Risk assessment for fish passing turbines, pumps and hydraulic structures:

A methodological framework and innovative methods

Falko Wagner et al.

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Authors

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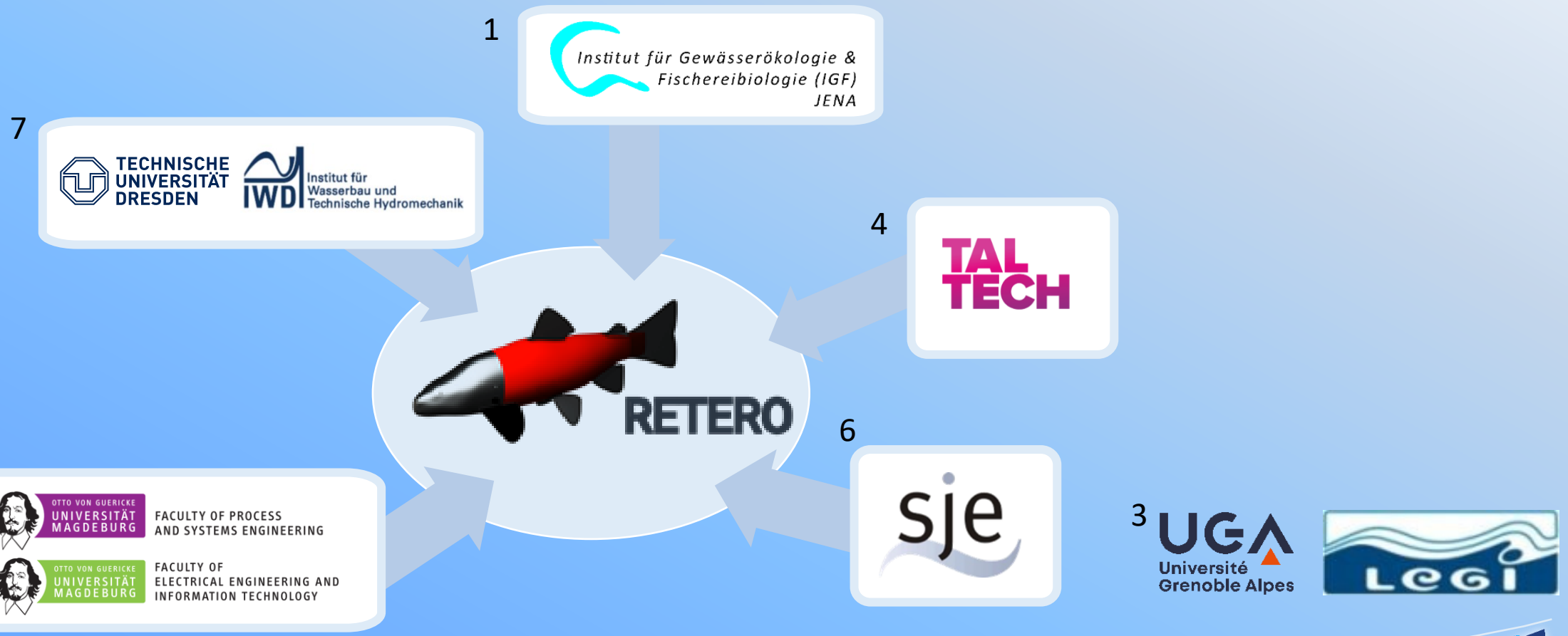


Background

- Status quo evaluation „fish friendliness“ of turbines and pumps

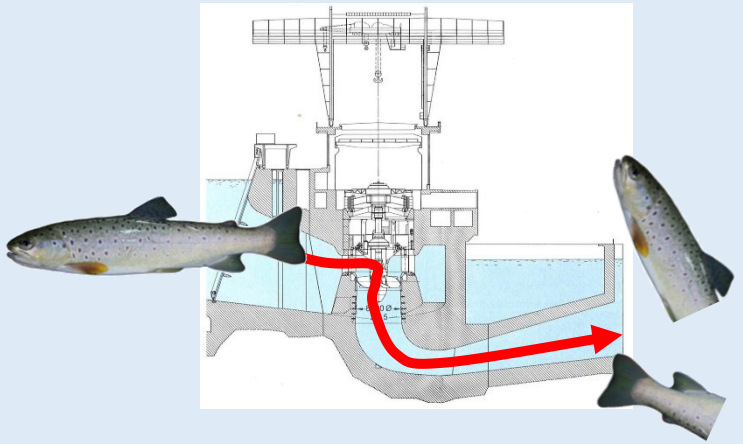
DIVE (Source: Wasserkraft & Energie 4/2020)

Evaluation Method

Experimental Approach

Model Approach

Live Fish Tests



Blade Strike Models

$$M = \frac{1}{Q}\iint_A f_{MR}(r)P_{th}(r)v_m dA$$

(NEN 2020)

