DESIGN OF A BUOYANT AND AUTONOMOUS PRESSURE SENSOR FOR IN-SITU TUNNEL MEASUREMENTS

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The conundrum of hydropower tunnels

- Present methods of evaluation are old and crude
- All Hydropower tunnels suffer from rock falls, some suffer worse fates! Why?
- Several options:
  - Numerical modelling
  - Experimental studies
  - Field measurements

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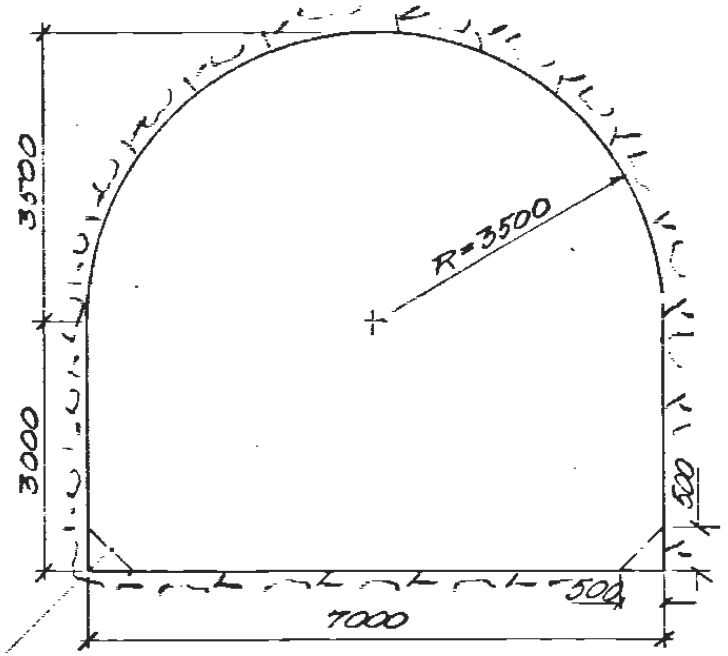
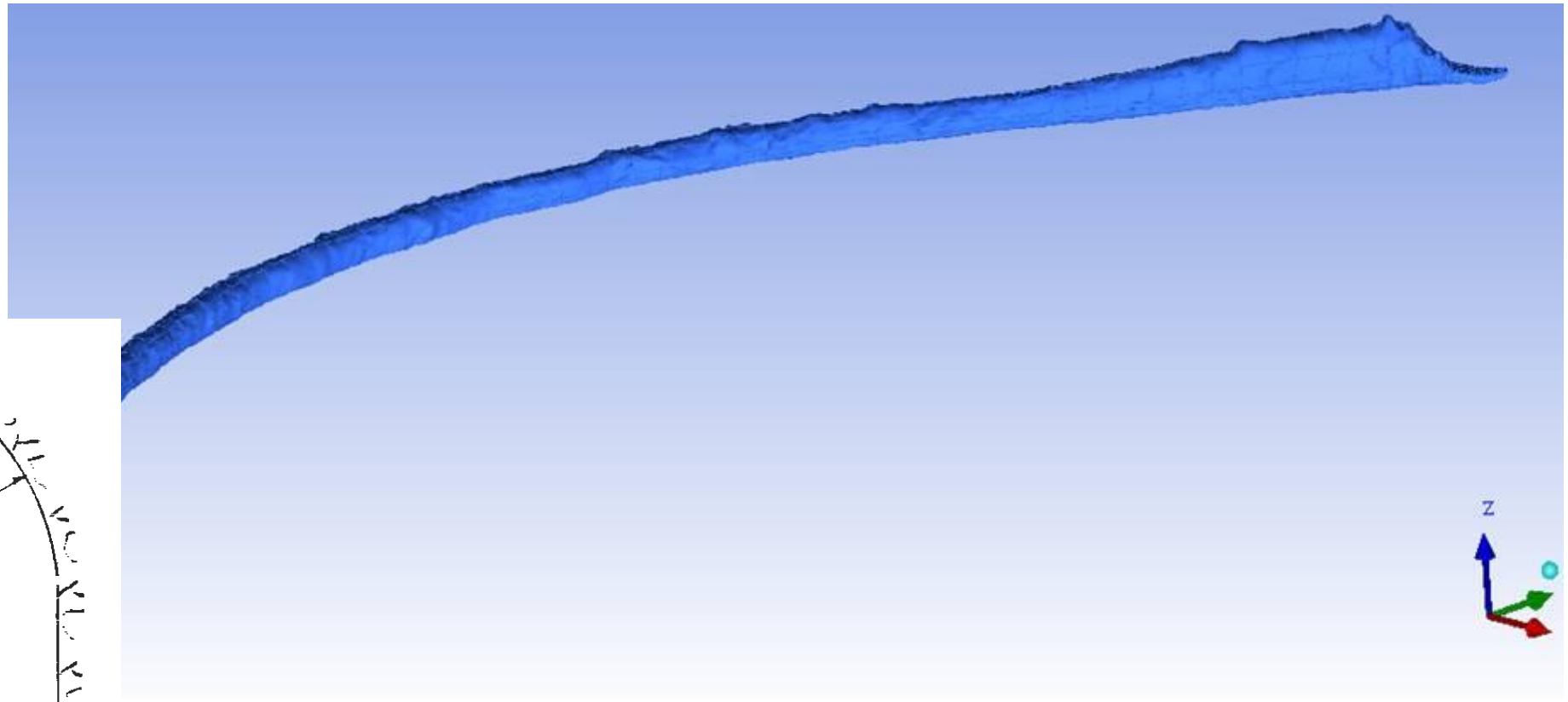
Example: Gävunda Hydropower tunnel





