Numerical **Optimisation** of a **Jointed**, Multibody Wave Energy Converter

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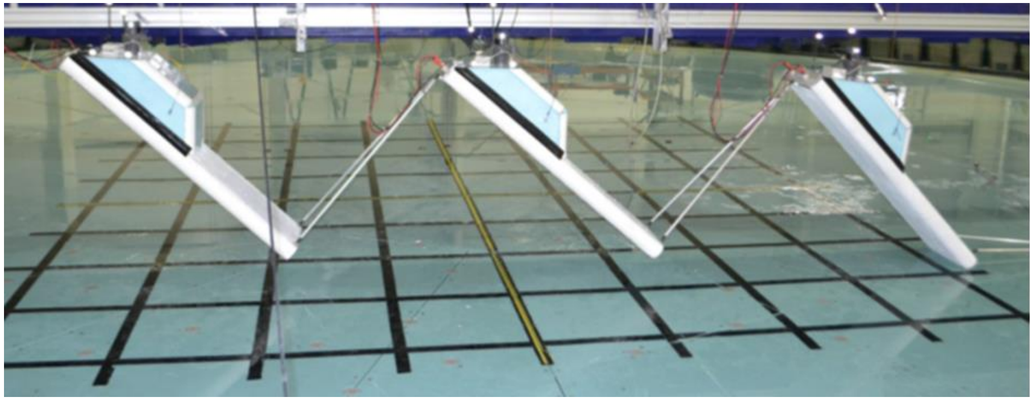
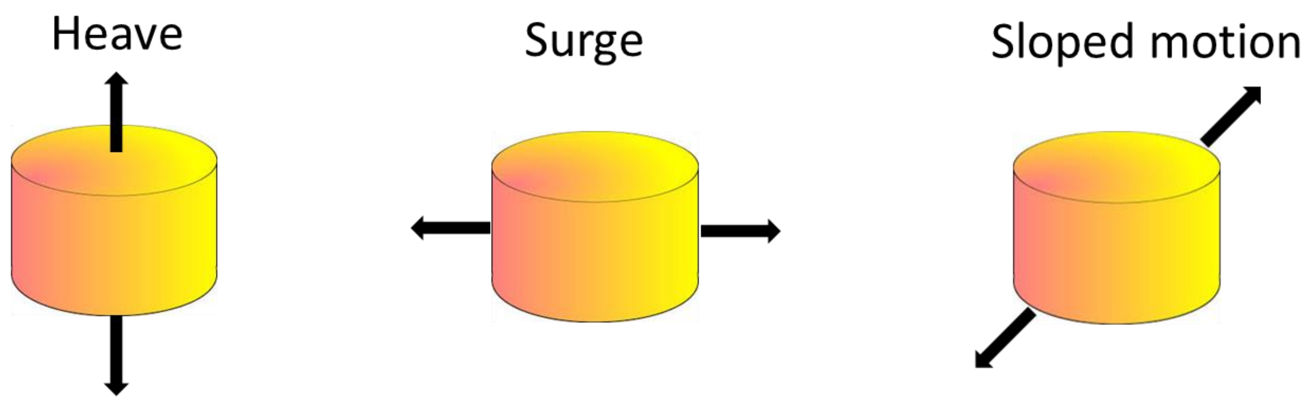


WaveTrain Wave Energy Converter, courtesy of Joules E. E. S.