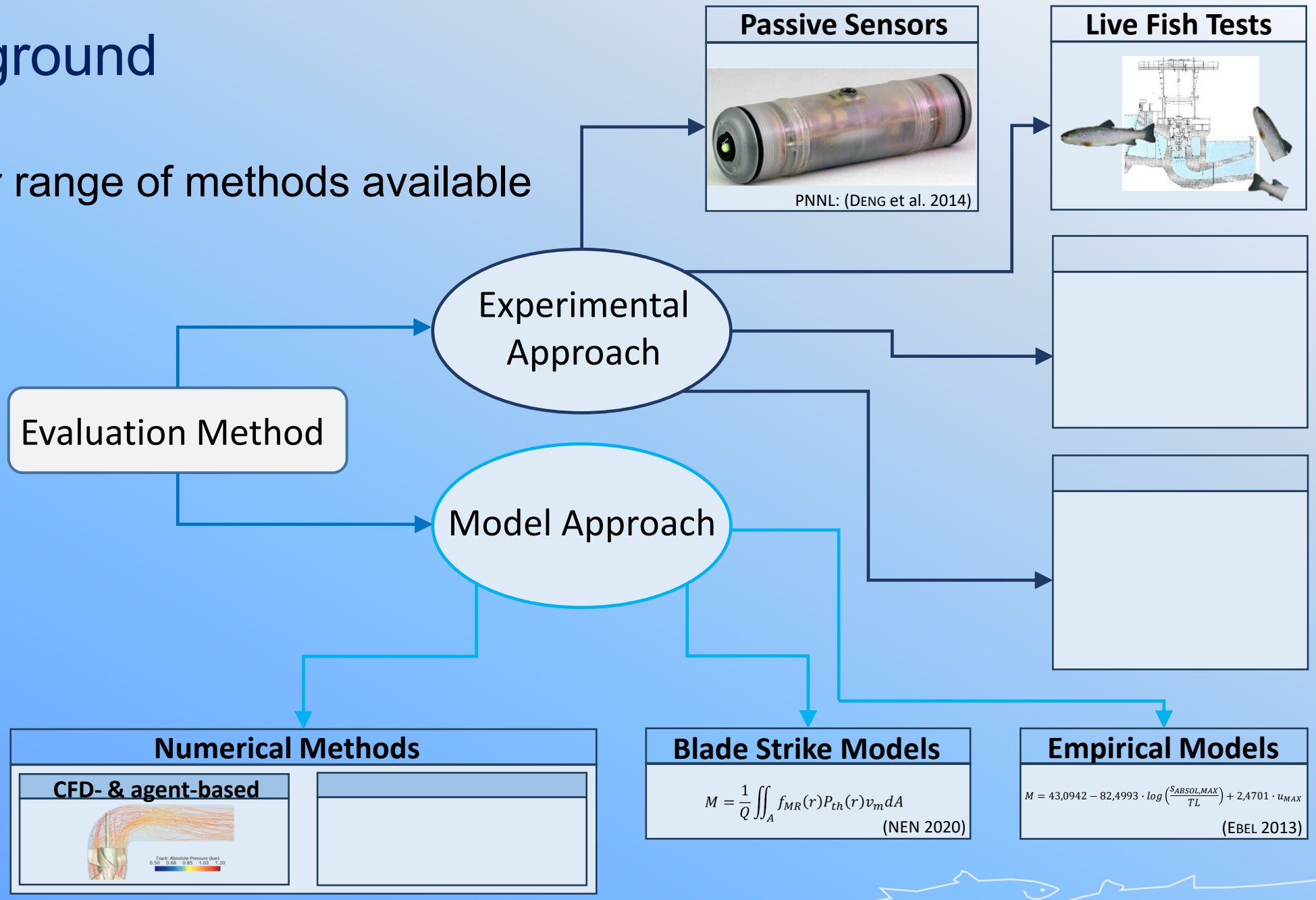
Empirical Models

$$M = 43{,}0942 - 82{,}4993 \cdot log\left(\frac{S_{ABSOL,MAX}}{TL}\right) + 2{,}4701 \cdot u_{MAX}$$

(Ebel 2013)

Background

- Broader range of methods available



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Evaluation Method

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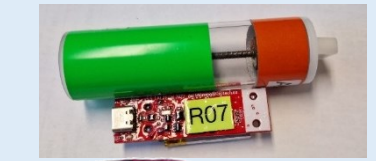
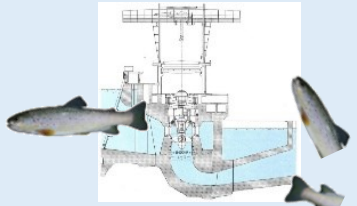
Passive Sensors

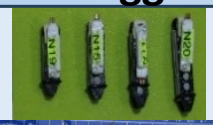


Live Fish Tests



Active Sensors

Biologger



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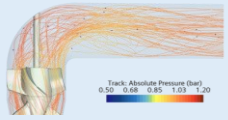
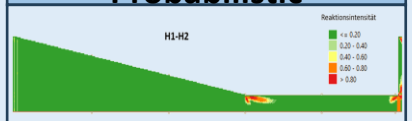
Numerical Methods

CFD- & agent-based



Probabilistic



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(Ebel 2013)

I. **Models**

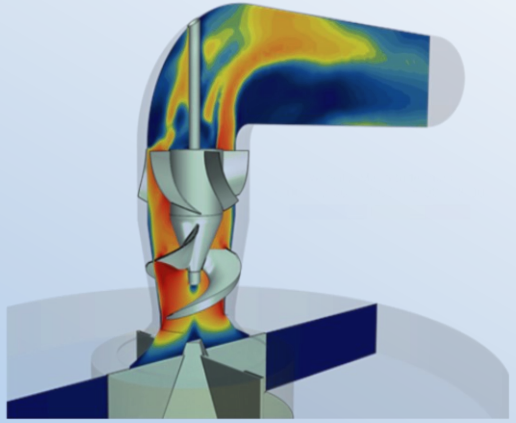
II. Experimental Methods

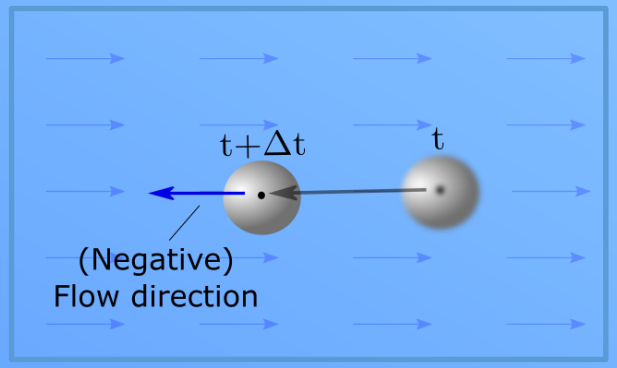
III. Framework for Method Application

Models

Virtual Fish (CFD-Simulation & Agent-based Model) [1, 2]

