Port Said University

Wave Generation Laboratory

P9389

Simon Tiedeman

12th February 2023

Agenda

- HR Wallingford Ltd Introduction
  - Worldwide presence
  - UK HQ
  - Froude Modelling Hall
- Other Example Shallow Water Facilities
  - 3D Basins
  - Flumes
- Wave Generation System Design
- Essential Instrumentation

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HR Wallingford Ltd

Company Introduction

Company Introduction

HR Wallingford

- One of the world's leading hydraulics laboratories & world leader in the development and application of physical modelling.
- 70 years experience in physical modelling of coastal and offshore projects.
- Flexibility to have completed over 180 physical model studies in five years.
- Major supplier of laboratory wave generation systems and a major user of our own systems for research and consultancy projects.
- 30 years experience in the supply of equipment and instrumentation for other hydraulics laboratories throughout the world.
- Limited by guarantee, non profit distributing, and independent.
- Extensive CFD and FE capabilities.

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Company Overview

HR Wallingford Ltd.

- Limited by guarantee, non profit distributing, and independent;
- Turnover £28.5 million (2019/20) / £37.9 million (2020/21);
- Over 250 staff including many world leading experts;
- 35 staff in civil, mechanical and electrical design;
- >60% of projects from overseas;
- Head Office at Wallingford, UK:
  - Manchester (UK),
  - Houston, Kuala Lumpur, Shanghai,
  - Mumbai, Abu-Dhabi, Milan and Perth
- Clients in over 60 countries;

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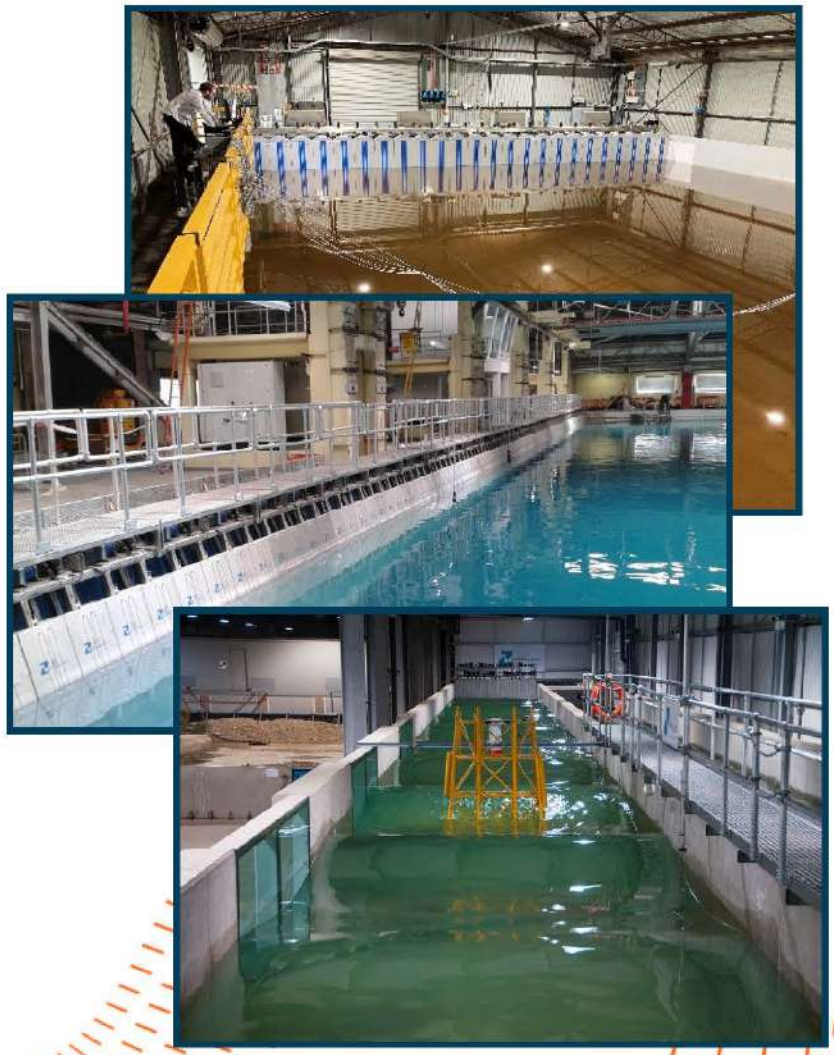
Why Wallingford



Appreciation of what is required within the available budget

- State of the art equipment for 2D or 3D physical modelling environments;
- Products specifically designed for a range of physical modelling applications:
  - Deep water offshore wave basins;
  - Seakeeping & Manoeuvring Basins;
  - Towing tanks;
  - Shallow water coastal wave basins;
  - Flumes;
  - Tsunami generator;
- Engineering design support capability;
- Able to accommodate the technical sophistication and accuracy demanded by researchers and the commercial expediency required for consultancy;
- We are users as well as suppliers of this equipment.

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Reference Projects

Track Record – Wave Generation Systems

Europe

- HR Wallingford Ltd - UK
- University of Salento - Italy
- Flanders Hydraulic Research – Belgium
- QinetiQ – UK
- University of Southampton – UK
- University of Swansea - UK
- Universita Degli Studi di Palermo – Italy
- University of Oporto – Portugal
- UPC Barcelona – Spain
- ENEL – Italy
- University of Liege – Belgium
- IST Lisbon – Portugal
- University of Padua – Italy
- National Technical University Athens – Greece
- University of Naples – Italy
- University of Liverpool – UK
- Università Politecnica delle Marche Ancona – Italy
- Université du Havre – France
- University of Nottingham – UK
- LWI, Braunschweig – Germany
- Southampton Solent University – UK
- Universidad Politecnica Madrid (UPM), Spain
- INUEM – Albania
- Universidad de Granada – Spain
- Bari Polytechnic – Italy
- Hull University – UK

Americas

- USACE
- Texas A&M – USA
- UNAM – Mexico
- Cordoba University – Argentina
- University of Miami – USA
- Universidad de Colima – Mexico
- Naval Research Laboratories – USA
- University of Alabama – USA
- Universidad Nacional Colombia – Colombia
- IPN Mexico City – Mexico
- INC – Venezuela
- Drexel University – USA

Asia

- SSSRI – China
- SJTU – China
- BRIN – Indonesia
- Institut Teknologi Bandung – Indonesia
- University of Hasanuddin – Indonesia
- NSTL – India
- Institute of Hydraulics Research – Vietnam
- Haiphong Maritime University – Vietnam
- UTP – Malaysia
- NAHRIM – Malaysia
- National University – Singapore
- NTU – Singapore
- IIT Mumbai – India
- Vietnamese Towing Tank facility – Vietnam
- SIWRR – Vietnam

Rest of the World

- Suez Canal Research Center - Egypt
- University of Western Australia – Australia
- Queensland Hydraulics Lab – Australia
- Australian Maritime College – Australia
- University of New South Wales - Australia
- Swinburne University – Australia
- Griffith University – Australia
- CSIR – South Africa
- Stellenbosch University – South Africa
- Manly Hydraulics Laboratory – Australia
- Niger Delta University – Nigeria

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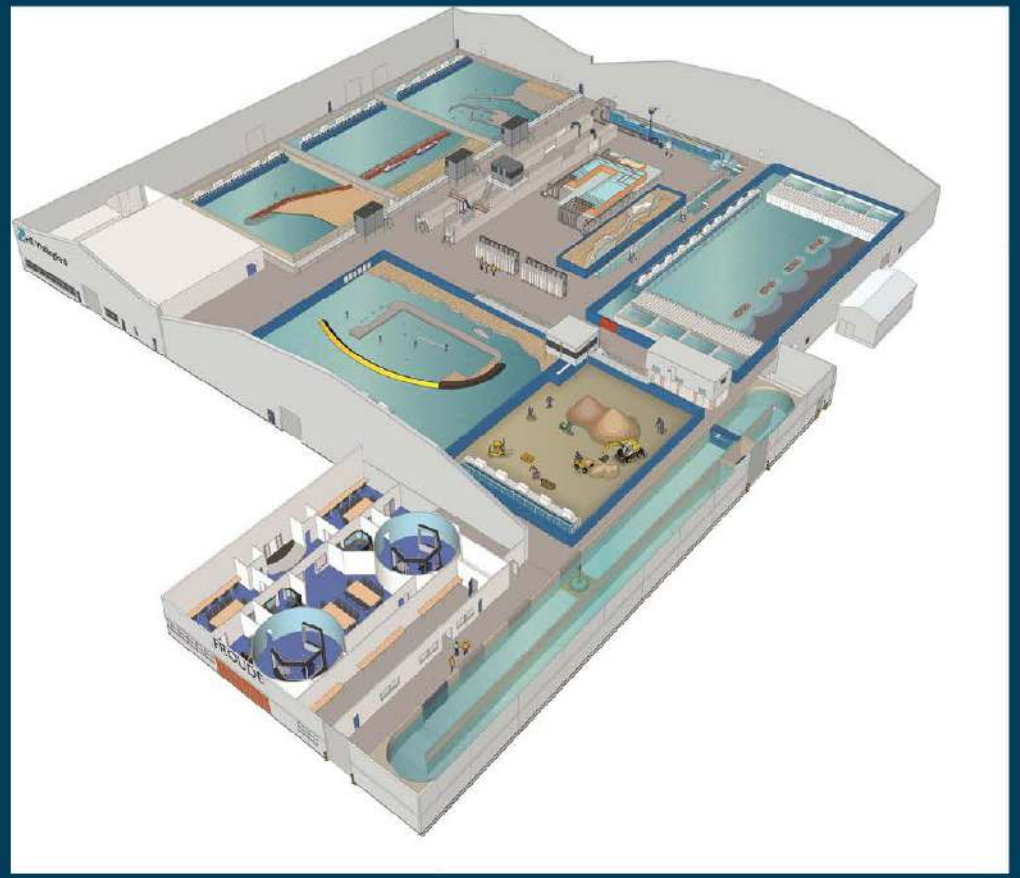
- Physical Modelling Capability

Introduction

Physical Modelling Capability

- Froude Modelling Hall (1);
- Fountain Building (2);
- Large Flume Building (3);



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HR Wallingford Froude Modelling Hall

Wave basins

- Six basins of varying sizes with maximum water depth of 1.0m
- Basins A,B and C can be joined to create a 75mx32m
- Wave basin E has flow capability
- Maximum wave heights mainly depth limited rather than wavemaker performance constrained

Flumes

- Two flumes 45m long, 1.2m wide

Fast Flow Flume

- 4m wide flume with both wave and flow capabilities

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Typical Tests (Combined A,B & C Basins)

- Basin bathymetry prepared to client requirements; (Video)
- Wavemakers moved into position;
- Instrumentation set up;
- Wave calibrations conducted;
- Test model constructed;
- Testing begins with the wave test series increasing in intensity;
- Data analysis conducted between each tests until the structure

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Wave Basin A,B&C 75m x 32m – 96 paddles

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- Shallow Water Facilities

Reference Projects

Shallow Water Basins: - Various locations

- *HR Wallingford (Oxfordshire)*
- Largest basin dimensions:
  - Width: 75m
  - Depth: 1.0m
  - Length: 30m
  - Water depth: 0.8m
- Paddle type: Piston
- Number of paddles: 200
- Lessons learnt:
  - Operational flexibility;
  - Specialist fabricators;
  - Digital system upgrade.