The benefits of sloped motion



Intermediate stiffness

⬇

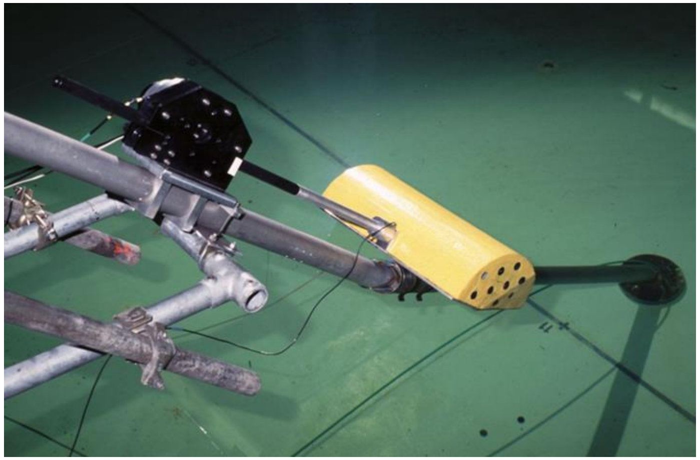
$\omega_{resonant} = \omega_{wave}$

⬇

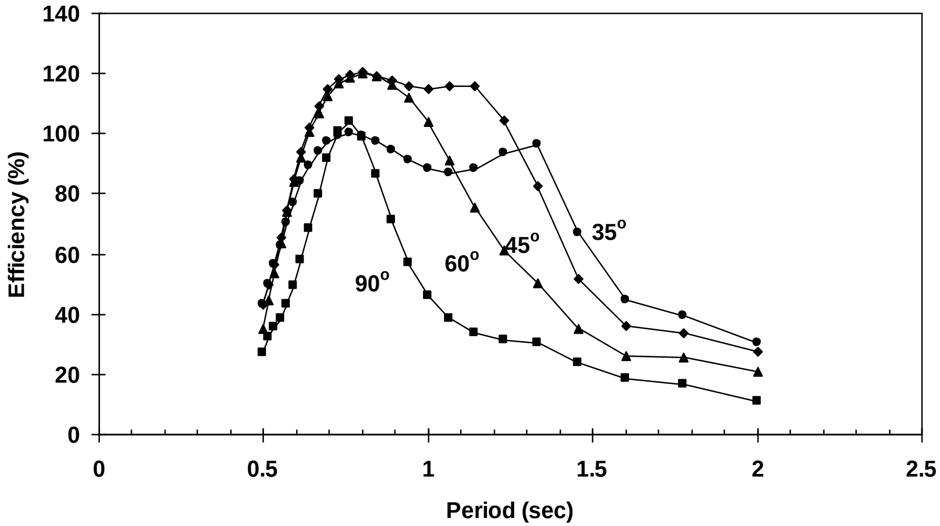
Better power capture

Geometry can more readily be used to tune to the incident sea state

The benefits of sloped motion



Sloped rig at Edinburgh in mid-late 90s



Power absorbed well in a wide range of conditions with intermediate slope angle

For exploitation of deep water waves, device needs to be **freely-floating**

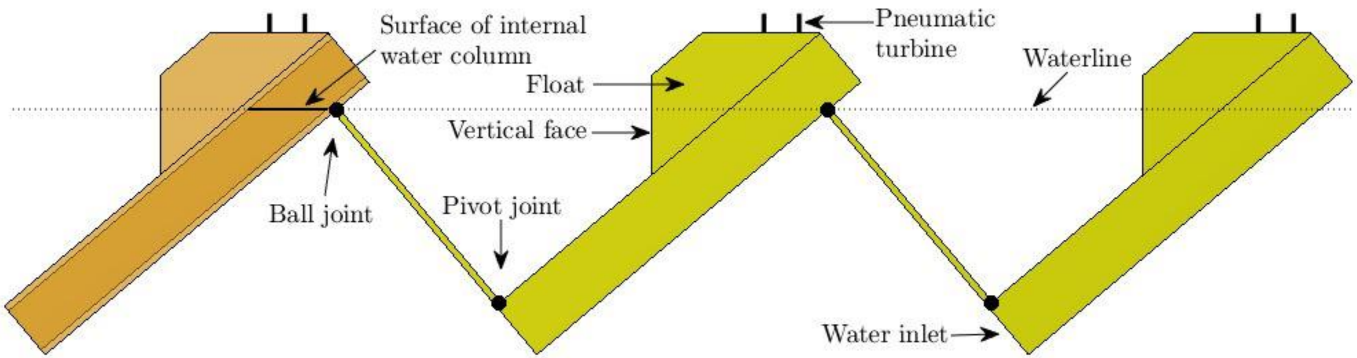
For further information, see: Lin C-P, 1999 'Experimental studies of the hydrodynamic characteristics of a sloped wave energy device', PhD thesis, University of Edinburgh.

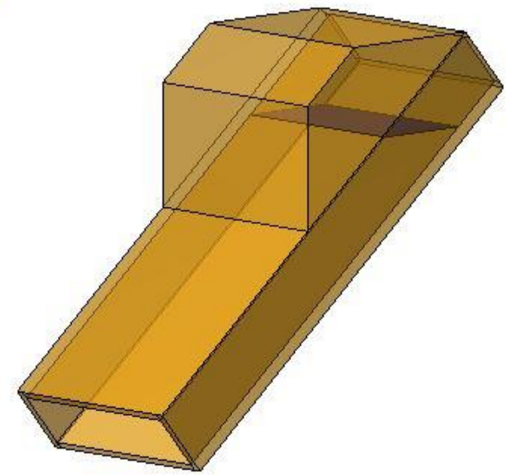
Bandwidth collapse in freely-floating version

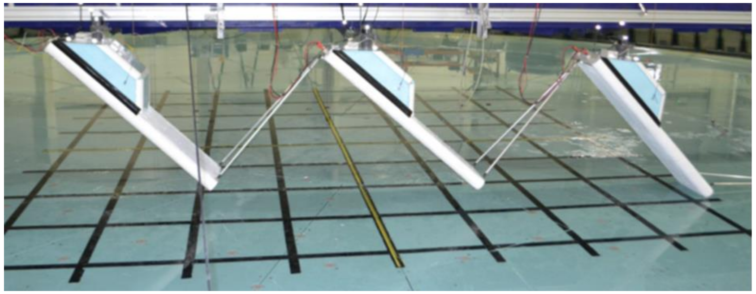
Excessive pitching (rotating) was found to diminish performance