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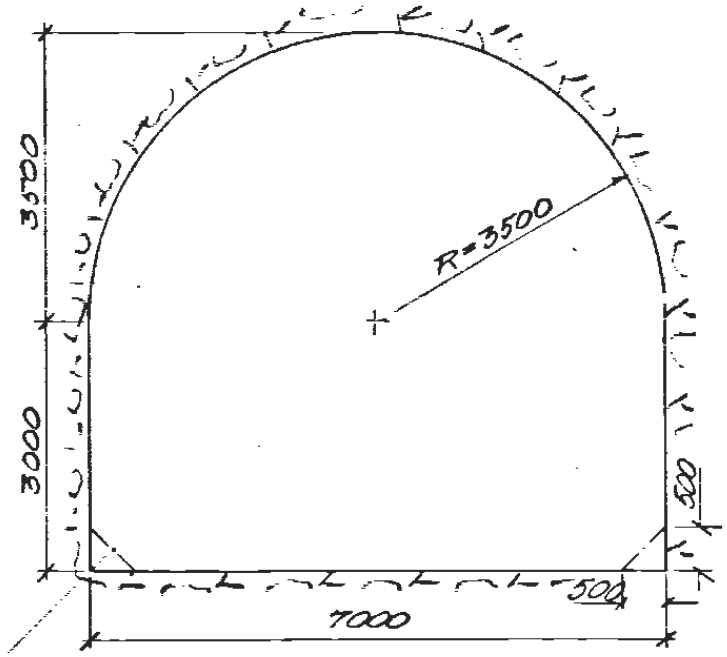

