Wave Energy Scotland Annual Conference, 28 November 2017
Elevator Pitches

Advanced Concrete Engineering – WEC (ACE-WEC)
Structural Materials and Manufacturing Processes

Jon Benzie, Senior Consultant Engineer, Quoceant Ltd

David Kerr Engineering Consultant

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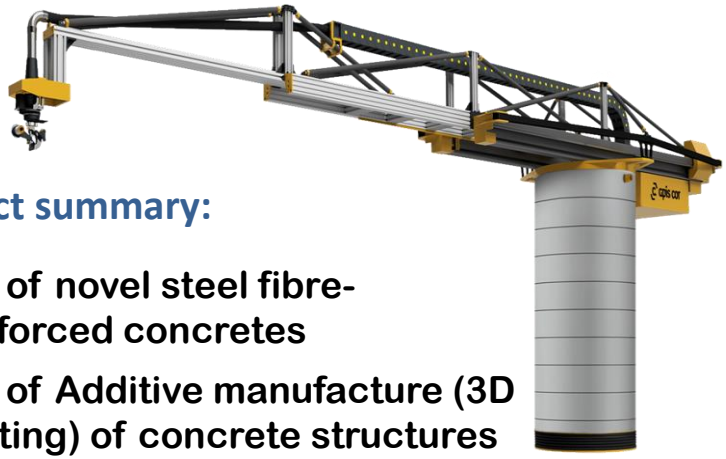
ACE-WEC (Advanced Concrete Engineering -WEC)

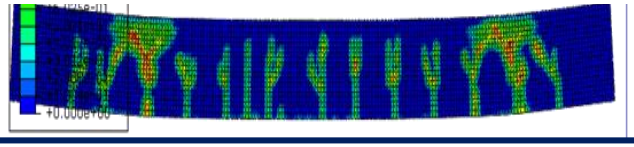


Project summary:

- Use of novel steel fibre-reinforced concretes
- Use of Additive manufacture (3D printing) of concrete structures

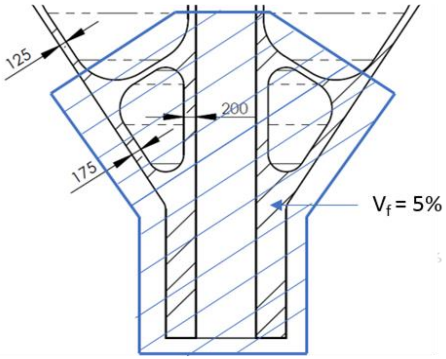
Challenges:

- No commercial 3D printing in UK
- Experience and Code limitations on use of fibre reinforced concretes
- Accurate definition of the material properties (i.e. design compressive and tensile strengths)



Technical product or integration offering:

- Development of lower cost primary structural material
- Development of flexible manufacturing techniques for concrete structures



Skills, expertise and technology required:

- Laboratory testing to quantify material properties and address qualification of material for use
- Once qualification of material achieved, adoption of technology by a WEC developer for application in a demonstrator device

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Rotational Moulding of Polymers, Composites and Hybrid WEC Structures (RotoHybrid)

Prof. Conchúr Ó Brádaigh
University of Edinburgh (Lead Contractor)