- CFD (computational fluid dynamics) – simulation turbine, pump other corridors
- Particles – fish behavior implemented
- Rules: rheotactic orientation / migration instinct / avoidance





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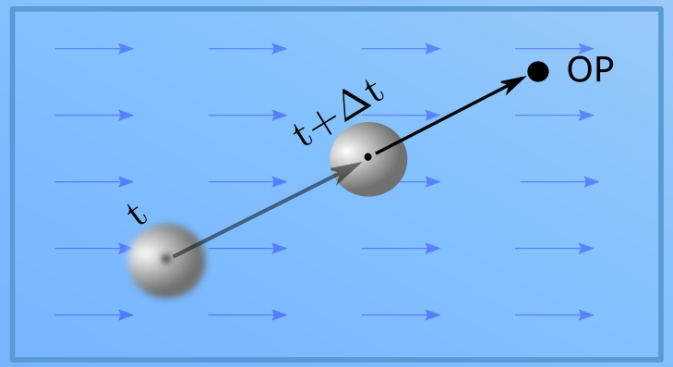

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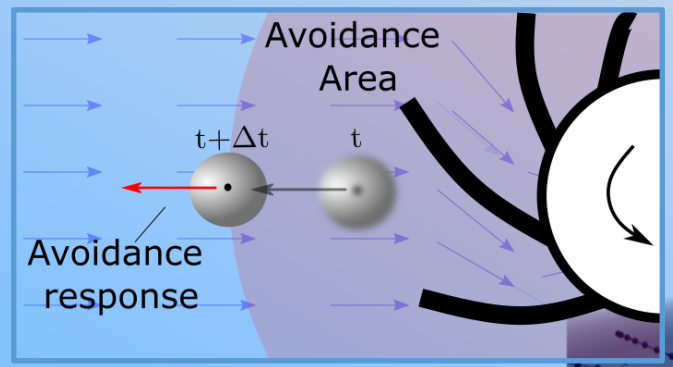
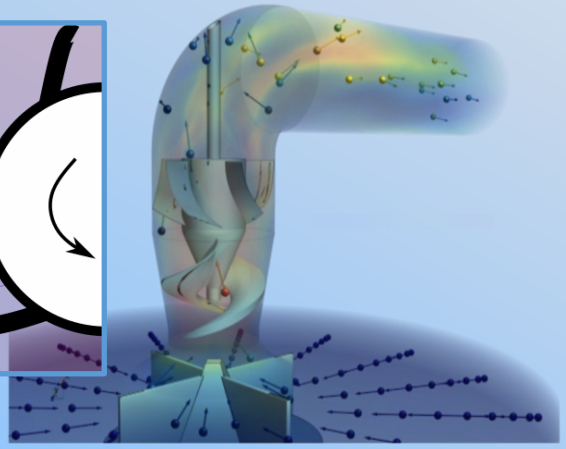


