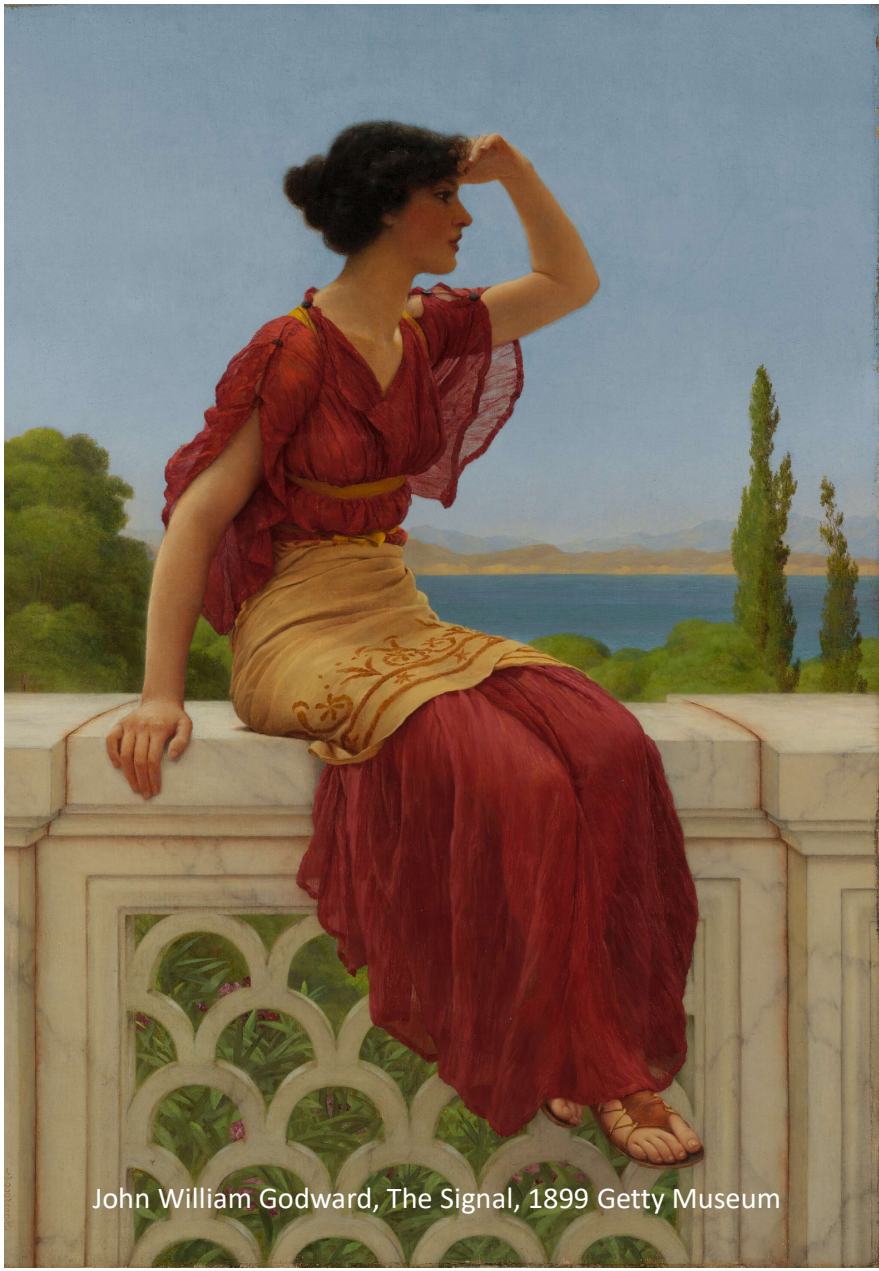
Sfide tecnologiche per le rinnovabili dal mare e l'eolico offshore: (Può una progettazione sostenibile dei dispositive per le rinnovabili marine contribuire alla 'biodiversity restoration'?)

Claudio Lugni

Università degli Studi di Napoli
Federico II

A huge thank you to the CNR-INM team I had the honor to work with:
Researcher: Andrea Bardazzi, Alessia Lucarelli, Chiara Pilloton, Sara Russo
PhD: Luis Daniel Aguilar, Damiano Paniccia, Luca Padovani, Hui-Li Xu
Master degree students: Flavio Cetorelli, Camilla Luvisetto
All the Batchelor degree students



John William Godward, The Signal, 1899 Getty Museum

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Corso di Studi Ingegneria Navale

Marine **Te**chnology **R**esearch (**MaTeR**) Team

Scientific Coordinator

Prof. Claudio Lugni: claudio.lugni@unina.it

Research team:

Prof.ssa Ermina Begovic

Prof. Claudio Pensa

Prof. Fabio De Luca

Prof. Simone Mancini

RTDB Luigi Vitiello

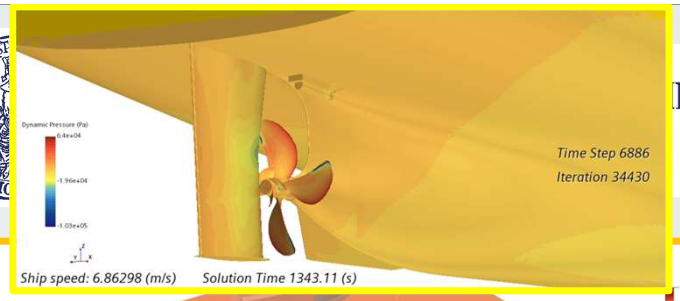
Technicians

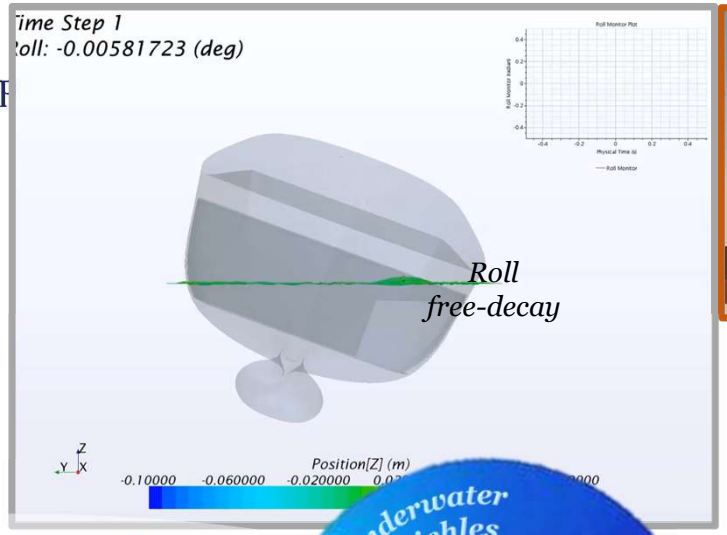
- Dr. Andrea Bove
- Ing. Paolo Marsilia
- Ing. Sebastiano Caldarella
- Ing. Luigi Ombrato

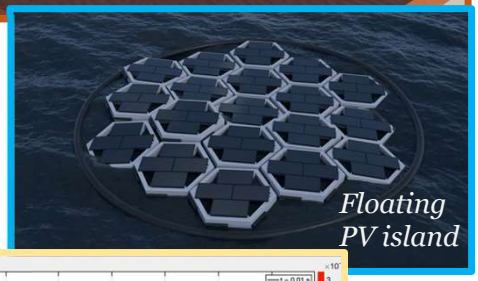
PhD e Post-Doc

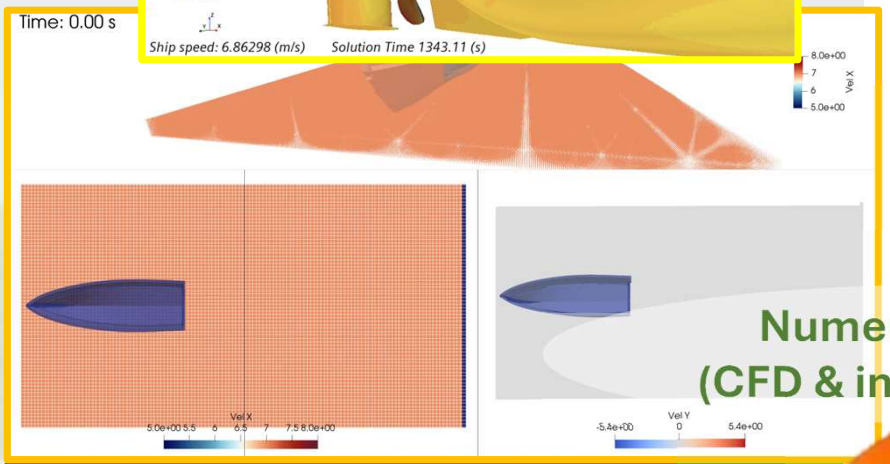
- Ing. Claudia Chianese
- Ing. Vincenzo Sorrentino
- Ing. Riccardo Pigazzini
- Ing. Gennaro Rosano

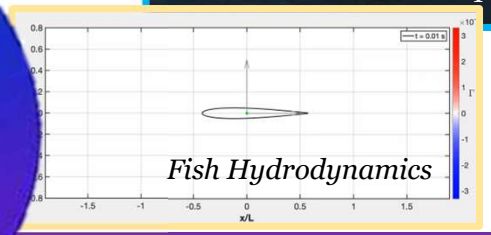
John William Godward, The Signal, 1899 Getty Museum



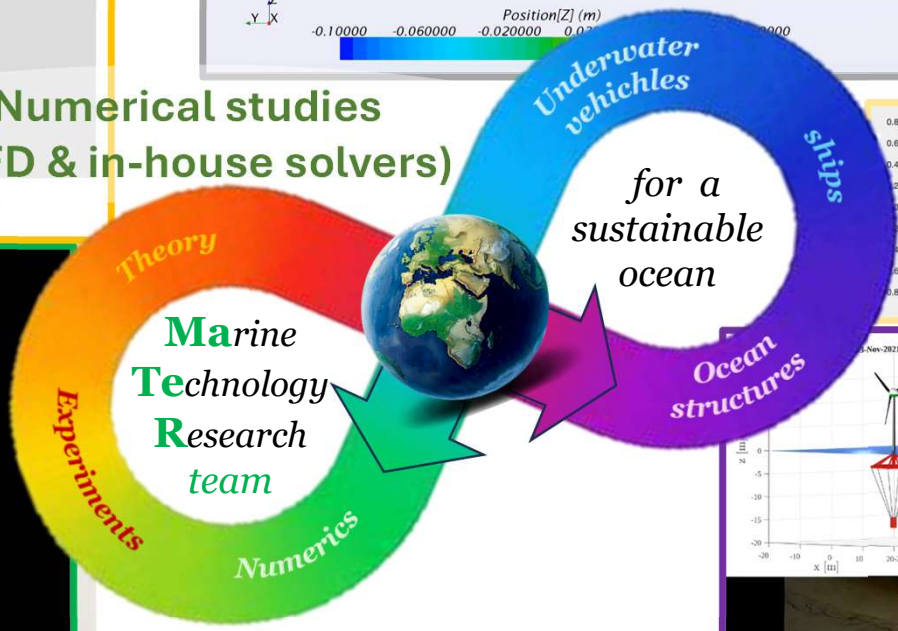


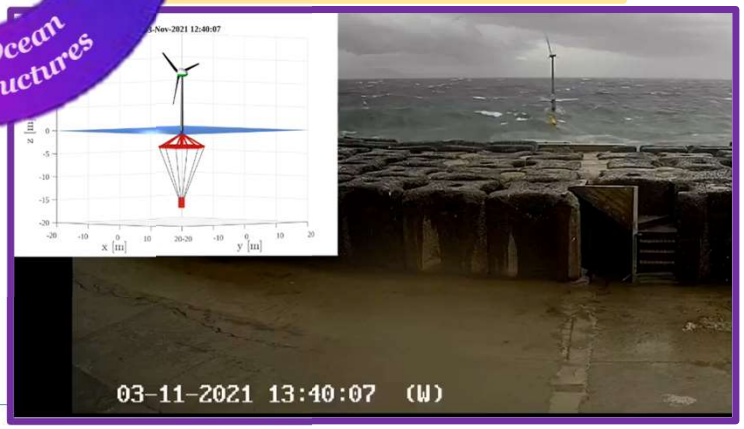






Numerical studies
(CFD & in-house solvers)





Experimental studies

@ Indoor Lab (LEIN)

@ Sea Lab (MaRELab)

Un salto nel passato:
Il futuro del mare negli anni 90…

John William Godward, The Signal, 1899 Getty Museum

E le relative conseguenze…

Lezione nr 1 …Imparare dagli errori del passato!!!

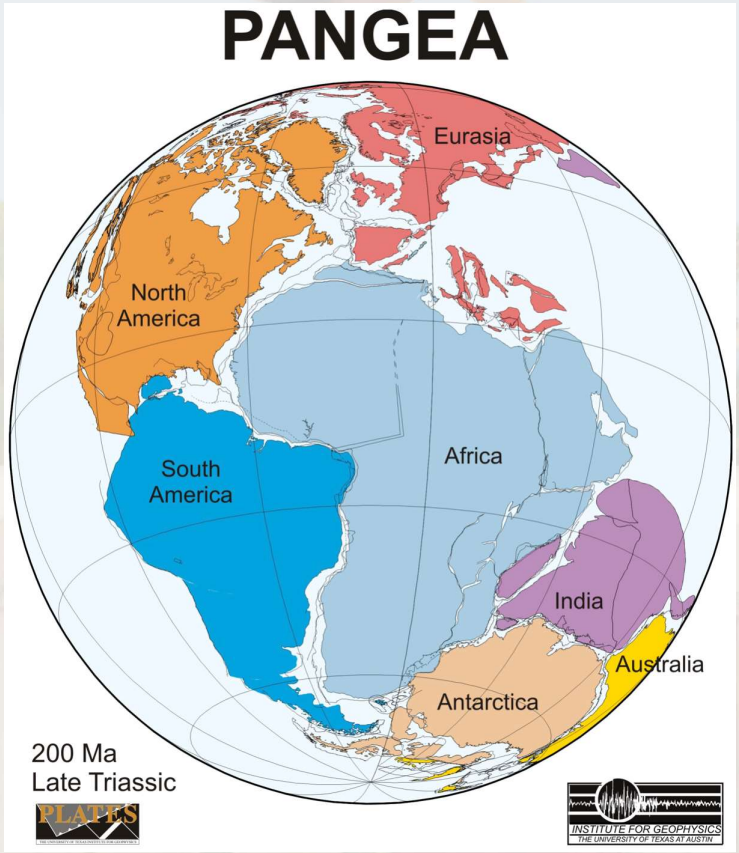
La ricerca considera il genere umano e la salvaguardia dell'ambiente come prioritario

A twist: the actual scenario of our planet

(by courtesy of Prof. Fabio Trincardi)