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Basin Facility 2

- *University of New South Wales (Australia)*
- Basin 15m x 30m
- Max water depth 0.8m
- 4 modules
- 24 paddles 0.625m wide
- Movable modules
- Cabinet on modular frame

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Basin Facility 3

- *Lecce (Italy)*
- Basin 28m x 30m
- Max water depth 1m
- 56 paddles 0.5m wide
- Movable modules
- Cabinet on frame

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Basin Facility 4

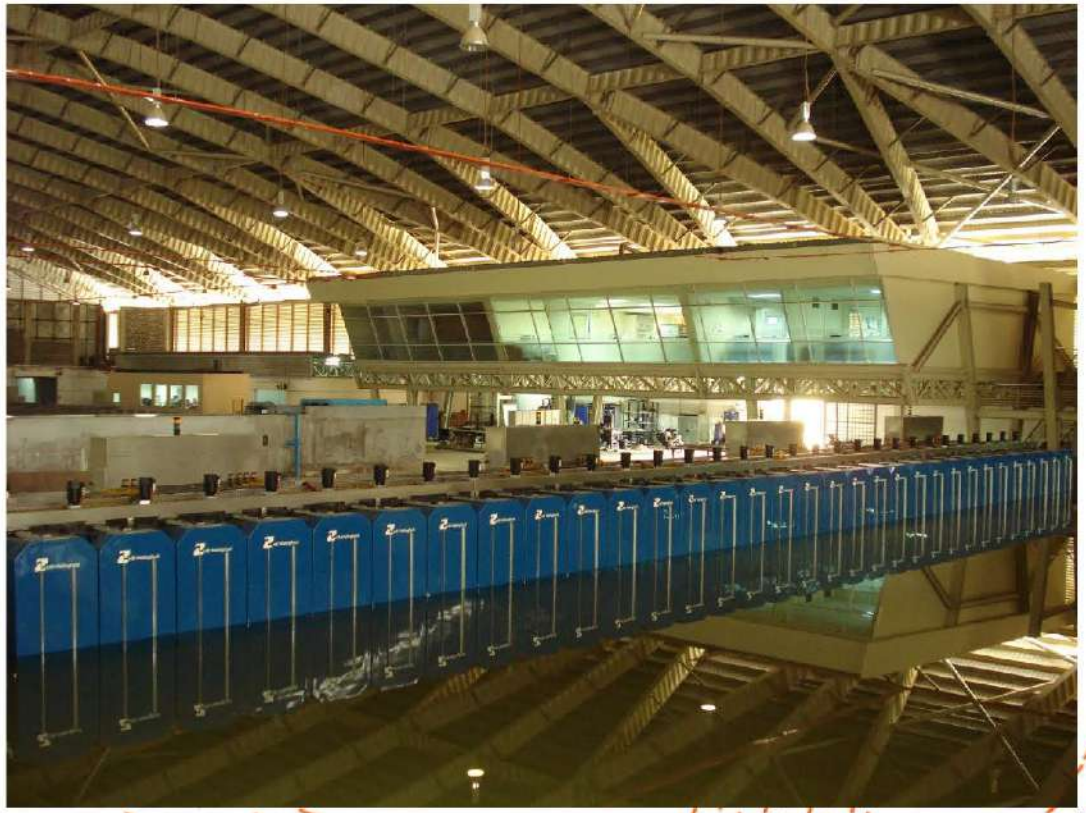
- *FHR (Belgium)*
- Basin 12m x 22m
- Max water depth 1m
- 30 paddles 0.4m wide
- Fixed modules
- Single cabinet on walkway

Basin Facility 5

- *CSIR (South Africa)*
- Basin 60 x 30m
- Max water depth 0.8m
- 48 paddles 0.5m wide
- Movable modules
- Cabinet on frame

Basin Facility 6

- *NAHRIM (Malaysia)*
- Basin 30m x 30m
- Max water depth 0.8m
- 32 paddles 0.75m wide
- Movable modules
- Cabinet on frame



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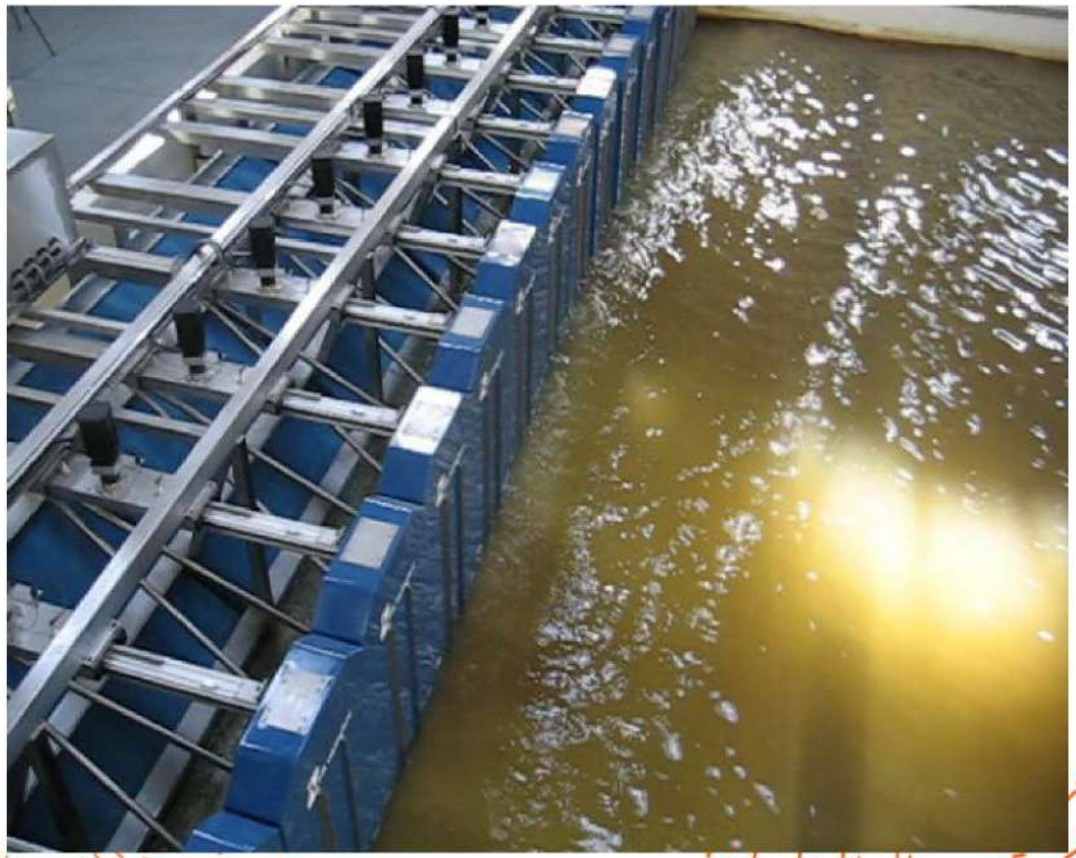
Basin Facility 7

- *FEUP (Portugal)*
- Basin 12m x 30m
- Max water depth 0.7m
- 16 paddles 0.75m wide
- Movable modules
- Cabinet on frame



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Basin Facility 8

- *IHMT (Taiwan)*
- Basin +30m x +30m
- Max water depth 0.7m
- 4 dual actuator paddles 6m wide
- Movable modules
- Cabinet on frame
- Ability to run in conjunction with WR Davis wavemaker paddles.

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Basin Facility 9

- *Queensland Government Hydraulics Laboratory (Australia)*
- Basin 20m x 42m
- Max water depth 0.6m
- 4 dual actuator paddles 5m wide
- Movable modules
- Cabinet on frame

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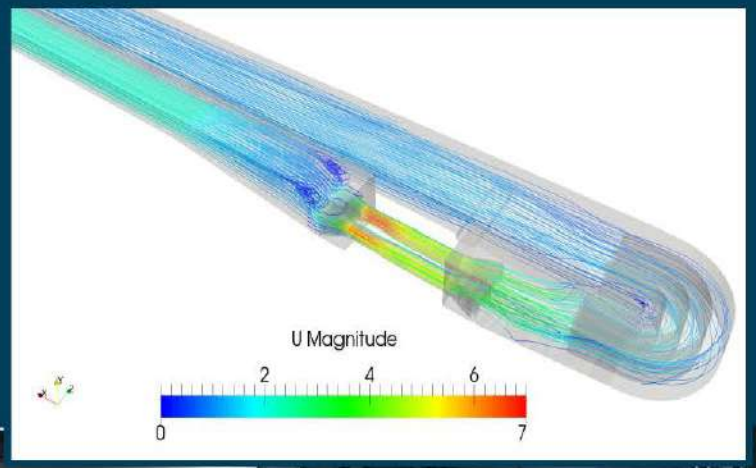
Reference Projects



Deep Water Current Flumes :-

HRW (UK)

- Flume dimensions:
  - Width: 4m
  - Depth: 2.5m (VWL to 2.0m)
  - Test Length: 70m
- Paddle type: Hinge
- Hinge Depth: 2.1m
- Number of paddles: 10
- Lessons learnt:
  - Construction tolerance;
  - Waves, currents & sediment;
  - Development of CFD prediction tool;
  - Combination of bi-directional waves and currents;
  - Construction & operation health & safety;
  - Access to the facility;

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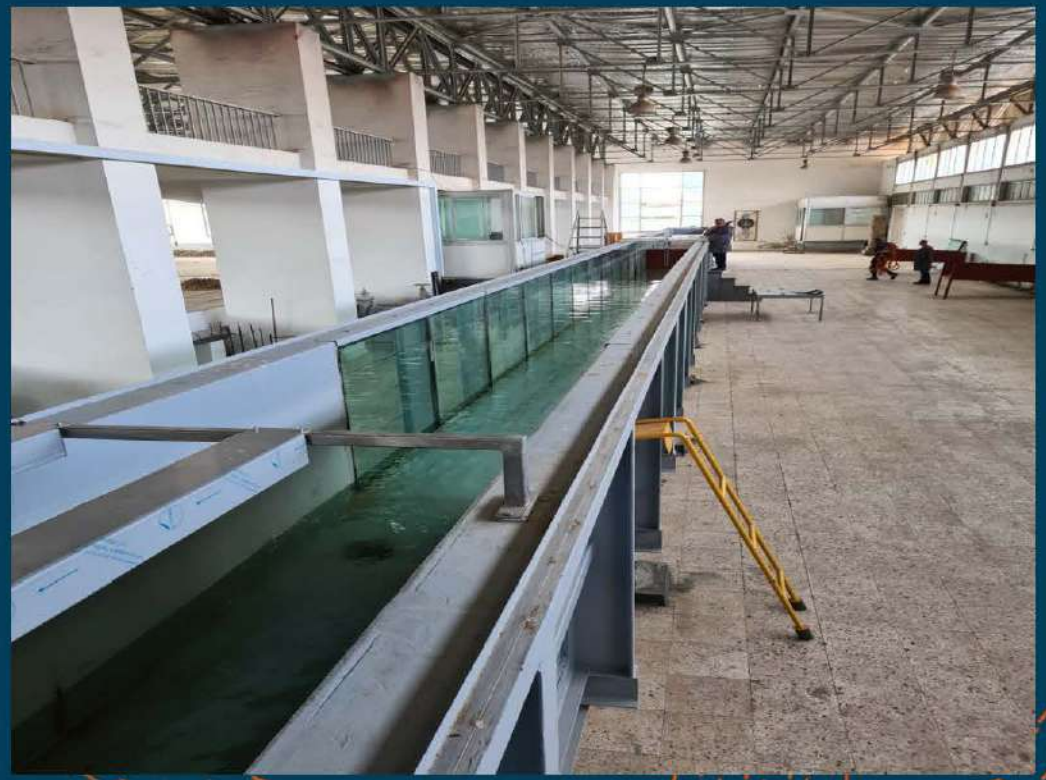
Flume Facility 2

- *Ismailia (Suez Canal Research Centre, Egypt)*
- Flume 1.2m x 1.5m x 30m long
- Max water depth 1.2m
- Single paddle
- Paddle width: 1.2m wide



