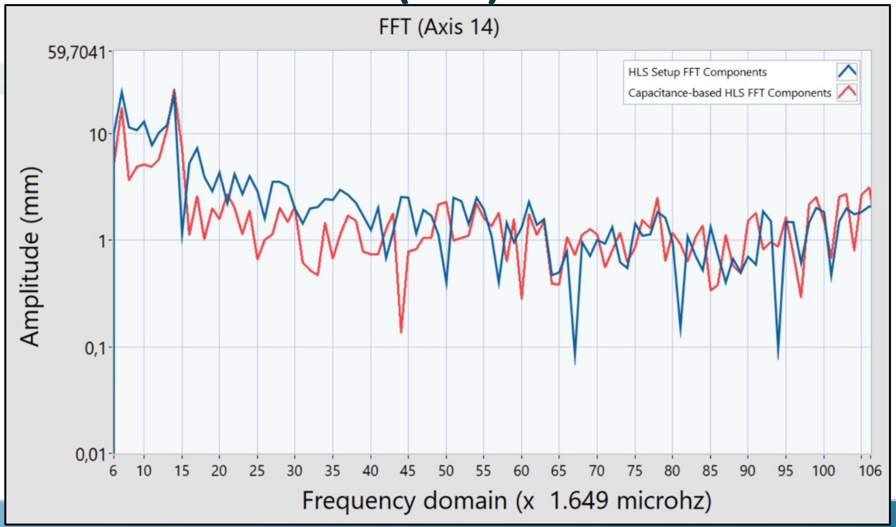
Fast Fourier Transform (FFT) for hidrostatic level:



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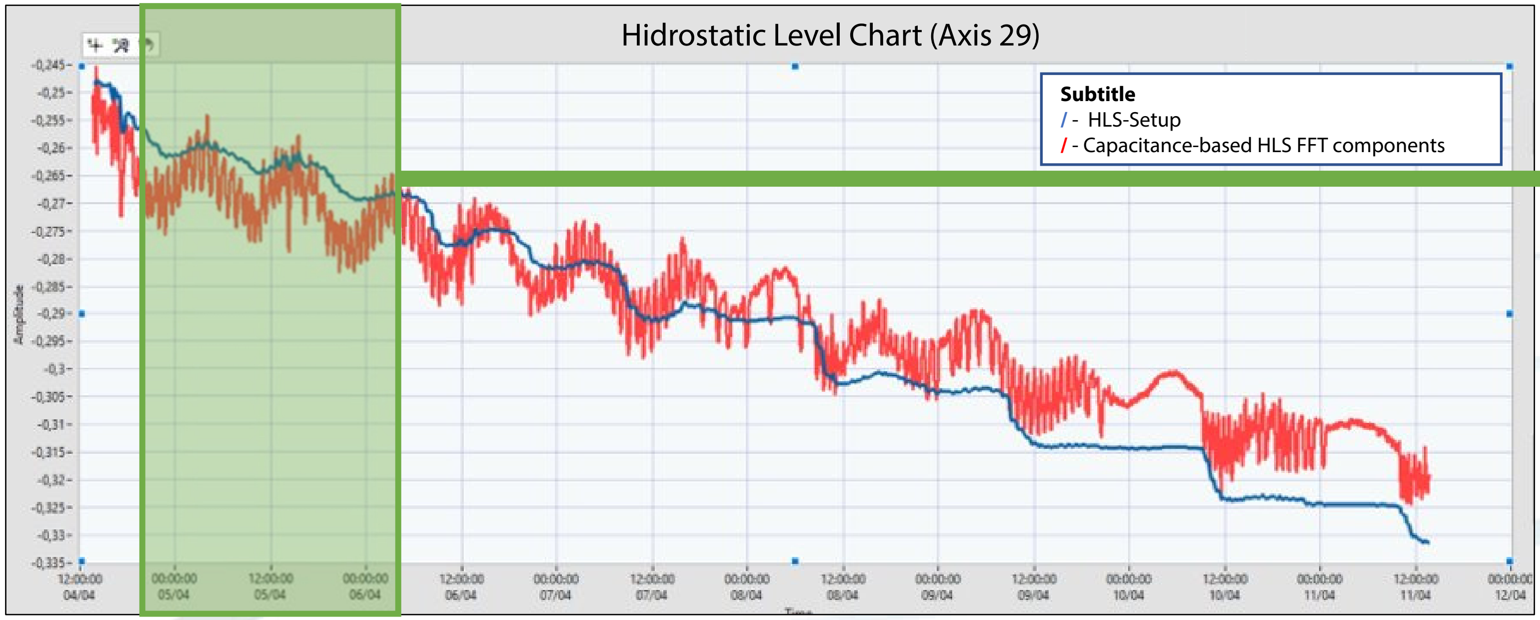