THE UNIVERSITY of EDINBURGH

Pelagic Innovation

Carnegie CLEAN ENERGY

Queen's University Belfast

Kingspan

ÉIRECOMPOSITES

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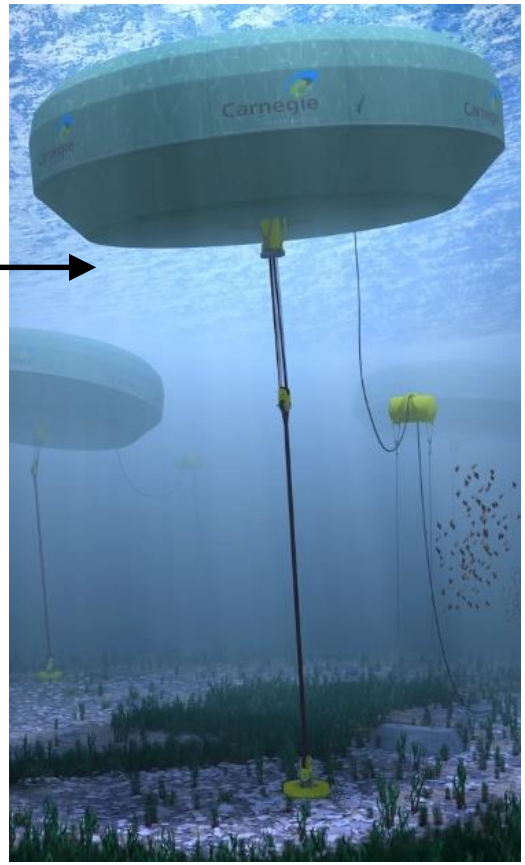
ROTOHYBRID Project

Can we apply

This

To this?



ROTOHYBRID Project

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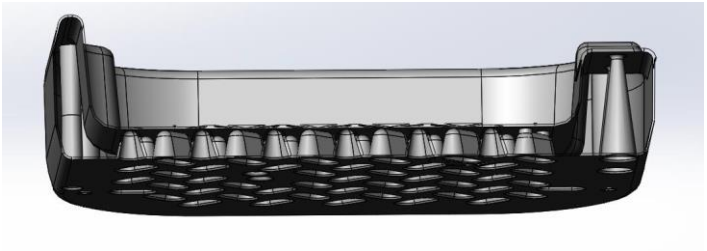
Inputs

Materials / process (QUB / UoE)

Manufacturing (Kingspan)

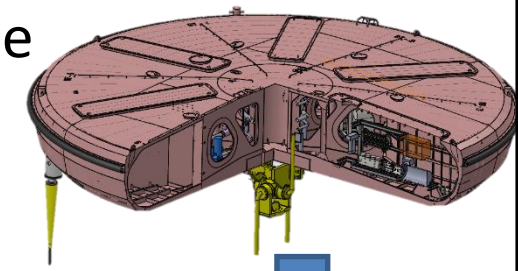


Specific testing (UoE)

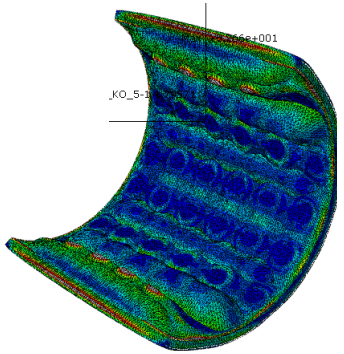
Knowledge Transfer

Case Study

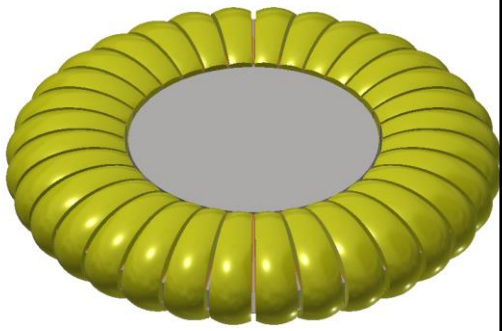
CETO 6 Baseline (Carnegie)



Analysis and design (UoE / PI)



LCOE (PI)



ROTOHYBRID Project

Project Summary

- Investigation of hybrid WEC structures made from rotational moulding of plastics, combined with polymer composites
- Finite element structural analysis/design
- Mechanical testing of materials and coupons, mech. fastening and seawater
- Linear hydrodynamic analysis of CETO 6 BA

Challenges

- Limited mechanical props. of polyethylene
- Designs tend to be buckling-critical and need reinforcing structures in composites or metal
- Mechanical fixing while maintaining water-tightness
- Assessing hydrodynamic performance of large doubly-curved structures