Flume Facility 3

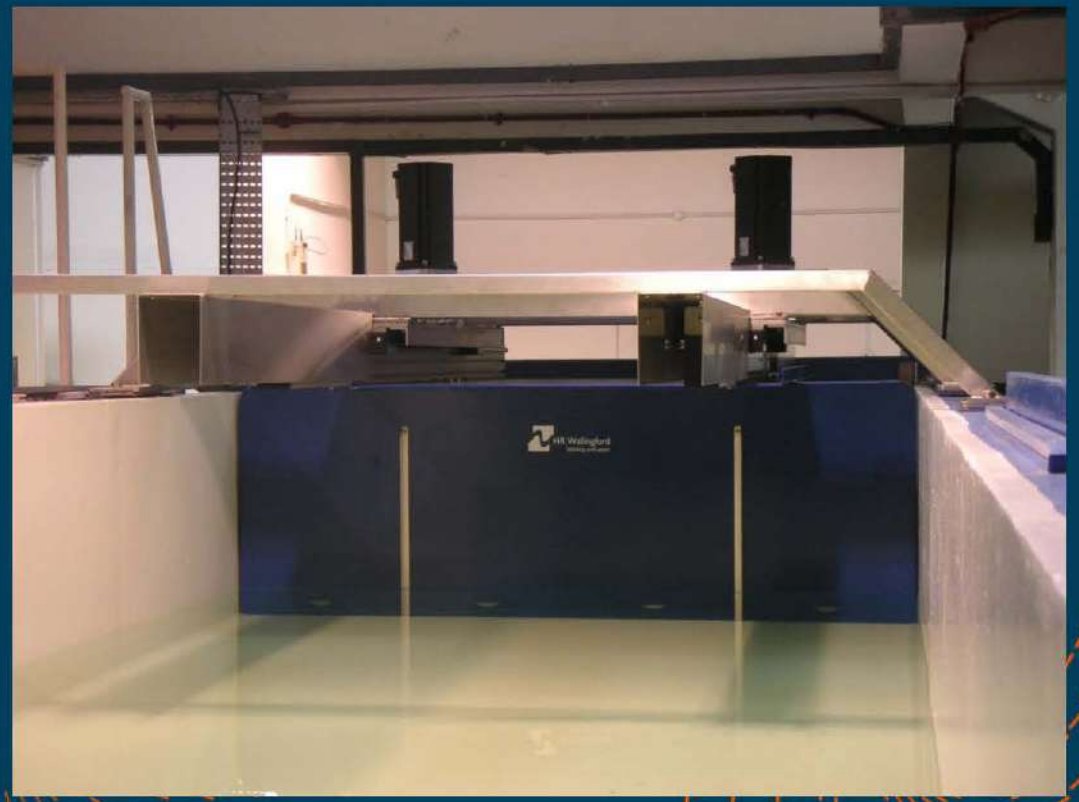
- *Palermo (Italy)*
- Flume 1.8m x 2.0m x 30m long
- Max water depth 1.5m
- Single paddle
- Paddle width: 1.8m wide

Flume Facility 4

- *NAHRIM (Malaysia)*
- Flume 1.4m x 1.8m x 100m
- Max water depth 1.3m
- Single paddle
- Paddle width: 1.4m wide

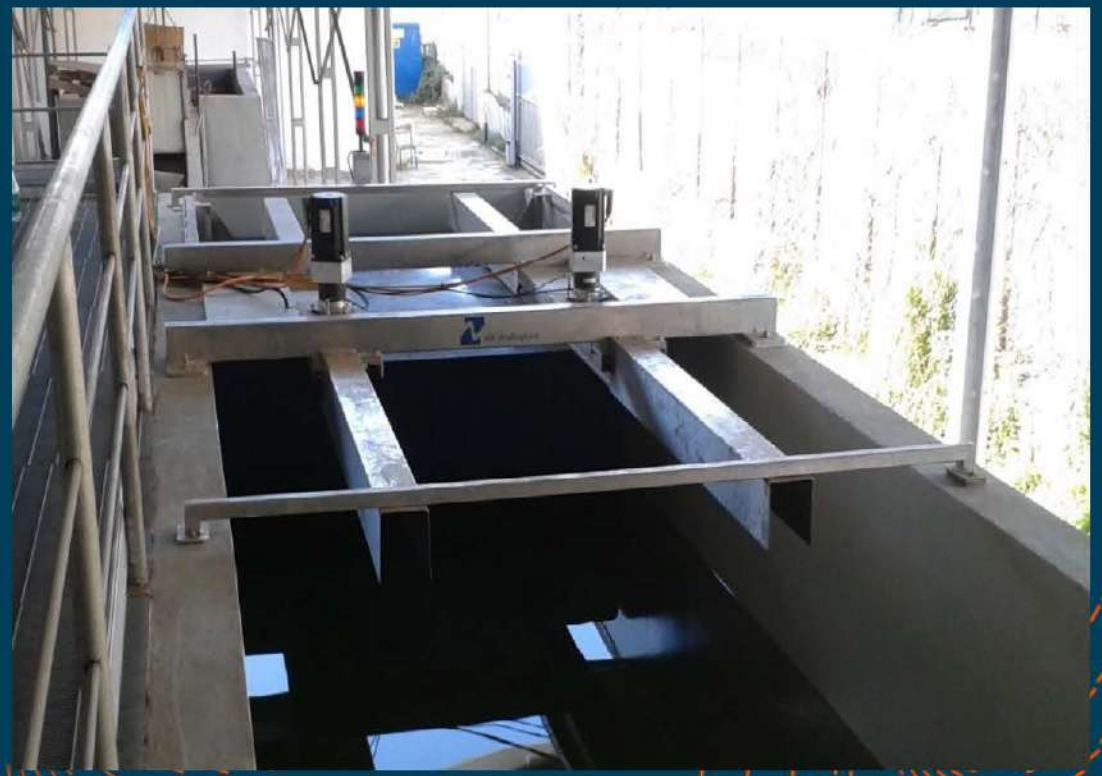
Flume Facility 5

- *NUS (Singapore)*
- Flume 2.0m x 1.3m x 28m in length
- Max water depth 1.7m
- Single paddle
- Paddle width: 2.0m wide



Flume Facility 6

- *Palermo (Italy)*
- Flume 2.0m x 2.0m x 30m
- Max water depth 1.5m
- Single paddle
- Paddle width: 2.0m wide



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- Wave generation systems design

Hardware

Wavemaker systems

- Each wavemaker system is designed to meet the requirements of each client
- Piston or hinged flap type long crested or multi-element and flume wavemakers
- Shallow water systems are modular for ease of mobility around the basin

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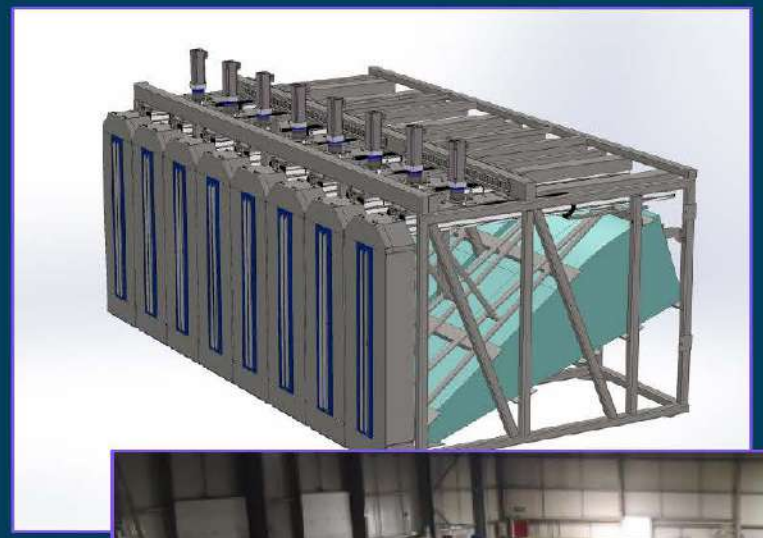
HR Wallingford Wavemaker Modules



Wavemaker systems

- HR Wallingford's standard shallow water piston wavemaker module is 4m long with 8 x 0.5m wide paddles;
- The multi-element design allows waves to be generated at oblique angles to the paddle face:
  - No need to move paddles for small changes in wave direction
  - Short crested seas can be generated
  - Side wall reflection can be used
  - Active absorption of multi-directional seas

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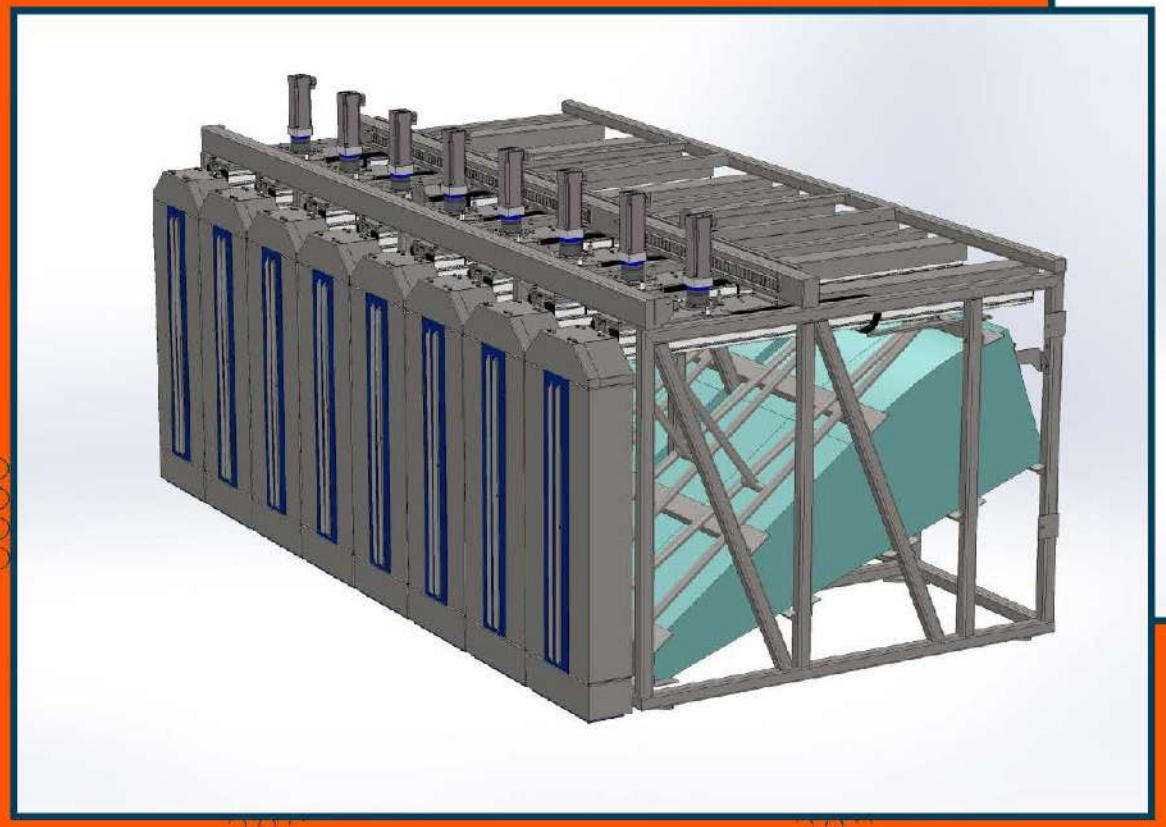
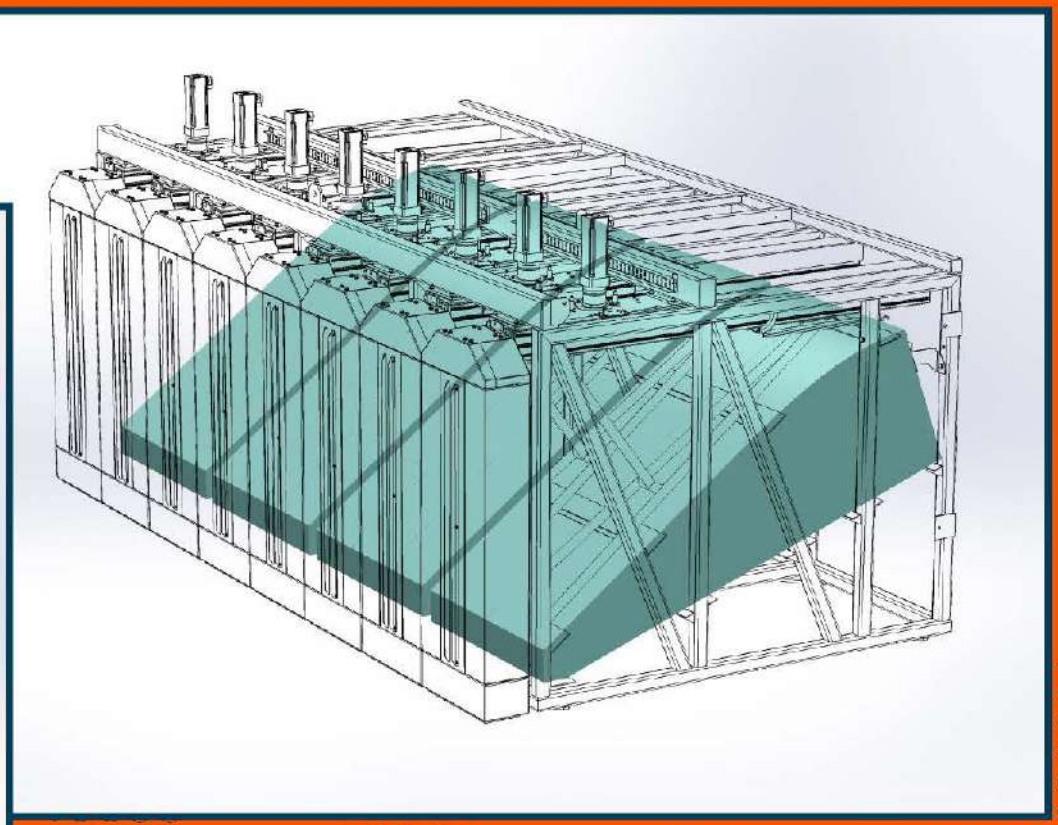
Hardware