Folke et al, Ambio 2021, 50:834–869

John William Godward, The Signal, 1899 Getty Museum

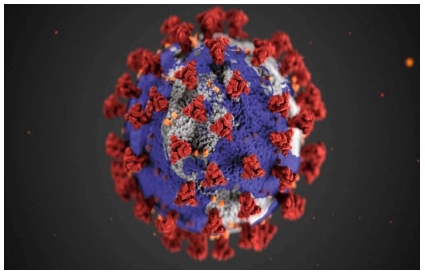


John William Godward, The Signal, 1899 Getty Museum

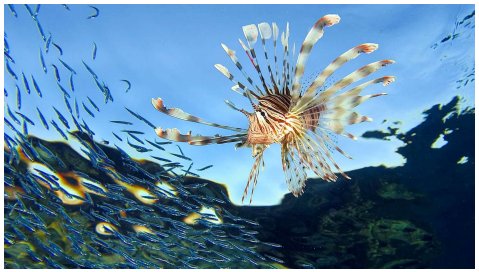
A twist: the actual scenario of our planet

(by courtesy of Prof. Fabio Trincardi)

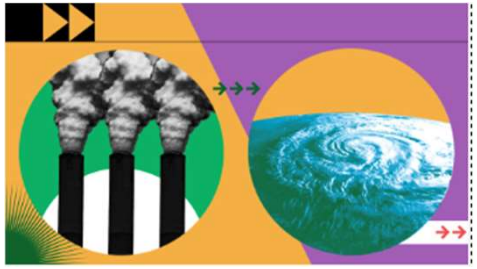
Pandemic



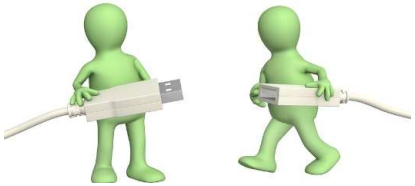
biodiversity loss

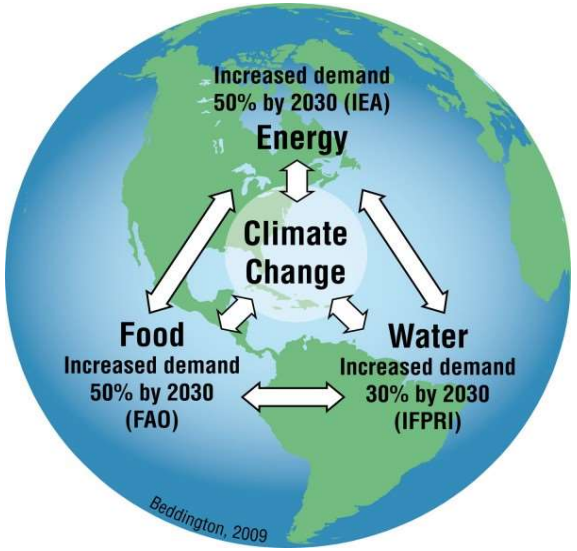


climate change



For answering the challenges of the future.
Higher demand for
- food,
- fresh water
- energy





John William Godward, The Signal, 1899 Getty Museum

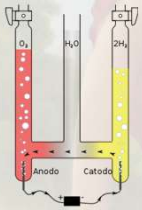
A vision for the future of the sea… and of the green shipping

John William Godward, The Signal, 1899 Getty Museum

Energy Archipelago

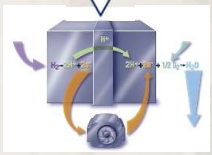
How to use the energy?

a) in situ use & storage



H_2 production through water elettrolisys

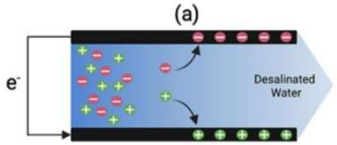
Methanol prod. elettrocatalisys
CO2+3 H2=>H20 + CH3OH



Fuel Cell and Charging hubs

John William Godward, The Signal, 1899 Getty Museum

An Energy Hub… towards a Floating Smart City

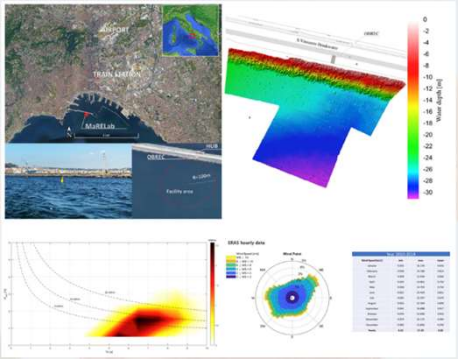


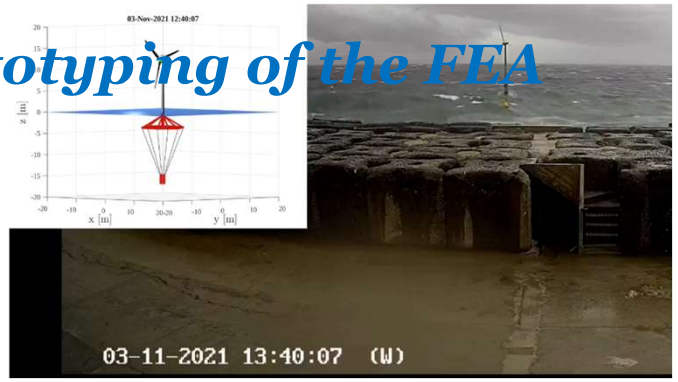
Desalination Battery

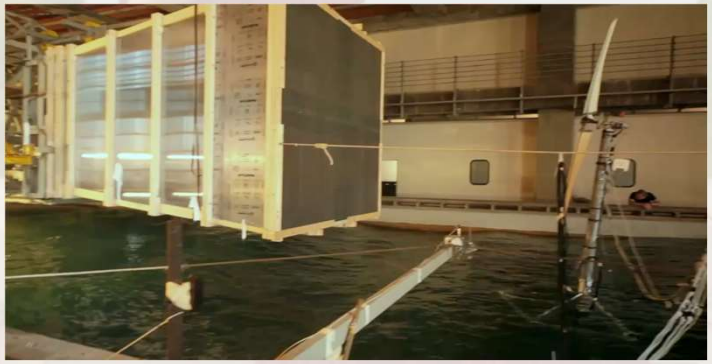
Sodium-ion battery

Challenge: Prototyping of the FEA

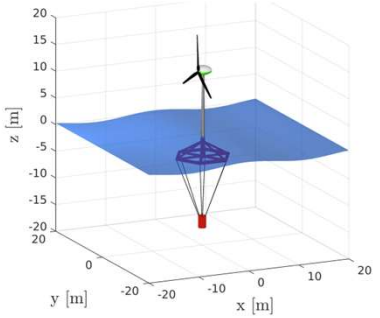
Prototyping
in real environment

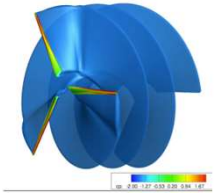


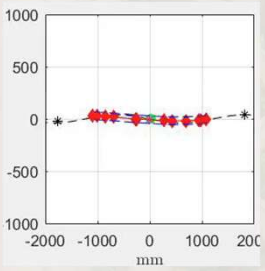




Digital
Twin
& AVR

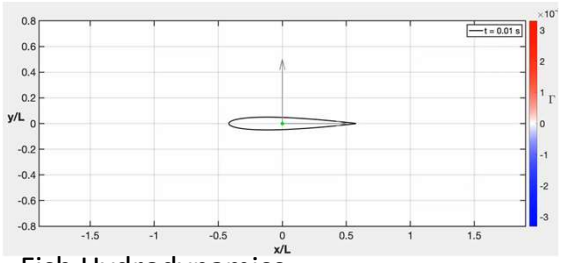






Experimental Study
in indoor lab

Numerical Study



Fish Hydrodynamics
(Phd Damianno Paniccia, 2022, Sapienza)

Challenge: Prototyping of the FEA

Breakthrough:

- First Multidisciplinary lab (wind-sun-wave) of the Mediterranean sea.

- Available for testing novel marine renewable energy devices

- Ready to host the first energy archipelago prototype

Funding:

- Italian RP (MiSE, MaSE),
  2.5 MEuro (2019-2021) +
  3 MEuro (2022-2024)
  3.5 MEuro (2025-2027)

Coordinator: C. Lugni

John William Godward, The Signal, 1899 Getty Museum

ISTITUTO DI INGEGNERIA DEL MARE

Università degli Studi della Campania *Luigi Vanvitelli*

Ricerca di Sistema

I-MaRELab: Interdisciplinary Marine Renewable Energy seaLab

It hosts the first prototyipe of Hexafloat (CNR-Saipem)

it hosts the OBREC (Unicampania) (Overtopping BReakwater wEC)

Challenge: Prototyping of the FEA

- ***First Italian sea lab for MRE (400 m x 400 m)***
- ***Equipped with fiber optics lines for data transfer***
- ***Monitoring system for structures and metocean conditions, time and space-resolved***

Availability of a sea lab for prototypes with intermediate scale factor, enables low initial investments to get relevant results for full scale development. This is relevant for a complex system as the AE, as well as for novel technologies instrumental to the AE. For instance:

Hexafloat FOWT with intermediate scale (1:6,8) installed at the sea lab has allowed , with a small investment (less than 1 Meuro), a technological jump from TRL 3-4 to TRL 6-7

John William Godward, The Signal, 1899 Getty Museum

ISTITUTO DI INGEGNERIA DEL MARE

Università degli Studi della Campania *Luigi Vanvitelli*

I-MaRELab: Interdisciplinary Marine Renewable Energy seaLab

Ricerca di Sistema CNR

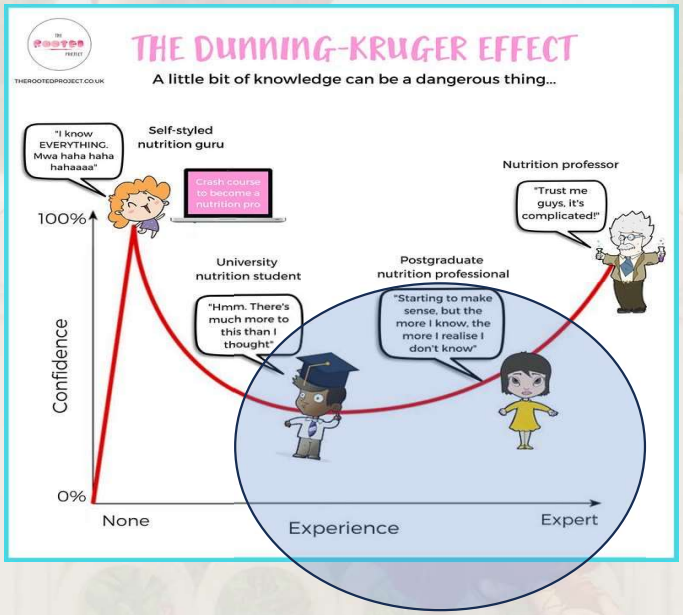
Napoli, 25 Novembre 2025

John William Godward, The Signal, 1899 Getty Museum

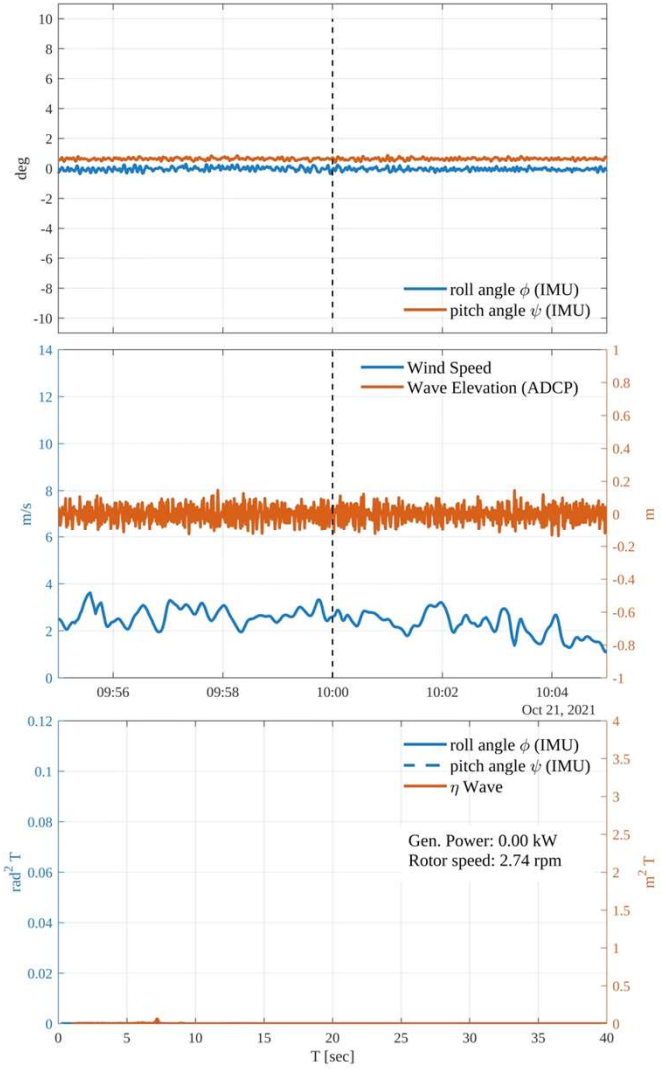
Napoli, 25 Novembre 2025

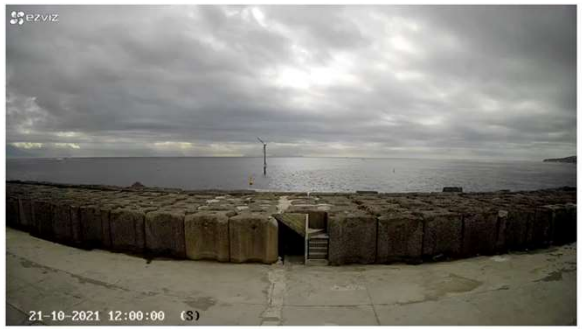
John William Godward, The Signal, 1899 Getty Museum

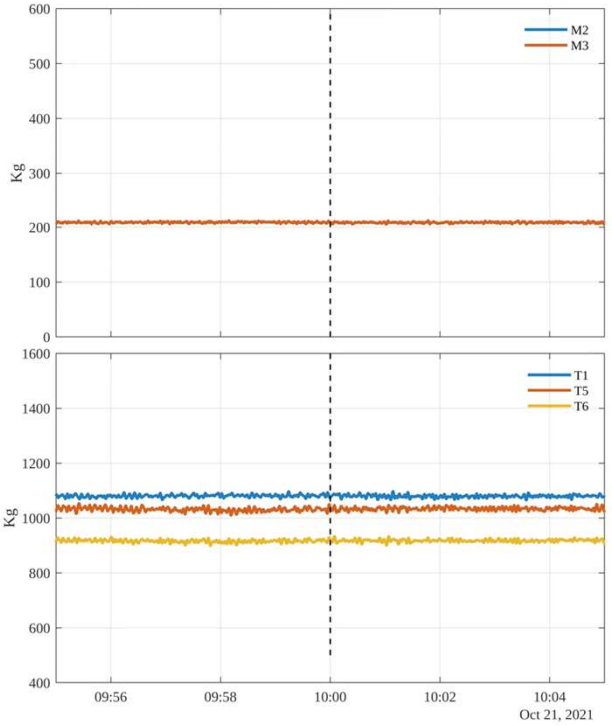
Challenge: Prototyping of the FEA



John William Godward, The Signal, 1899 Getty Museum







Challenge:

design low cost structures minimizing environmental footprint

- A large skepticism against the OWF exists in Italy, mainly related to the environmental footprint and the marine space sharing
- However, OWF and MRE represents a good opportunity for a novel strategy of economic development.