Technical product or integration offering

- Rotational moulding of HDPE, combined with polymer composites offers the ability to mould large buoyant structures more cheaply than construction in traditional welded steel (poss. 30% reduction in CAPEX)
- Process also allows modular construction of large buoyant WECs, saving on logistics and transport costs

Skills expertise or technology required

- Large-scale composite equipment supplier
- Access to greater computing power for non-linear hydrodynamic performance modelling
- Pressure testing of large buoyant actuators
- Developer of second type of WEC

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ARMWET - **A**dvanced **R**otational **M**oulding for **W**ave **E**nergy **T**echnologies

Presenter - Rob Eavis

Lead Contractor - PolyGen Ltd

PolyGen

Partners

WaveVenture

ROTOTEK

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ARMWET

Advanced **R**otational **M**oulding for **W**ave **E**nergy **T**echnologies

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Project Summary

- Enable the implementation of rotational moulded polyethylene
- -> Reduce CAPEX and OPEX

Challenges

- Product design limitations
- Reducing risk
- LCOE system integration

Technical product or integration offering

- Spreading Point Loads
- Overmoulding
- Internal Bulkheads

Skills expertise or technology required

- Designing with nonlinear materials
- Manufacturing knowledge
- Techno-economic modelling

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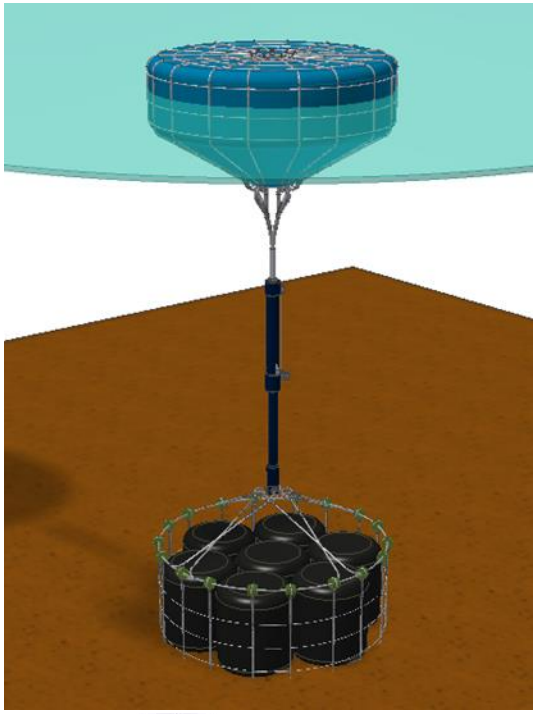
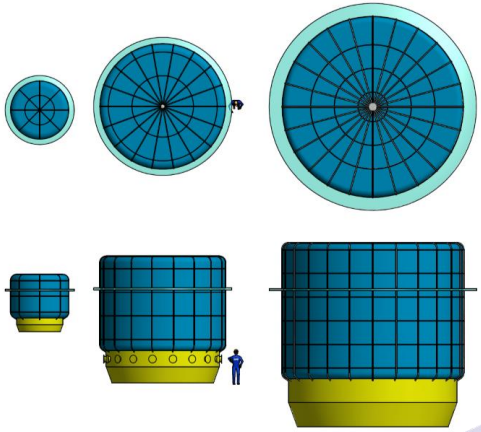
NetBuoy – Structural Materials & Manufacturing Process

Ben Yeats

Lead Contractor: Tension Technology International Ltd





BLACK & VEATCH

Quoceant Innovation Offshore

OPTIMUS

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Netbuoy

Project Summary

The project focusses on two key areas on the path towards cost competitive wave energy – impermeable fabrics to provide compliant and thus load shedding/peak load resistant buoyant modules and fibre rope 'load nets' to encapsulate the buoyant modules, applying distributed restraint loads and agglomerating the distributed load back to a single structural point to connect to the WEC PTO.