Wavemaker systems

- Developed using 3D Solidworks software

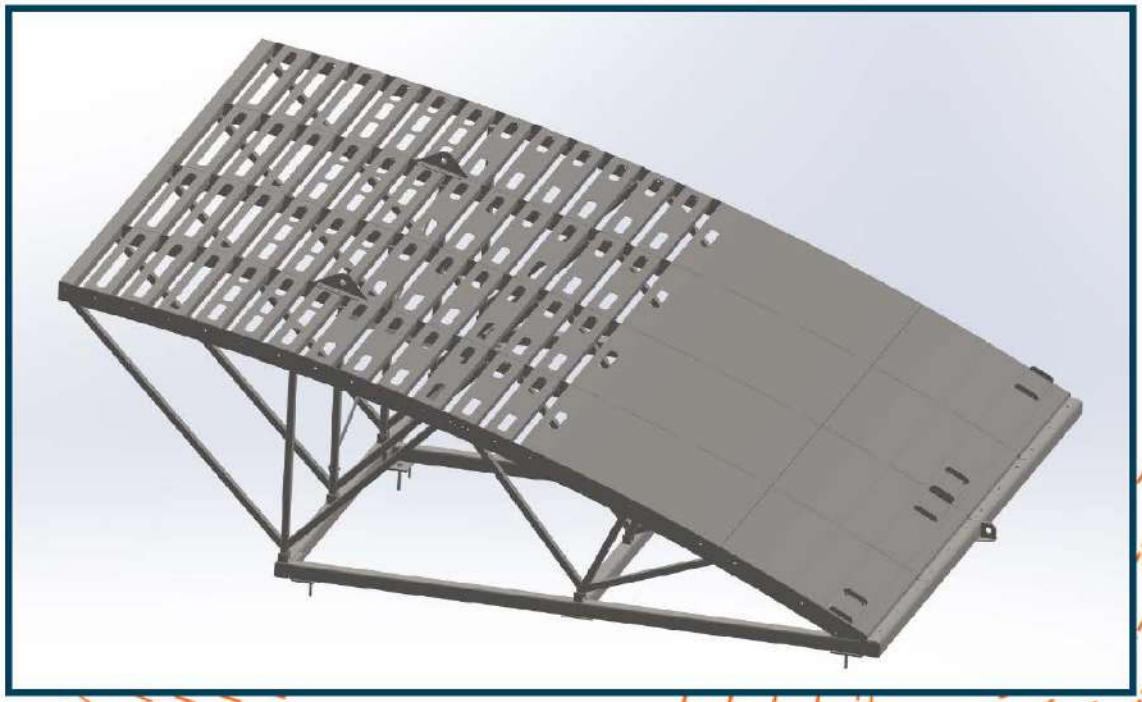




Hardware

Passive wave absorber systems

- Parabolic permeable beach
- Fixed or lowerable systems available



Hardware

Mechanical Components

- System is fabricated and assembled in the UK;
- Modular frame & component material from high quality, type 304, stainless steel;
- Piston paddle material GRP / hinge stainless steel (304);
- Electric drive actuator with fixed ratio gearbox;

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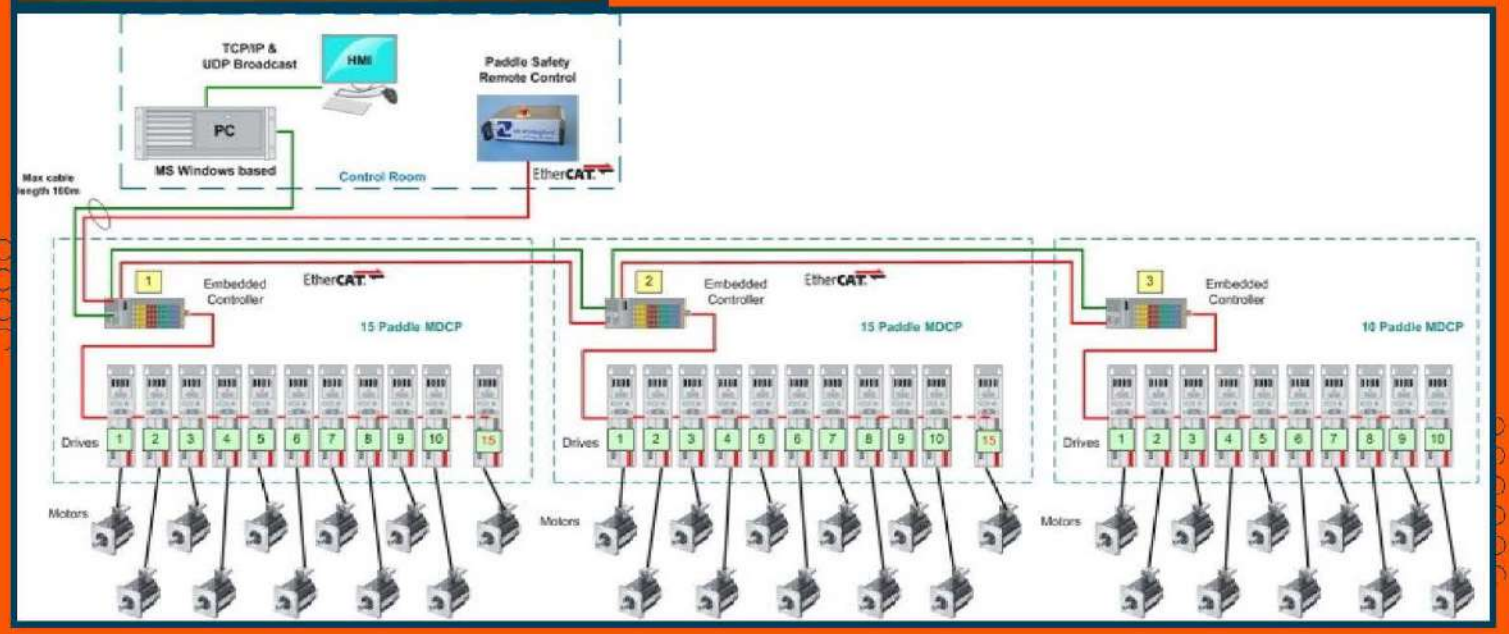
Hardware



Control System

- Industry standard real time EtherCAT over Ethernet -2-way communication bus PLC control system identifying paddle position and surface elevation at paddle;
- All paddle elements controlled independently;
- Feedback control is obtained using paddle demand and actual position as well as water surface elevation at the paddle when absorption is activated.

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Hardware

Motor Drive Control Panel (MDCP)

- MDCP contains the servo drives, associated power distribution and control hardware;
- Located either on the module for mobile units or in close proximity to wavemaker module to minimise cable lengths;
- Air conditioned depending on climate and location.

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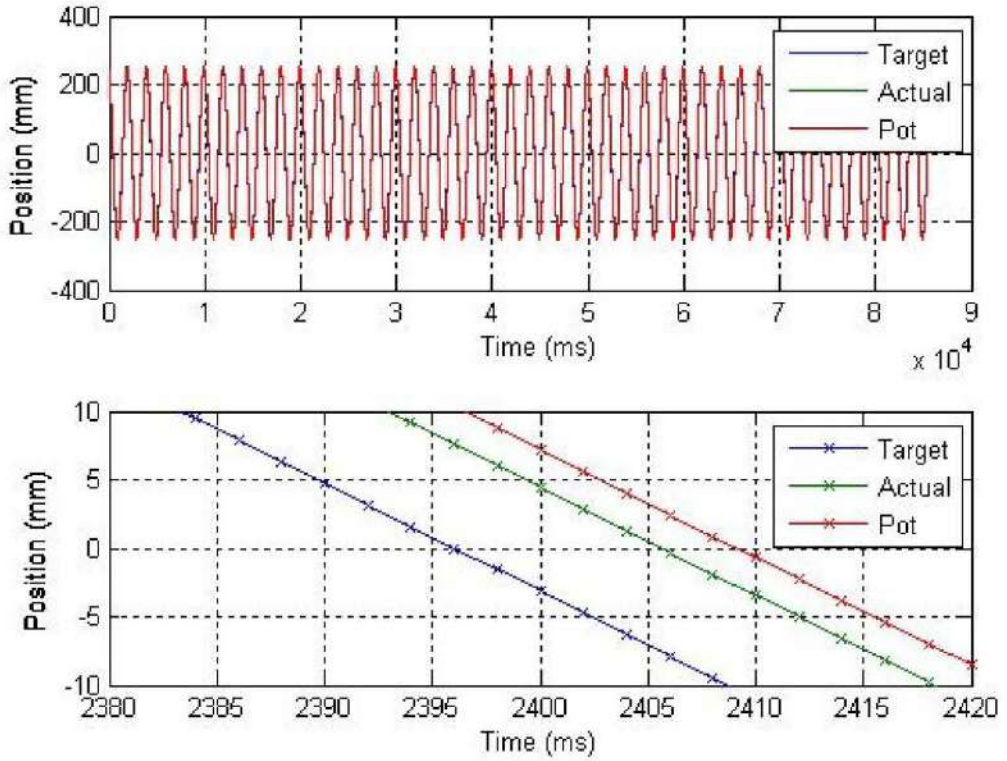
Hardware



Control System

- Following Error :
- Position error: ~1%
- Position lag: ~15ms
- System monitoring:
- Actual position and paddle velocity
- Motor temperature
- Error history
- Actuator torque
- Motor and drive status