Floater & installation
Anchoring & moorings
Electrical Substation & cables

John William Godward, The Signal, 1899 Getty Museum

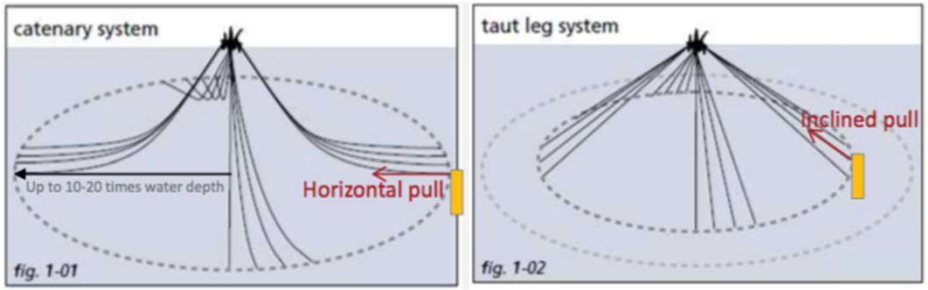
TETRASPAR

Fincantieri's Technology

HEXAFLOAT SAIPEM

FLOATGEN IDEOL

*CAISSON –TYPE **OR TRANSPARENT FLOATER?***



*CATENARY **OR (SEMI-)TAUGHT?***

*STEEL **OR SYNTHETIC FIBERS?***

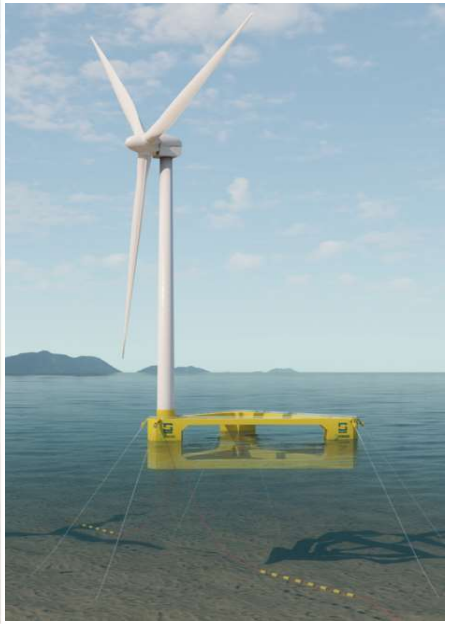
2nd Challenge: Construction of the FEA

Which floating technology for the Med Sea?

Saipem's Technologies

STAR 1

X:BASE



HEXAFLOAT

Three different designs to unlock the Floating Wind market potential without Water Depth limitations

John William Godward, The Signal, 1899 Getty Museum

2nd Challenge: Construction of the FEA

Napoli, 25 Novembre 2023

Which floating technology for the Med Sea?

Saipem's Technologies

STAR 1

- ✓ High stability, Robust behaviour also in harsh environment
- ✓ Compatible with all mooring configurations (catenary, taut, semi-taut)
- ✓ Stable and steady at all phases (towing and hook-up with small conventional tugboats and easy installation at final location)
- ✓ Complete Manufacturing in one site or fabrication of modules in multiple yards for assembly at a final site
- ✓ Low number of connections and small elements ease the manufacturing process

X:BASE

- ✓ High stability, Robust behavior compatible to harsh environments with airgap designed to accommodate for significant waves
- ✓ Pontoons designed to eliminate the need for damping plates
- ✓ Low pre-tensional conventional mooring system
- ✓ Designed for 15 MW platforms and scalable to any size of turbines
- ✓ Block fabrication based on well-known shipbuilding construction methods to meet fabrication requirements globally

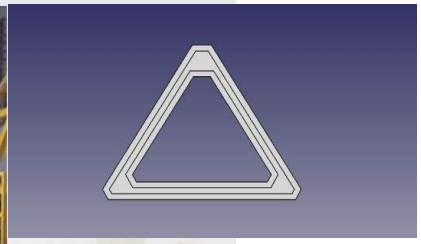
HEXAFLOAT

- ✓ Low structure weight
- ✓ Design scalability: limited design growth for large WTG (15-20MW+)
- ✓ Allows access to quayside in any harbour
- ✓ Low draft during WTGs integration
- ✓ Suitable for deep water sites
- ✓ Fabrication of modules in multiple yards for assembly at final site or full on-site manufacturing
- ✓ Low number of connections and small elements to make production easier and faster

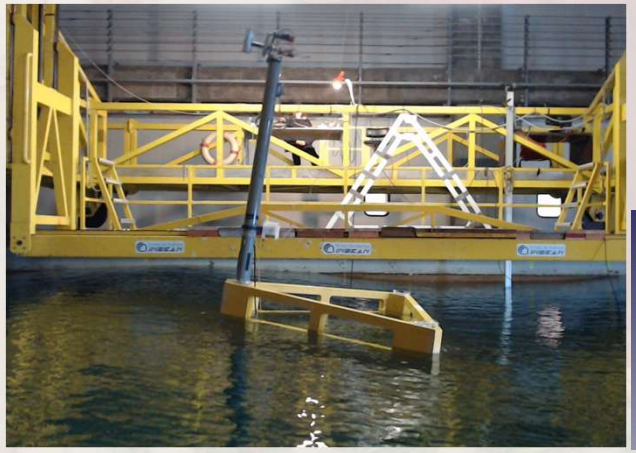
Three different designs to unlock the Floating Wind market potential without Water Depth limitations

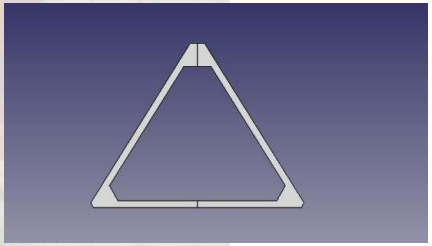
John William Godward, The Signal, 1899 Getty Museum

Idea: ***Uso di flat plates per incrementare i periodi naturali dei moti verticali della struttura (X-Base)***



Regular wave
(scale factor = 66)
T = 15s s
H = 12 m





John William Godward, The Signal, 1899 Getty Museum

Sea spectrum
(scale factor = 60)
T = 6 s
Hmax = 6 m

Idea: ***Studio dell'occorrenza di un'onda anomala durante una mareggiata del 2021 (Hexafloat -)***

How to reduce FOWT footprint on the sea bottom (and at a low cost)?

For millennia, fisheries have driven the "blue" economy of the Mediterranean, providing the basis for the so-called "Mediterranean diet"

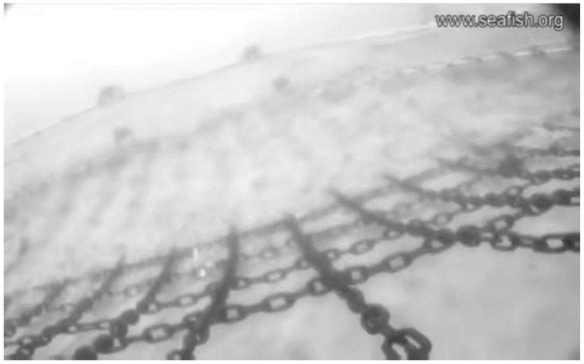
We need to find a coexistence between trawling and FOWT park. This implies the reduction of the sea bottom footprint: (semi-)taught mooring line solutions

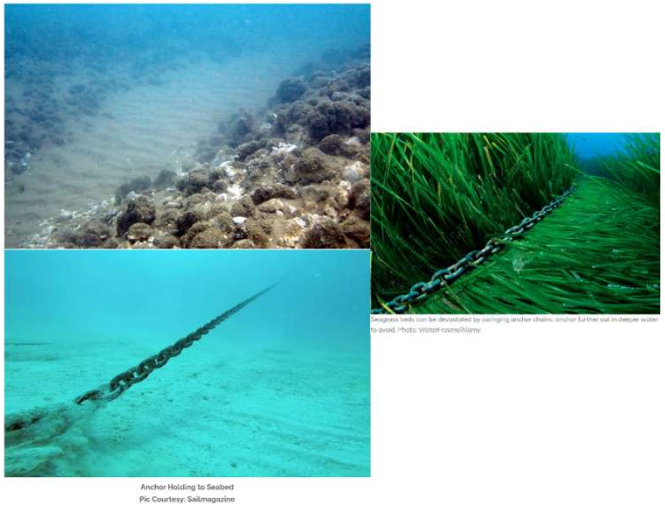
Trawling disturb sediment C stores, leading to release of sedimentary carbon to CO_2, which increase ocean acidification, reduce the buffering capacity of the ocean and add to the build-up of atmospheric CO_2

John William Godward, The Signal, 1899 Getty Museum

Environmental sustainability issues:
Coexistance with other uses of the sea

- *Minimize footprint on the sea bottom*
- *Birds migration*
- *Minimize electrical cables on the sea bottom*
- *Noise minimization*
- *Is coexistance with trawling possible?*
- *Ship trasnportation*



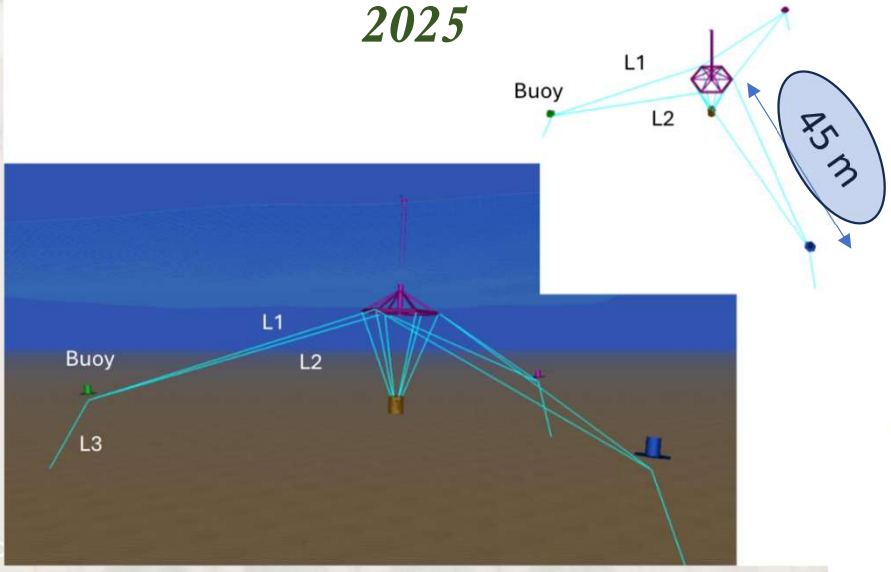


Challenge:

design low cost structures minimizing environmental footprint

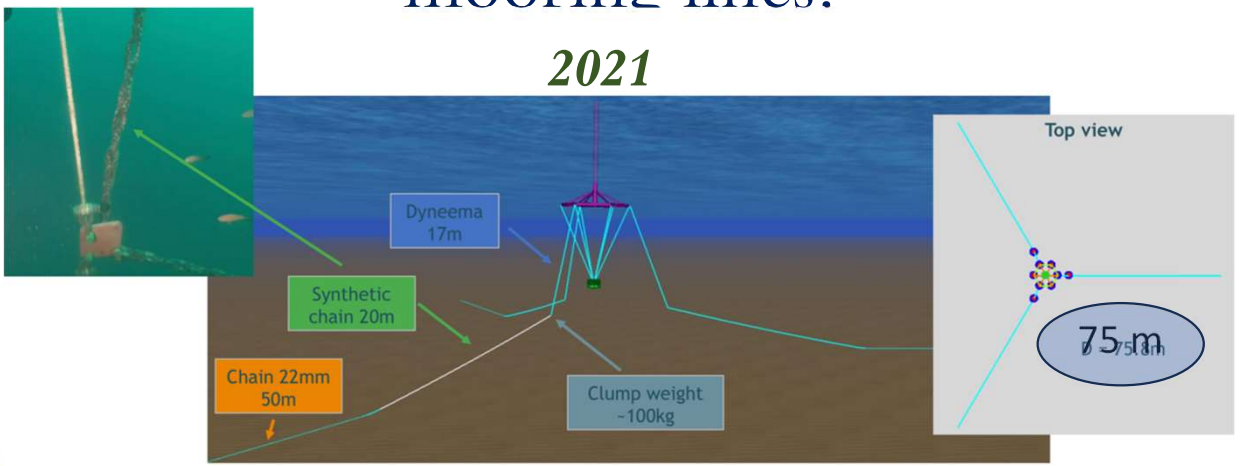
From catenary …

2025



What benefits from (semi-)taut mooring lines?

2021



… to semi-taut

Challenge:

design low cost structures minimizing environmental footprint

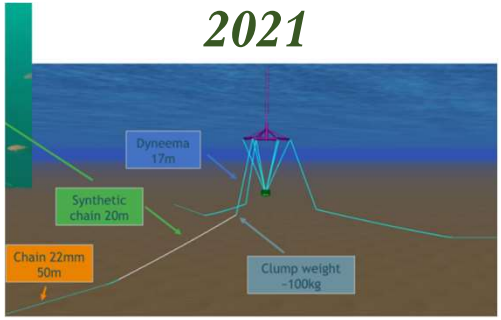
From catenary …

… to semi-taut

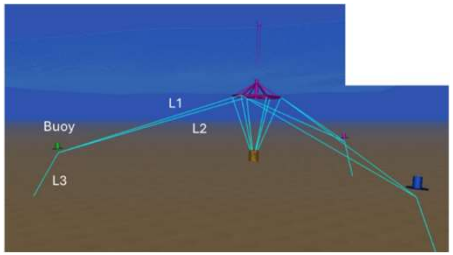
John William Godward, The Signal, 1899 Getty Museum

What benefits from (semi-)taut mooring lines?

