Floating Wind *Solutions*

A systems engineering vision for floating offshore wind cost optimization

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NREL Transforming ENERGY

Organized by QFWE Quest Offshore

FWS

Acknowledgements

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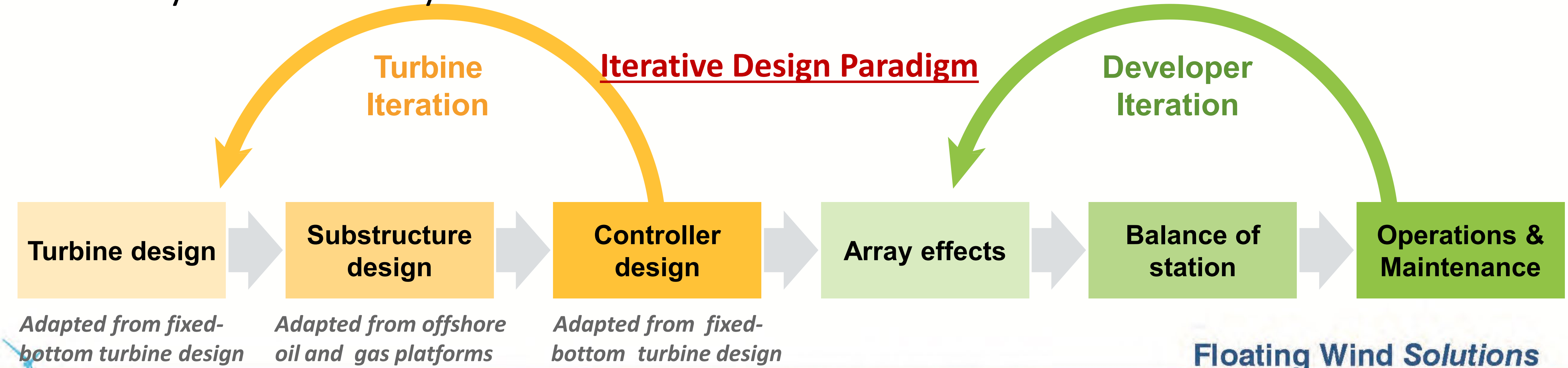
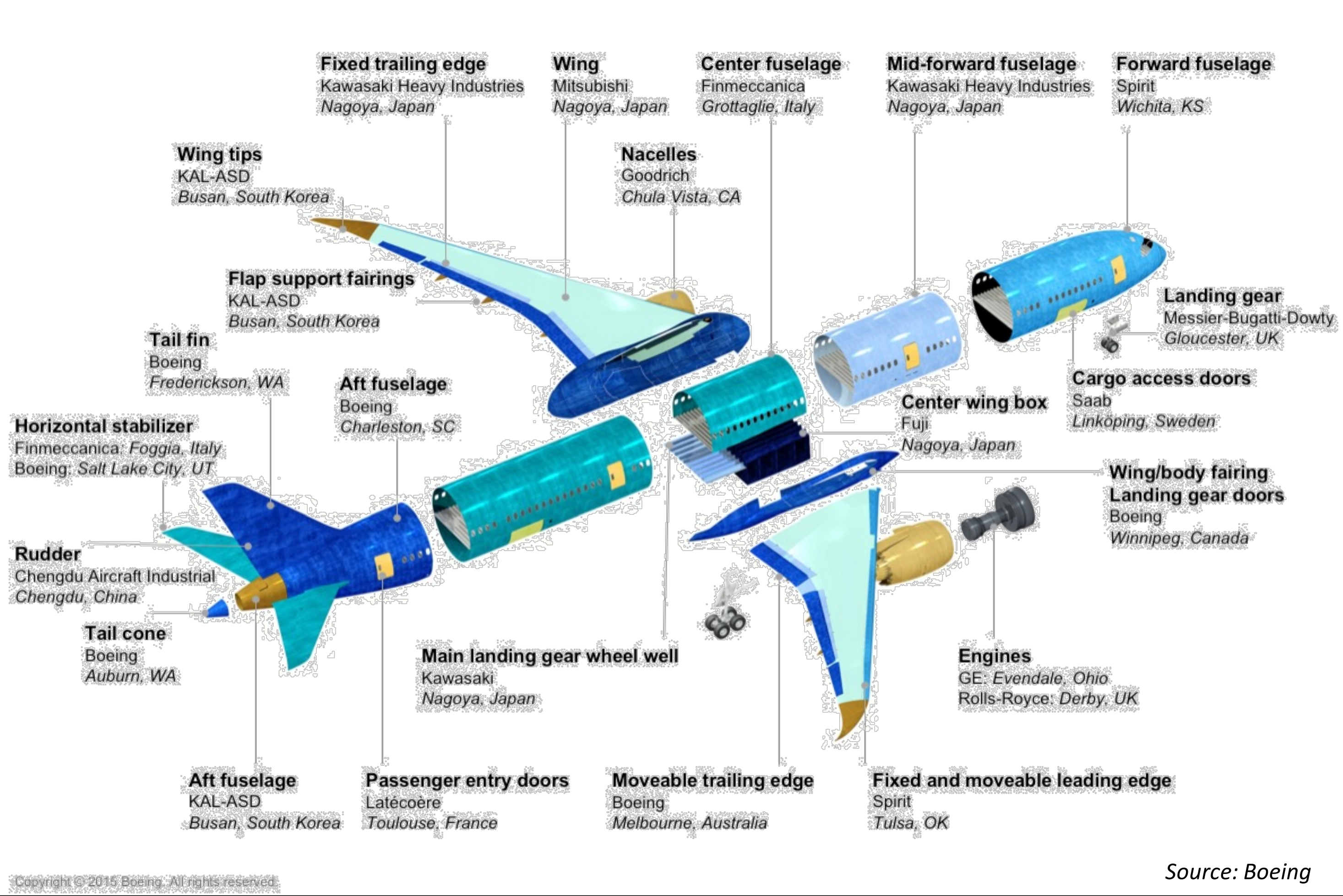
Current offshore turbine design is more “Iterative” than “Integrated” because of market realities