Video by Jamie Taylor, “Power for Change”, https://www.youtube.com/watch?v=IQhnNQw9408&list=PLDlE-GBjzmBY1LR71FVwZUznj0MlsB-od&index=8

WaveTrain as the solution







Incoming Waves

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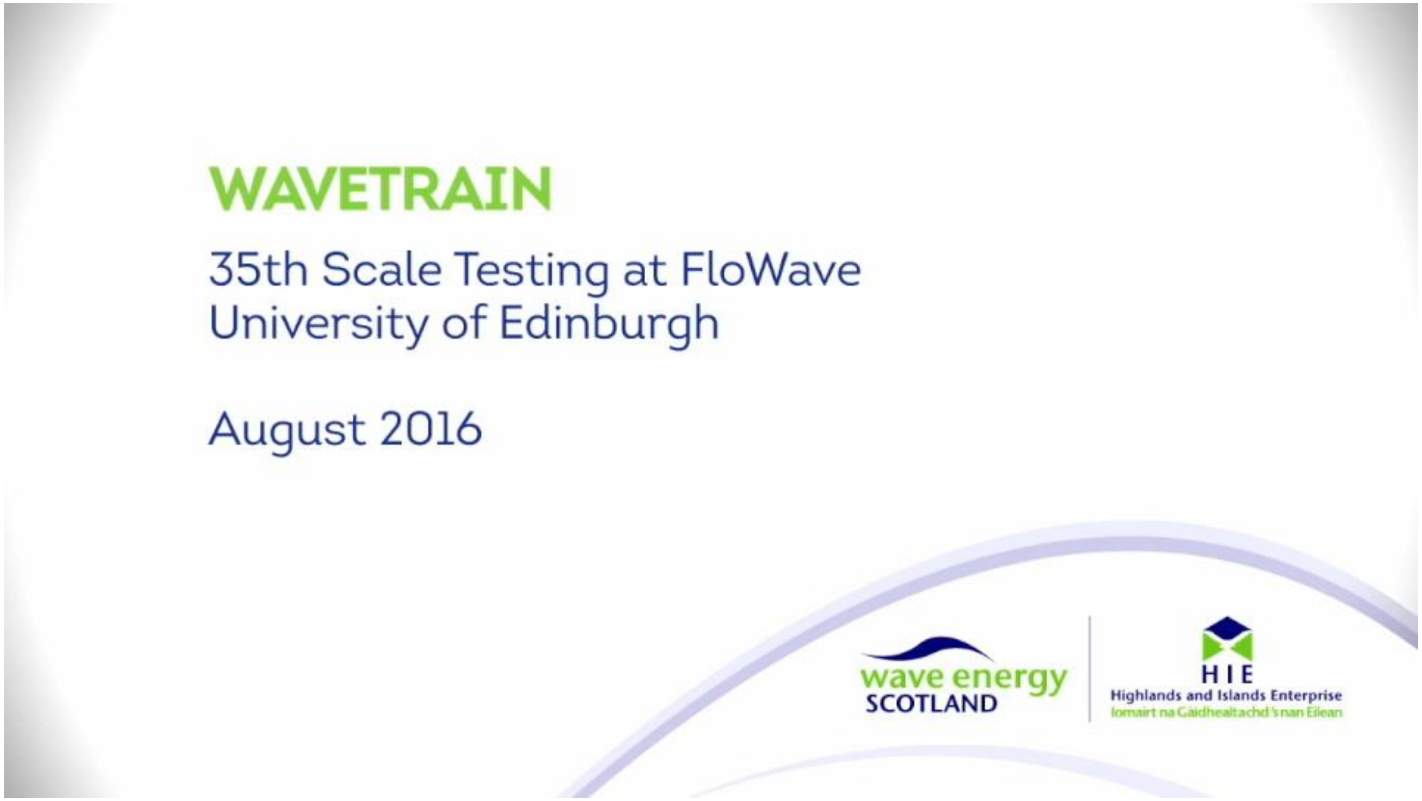
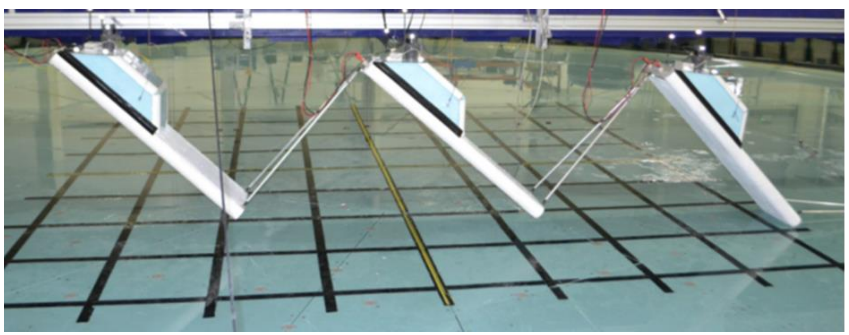