2021



2025



	Catenary	Semi-taught
Max Mooring Load (ton)	4.5	7.1
Floater Offset (m)	6.2	8.3

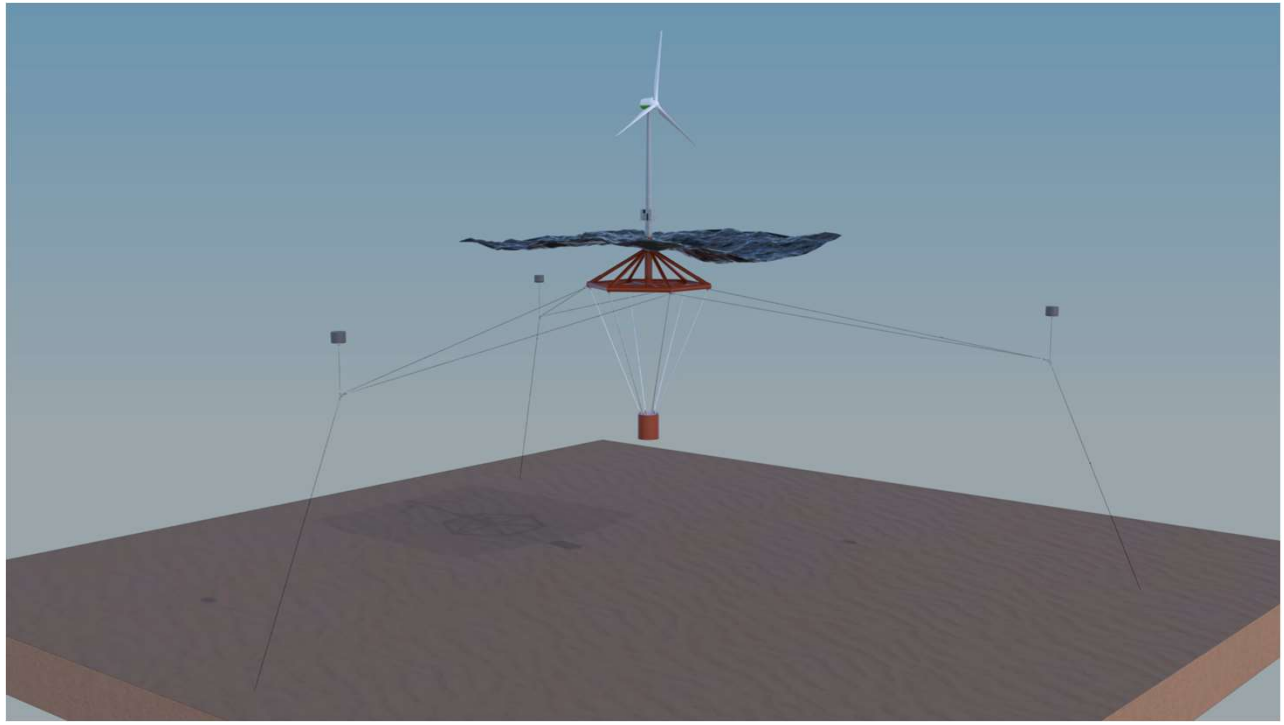
Challenge:

design low cost structures minimizing environmental footprint

- ***Some wise choices for a sustainable design of a FOWT:***
  - ***Floater transparent to waves***
  - ***Natural material or recycling material***
  - ***Syntethic taught (or semitaught) mooring lines***
  - ***Suction pile (where possible) or driven pile***
  - ***Electrical substation***
  - ***Mooring sharing***
  - ***Anchoring sharing***

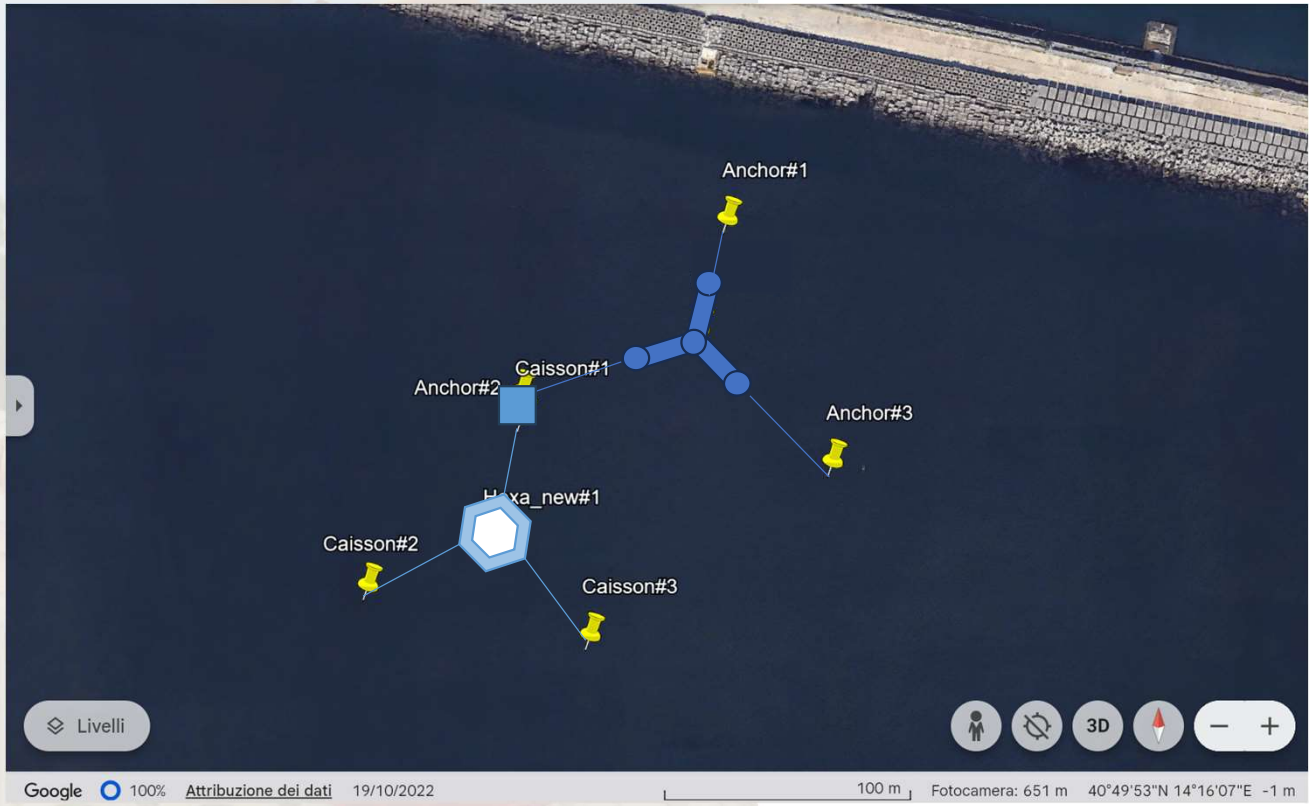
John William Godward, The Signal, 1899 Getty Museum

What benefits from (semi-)taut mooring lines?



FLOATFARM

Shared anchor point (caisson#1)



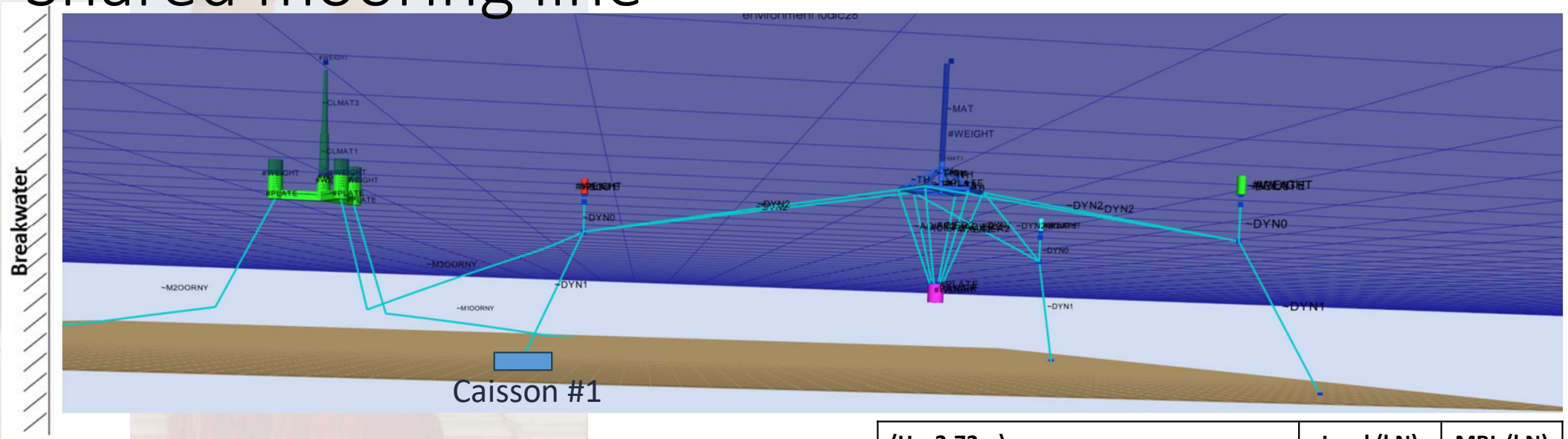
Remarks:

- Keep the same mooring system
- Need to check the feasibility in term of load for the anchoring point

John William Godward, The Signal, 1899 Getty Museum

FLOATFARM

Shared mooring line



Remarks:

- Keep the same mooring system + modification for the connection point on buoy element
- Need to check the feasibility in term of load for the anchoring point
- Installation procedure

-> 2 floating systems to install at the same time

(Hs=3.72m)	Load (kN)	MBL (kN)
Star1 - Line #all fairlead/buoy	29	39.7
Hexafloat – Line #all fairlead/buoy	7.1	12.6
Line between buoy/anchor	20.12	36.3
Line between Star1-Hexafloat-Buoy	16.8	33

John William Godward, The Signal, 1899 Getty Museum

Napoli, 25 Novembre 2025

Monitoraggio Meteo-Marino: disponibilità strumentale del laboratorio a mare

Attività A: Monitoraggio Meteo-Marino

1. Stazione meteo
2. Lidar
3. Radar
4. Boe ondametriche
5. ADCP
6. Telecamere

Attività B: Configurazione dinamica del campo prova

7. Installazione simultanea di più piattaforme galleggianti
8. Acquisto e installazione di una sottostazione marina
9. Installazione di una boa realizzata in materiale ecosostenibile che sarà strumentata

1.

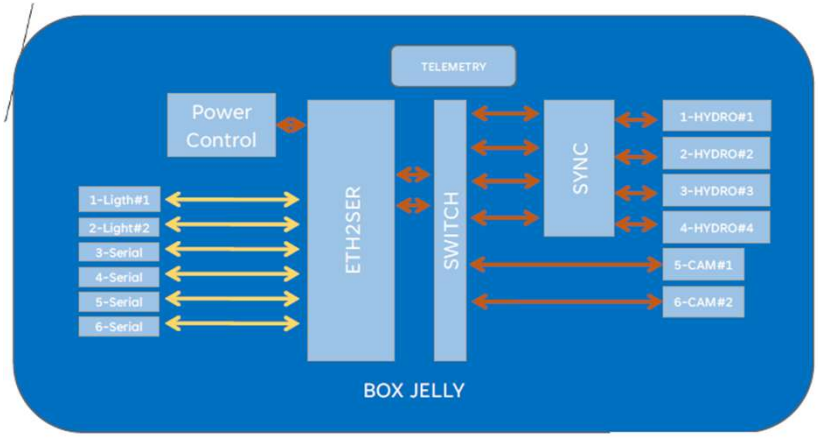
2.

3.

4.

5.

8.



John William Godward, The Signal, 1899 Getty Museum

E’ previsto un nuovo periodo di monitoraggio meteo-marino e della piattaforma Hexafloat presso il laboratorio a mare MaRELab. Un aspetto fondamentale di questa fase sarà l’installazione simultanea del prototipo insieme alla piattaforma Star1, sempre di Saipem, nell’ambito del Progetto Floatfarm, con una configurazione di anchor/mooring sharing.

- Caratterizzazione della scia a valle delle due FOWT
- L’indagine della scia sarà realizzata mediante l’impiego del Lidar
- Ad oggi, misurazioni di questo tipo, specialmente su queste scale, rivestono un’importanza scientifica significativa.

John William Godward, The S

Esperimento in vasca su piattaforma galleggiante costruita utilizzando materiale biorock

L'idea | I sistemi di Protezione Catodica a Correnti Impresse (ICCP) hanno come effetto collaterale la deposizione di carbonato di calcio/idrossido di magnesio. Operando opportunamente sul voltaggio e amperaggio, si può migliorare la qualità del minerale depositato sulle parti in acciaio del palo eolico flottante. Le formazioni carbonatiche consentono di realizzare un «bio-cemento» dalle elevate prestazioni meccaniche e dalla totale compatibilità ambientale (è lo stesso materiale dei gusci dei molluschi). In prospettiva, si potrà ridurre il quantitativo di acciaio, migliorando l'impronta di CO_2 ed i costi di produzione delle F-OWF.

- **Il prototipo in scala realizzato in LA 2.3-2.4 verrà testato presso il laboratorio vasca navale della Università di Napoli Federico II e sottoposto a spettri di mare e onde 'anomale' opportunamente progettate. A tal fine sarà necessario un revamping dell'ondogeno attualmente esistente. Verranno eseguite prove di diffrazione sulla sola struttura immersa al fine di misurarne i carichi idrodinamici.**

Università degli Studi della Campania *Luigi Vanvitelli*

Signal, 1899 Getty Museum

Università degli Studi di Napoli Federico II

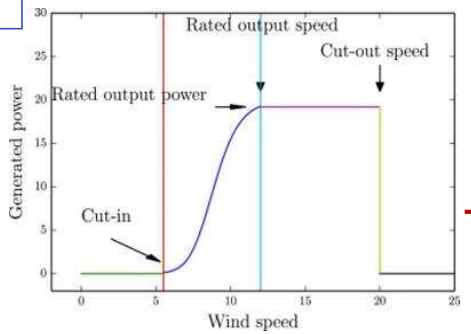
... and the Turbine?