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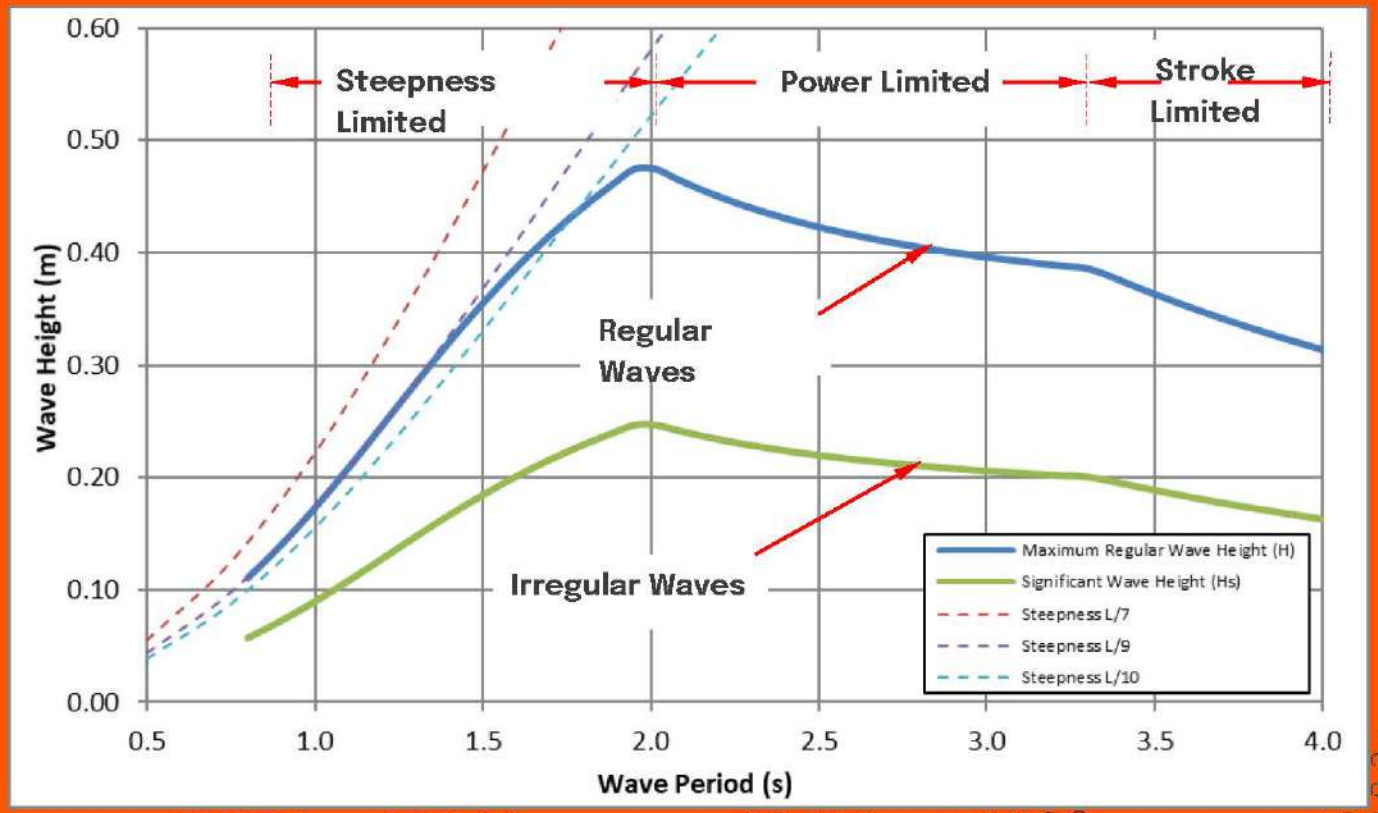
Wavemaker performance



Parameters

- Water Depth 1.0m
- Max Semi Stroke 0.55m
- Paddle Width 0.5m
- Servomotor 6.13kW
- Regular to irregular relationship
- $H = Hs\left(\frac{\ln N + \gamma}{2}\right)^{0.5}$
- $Hs = 0.52\ H\ where\ N = 1000$
- H – average maximum wave height
- Hs – significant wave height
- N – Number of waves
- γ- Euler's constant 0.5772

- Wavemaker performance limited by physical constraints as well as design
- Paddle width and maximum semi stroke are main design criteria

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Wavemaker performance

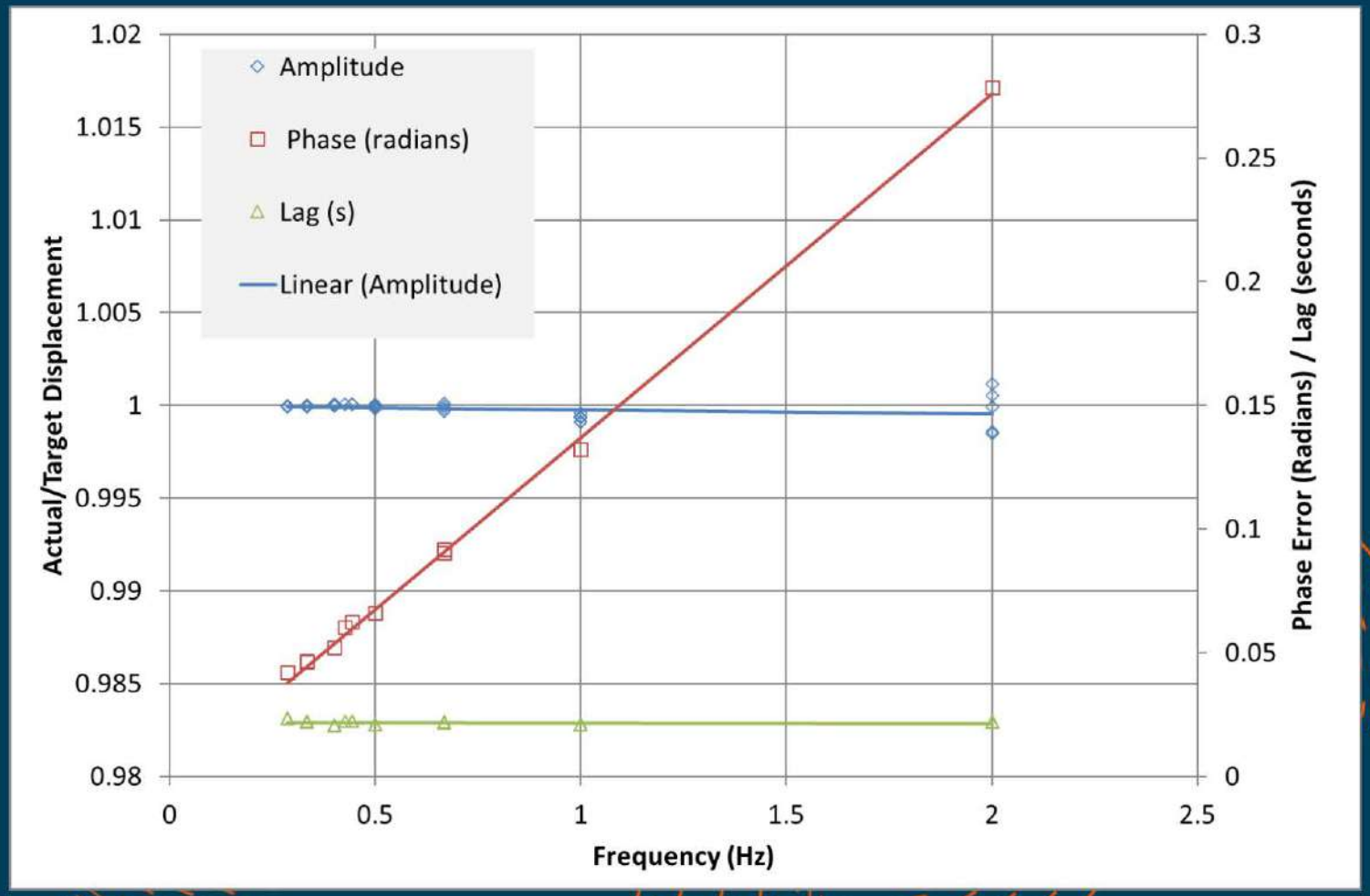
Wave Synthesis – Wave Set Up

- Regular waves
- Monochromatic
- Bi-cromatic
- Irregular waves
- Random phase
- Filtered White Noise
- Multi-directional waves
- Short crested waves
- Focused waves
- Solitary waves
- Side wall reflection (Virtual Paddles)
- Multiple wave components

Additional functionality

- Second order wave generation
- Second order compensation
- Spurious wave identification/correction
- Repeatability and monitoring
- Active Wave Absorption
- Multiple wave paddle groups

Wavemaker performance



Position Control

- Following Error
- Open or closed loop
- Force or position feedback
- Control stability
- Lag compensation

Key measures of paddle performance

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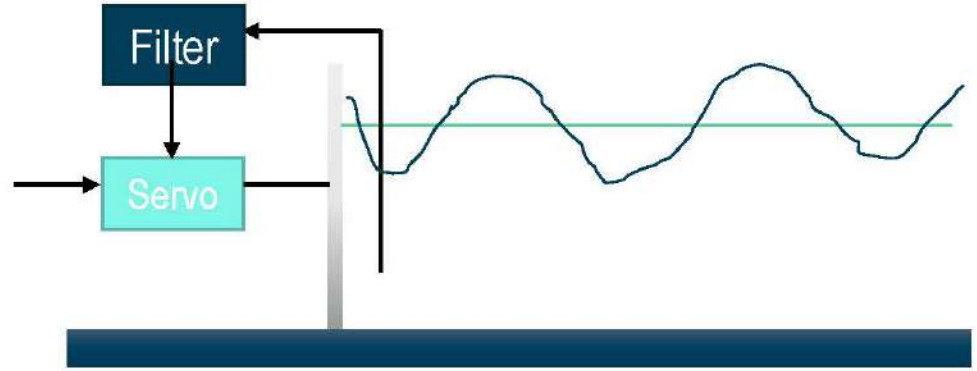
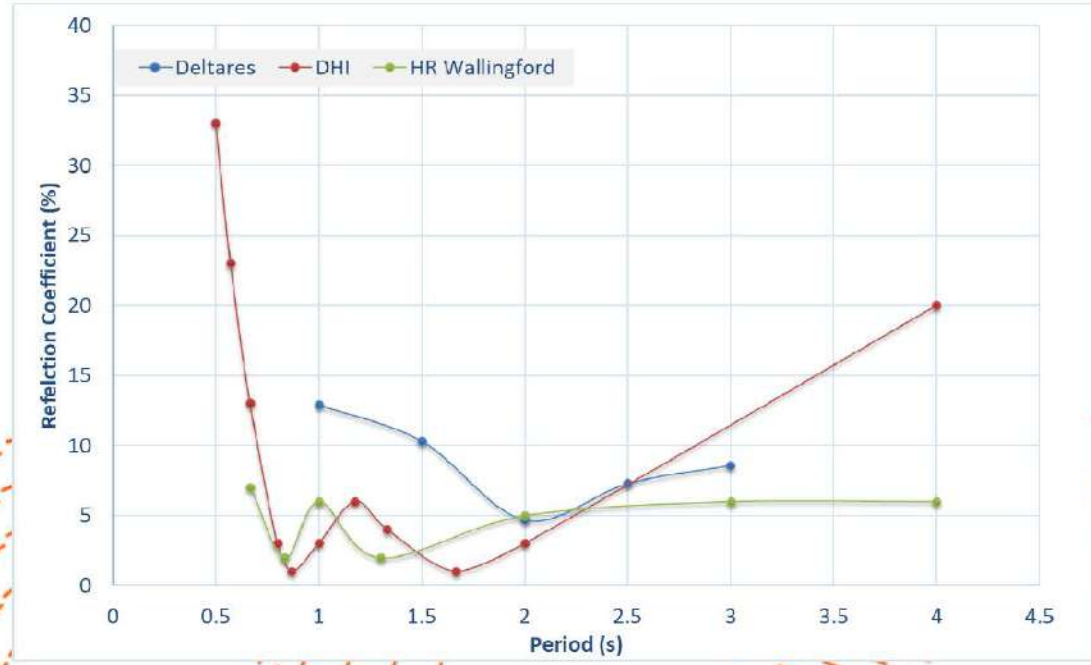
Wavemaker performance

Active Absorption

- Realtime feedback system;
- Identification of spurious waves;
- Filter type (FIR/IIR);
- Phase errors critical;
- Capable of handling a broad frequency range;
- Stable;
- Flexibility for modification and optimisation;
- Hardware or software (analogue or digital).