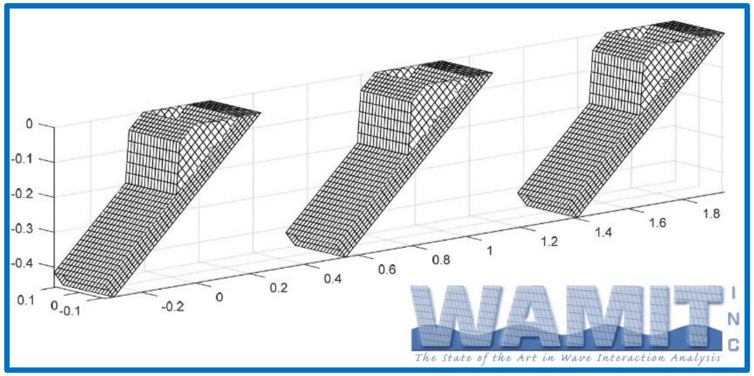


Incoming Waves

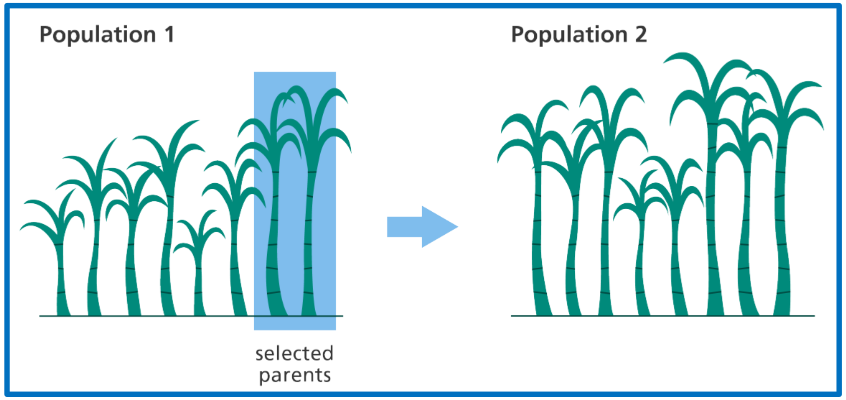
Video by Wave Energy Scotland, “Novel Wave Energy Converter Stage 1 projects”, https://www.youtube.com/watch?v=MCs8W2sxMKY

Hydrodynamic model and optimisation

Aim: ***Use genetic algorithms with hydro numerical model to find optimal geometries/mass distributions***



Efficient model of the device



Genetic algorithm:

Heritable genetic variation

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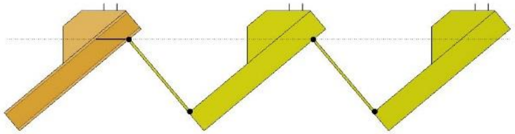
differential reproductive success

Ensuring the genetic algorithms produce sensible results is difficult

Automated generation of hydrodynamic models

Complex geometry; pushing computational limits



Numerical solver failure

OR

Insufficient accuracy

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Ensuring the genetic algorithms produce sensible results is difficult

One part of the solution:

- Measure amount of symmetry of added mass matrix
- Computationally efficient but relies on empirical judgement

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \cdots & a_{3n} \\ \vdots & \vdots & \vdots & & \vdots \\ a_{m1} & a_{m2} & a_{m3} & & a_{mn} \end{pmatrix}$$