- *Wind conditions at Med Sea require novel solutions for the blades and control system*

- *Bioinspired (from nature, e.g. PhD thesis Hui Li, 2023)*

John William Godward, The Signal, 1899 Getty Museum

$V_{wind} = V_{rated}$



What we need in the Med Sea
(typical mean wind speed 5-9 m/s)

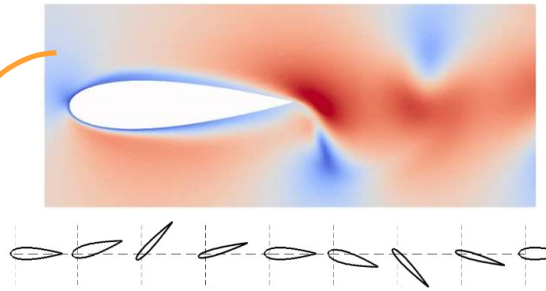
- lower V_{cut-in}
- lower V_{rated}
- higher $V_{cut-out}$ (North Sea)

Issues:
-Technology readiness
-Smart material (or Metamaterial) for active shape
- Energy consumption

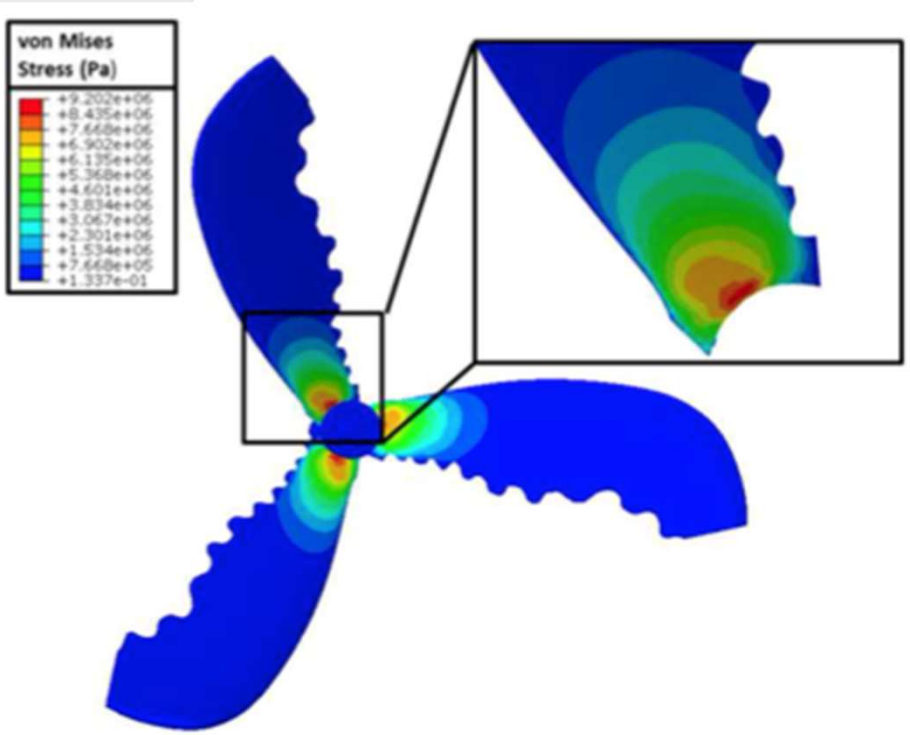
$V_{wind} > V_{cut-out}$

Novel blade's shape and turbines must be suitably designed for the Med Sea

Morphing-foil strategy
Hui-Li (PhD student, NTNU)

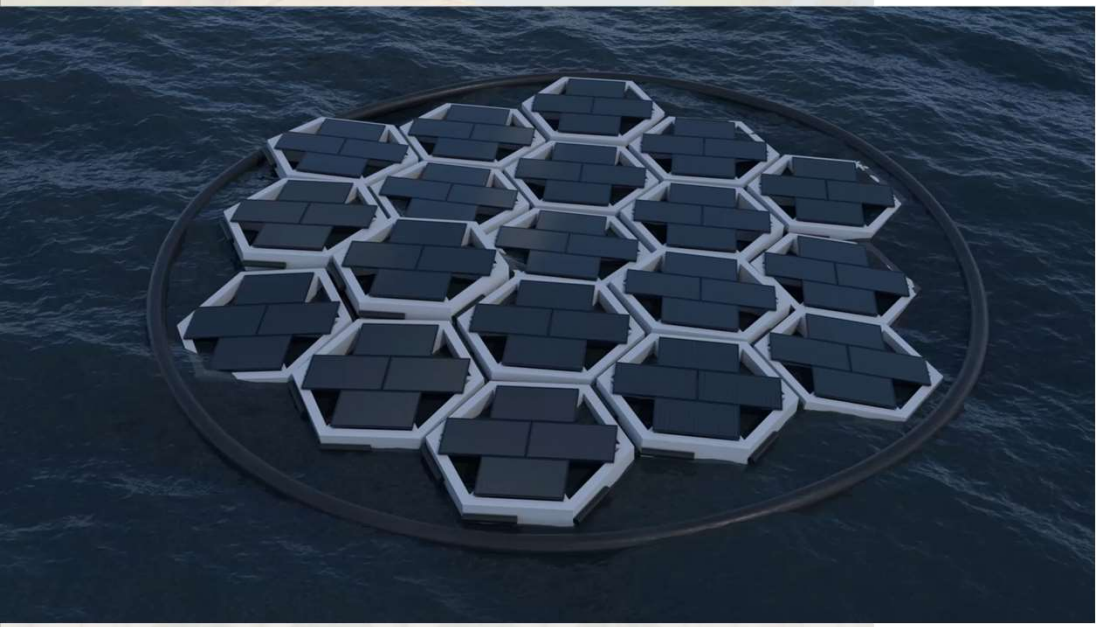


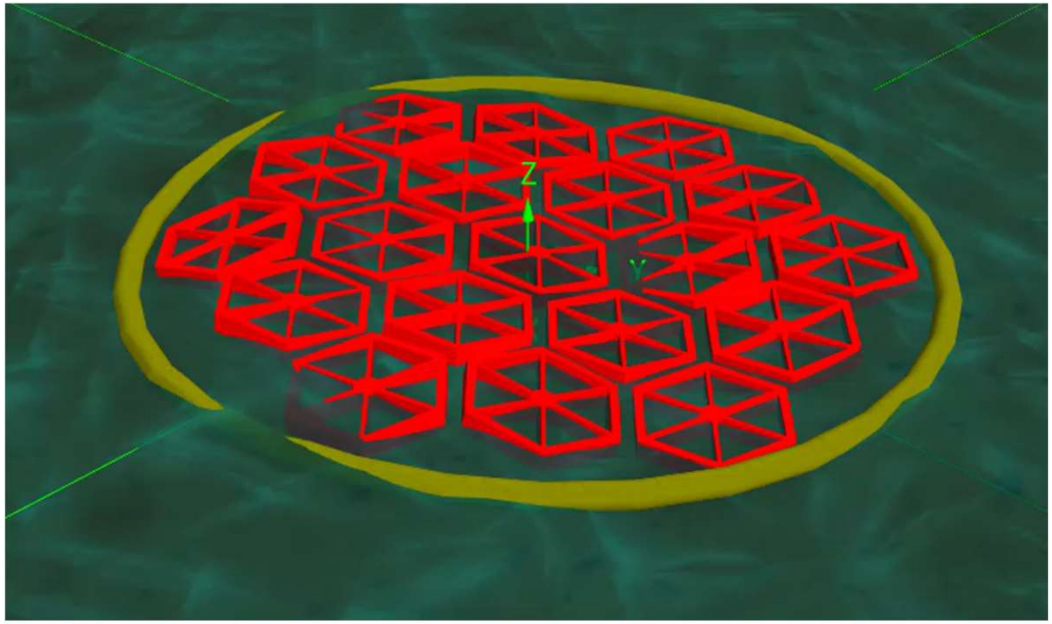
Challenge:
bio-inspired solutions for improving energy production



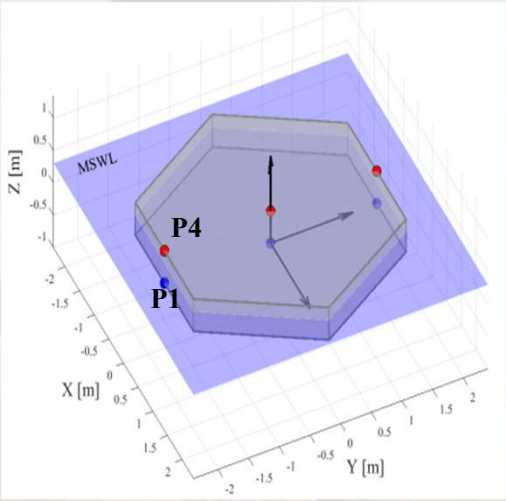
Efficiency increase: lower C_d & larger C_l

John William Godward, The Signal, 1899 Getty Museum

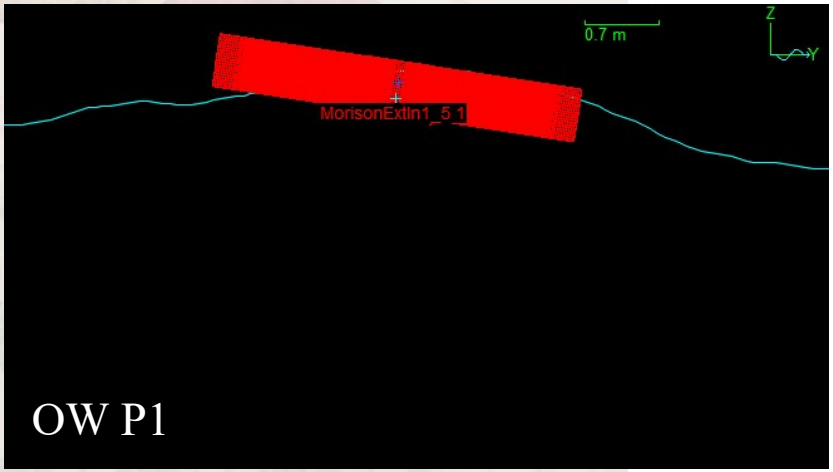


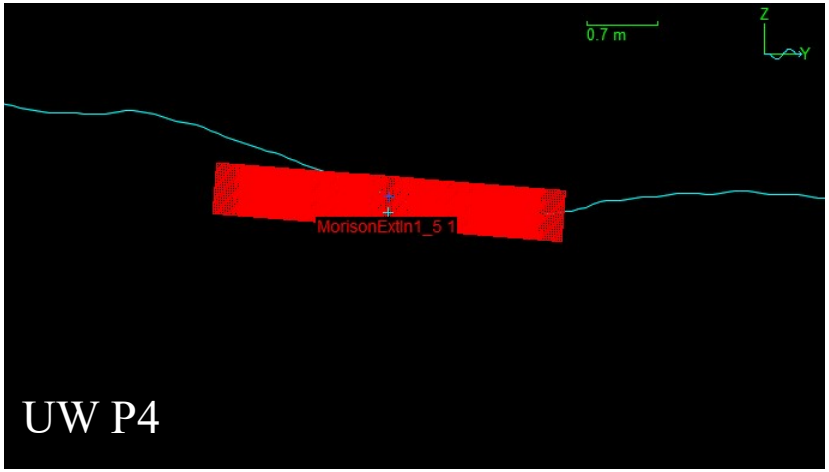

Z
Y

Esagono – Analisi locale nel Tempo



H_s	Model	Pot		Pot+Mor$_{Ext}$		Pot+Mor$_{Ext+Int}$	
	Point	OW P1	UW P4	OW P1	UW P4	OW P1	UW P4
0.75	Perc of time [%]	0.00	0.00	0.00	0.00	0.00	0.01
	Time [s]	0.00	0.09	0.00	0.38	0.00	1.11
1.50	Perc of time [%]	0.01	2.09	0.13	4.37	0.31	6.10
	Time [s]	0.94	226.01	13.53	471.66	33.85	658.82





John William Godward, The Signal, 1899 Getty Museum

MSc thesis Camilla Luvisetto 2025)

Challenge: bio-inspired solutions for green underwater and surface marine vehicles (for monitoring and maintenance)

John William Godward, The Signal, 1899 Getty Museum

Two Marine Drone Classes:

- **Bio-mimic Guardian drones:**

Challenge: *long-monitoring time, capability of real-time analysis, identification of critical scenarios that require worker drones. Drones for fish schooling.*

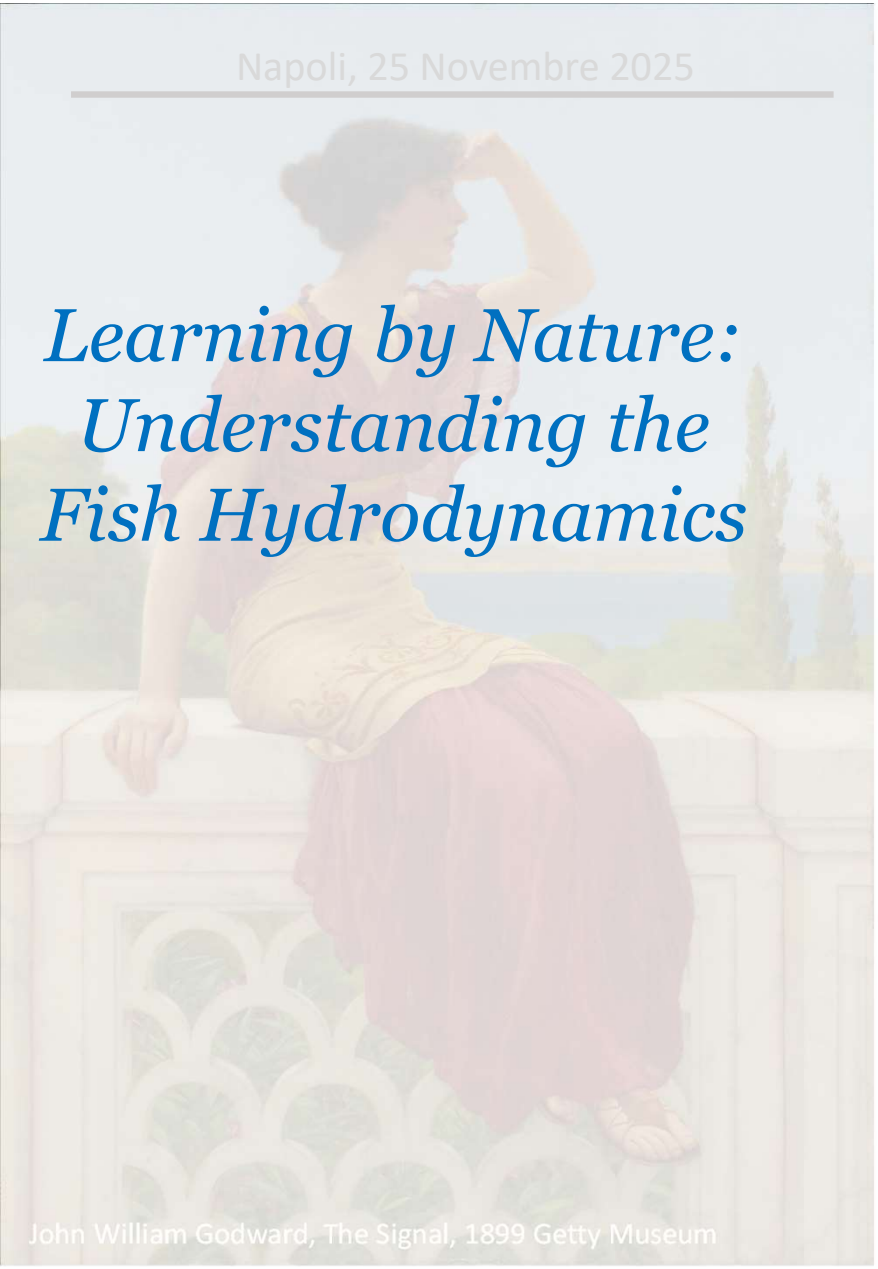
- **Worker Drones**

Challenge: *stability in waves, current and local turbulence. Equipped with robotic arms to work on site*