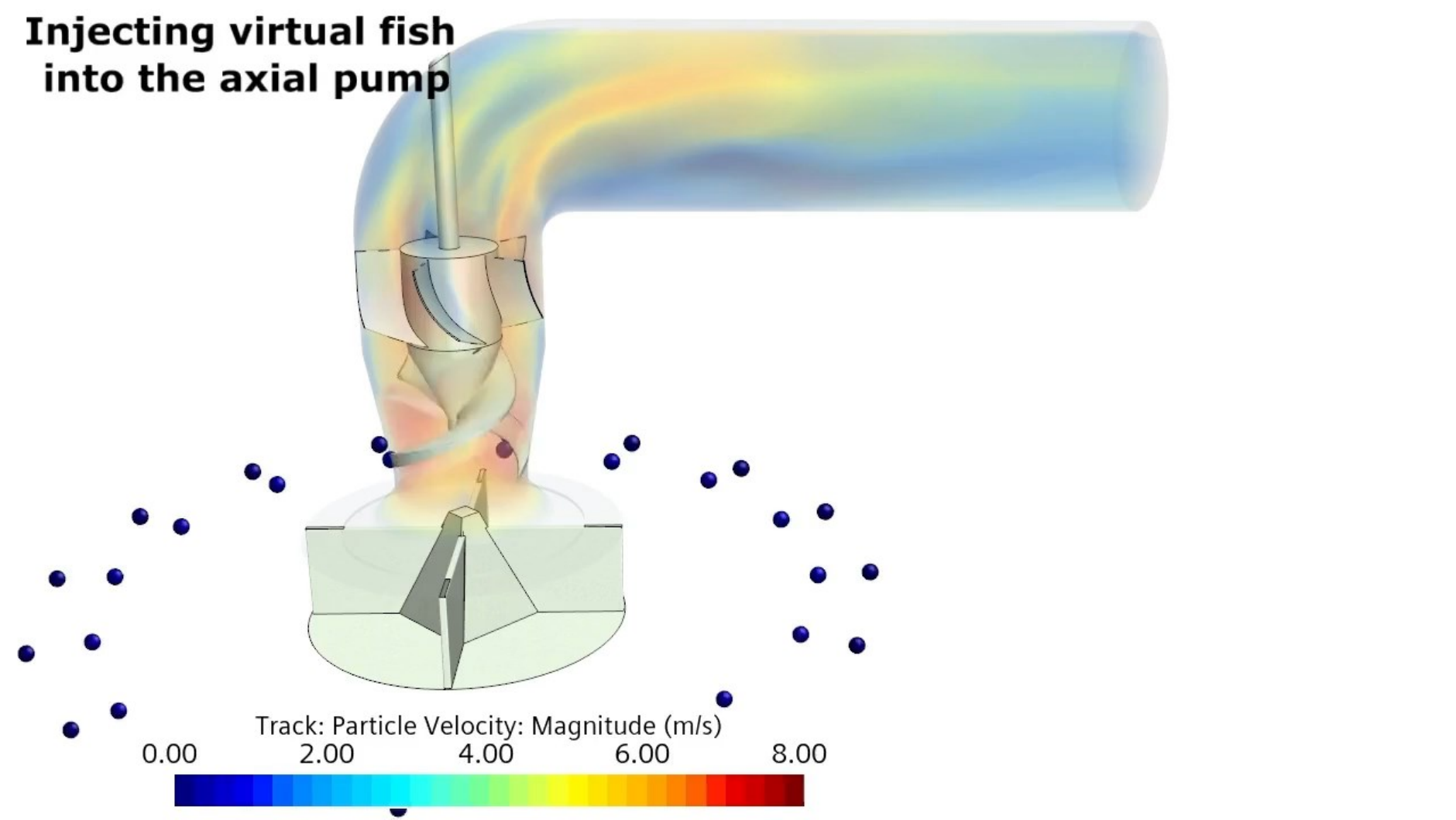


[1] POWALLA, D. et al. (2021): A Computational Fluid Dynamics Model for a Water Vortex Power Plant as Platform for Etho- and Ecohydraulic Research. Energies (14).

[2] POWALLA, D. et al. (2022): A numerical approach for active fish behaviour modelling with a view toward hydropower plant assessment. Renewable Energy 188(2).

Models

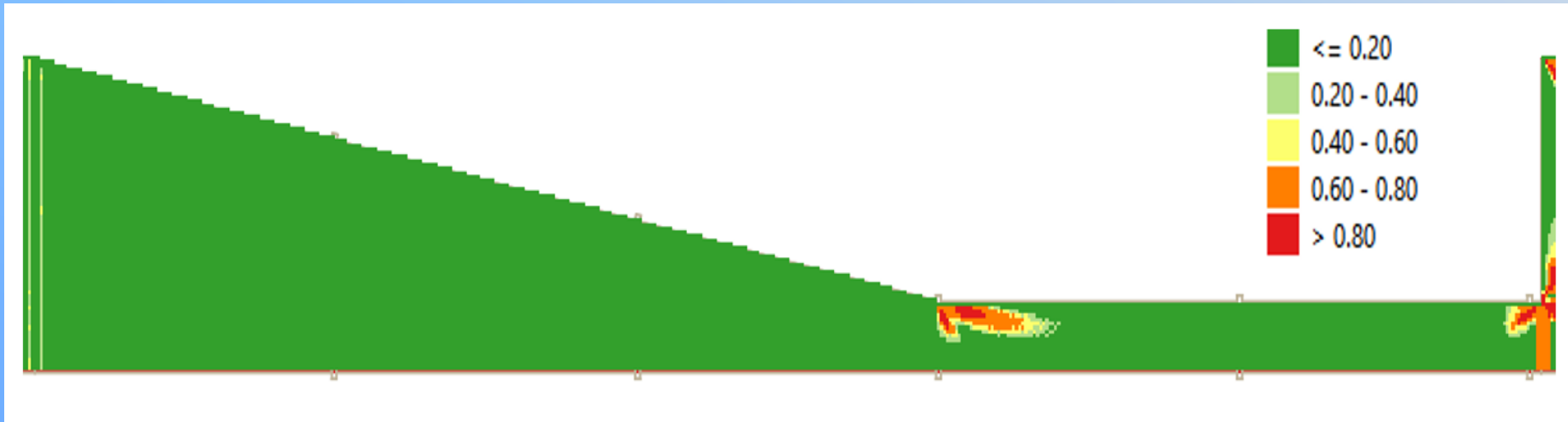
Virtual Fish (CFD-Simulation & Agent-based Model) [1, 2]



Models

Probabilistic Model CASiMiR

- Combined analysis hydraulic / fish behavior
- Raster based prediction of behavior and mortality risk
- Input variables: flow velocity, spatial velocity gradient, light conditions



Probability of avoidance reaction of fish in a pump inlet model

I. Models

II. Experimental Methods

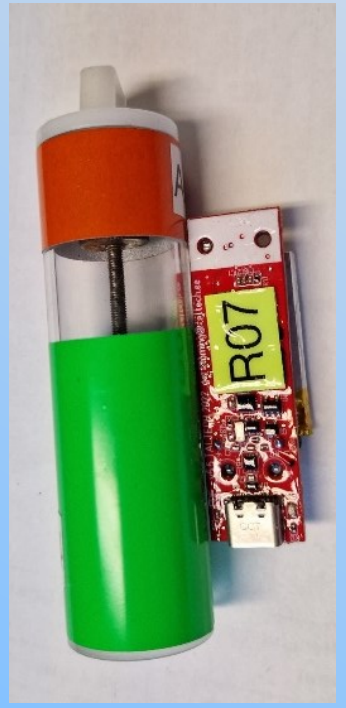
III. Framework for Method Application

Experimental Methods

- Passive Sensors -

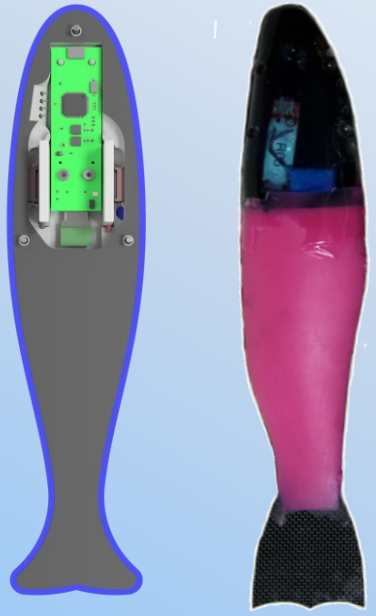
Quelle: TalTech

Barotrauma **D**etection **S**ensor (BDS)



Robust **A**utonomous **P**ressure and **I**nertia **D**evice (RAPID)