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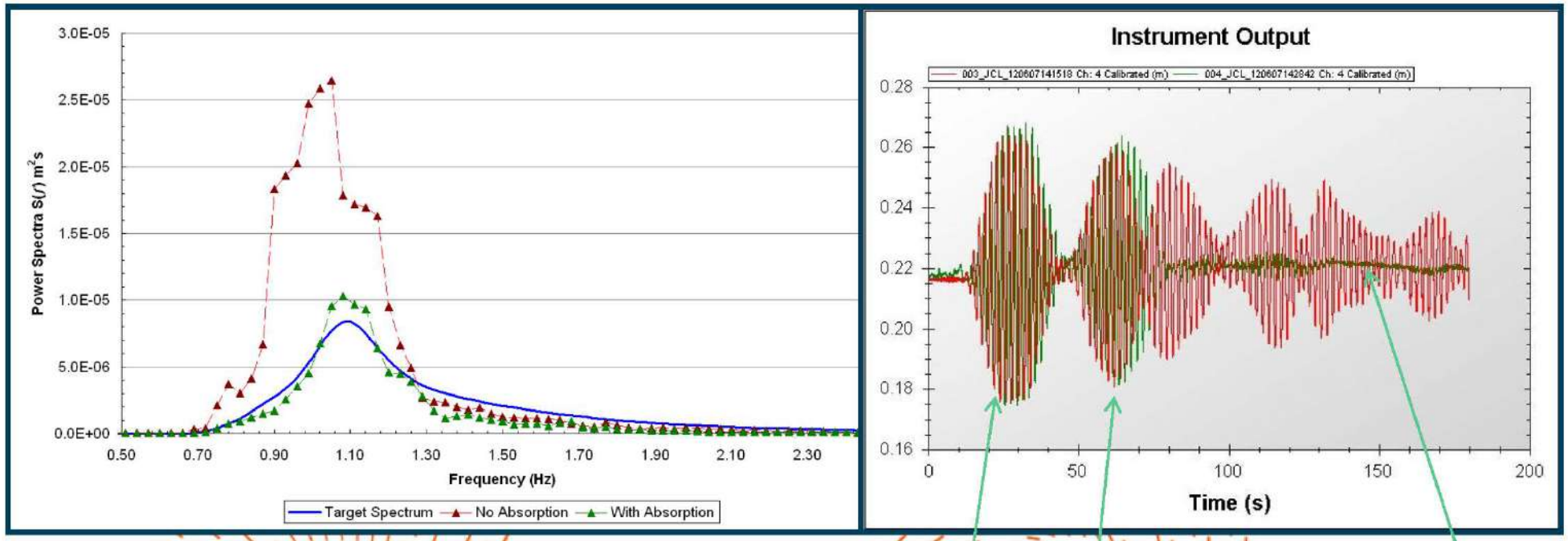
Wavemaker performance

Active wave absorption -2D Flume

Red – no absorption
Green – with absorption



Generated

Reflected

Absorbed (green)

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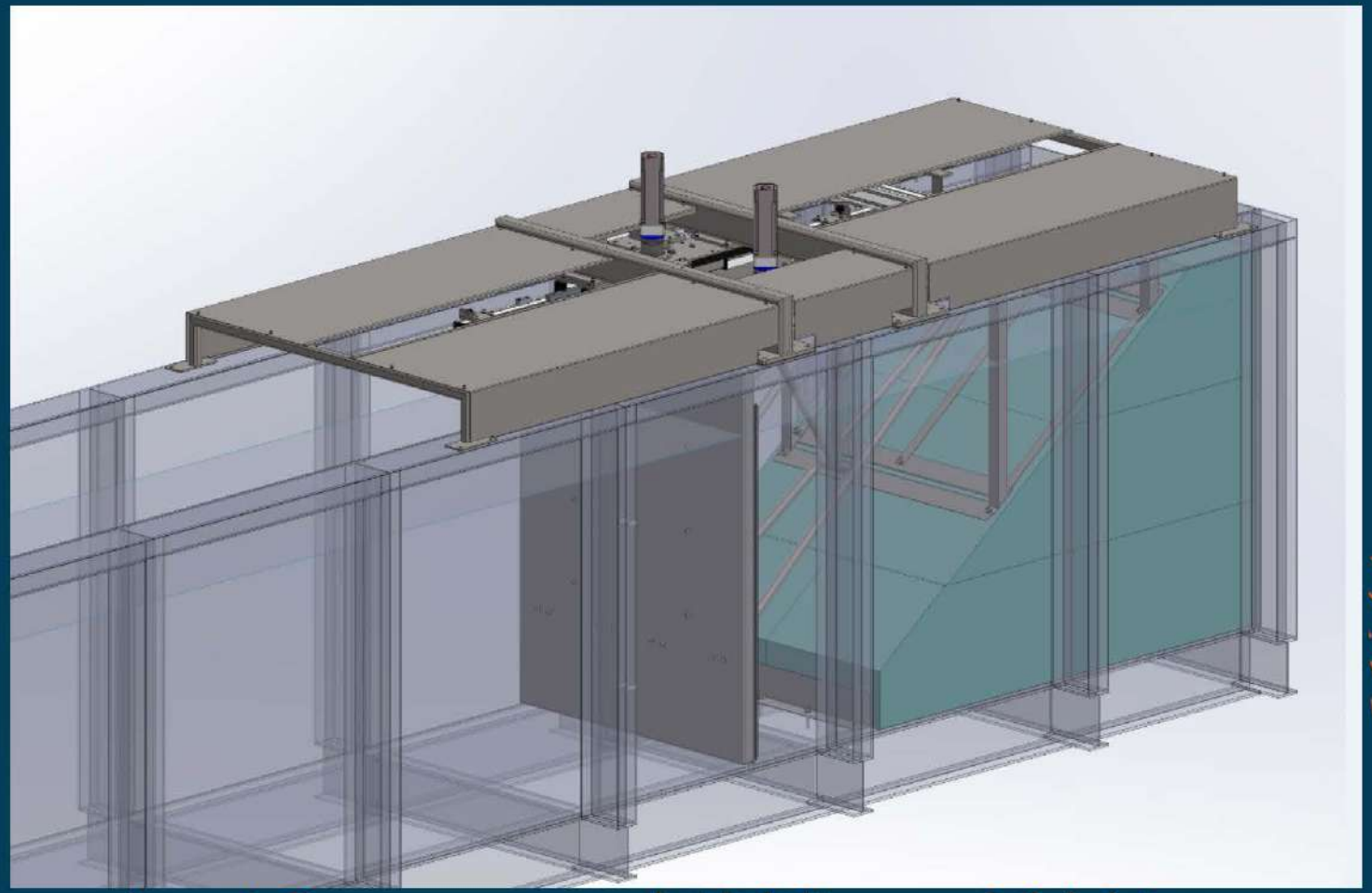
- Wave generation system installation

Installation



Installation - Flume

- Setting out;
- Locate top beams;
- Attach actuators;
- Attach wishbones & paddle;
- Check paddle alignment;
- Secure & add cover plates;
- Route cables back to the control panel;

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Installation

Installation - Basin

- Setting out;
- Place & align modules;
  - Horizontal;
  - Vertical;
  - Clearance for paddle motion;
- Route communication cable from Module 1 to control room;
- Interconnect module comms;
- Route power supply cables back to the distribution panel;

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- Port Said University Laboratory

Port Said University Wave Flume

- Overview of proposed S60 flume specification:-
  - Flume 0.6m wide x 0.8m deep x 17.5m working length with maximum water depth of up to 0.6m;
  - Options for recirculation current flow and tilt capability;
  - Piston paddle type wavemaker system;
  - 2D bed profiling traverser covering 4m of the test area;
- What type of physical modelling studies to be conducted in the facility:-
  - 2D Wave, current flow and river flow physical models;
  - Wavemaker has liftable paddle for flow studies;
  - Active Wave Absorption very important to minimise reflected wave energy from models from being re-reflected into the flume;

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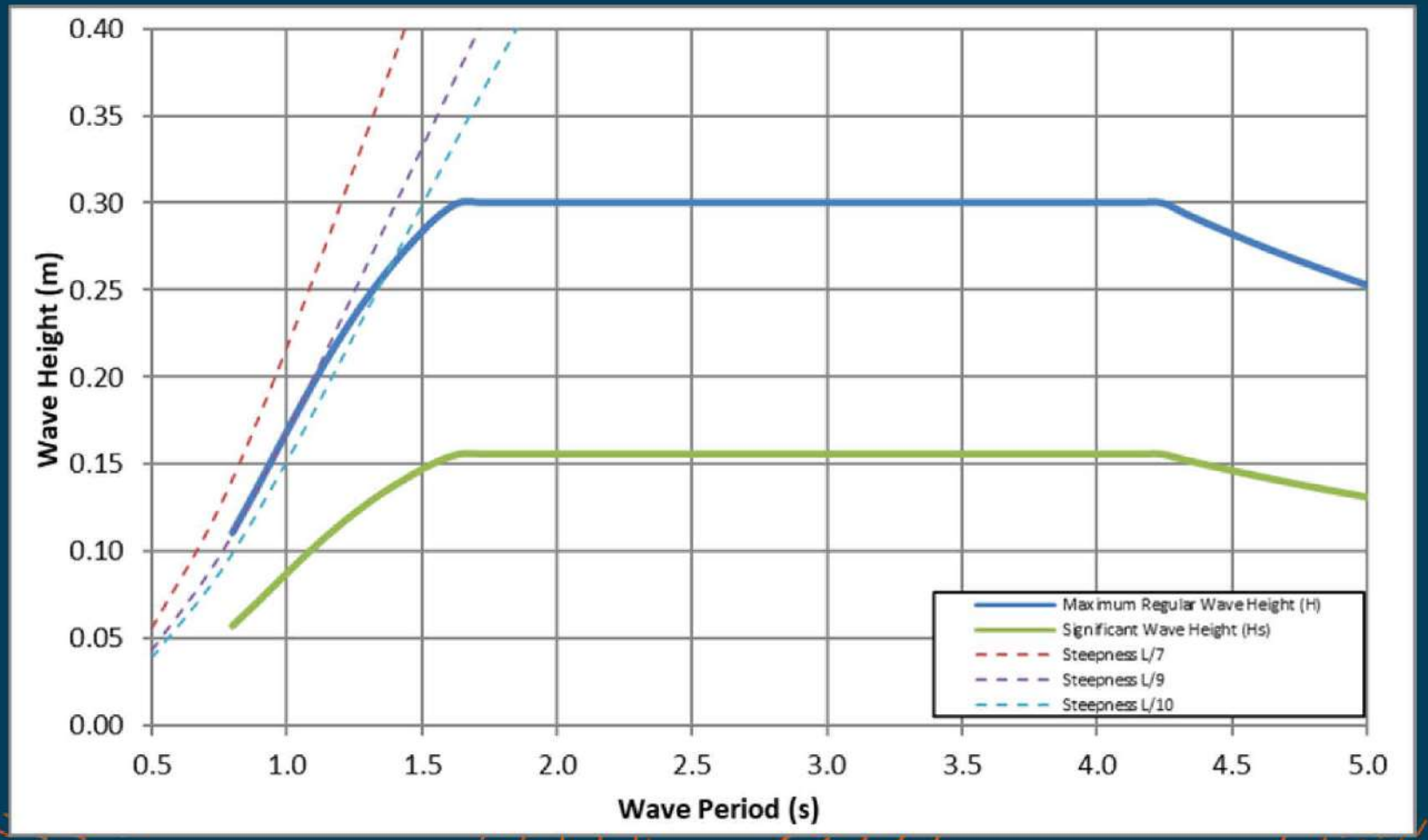
Wavemaker performance

Port Said Proposal – 2D Flume



Key data :-

- Water depth 0.6m
- Paddle width 0.6m
- Drive actuators 1
- Max paddle stroke 0.8m
- Max paddle velocity 0.6m/s
- Max paddle force 1.0kN
- Max power demand 0.7kW

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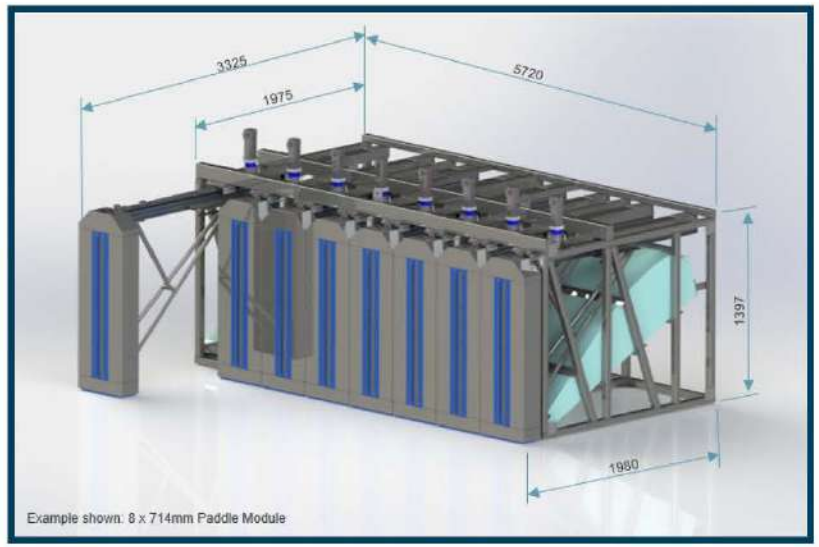
Port Said University Wave Basin