Fish Hydrodynamics

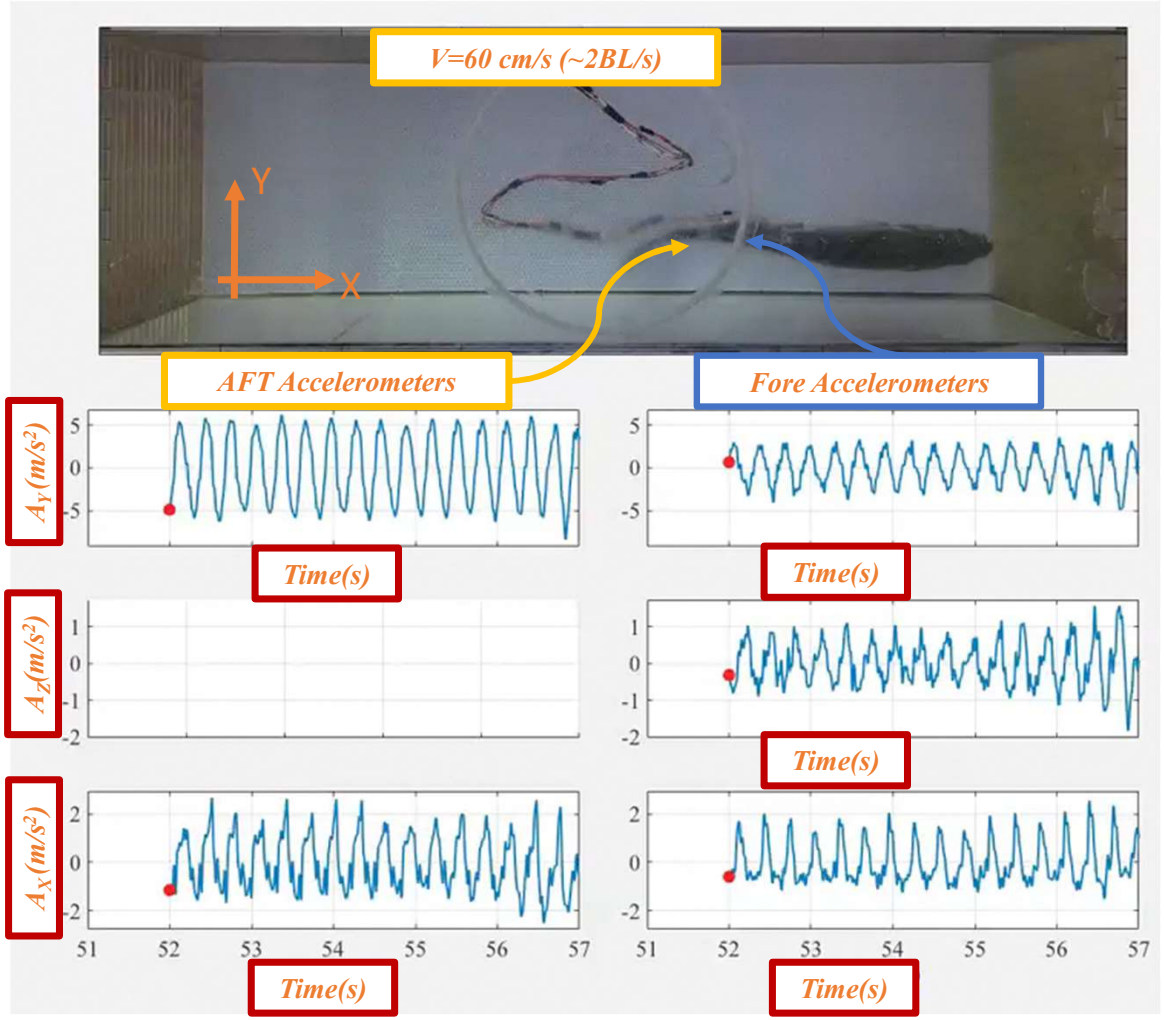
Lugni & Domenici (2017)

Learning by Nature: Understanding the Fish Hydrodynamics



John William Godward, The Signal, 1899 Getty Museum

(Lugni,Dominici, 2017)



Learning by Nature: Understanding the Fish Hydrodynamics

(Damiano Paniccia, PhD activity)

$$\frac{d}{dt}\left[\int_{\mathcal{B}} \rho_b \boldsymbol{u}_b \, dV + \int_{\mathcal{V}} \rho \boldsymbol{u} \, dV\right] = 0$$

2D Linear and angular momentum conservation

Fluid impulse

$$\int_{\mathcal{B}} \rho_b \boldsymbol{u}_b \, dV + \rho \boldsymbol{p} = 0$$

Total impulse

$$\boldsymbol{u} = \boldsymbol{\nabla}\phi_{sh} + \boldsymbol{\nabla}\phi_{loc} + \boldsymbol{\nabla} \times \boldsymbol{\psi} = \boldsymbol{u}_{sh} + \boldsymbol{u}_{loc} + \boldsymbol{u}_w$$

$$\phi = \phi_{sh} + \phi_{loc} = \phi_{sh} + V_1\phi_1 + V_2\phi_2 + \Omega\phi_\Omega$$

$$\boldsymbol{u} = \underline{\boldsymbol{R}}\, \boldsymbol{V}$$

inertia + added mass terms

$$\begin{cases} V_1\,(m_{11} - m_b) + V_2\, m_{12} + \Omega\, m_{13} = P_{sh1} + P_{v1} \\ V_1\, m_{21} + V_2\,(m_{22} - m_b) + \Omega\, m_{23} = P_{sh2} + P_{v2} \\ V_1\, m_{31} + V_2\, m_{32} + \Omega\,(m_{33} - J) = \Pi_{sh} + \Pi_v \end{cases}$$

Shape deformation impulse

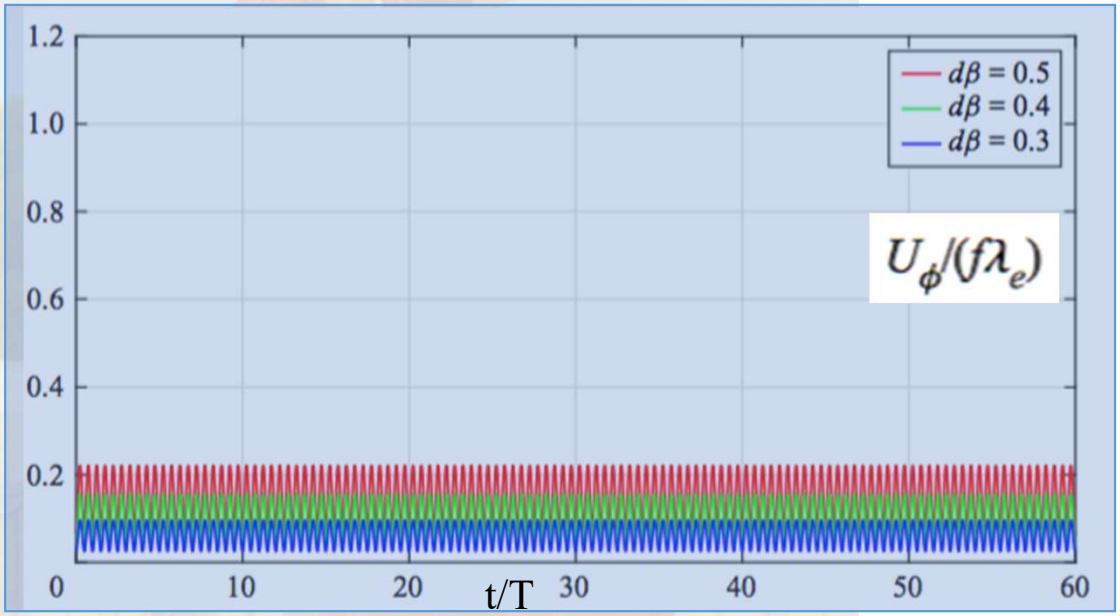
vortical impulse

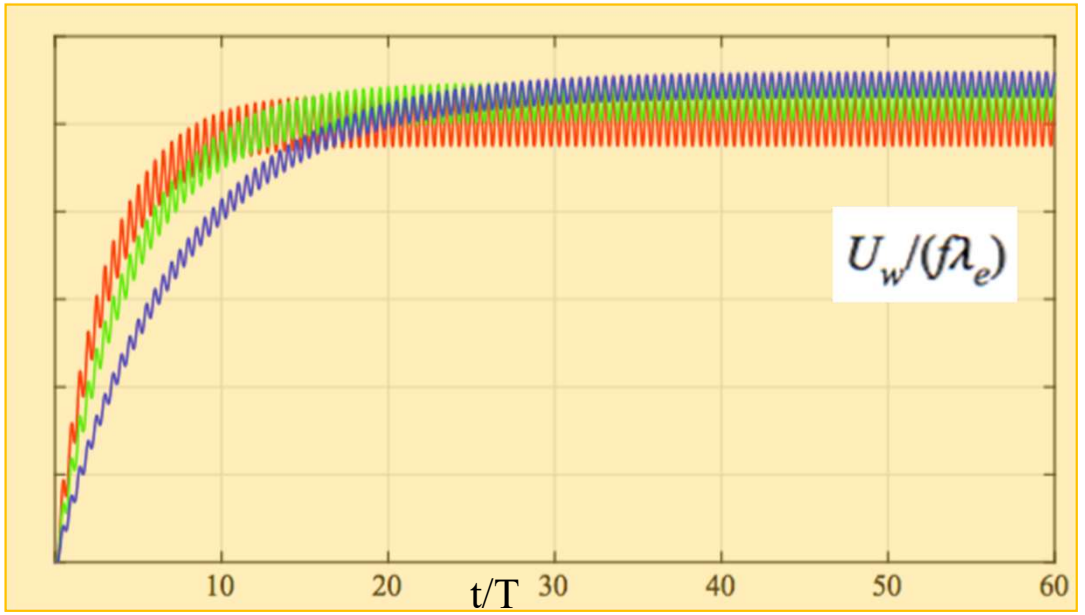
Paniccia, Graziani, Lugni, Piva, (JFM, 2021)

John William Godward, The Signal, 1899 Getty Museum

Learning by Nature: Understanding the Fish Hydrodynamics. What is the role of the added mass?

(Damiano Paniccia, PhD activity)



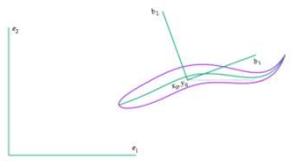


Paniccia, Graziani, Lugni, Piva, (JFM, 2021)

slip velocity = U/c

U = forward speed = $U_f + U_w$

c = phase speed = w/k = f l



the only Input!!!

$\beta(s,t) = d\beta \sin(ks - \omega t),$

P_{sh} P_{sh}

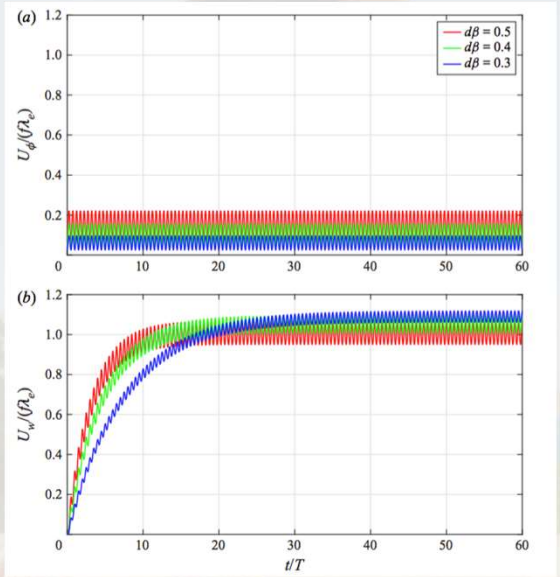
John William Godward, The Signal, 1899 Getty Museum

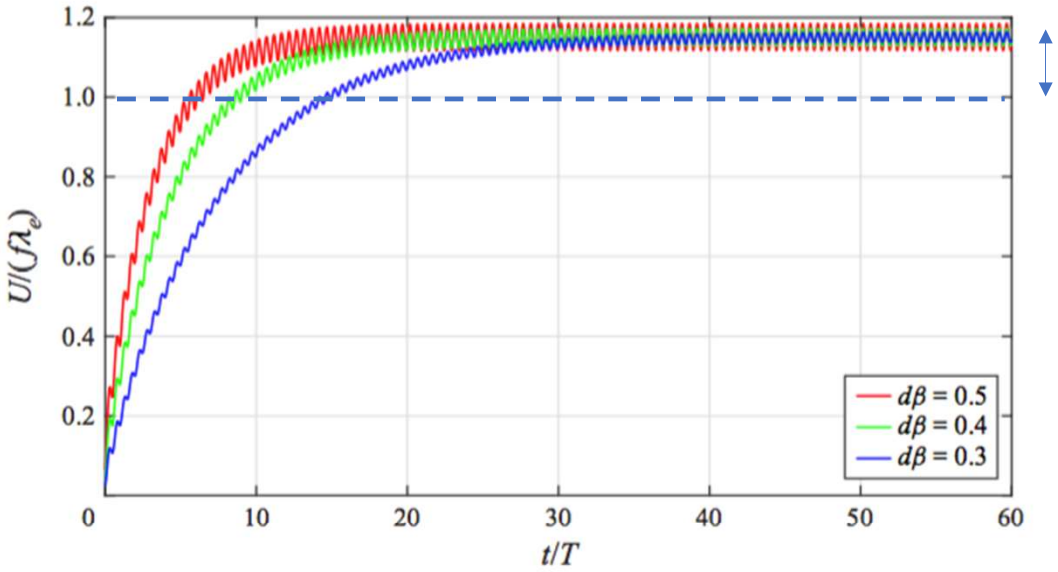
Learning by Nature: Understanding the Fish Hydrodynamics.

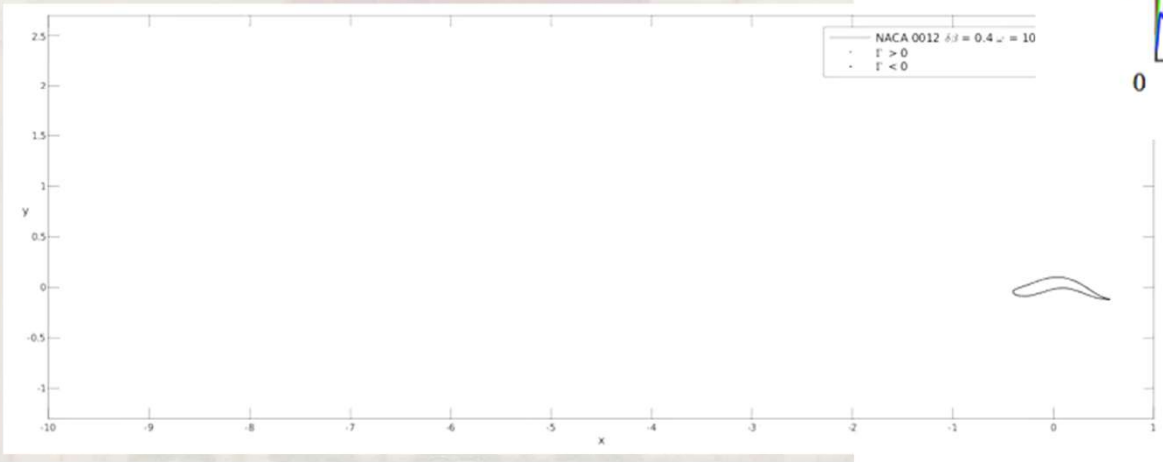
What is the role of the added mass?