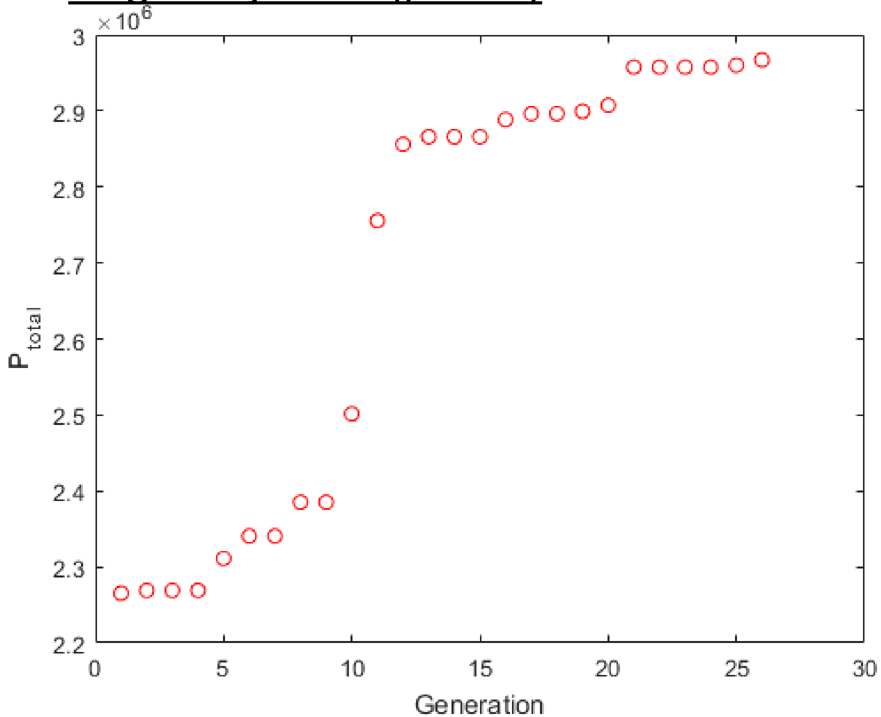
Genetic algorithms – two types

Objective 1: Annual average **power** in West Shetland Shelf wave climate

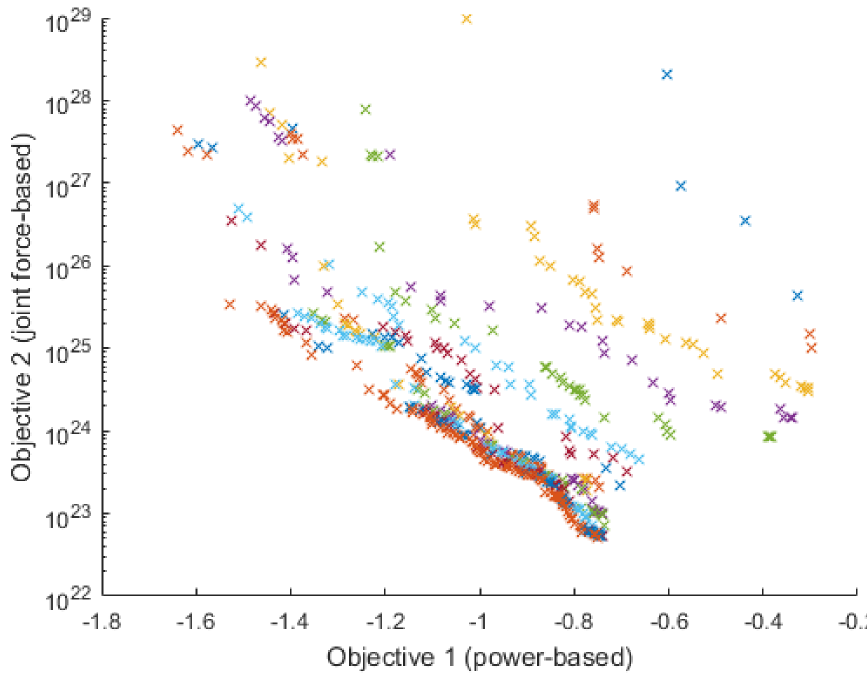
Objective 2: Annual average **cyclic stresses on joints** in West Shetland Shelf wave climate

Provides indication of relative "damage", absolute lifetimes surplus

Single-objective (power)