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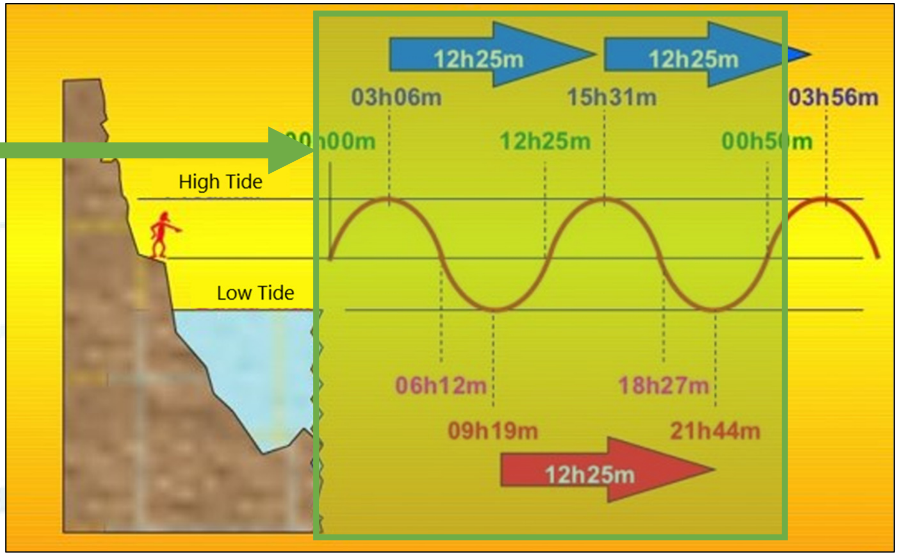

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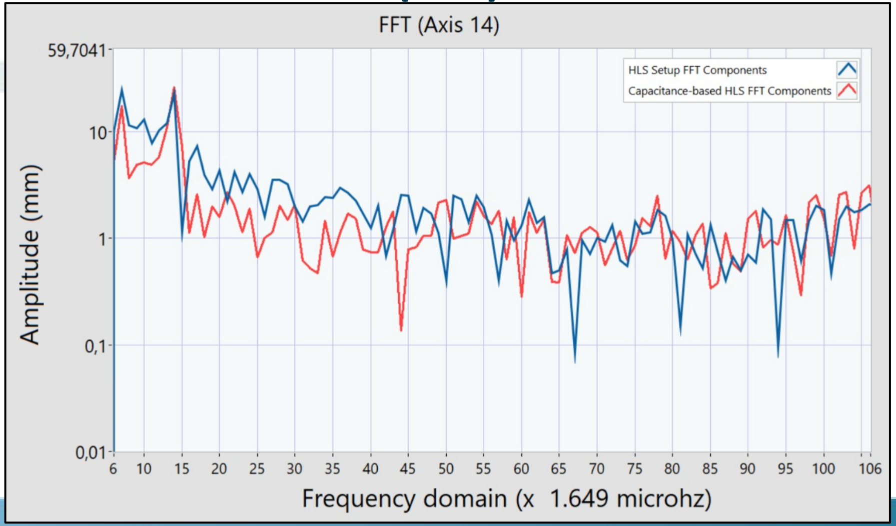


Main FFT components:

Setup-HLS FFT components		*Capacitance-based HLS FFT components*	
Period (hours)	*Intensity (mm)*	*Period (hours)*	*Intensity (mm)*
24.06	*24.68*	*24.00*	*17.39*
12.03	*22.50*	*12.00*	*26.06*
16.84	*13.10*	*12.92*	*10.96*
12.96	*12.96*	*11.20*	*7.20*