(Damiano Paniccia, PhD activity)

recoil effect



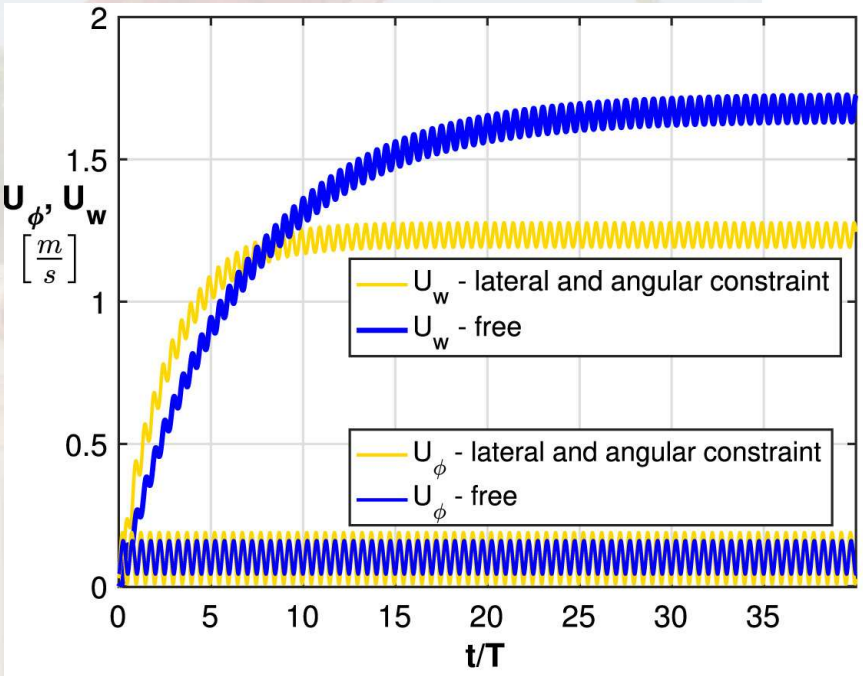


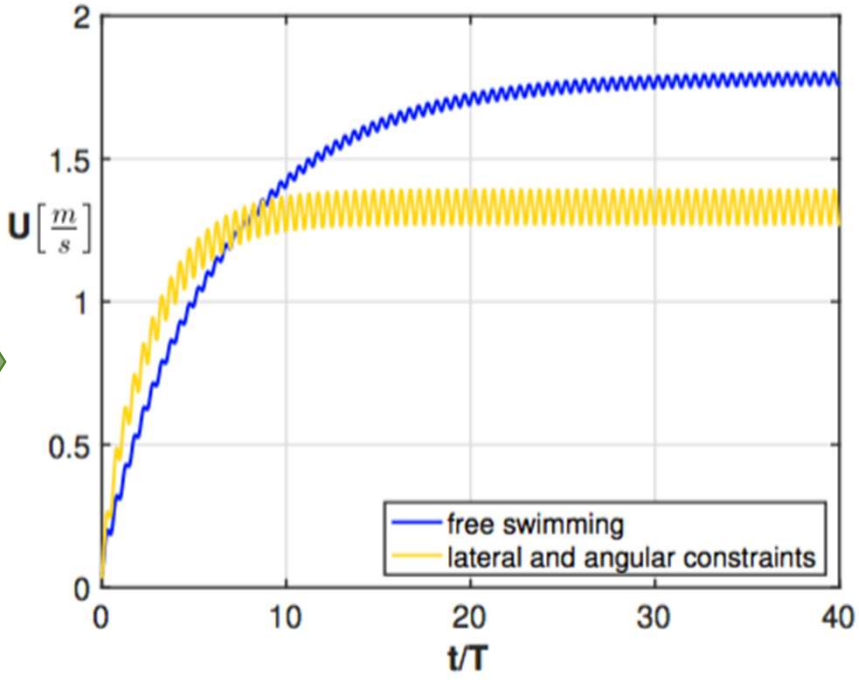


Paniccia, Graziani, Lugni, Piva, (JFM, 2021)

Learning by Nature: Understanding the Fish Hydrodynamics. What is the role of the Recoil?

(Damiano Paniccia, PhD activity)



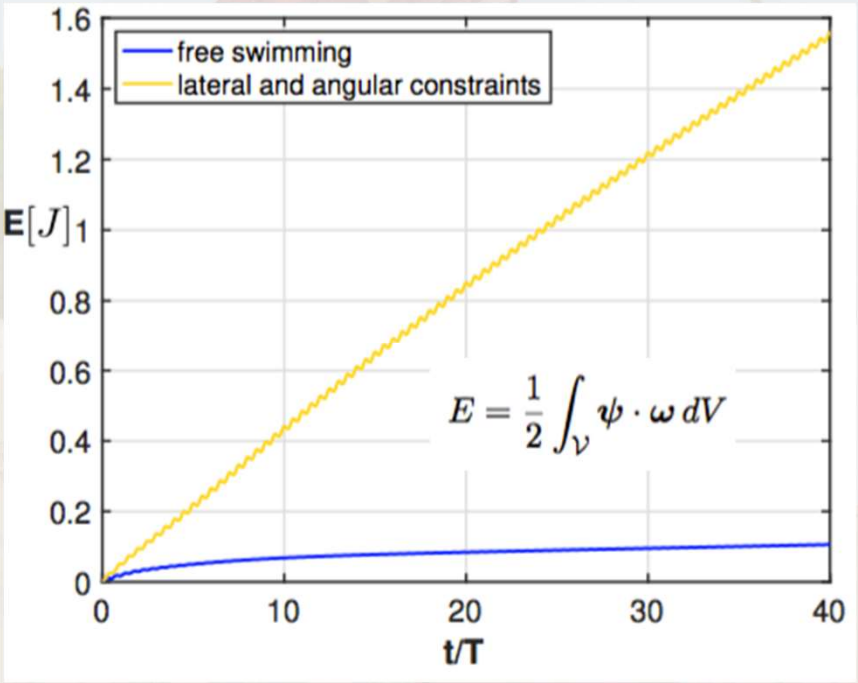


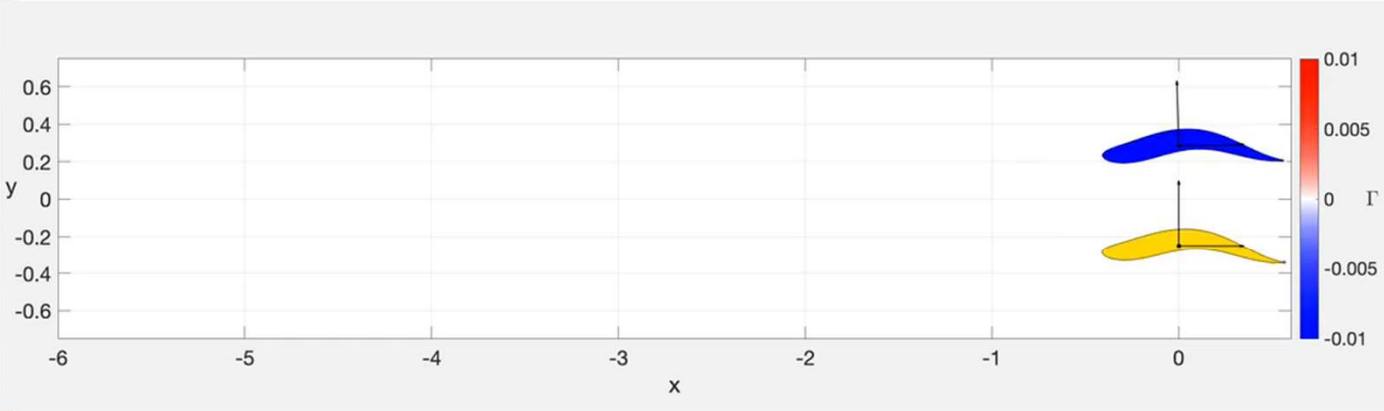
Paniccia, Graziani, Lugni, Piva, (JFS, 2021)

John William Godward, The Signal, 1899 Getty Museum

Learning by Nature: Understanding the Fish Hydrodynamics. What is the role of the Recoil?

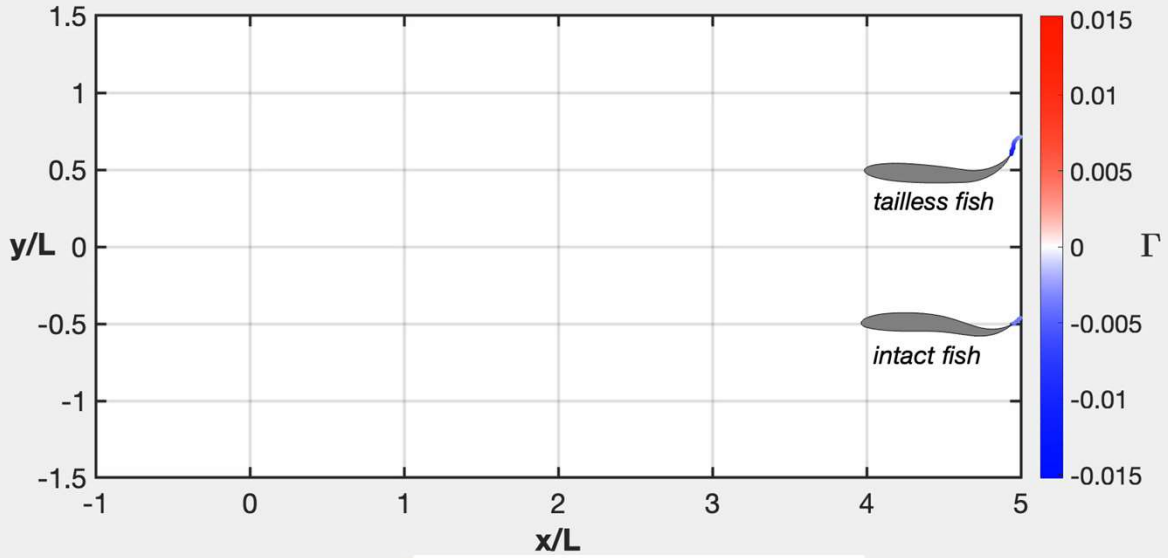
(Damiano Paniccia, PhD activity)

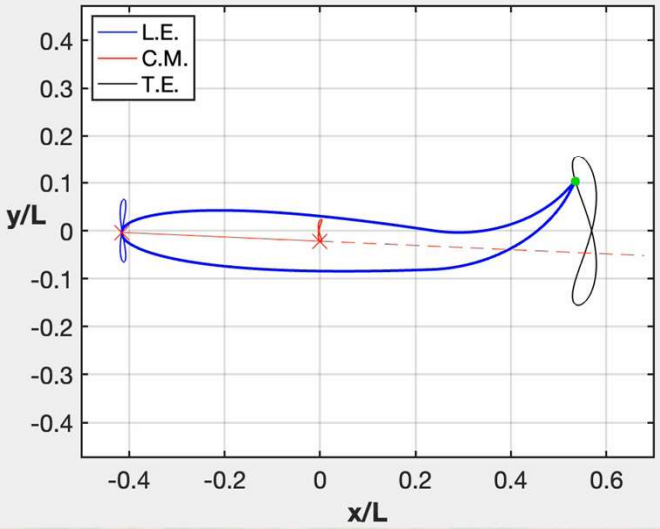


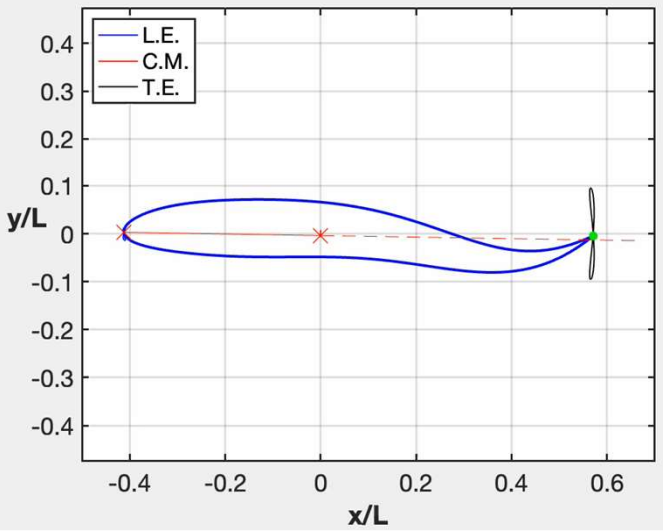


Paniccia, Graziani, Lugni, Piva, (JFS, 2021)

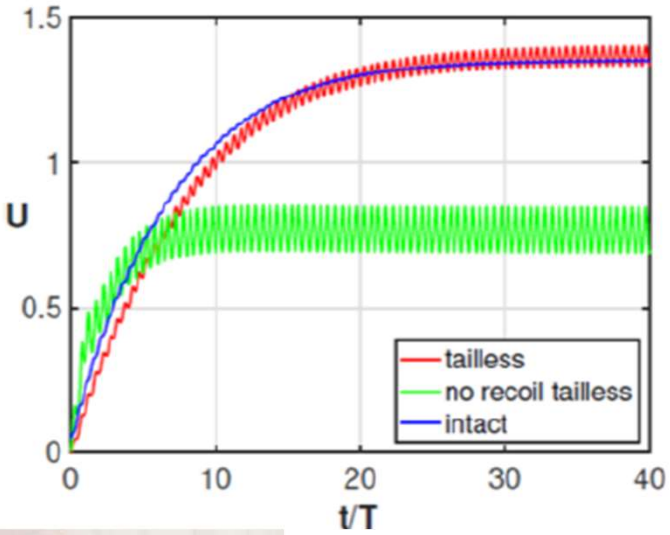
John William Godward, The Signal, 1899 Getty Museum

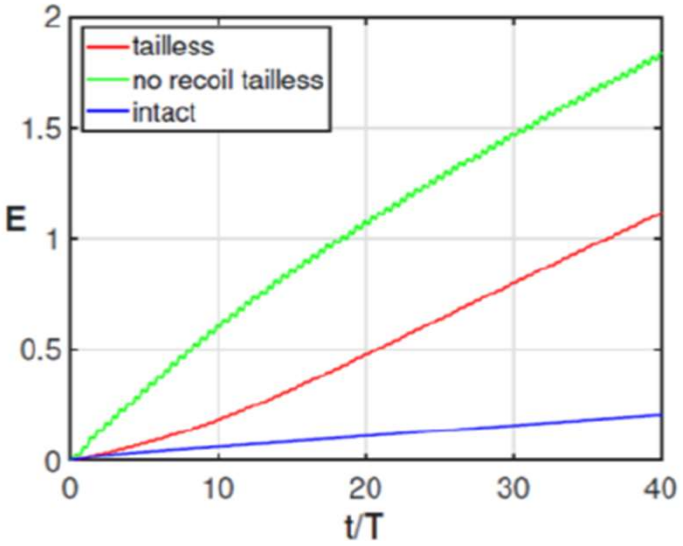

tailless fish
intact fish
y/L
x/L
Γ


L.E.
C.M.
T.E.
y/L
x/L


L.E.
C.M.
T.E.
y/L
x/L

- For the tailless fish, a lower locomotion velocity is reached for the constrained motion with respect to the free swimming mode.
- The energy consumption is significantly larger for both tailless fish motions with a larger value for the constrained gait.