Challenges

- Material selection and durability
- Manufacturing Process
- Geometry change (e.g. creep, volume change)
- Machine room interfacing
- Ballasting
- Environmental degradation
- Supply chain partnering

Note: no insurmountable or unforeseen challenges

Technical product or integration offering

- Scalable and cost-effective prime mover used to replace conventional point absorber buoys
- Applicable to other WEC categories

Skills expertise or technology required

- Product development & qualification
- High end FEA Modelling (e.g. hyperelastic material using the Neo-Hooke material model)
- Material development expertise (Rope and elastomeric materials)
- Material testing laboratories
- Scale testing expertise

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CREATE - Concrete as a Technology Enabler

George Walker

Lead Contractor: ARUP

cruz atcheson CONSULTING ENGINEERS

mpa The Concrete Centre

Carnegie wave energy

SEA POWER Ltd.

Wello

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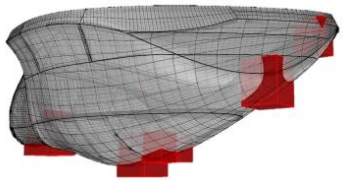
CREATE – Stage 1

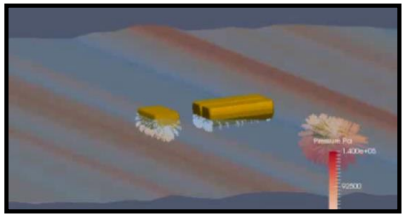
Project Summary

- Reinforced concrete has the potential to offer a **low cost solution** taking advantage of a **mature supply chain.**
- The CREATE project has identified **where concrete has potential** and developed the most promising option to a **FEED level design** with potential for commercialisation.

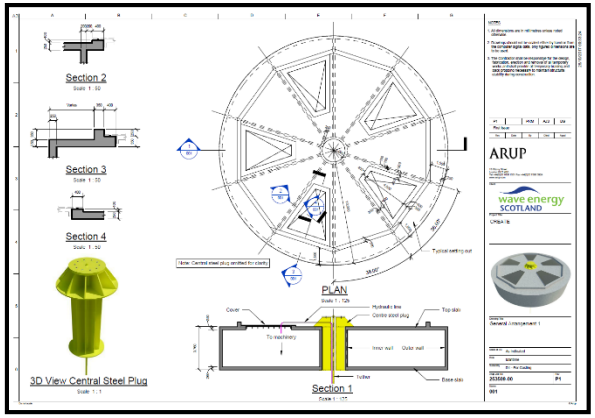
Challenges

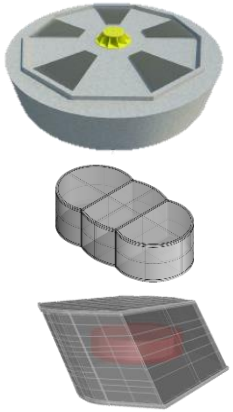


- Construction of complex geometries.
- Lack of guidance and validation of loads analysis methods.



Technical product or integration offering





Skills expertise or technology required

- We are seeking **test facilities** for both loads validation and concrete component testing ahead of the Stage 2 of WES SMMP.
- We are interested in engaging with **more developers** to identify **other devices** where concrete would be of benefit.

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A feasibility study on Elastomeric-based WECs (ELASTO)

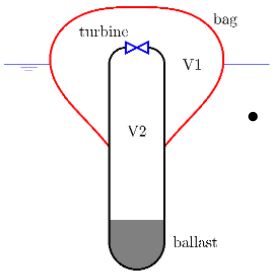
Structural Materials and Manufacturing Processes

Vasileios Koutsos

The University of Edinburgh

ELASTO

Compressible self-rectifying point absorber (SQ1) WEC in the form of an axisymmetric heaving buoy with a completely flexible elastomeric bag as the deformable body connected to a rigid ballast container. The flexible bag is in the form of a fabric (reinforced elastomer) encased within an array of meridional tendons. When the bag is inflated, the fabric forms lobes between the tendons. This effectively keeps the tension in the fabric to a minimum, and the tendons become the major load-bearing members. The performance and loading of SQ1 is investigated.