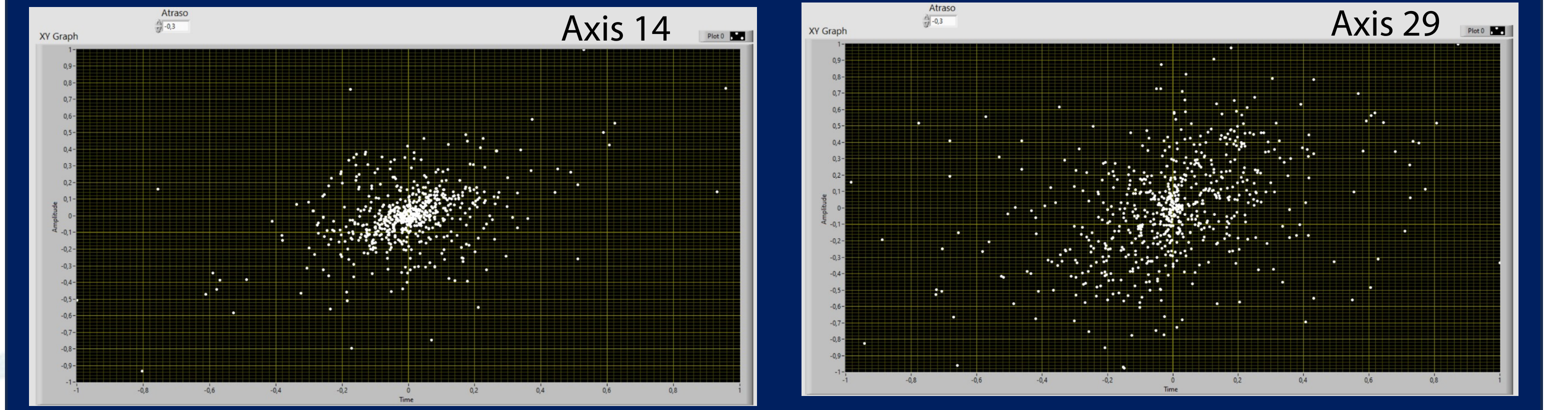
Results

Person Coefficient:

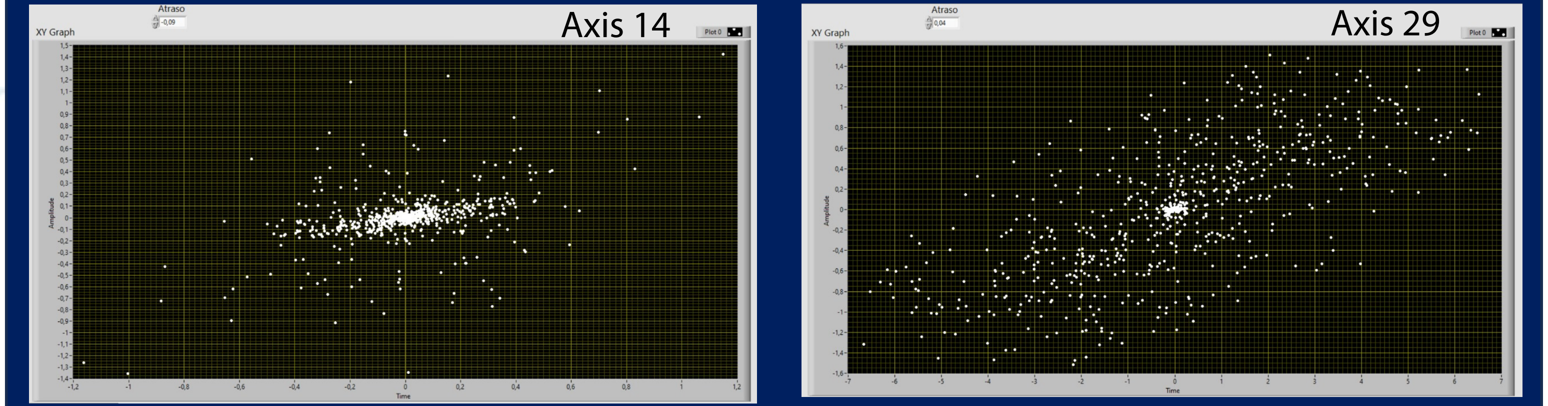
Location on Sirius	Level to Temperature – Pearson Coefficient		
	Setup-HLS[1]	Capacitance -based HLS[1]	Capacitance -based HLS[2]
Axis 14	0.42	0.44	0.63
Axis 29	0.37	0.69	0.84
Axis 44	0.61	0.82	0.91
Axis 59	0.03	0.19	0.45

Data acquisitian interval:
[1] 756 seconds,
[2] 31 seconds

Setup-HLS[1]



Capacitance-based HLS[1]



CONCLUSIONS

Conclusions

Independent of HLS type:

- Isolate uncertainty componentes and systems interferences;
- Utilize a periodic system calibration and reliability; analysis for reading repeatability is proposed.

HLS-Setup Features:

- Measure the effects of tides and building tilt in micrometer range;
- Acrylic transparent coating;
  - Thermal expansion coefficient close to that of water (both ~68.0µm/m-°C at 20.0°C);
- Less depend on temperature fluctuations;
- Calibration relies on the interchangeability of the upper ogive;
- Cost-effectiveness.

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Future works:

- Calibration jig;
- Online calibration System;
- Interference of the electromagnetics field and concrete expansion (Marques, et al., 2022)

References

Final Report of the NASA Technology Readiness Assessment (TRA) Study Team, https://ntrs.nasa.gov/api/citations/20170005794/downloads/20170005794.pdf, accessed on October 16, 2023.

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L. Arnaudon et al. “Effects of terrestrial tides on the LEP beam energy”, *Nuclear Inst. and Methods in Physics Research A*, 357, p.249, 1995, doi: https://doi.org/10.1016/0168-9002(94)01526-0

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Thank you for your time!

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