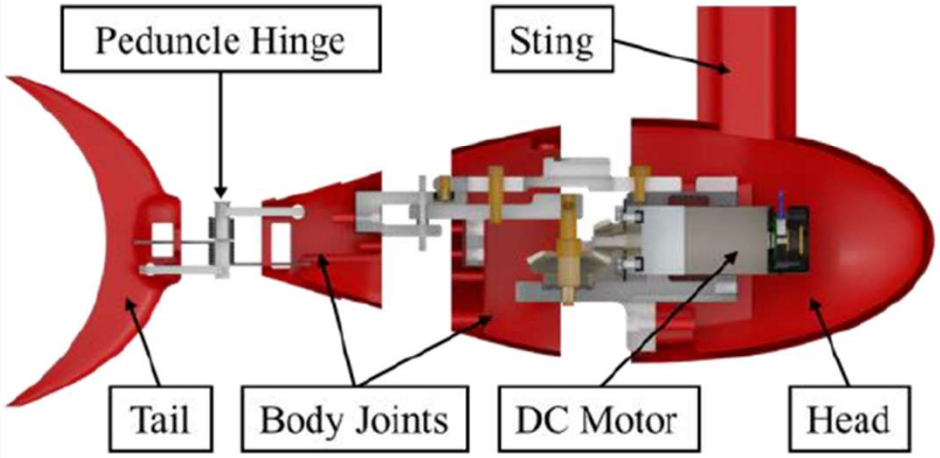


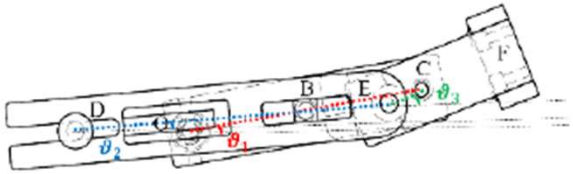
John William Godward, The Signal, 1899 Getty Museum

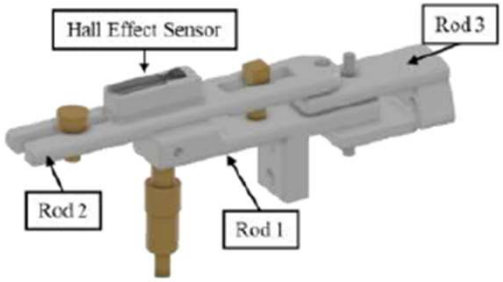
PhD Luca Padovani 2025

Kinematics
Red fish

- Mechanical coupling
- Parabola-like motion
- Inspired by Masoomi model







Input

$$\theta_1 = A\sin(2\pi ft)$$

$$\overline{DO} - \overline{DB}\cos\theta_2 = -\overline{OB}\cos\theta_1$$

$$\overline{DB}\sin\theta_2 = \overline{OB}\sin\theta_1$$

$$\overline{EC}\cos\theta_3 = \overline{DO} - \overline{DE}\cos\theta_2 + \overline{OC}\cos\theta_1$$

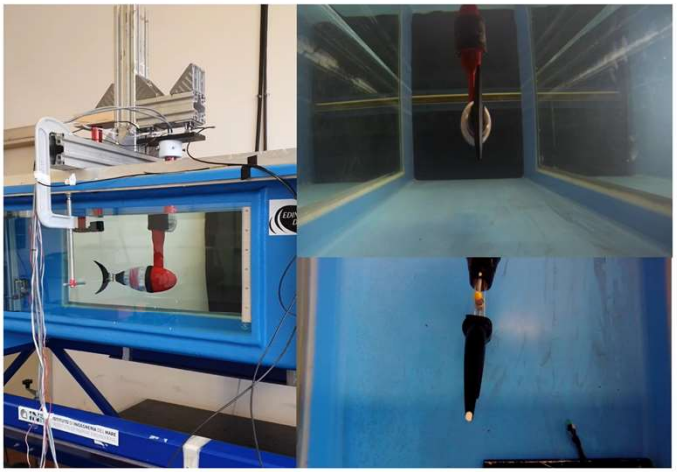
$$\overline{EC}\sin\theta_3 = -\overline{DE}\sin\theta_2 + \overline{OC}\sin\theta_1$$

Output

$$\theta_3 = \lambda\theta_1$$

John William Godward, The Signal, 1899 Getty Museum

PhD Luca Padovani 2025

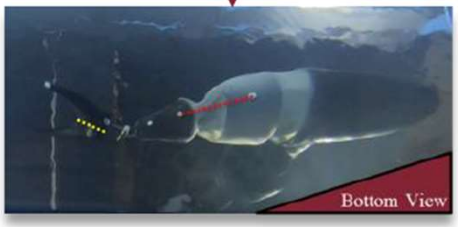


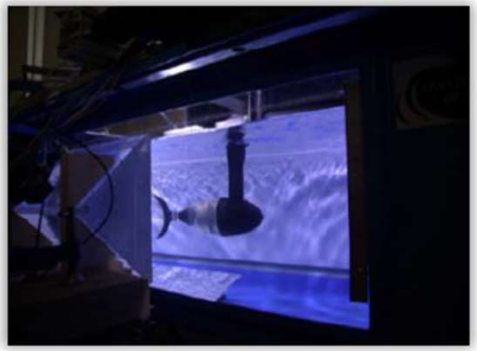
Water Channel Speed = 0

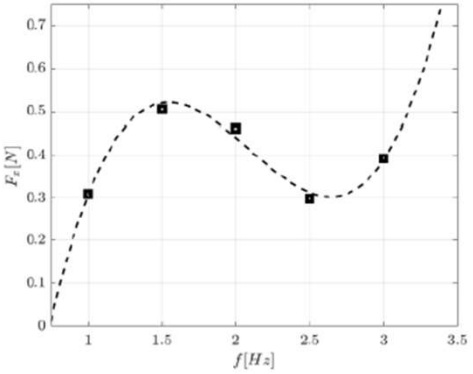
Oscillatory swimmers with passive tail with incoming flow

Resonant Effects: red fish experimental results (2)

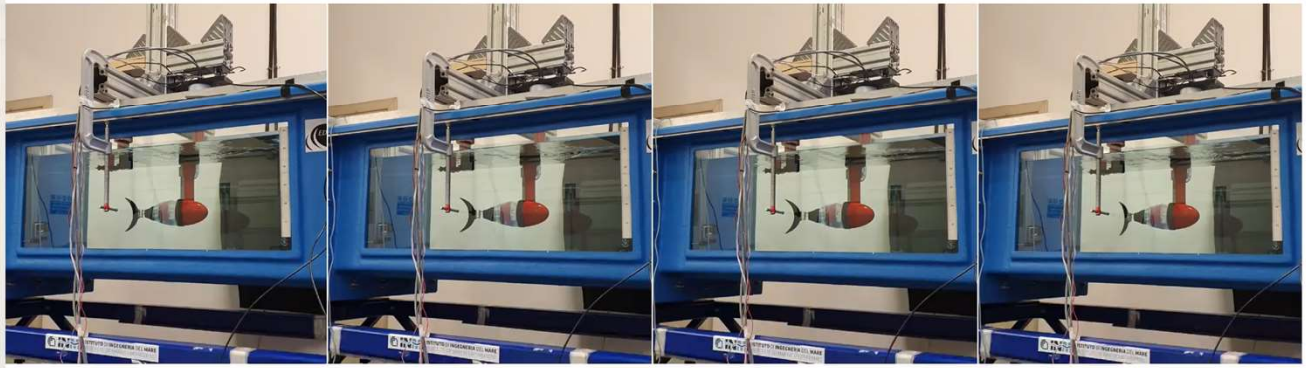
- With a given tail peduncle stiffness, measurement of axial force using load cells → maximum force at $f = 1.5\ Hz$ → Resonant effect
- We observe that force is maximized under resonance conditions, before continuing to increase monotonically with frequency
- Kinematic analysis







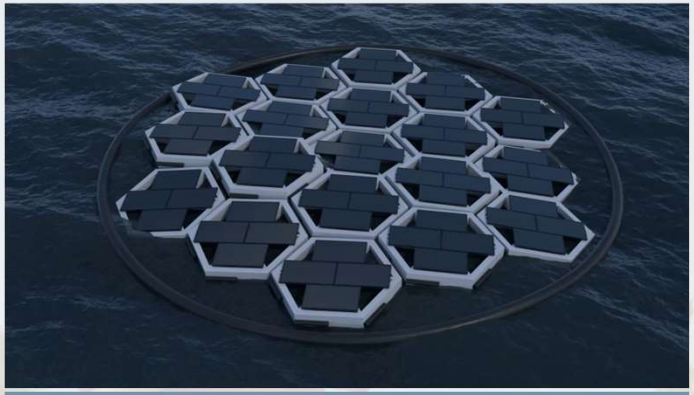
Increasing Tail Frequency

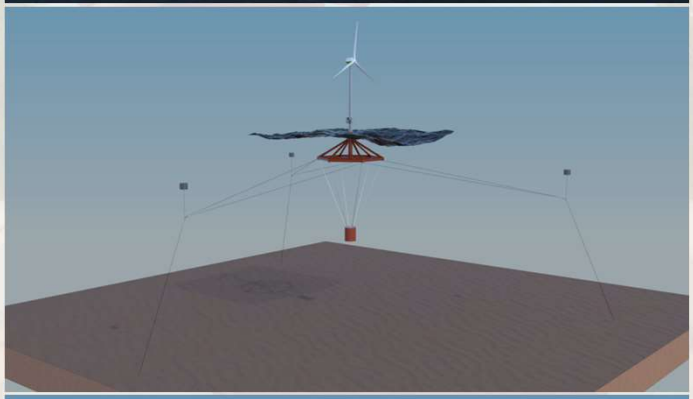


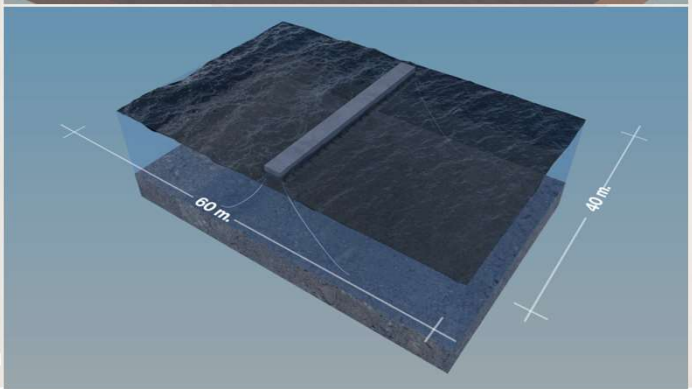
Water Channel Speed $\sim 1\ BL/s$

PhD Luca Padovani 2025

John William Godward, The Signal, 1899 Getty Museum



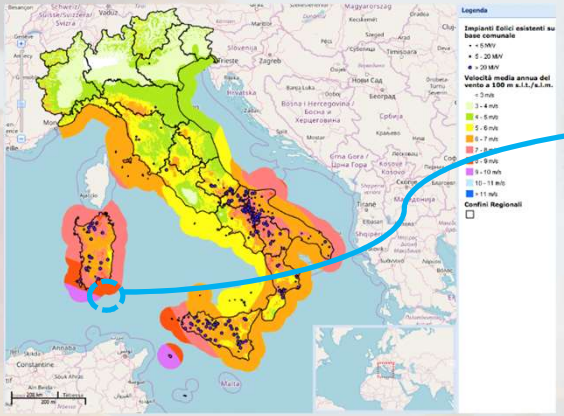




A novel Scenario for the future

Energy archipelago: an opportunity for the Med…

… and not only



Hypotheses for a possible scenario:

- Location: South Sardinia
- Protected Sea area: 16 km^2 (4 km x 4 km)
- Sea depth: ~100 m
- PV islands: 4 km^2 x (filling factor 0.2) = 0.8 km^2

  (500 islands, each 40m x 40m)

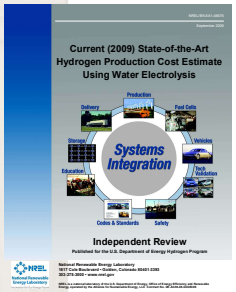
- Aquaculture: 4 km^2
- Rest of the area: Storage + electrolyzers + services
- nr. 12 FOWT 10MW

Annual Power Solar FPV = 140 GWh

Annual Power FOWT = 360 GWh

50 kWh/kg H_2

10000 ton of H_2



ZEUS
Zero Emission Ultimate Ship

L_{BP} = 25 m
Displ = 170 tons
tank = 50 kg H_2

8 hours at 7.5 knots => 60 nmi

12 Million of Nautical miles (nmi)

550 times the world tour (each 21600 nmi)

1 kg of H_2 produces 3 times the usable energy of 1 kg of natural gas

…however

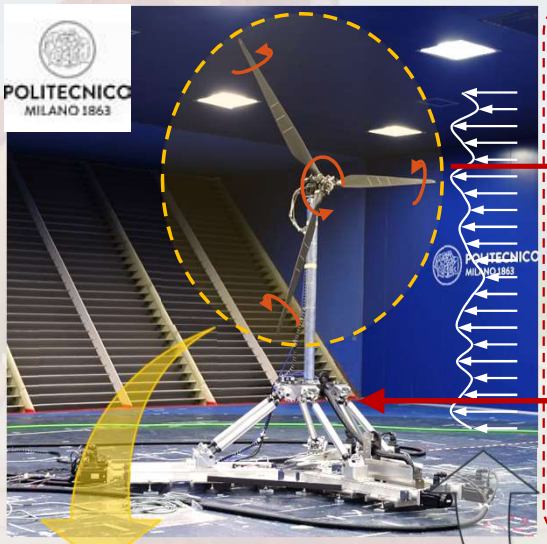
compressed hydrogen at 700 bar has 15% energy denstiy of the diesel, i.e. larger tanks (7 times larger) are needed

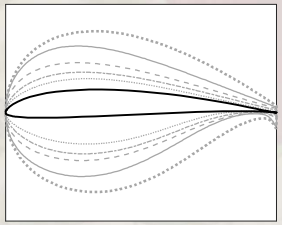
ammonia as hydrogen carrier, which requires additional enegy and equipment for the conversion to hydrogen

John William Godward, The Signal, 1899 Getty Museum

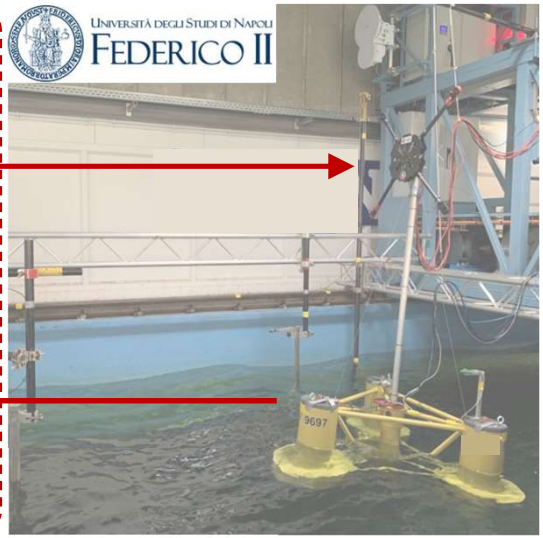
Sperimentazione Ibrida per lo Studio delle Turbine Eoliche Galleggianti

Galleria del vento





Vasca navale



Forze aero

Movimenti piattaforma

Obiettivo: Sviluppo di un metodo sperimentale innovativo per analizzare la risposta di una turbina eolica galleggiante

Approccio ibrido: Esperimenti simultanei in galleria del vento e vasca navale con misure in tempo reale

Risultati attesi:

- Nuovo metodo di scalatura aerodinamica del rotore
- Identificazione di un sistema robotico di movimentazione
- Valutazione delle incertezze nella misura delle forze aerodinamiche

John William Godward, The Signal, 1899 Getty Museum