Multi-objective



A sample of key findings

Feasible parameter space is inherently biased against inclination angle

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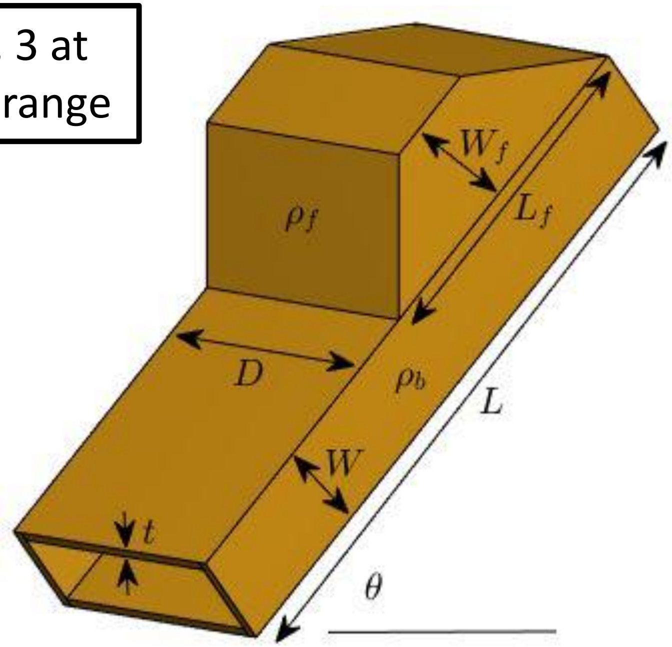
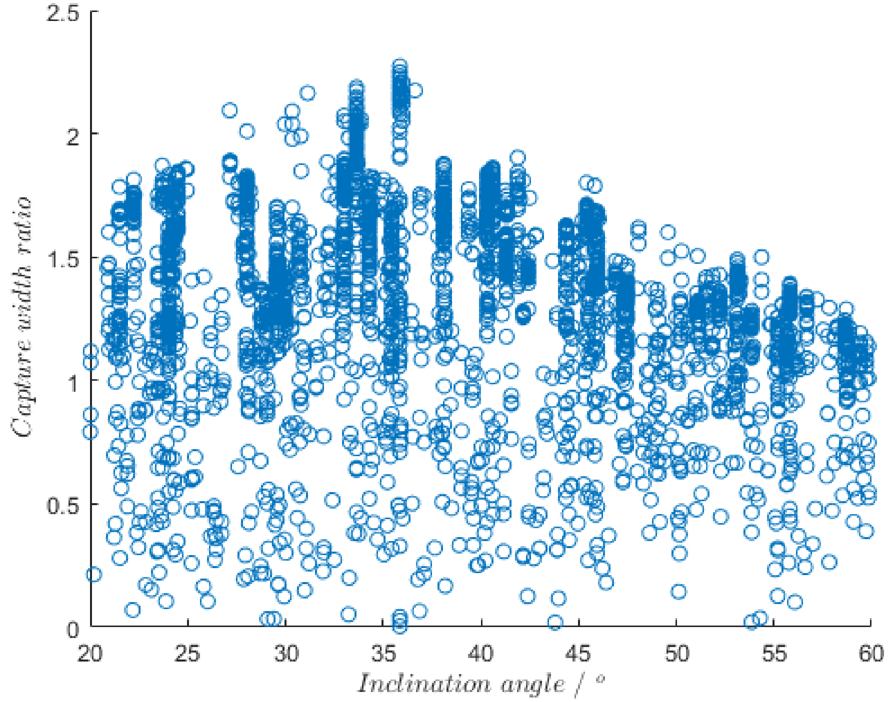
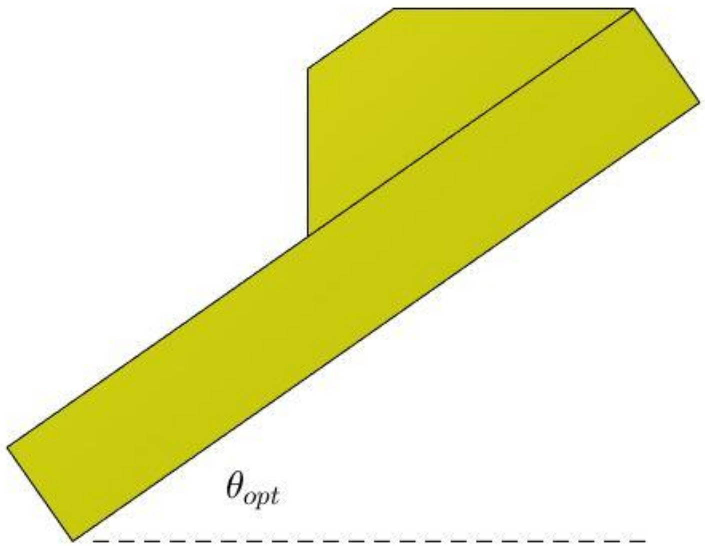
Want to explore multiple candidates for optimality