- ME Wavemaker specification:-
  - Basin 20m wide x 1.2m deep x 25m long with maximum water depth of up to 0.8m;
  - Piston paddle type wavemaker system;
  - HR Merlin wave generation software;
- What type of physical modelling studies to be conducted in the facility:-
  - 3D Wave physical models;
  - Oblique waves can be used for short crested, oblique and side wall reflection methods;
  - Again, the Active Wave Absorption very important to minimise reflected wave energy from models from being re-reflected into the flume;

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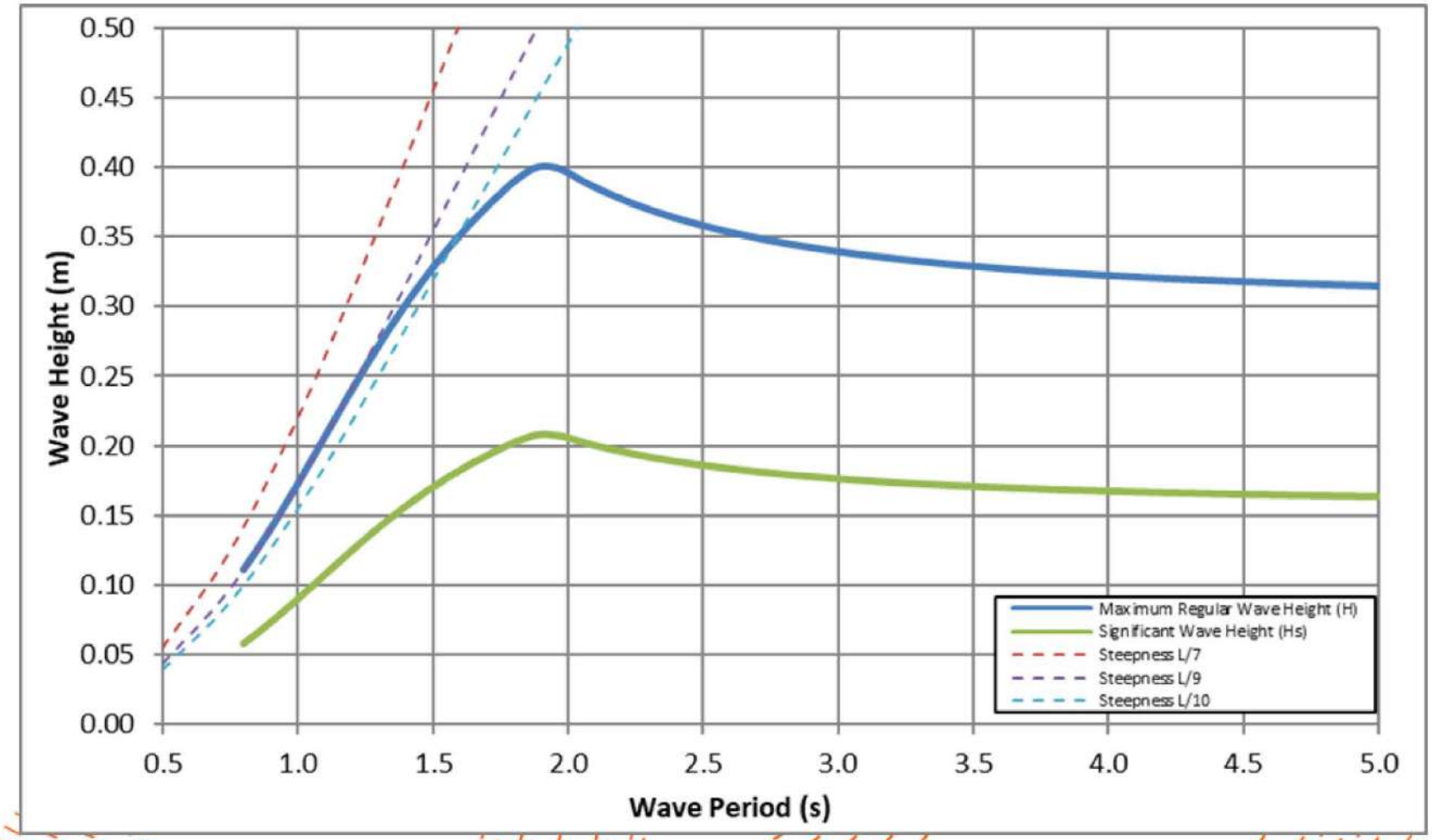
Wavemaker performance

Port Said Proposal – 3D Basin



Key data :-

- Water depth 0.8m
- Paddle width 0.714m
- Drive actuators 28
- Max paddle stroke 1.1m
- Max paddle velocity 0.6m/s
- Max module paddle force 1.8kN
- Max power demand 33.6kW

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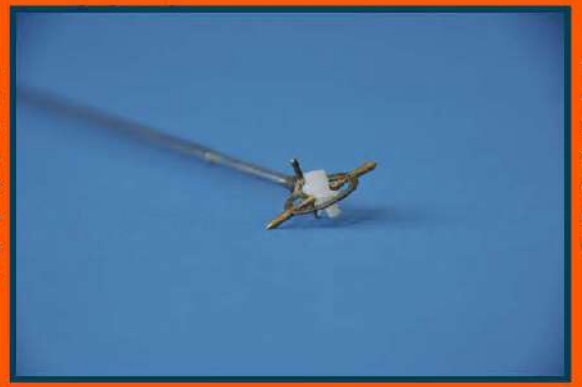
Port Said University Coastal Laboratory

– Instrumentation

- Set of wave gauges to independently measure and determine the waves generated;
- High Pprformance pressure sensors;
- Ship movement system;
- Force measurement system;
- Data acquisition and analysis software;
- Miniature propeller meter – low speed probe;
- Acoustic Doppler Velocimeter (ADV).



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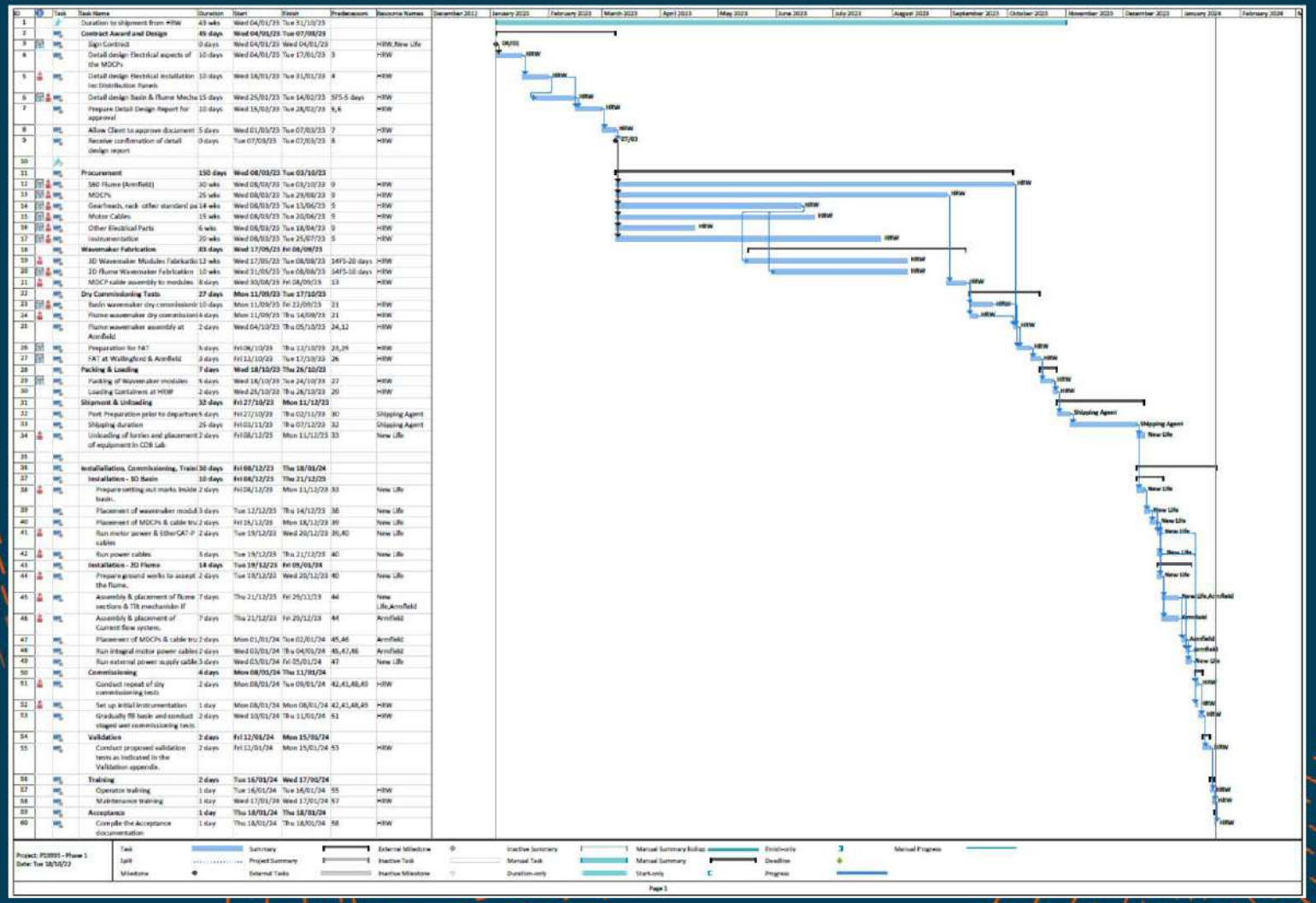
Coastal Laboratory

Predicted Project Delivery Programme :-



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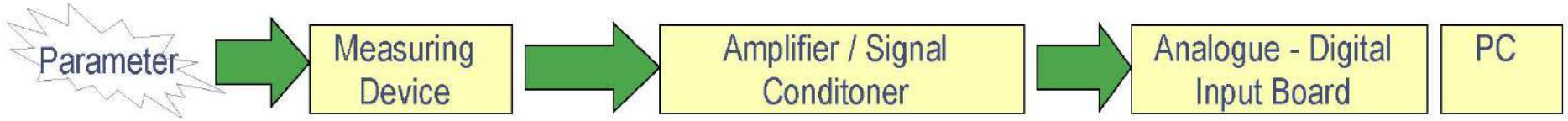
- Instrumentation

Instrument measurement principles



What parameters to measure ?