Challenges

- Model limitation: Models used are based on linear hydrodynamics and assume all the loads are carried by the tendons – a challenge is to model the response of the SQ1 in larger waves.
- Since SQ1's survival strategy is to deflate in the largest waves, ultimate loads should not be a problem. Fatigue in representative conditions is still an issue: Fatigue in the tendons, the membrane, the tendon/membrane connection and in the bag/substructure connection.

Technical product, skills and expertise of the team

- Deformable bag WECs like the SQ1 device itself.
- Construction methods for producing and integrating tendons and membranes.
- Hydrodynamic frequency-domain models of flexible bag WECs.
- Hydrodynamic time-domain models of flexible bag WECs.
- Materials testing facilities and expertise.
- Possible integration with DEG type PTO.
- Possible integration with rotational moulding projects (ballast container).

Skills expertise or technology required

- Mooring expertise: the mooring system will significantly affect the loads on SQ1
- PTO expertise: e.g. pneumatic or DEG PTO.
- Control systems expertise.
- Rubber manufacturer.
- Instrumentation of flexible materials specialist

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HydroComp – SM&MP Stage 1

Jéromine MAILLET

CorPower Ocean AB

HydroComp

Project Summary

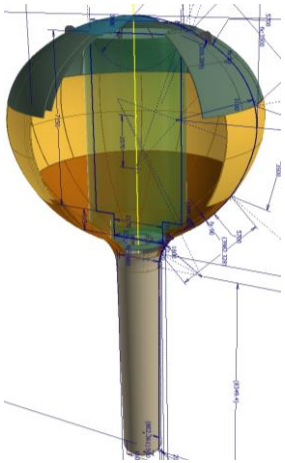
- Identify best material choice for hybrid polymer structures
- Deliver an innovative structural design concept with effective process for the manufacturing of hybrid FRP structures
- Evaluate the impact on cost of energy

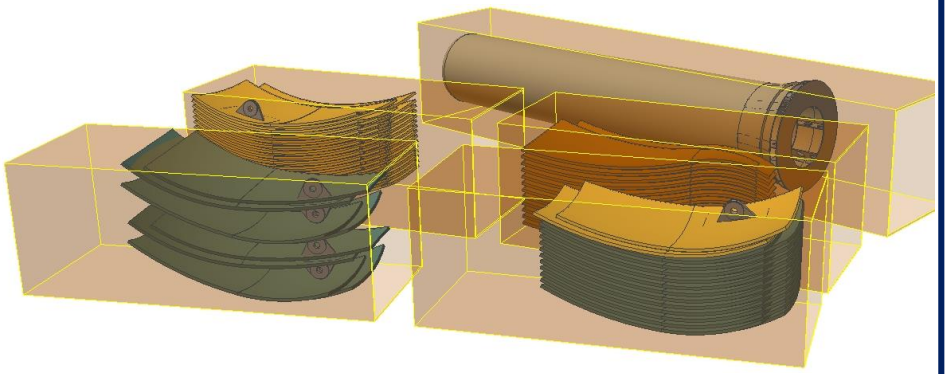
Challenges

- Cost effective materials & manufacturing process
  vs. optimized design for power production
- Logistics involved in overall production

HydroComp

Technical product





Skills expertise or technology required

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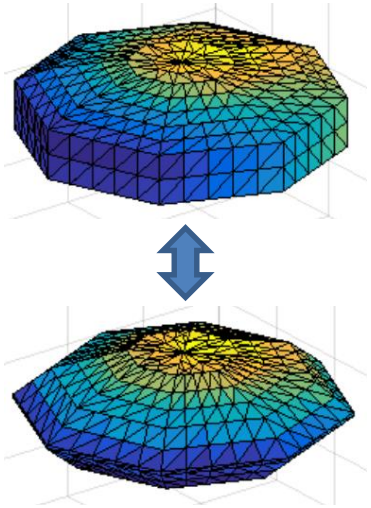
Title: **POLYSHELL Project** – SM&MP Call

"A Flexible Polymer Hull for WEC Devices"