⇒ 24 runs, 3 at each 5° range

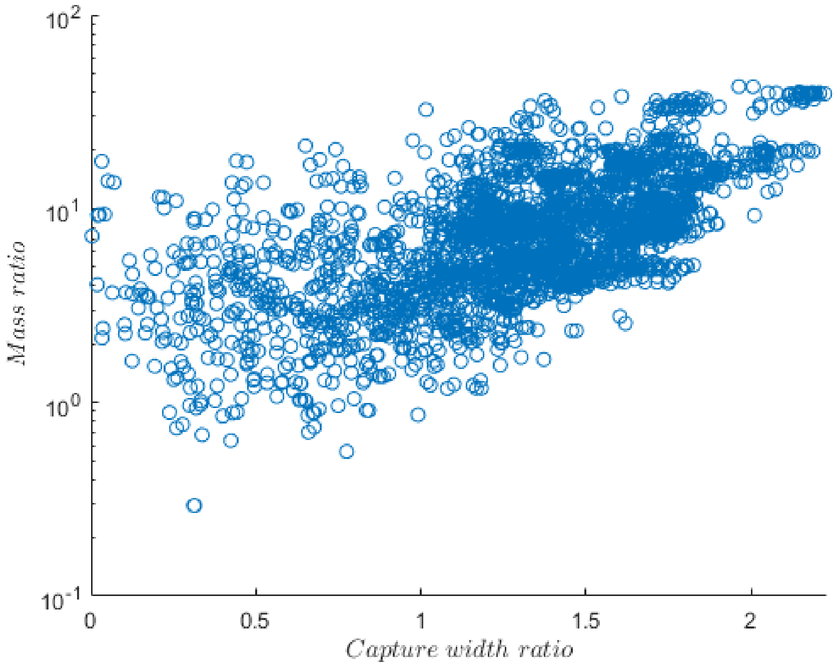


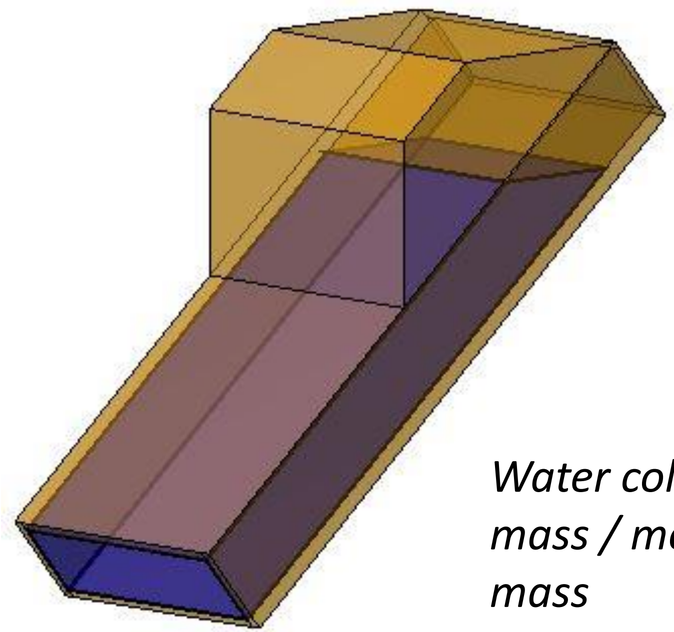
1) Inclination angle





2) Mass ratio



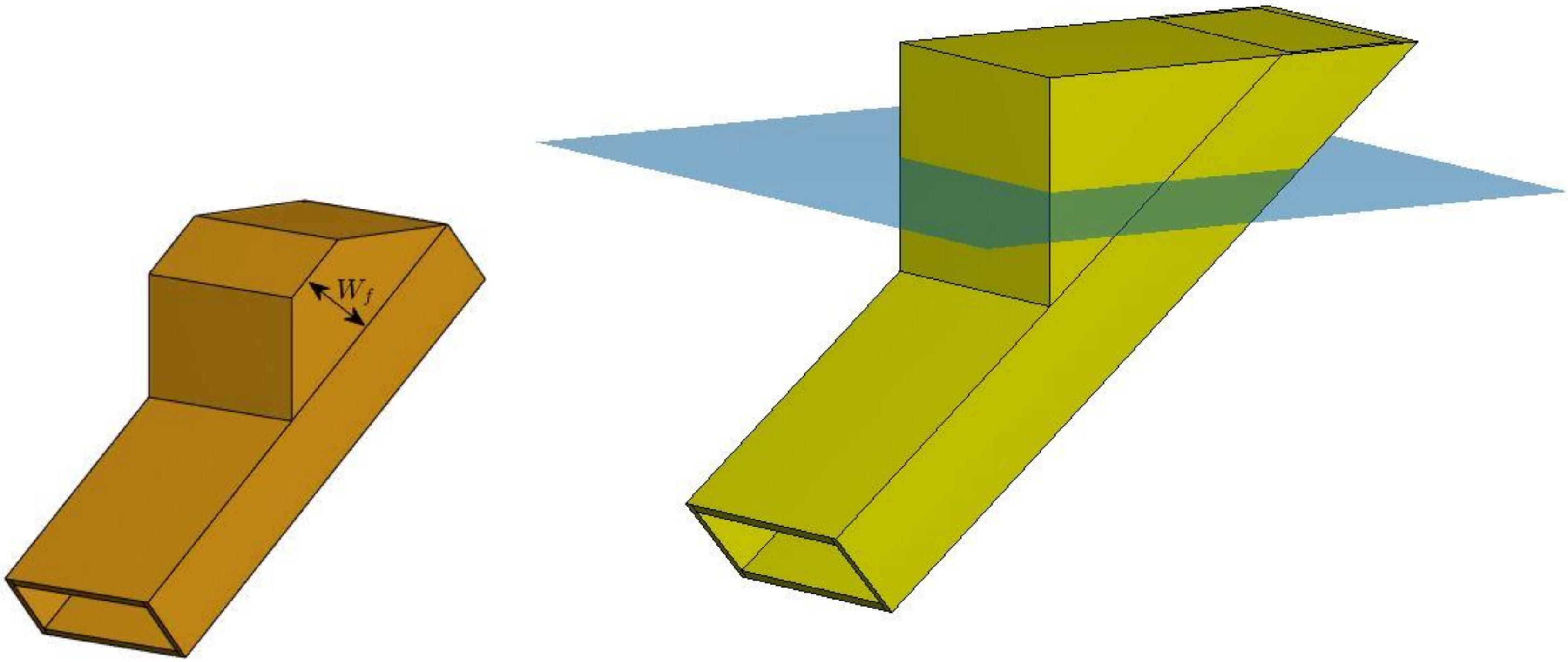


Water column mass / module mass

3a) Waterline height

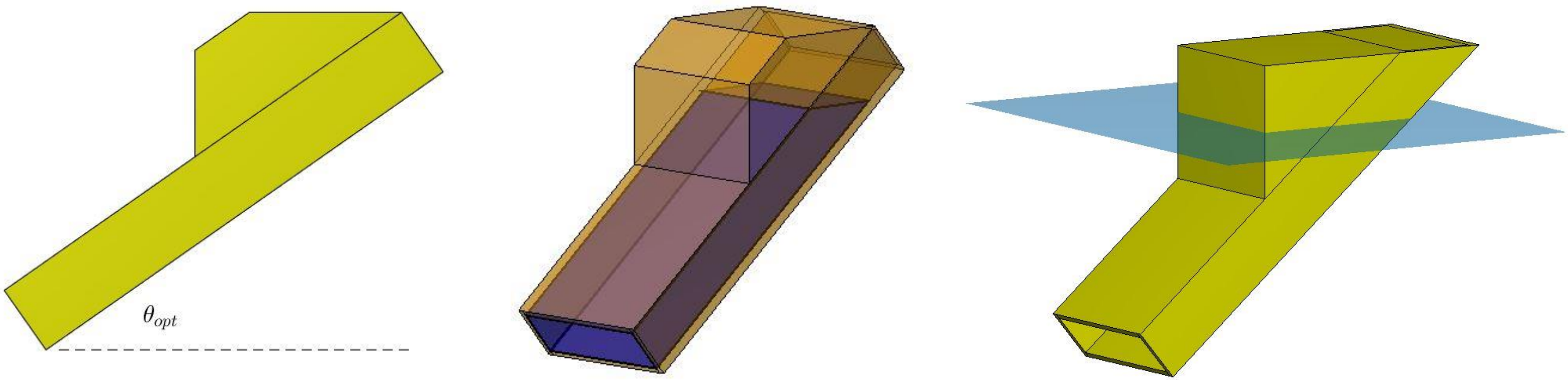
3b) Float thickness, W_f

3c) Bulk above water



A buffer for practical design

- Some degree of flexibility with remaining variables
- Practical design choices may not need to compromise performance