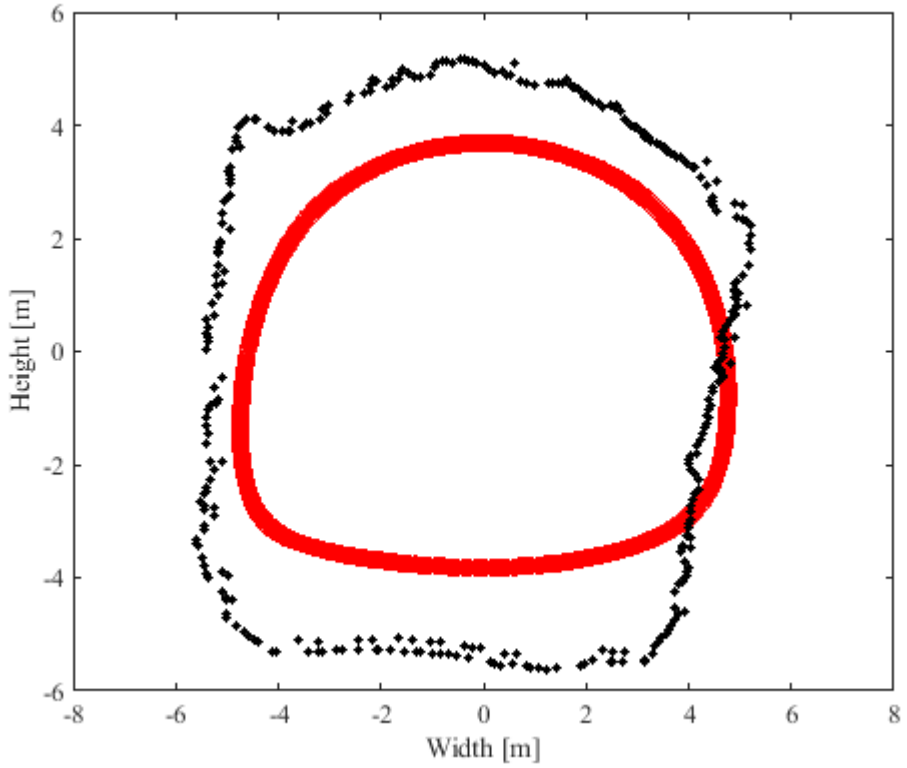

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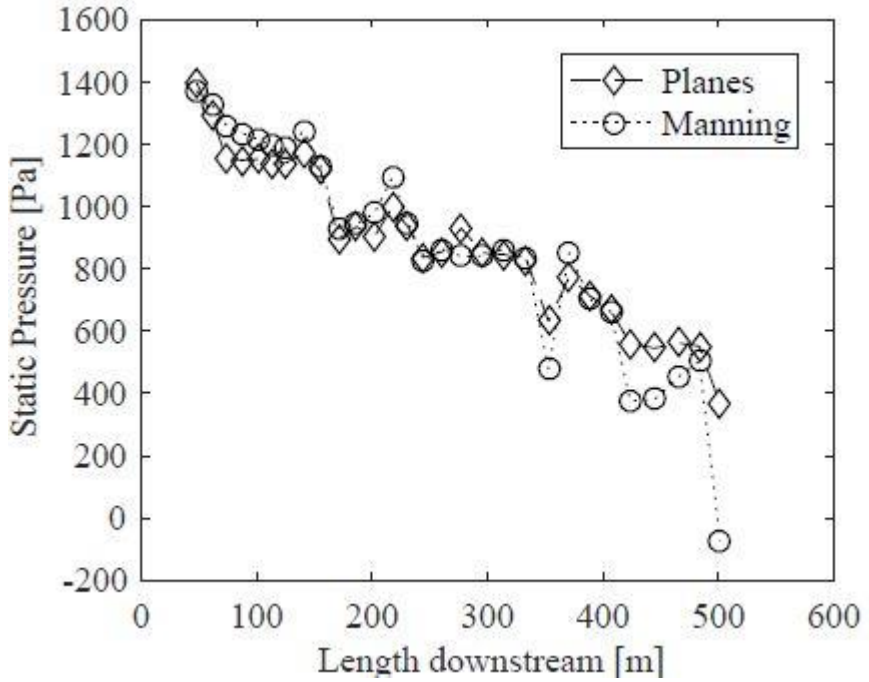
What are the implications on the flow?

$$\frac{Q}{A} = U = \frac{1}{n} R_h^{2/3} S_f^{1/2} = \frac{1}{\rho g} \frac{dp}{dx}$$

$$\frac{dp}{dx} \propto A R_h^{2/3}$$



Tunnelsensor, why?

- Cheap alternative to current methods of evaluation
  - ROV
  - Decomissioning of the tunnel in question
- Possibility to continously screen the tunnels durability (To discover changes over time)