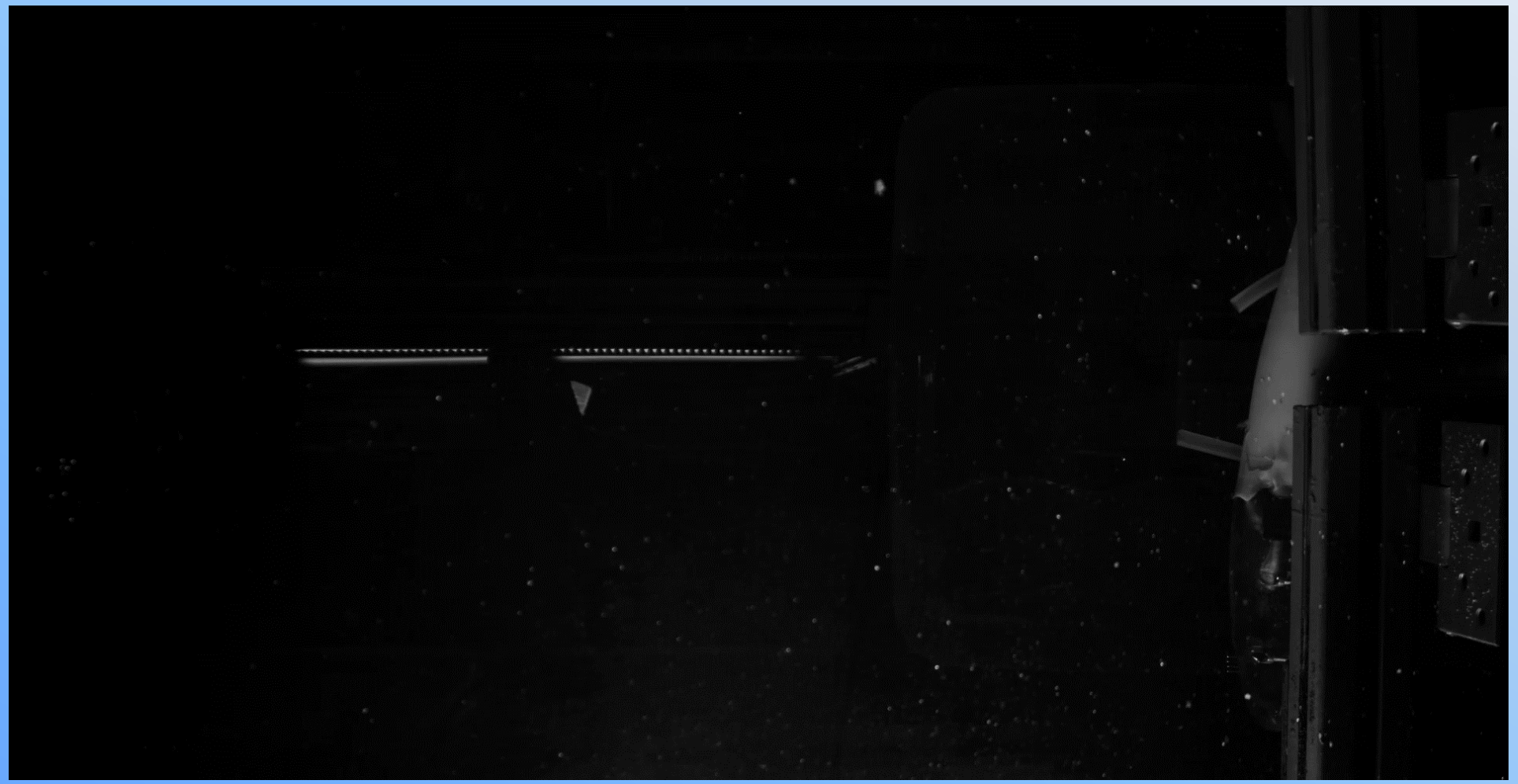
Fluid-Structure-Interactions



Strike Sensor

Experimental Methods - Passive Sensors -

Strike Sensor: Experiments to achieve more realistic data for strike events



Experimental Methods - Biologger -

Backpack sensor [3]

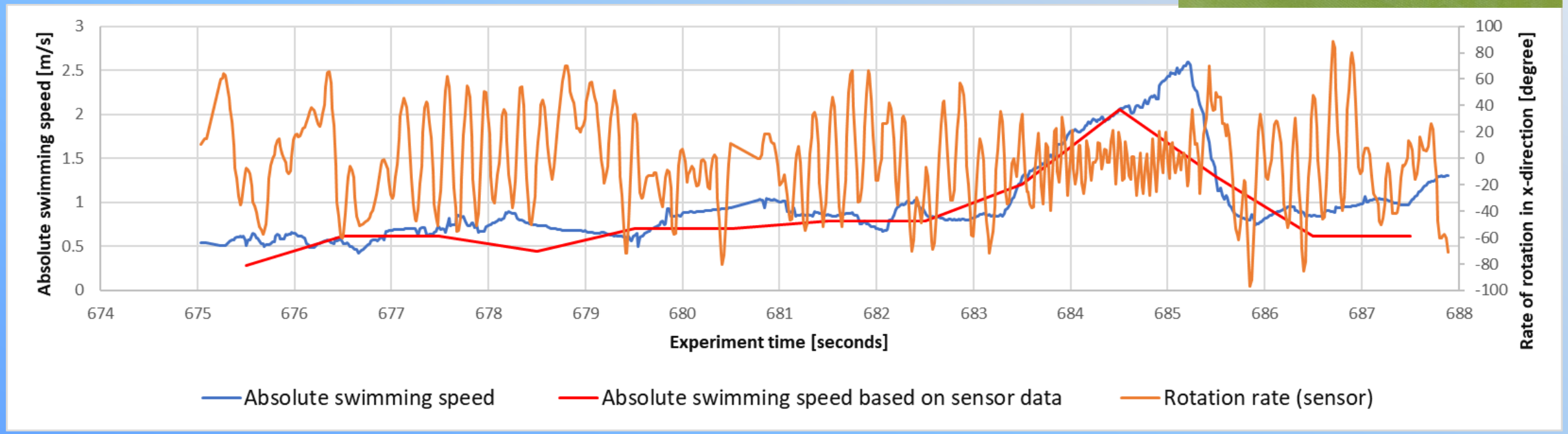
- Non-invasive, Multi sensor
- Total mass < 5 g

Parameters:
- Linear acceleration
- Pressure
- Rotation rate
- Orientation magnetic field

[3] WAGNER, F. et al. (2022): A new, non-invasive fish backpack biologger to measure the physical conditions experienced by swimming fish during downstream passage. Fish Passage 2022. Pacific Northwest National Laboratory, Richland USA, 13.-17.06.2022.