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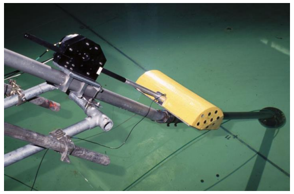
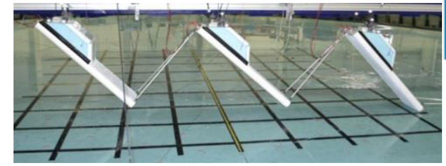
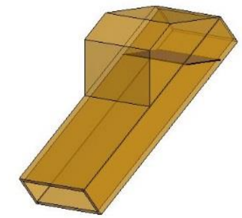
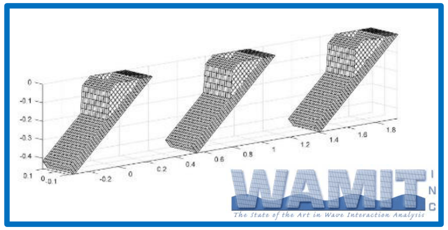
Thank you for listening!



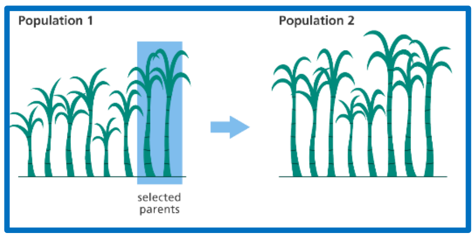
Motivation of design concept



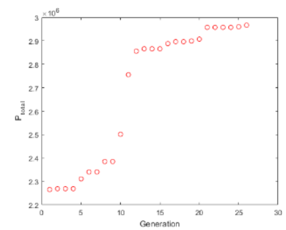


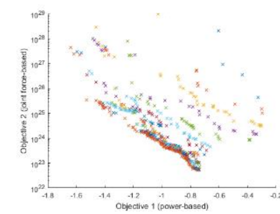


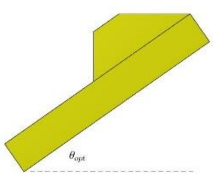
Efficient hydrodynamic model



Genetic algorithms for optimising geometry/mass/inertia







Key results