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Probe requirements

- Boyant
- Affordable
- Retreivable
- Easy to use

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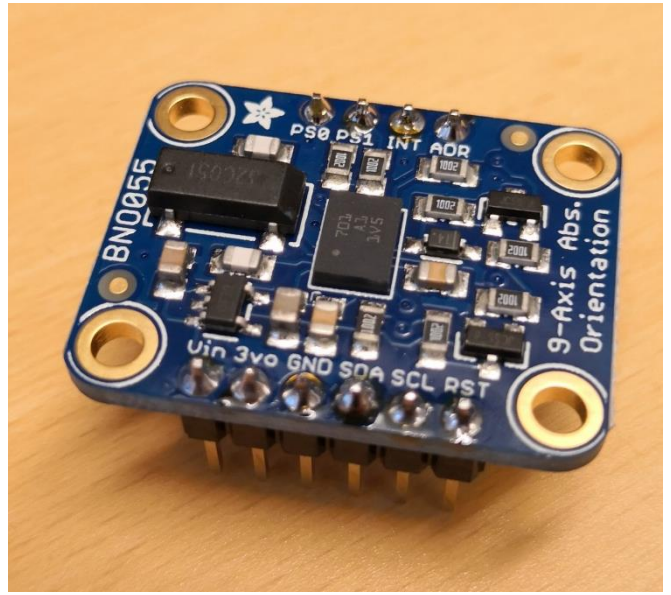
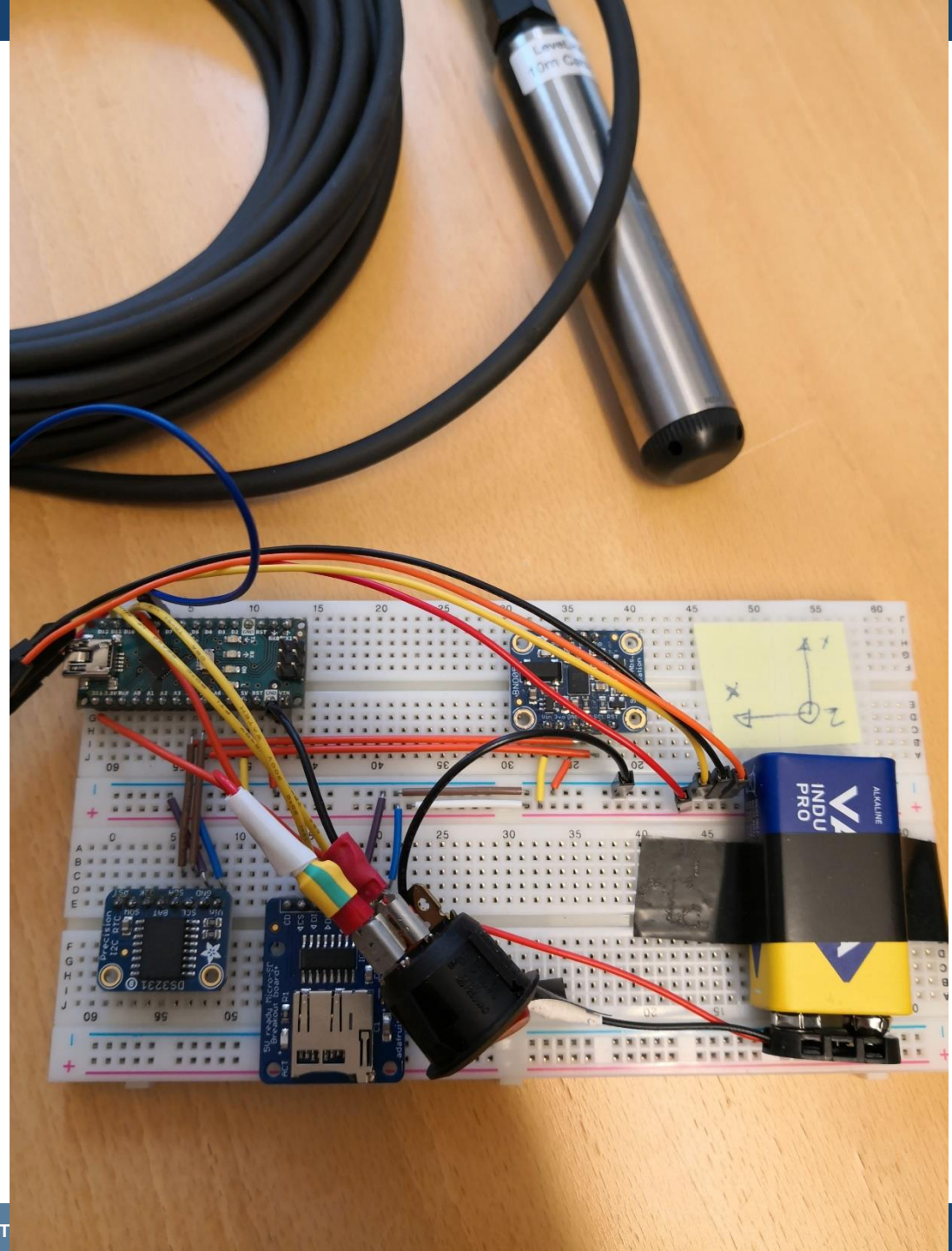
- Main board: Arduino Nano (ATmega328 processor)
- Accelerometer (IMU): BNO055
- Data storage: Adafruit micro-SD card breakout board
- Time measurement (Quartz based): PCF8523 Real Time Clock (RTC)
- Pressure sensor: Leveline mini
- Total price around 600 euros





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Algorithms

- To avoid Gimbal-lock we use Quaternions
- The IMU already has several algorithms for calculating the relative heading
- For redundancy we have added our own algorithms as following

Pitch

$$\theta = A_\theta * (\theta + \omega_x \Delta t) + B_\theta * \tan^{-1}\left(\frac{a_x}{a_z}\right)$$