Experimental Methods - Biologger -

- Rotation rate linked to tail beat frequency
- Related to swimming speed[4] (at high speeds)
- Movement data for inaccessible environments are provided



[4] KOPECKI, I. et al. (2024): Estimating fish swimming speed using non-invasive backpack sensors in a laboratory flume at high flow velocities. Submitted for ISE24 and Fish Passage Conference, Québec City, Canada.

Experimental Methods - Active Sensor -

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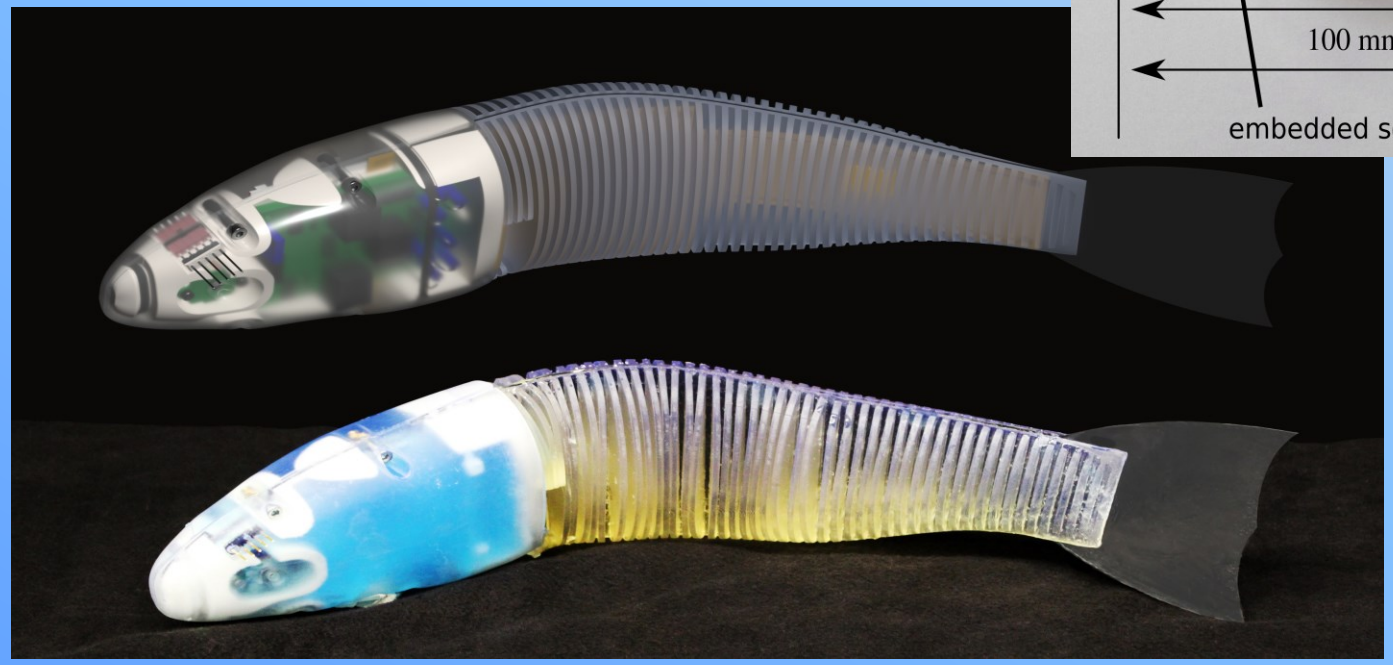
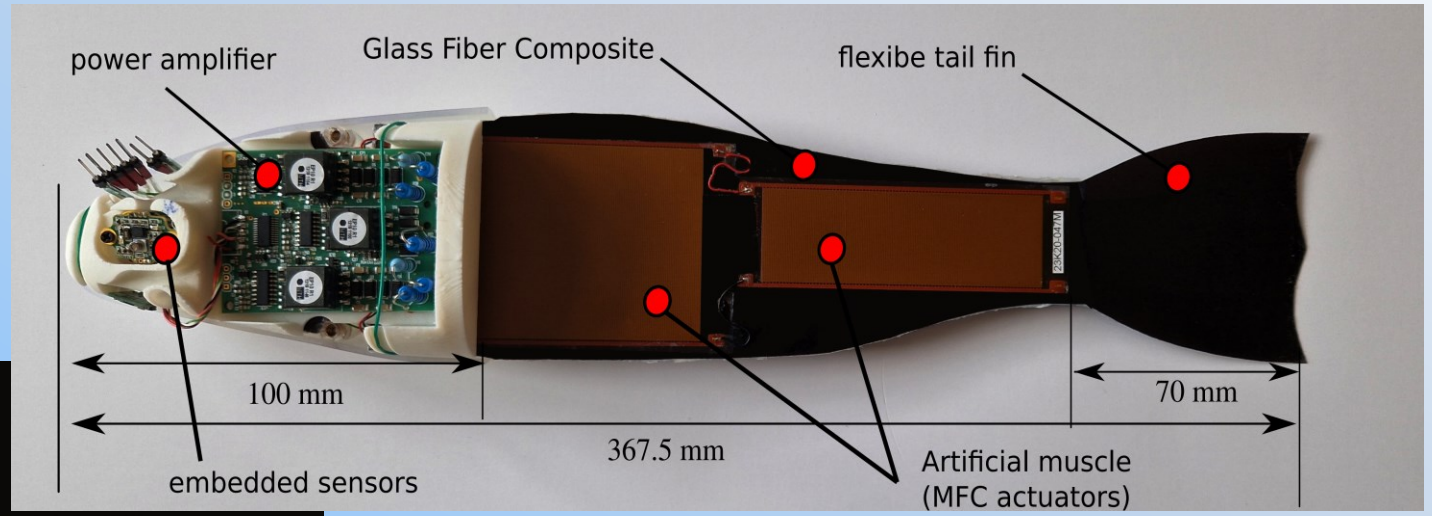
„Robofish“[5, 6]