Presenter: Stephen O'Sullivan



Lead Contractor – tfi

REMTec Consulting
Renewable Energy & Marine Technology

cruz atcheson
CONSULTING ENGINEERS

DUPONT

EXCEEDENCE
MAKING RENEWABLES COMMERCIAL

RADIUS Systems

Pelagic Innovation

DNV·GL

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POLYSHELL

A Flexible Polymer Hull for WEC devices

Project Summary

- Engineering Design Study to determine feasibility of Hytrel as a WEC material
- Detailed assessment of thermoplastic elastomer material properties
- Analysis of large scale polymer manufacturability
- Examined the performance of a WEC device with an outer hull that is designed to maintain its shape in normal operating conditions but, in extreme sea conditions, can bend and flex and thereby shed excess loads

Challenges

- Addressed in Stage 1
  - Material properties, Full scale manufacture, Integration into WEC structures, Environmental peak loads, Concept structure design
- Stage 2 Challenges
  - Time Domain Loadings
  - Localised loadings
  - Design of actual polymer components
  - Testing
  - Wider WEC device type designs / performance

Technical product or integration offering

- Polyshell's flexible hull design changes shape under applied loads in survival conditions, delivering:
  - up to 40% load reduction on moorings
  - greater survivability
- Lower load variations -> reduced fatigue
- Polymer hull -> no corrosion, lower bio-fouling
- Substantial LCOE Reduction
  - CAPEX – more expensive hull, reduced moorings costs
  - OPEX – lower O&M, lower refurbishment costs

Skills expertise or technology required

- WEC developers interested in incorporating Polyshell protection into their device
- Facilities capable of testing components to further reduce risks associated with the new technology

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RePOWER (Reinforced Polymers for Wave Energy)

Structural Materials and Manufacturing Processes

Joao Cruz

Lead Contractor: Cruz Atcheson Consulting Engineers

cruz atcheson CONSULTING ENGINEERS ARUP NATIONAL COMPOSITES CENTRE DNV·GL Carnegie wave energy CORPOWER OCEAN

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RePOWER (Stage 1)

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Project Summary

- Focus on composites as the structural materials for the prime mover
- Independent engineering design team – impartial views
- Address vast amount of key design / analytical questions in one single project

Challenges

- Lack of guidance in application of methods – potential to extend existing practices (impacts beyond RePOWER)
- Further validation of novel methods / initial estimates needed – hot spots, sectional level, prime mover level

Technical product or integration offering

- Deep understanding of load / stress analysis + manufacturing processes
- Two full iterations (range of metrics)
- Output: viable prime mover designs – suitable for detailed investigations

Skills expertise or technology required

- Fabrication / instrumentation
- Testing (Stages 2 and 3)
- Coupling with other WES initiatives where composite prime movers and / or prime mover detailed design support is needed

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Advanced Rotational Moulding for Ocean Renewables (ARMOR)

Angus Vantoch-Wood, Carbon Trust

haydale Composite Solutions

- **Lead project partner**
- Material design
- Sample testing
- Risk evaluation

CARBON TRUST

- Project Management
- LCOE Modelling

Crompton mouldings ltd

- Manufacturing study
- Sample fabrication

WaveVenture

- Design filtering
- Device design
- Load analysis

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ARMOR

Project Summary

- Our estimates indicate switching the structural material can reduce structural costs by ~50% and reduce OPEX
- Project consists of device refinement, detailed design concept, material testing and evaluation, assessment of manufacturing requirement, cost benefit analysis and risk evaluation

Challenges

- Difficulties in sourcing novel and new materials at a reasonable economic cost
- Manufacture of test samples – trial and error approach
- Software model optimisation of a BBDM wave energy device

Technical product or integration offering

- High level of practical industry specialist expertise within all areas including design for modular rotational moulding fabrication techniques
- We are device agnostic – As we are not associated with a device developer
- We are solution agnostic too!

Skills expertise or technology required

- We would like to engage with wave energy developer(s)