Roll

$$\phi = A_\phi * (\phi + \omega_y \Delta t) + B_\phi * \tan^{-1}\left(\frac{a_y}{a_z}\right)$$

Yaw (tilt-compensated)

$$\psi_c = \tan^{-1}\left(\frac{y_{Gc}}{x_{Gc}}\right)$$

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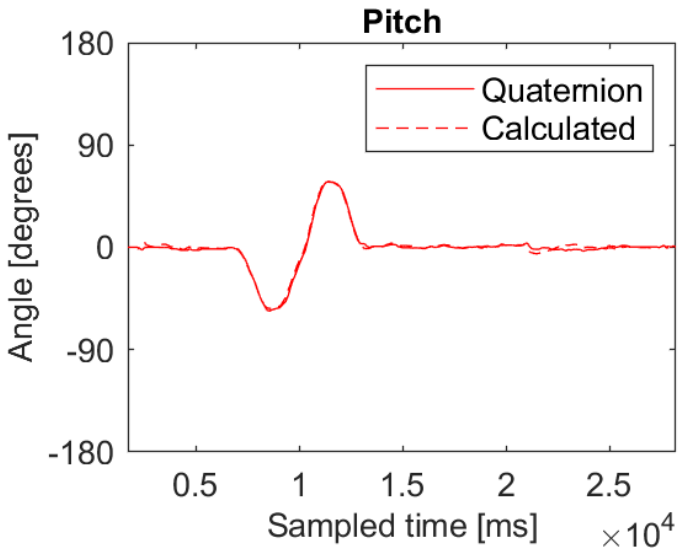
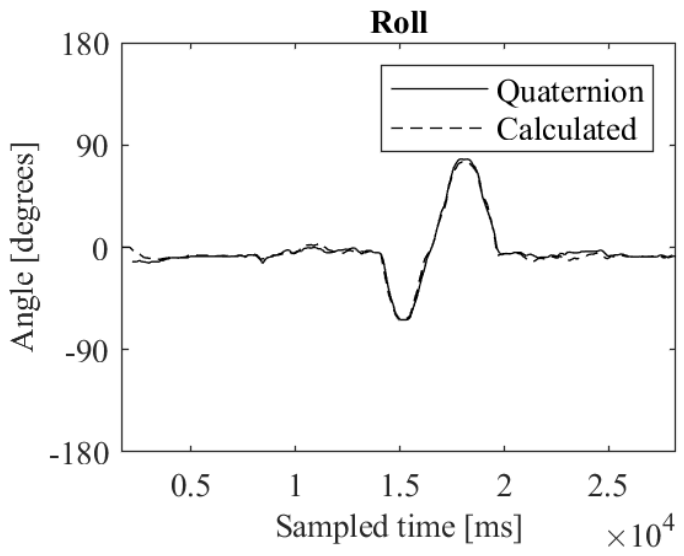
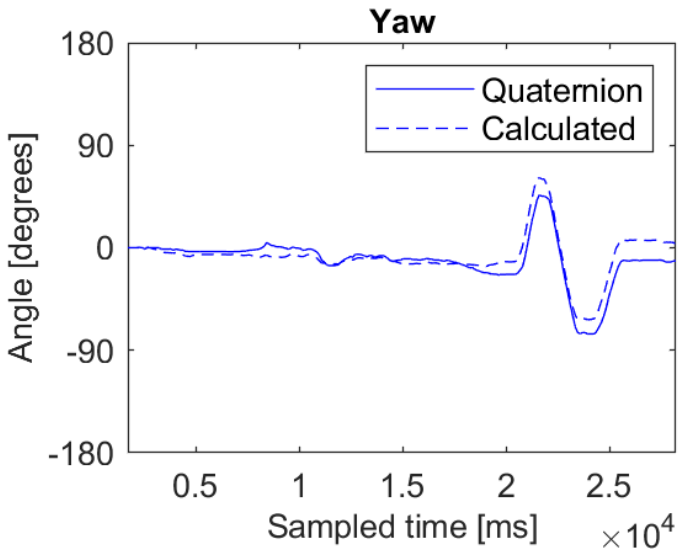
Evaluating the Algorithms







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Summary

TRL ≈ 5

- Evaluation of hardware took alot of time
  - Covid created long delivery-times
- Pressure sensor requires different approach
- Total cost of the probe is around 6000 SEK
- A Watertight shell and recovery system still needs to be constructed
- Large-scale tests remains to be conducted

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Thank you!

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