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[5] ABBASZADEH, S. et al. (2021): A Design Concept and Kinematic Model for a Soft Aquatic Robot with Complex Bio-mimicking Motion. Journal of Bionic Engineering, 19(1).
[6] ABBASZADEH, S. et al. (2023): On the influence of head motion on the swimming kinematics of robotic fish. Bioinspiration & Biomimetics, 18.

FREE FLOW

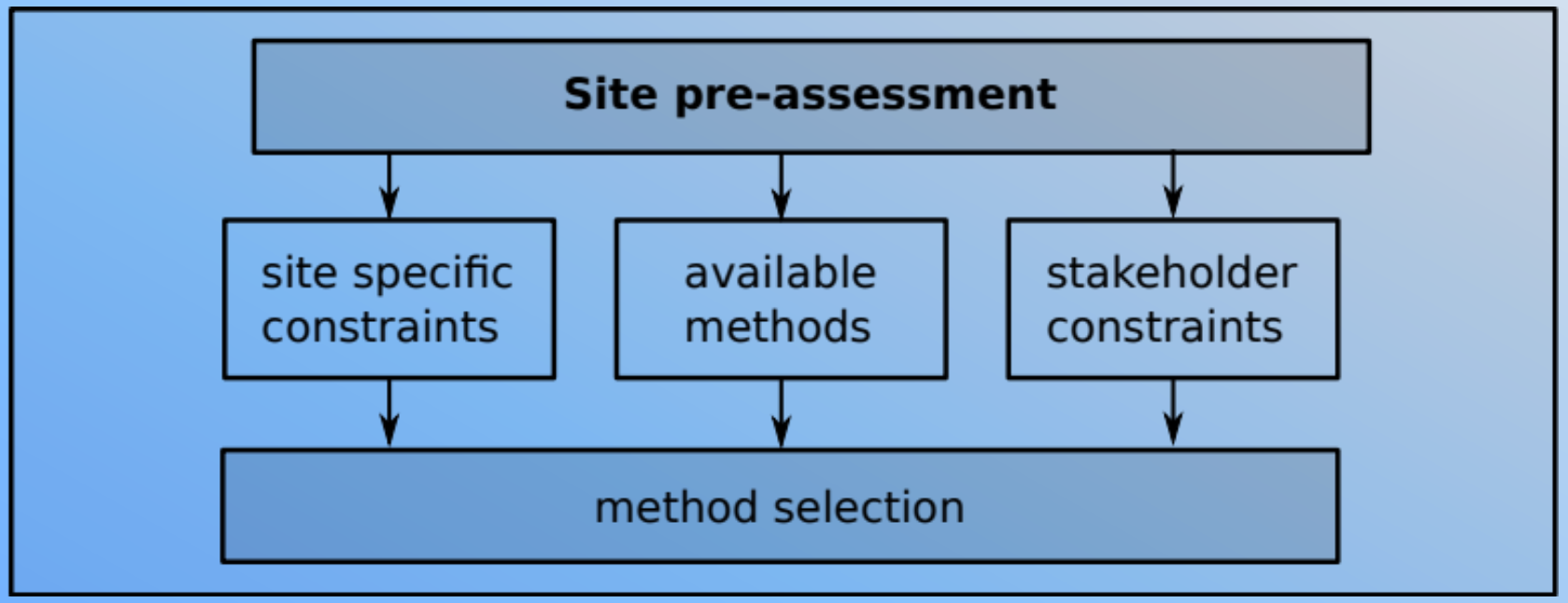
I. Models

II. Experimental Methods

III. Framework for Method Application

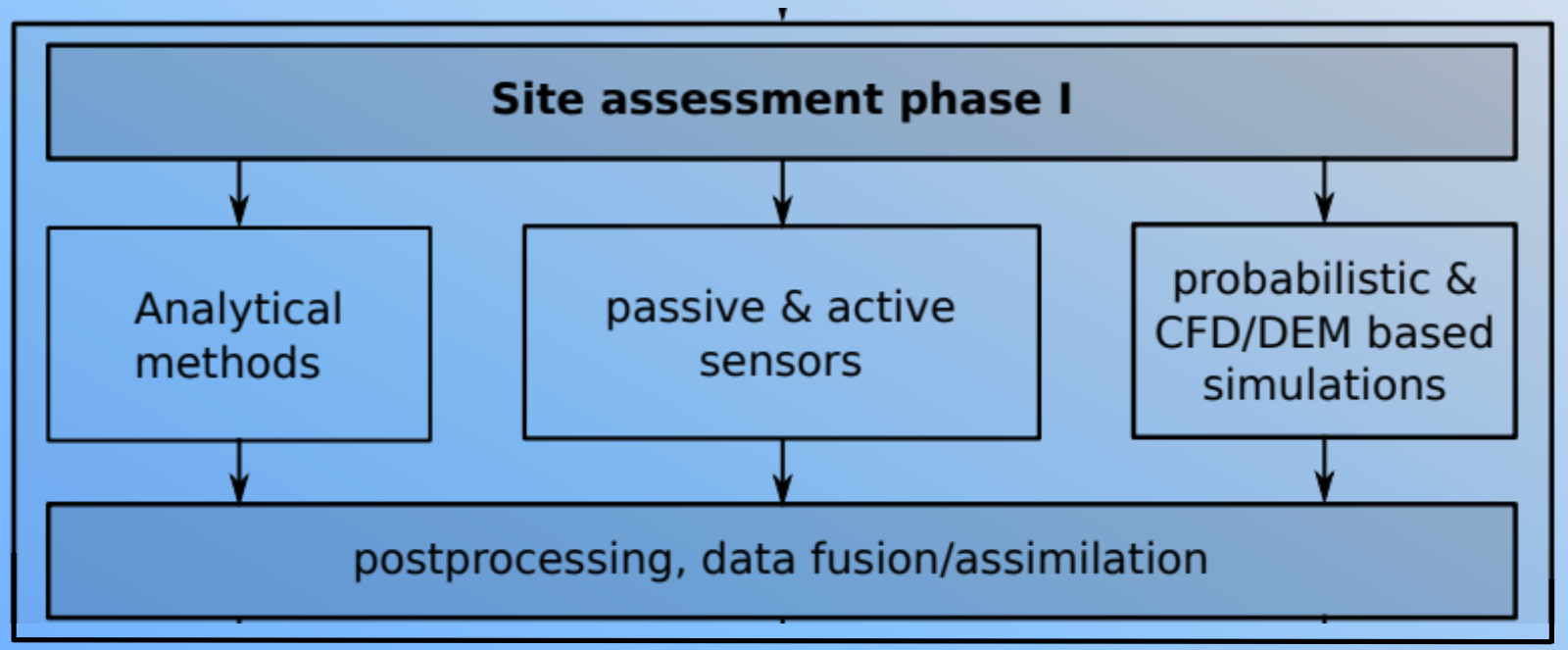
Framework

Step 1



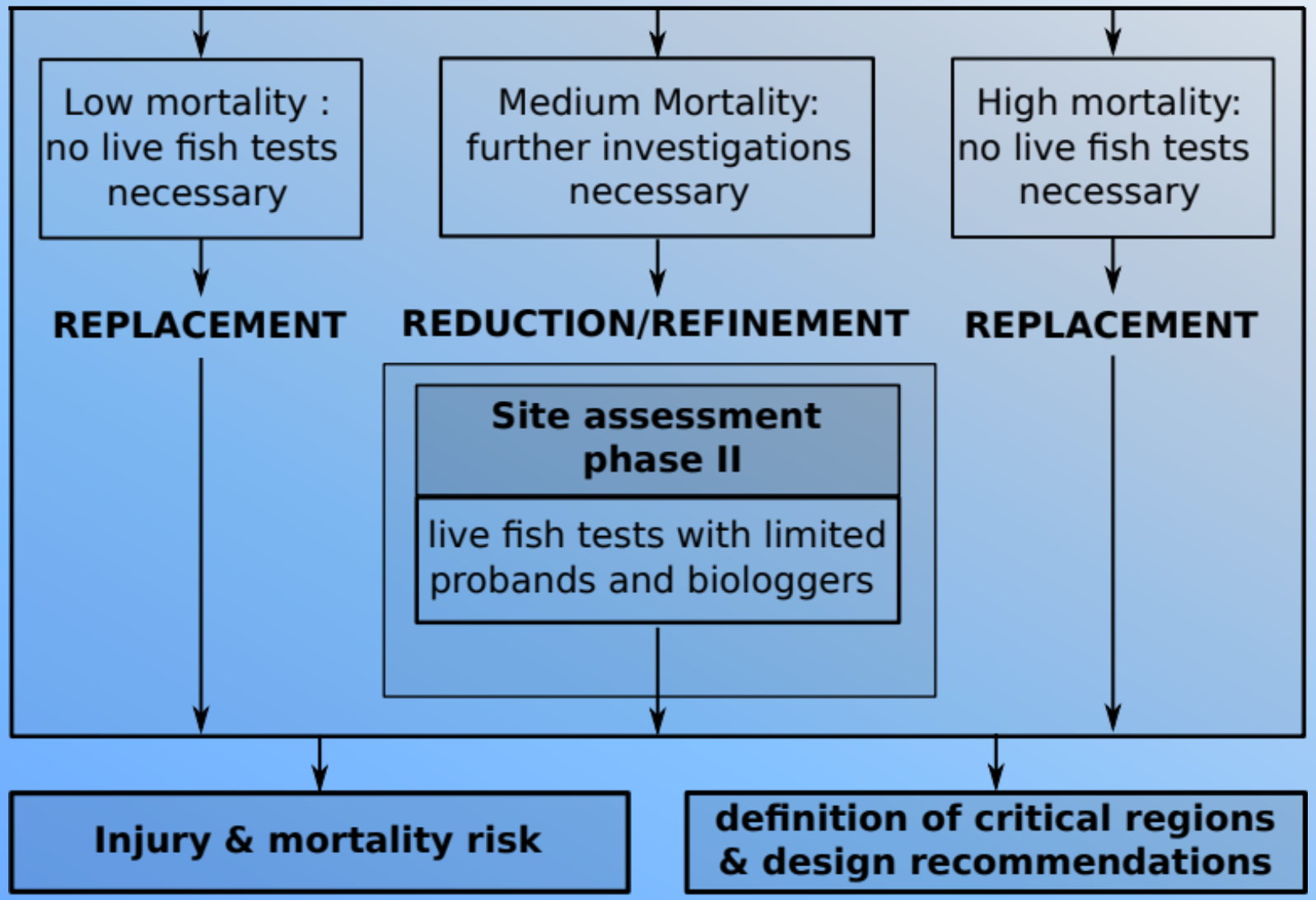
Framework

Step 2



Framework

Step 3



Thank you for your attention!