- *Surface elevation* (waves, gradients)
  Spatial, temperal, resistive, capacitive, acoustic, optic
- *Velocity* (current / air entrainment)
  Acoustic, electromagnetic, optical (laser), propeller, pitot
- *Discharge volume* (overtopping, tidal systems, river flow)
  Acoustic, electromagnetic, totaliser system
- *Pressure* (Porus media, impulse forces)
  Piezometric, Manometer, differential gauge
- *Forces / Ship Movement* (mooring lines, fenders, impact, drift, movement)
  Strain gauges, dynamometers, laser, spatial
- *Damage / Changes in profile* (erosion, sedimentation, displacement)
  Visual, digital image, bed profiler (electro-mechanical, laser)
- *Sediment transport* (under wave and current action)
  Sediment traps, turbidity, tracer dyes, digital imagery, optical (laser)
- *Water properties*
  Salinity, conductivity, density, temperature

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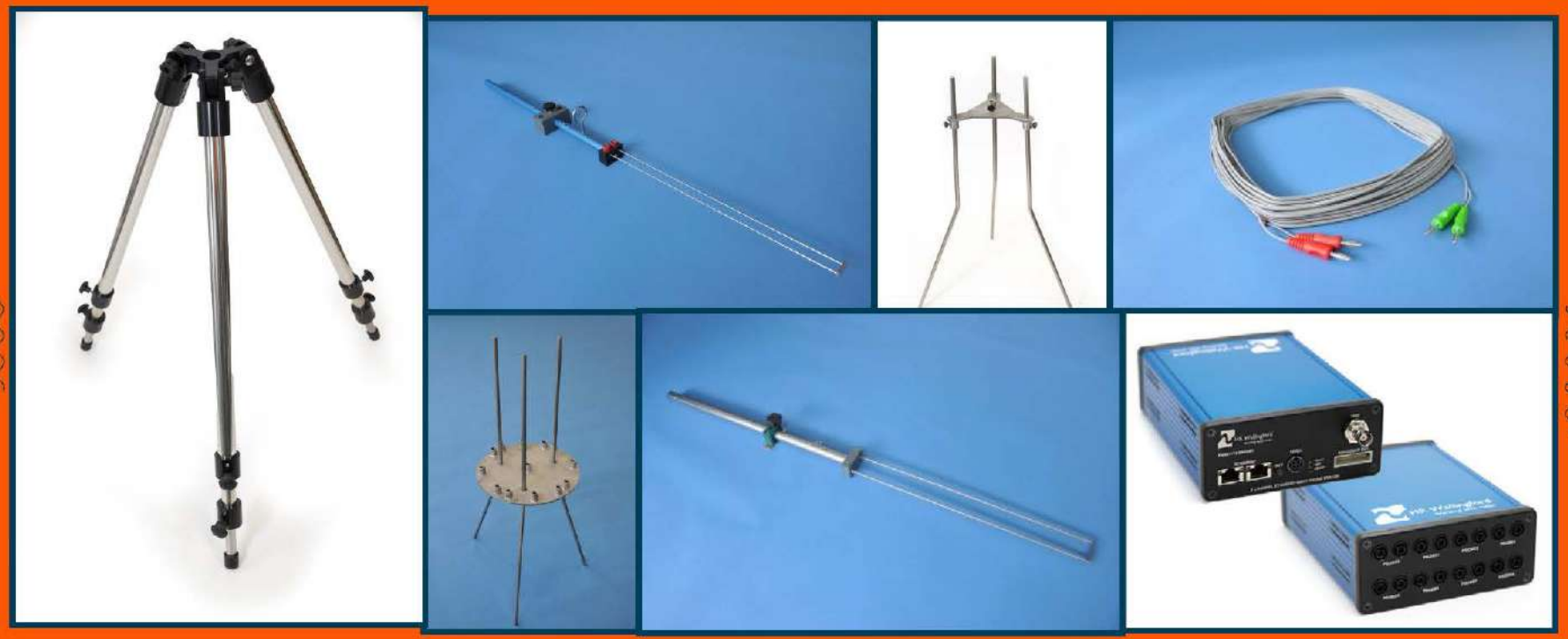
Instrumentation

- Wave Gauge System
  - Wave probe
  - Tripod / Array stand
  - Wave probe cable
  - Wave probe monitor
  - Digital output



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Instrumentation

- Pressure Sensors
  - High pressure sensors showing different membrane configurations
  - Transducer Output & Power Supply (TOPS) unit

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Instrumentation

- Mooring Line & Fender Force Transducers
  - Strain gauges;
  - Dedicated mounting brackets;
    - Mooring lines;
    - Fenders;
  - Selection of springs to simulate rope tensions.

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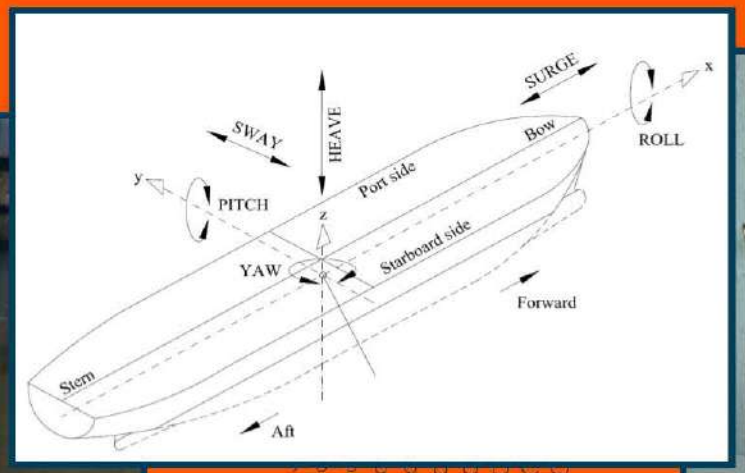
Instrumentation

- Ship Movement System
  - 6 Axis Laser Displacement;
    - Heave Sway
    - Pitch Surge
    - Roll Yaw
  - Uses Type 3 low power laser emitters



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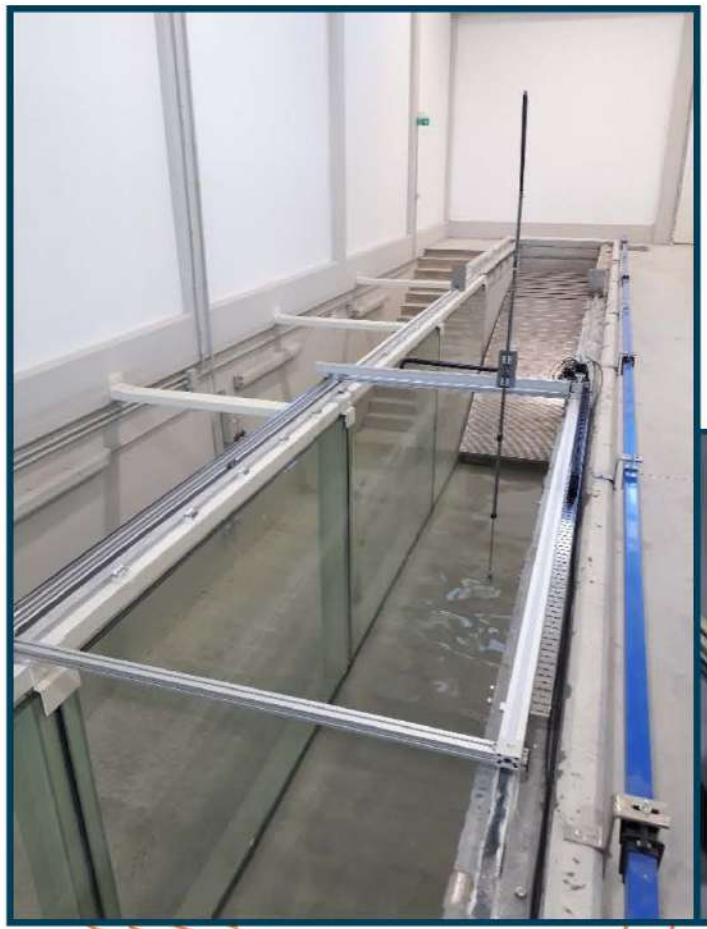
Instrumentation

- Traverser
  - Multiple position measurement
  - Can support the ADV
  - Bed profiling capability
    - Touch sensitive probe
    - Laser displacement probe



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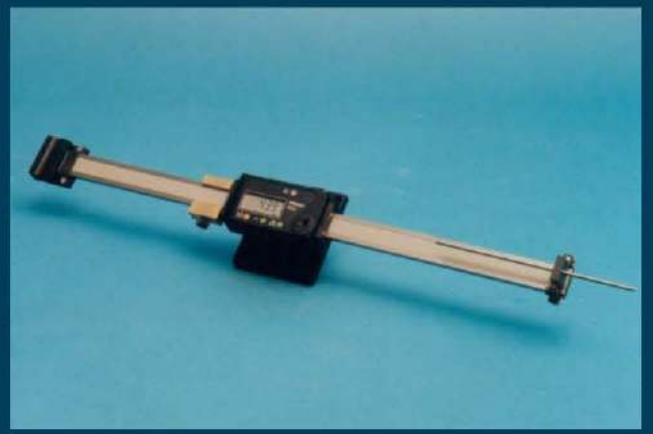
Instrumentation

- Other Instrumentation
  - Digital point gauge
  - Digital displays
  - Float gauge
  - ADV Vector (Nortek)



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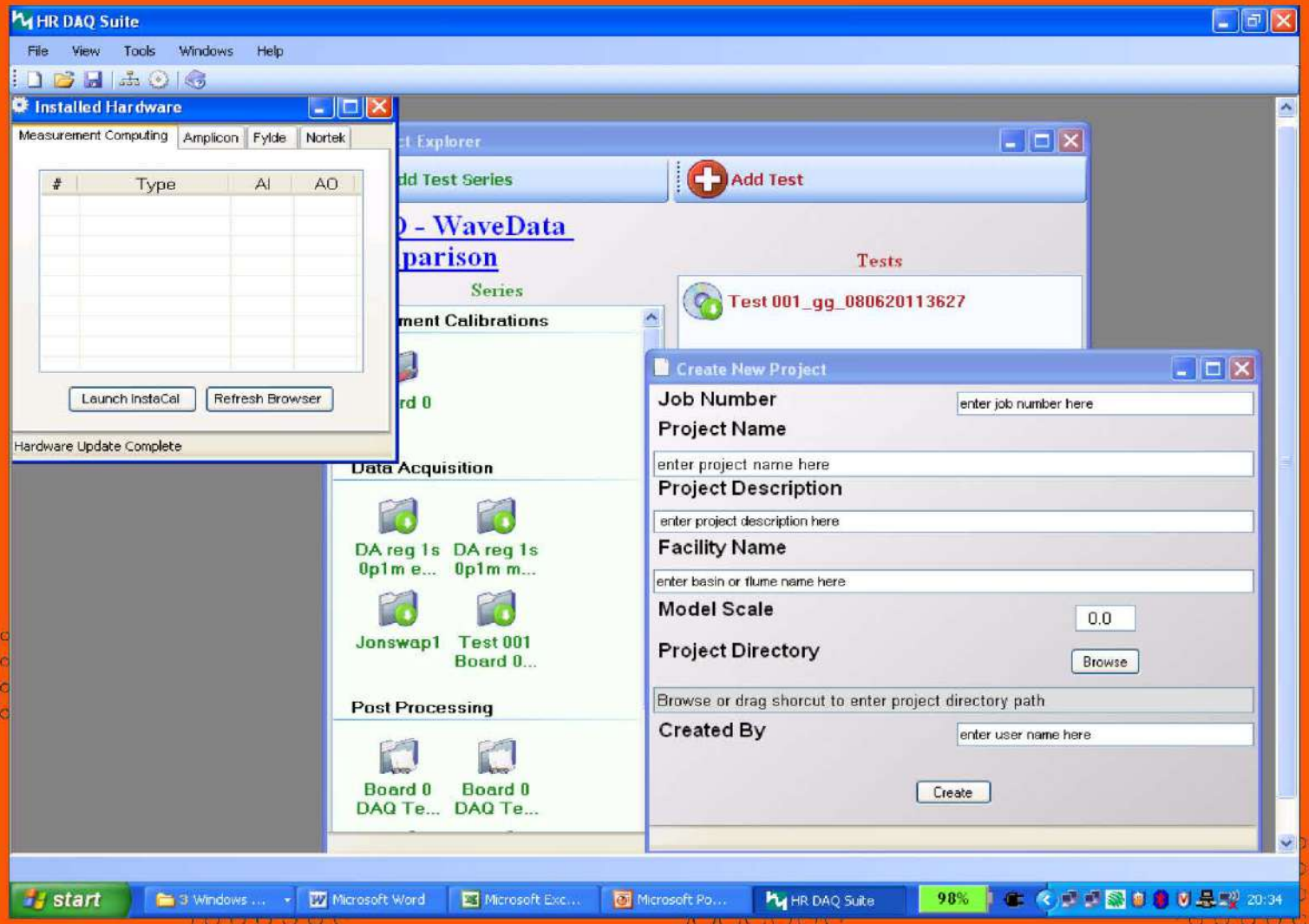
Data Acquisition Software

– HR DAQ Software - project explorer screen



Remote Platforms

ARB Boat / ARC Lite

- River gauging and reservoir surveys
- An instrument platform, currently ADCPs but also looking at echo sounders and boat mounted cameras
- Product now established with over 180 units operating around the world
- ARC-Lite is a reduced size platform launched by a single person.

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Thank you for your attention