- Iterative design approach is a byproduct of industry expertise, power purchase agreements, and financing agreements
  - Companies need to leverage their expertise and protect their intellectual property
- Growth of wind industry over the past 20 years is a testament to the success of the “Iterative” approach
- Floating wind turbines can be designed in this paradigm, but they will be more costly than necessary.



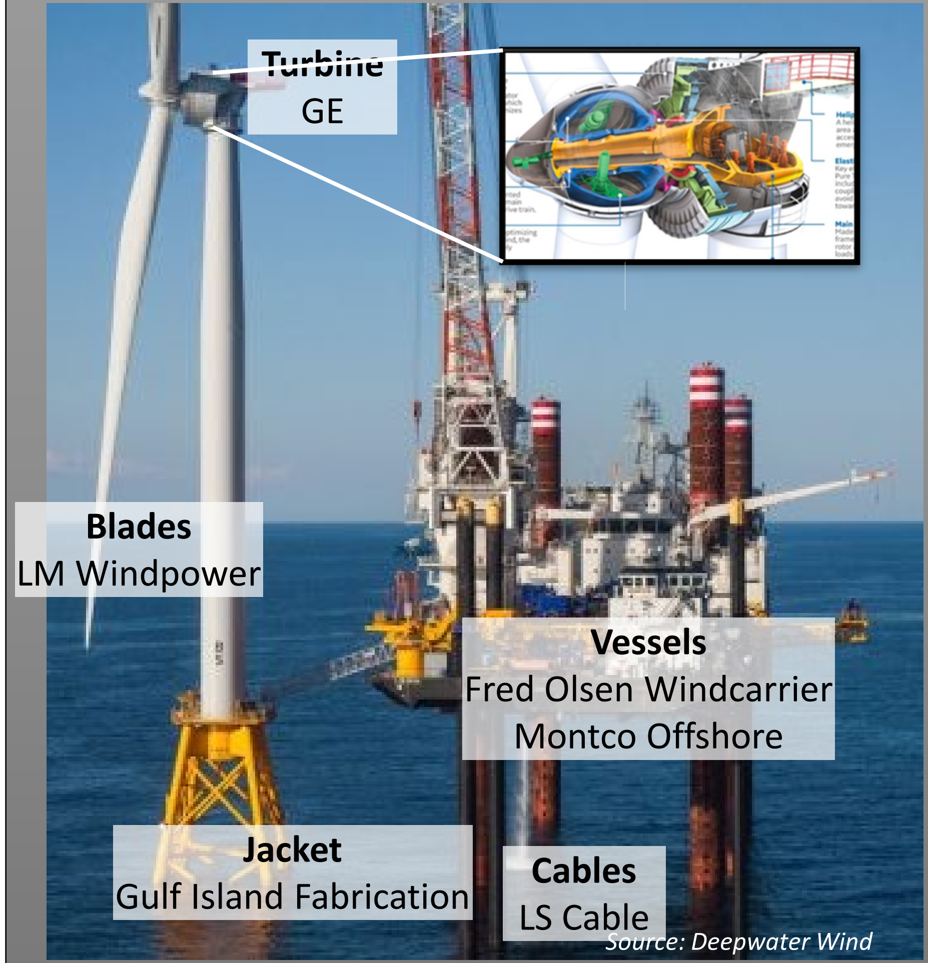
Both aircraft and wind turbines use a global supply chain, but aerospace prime contractors own whole system

Prime Contractor System Design and Integration: Boeing



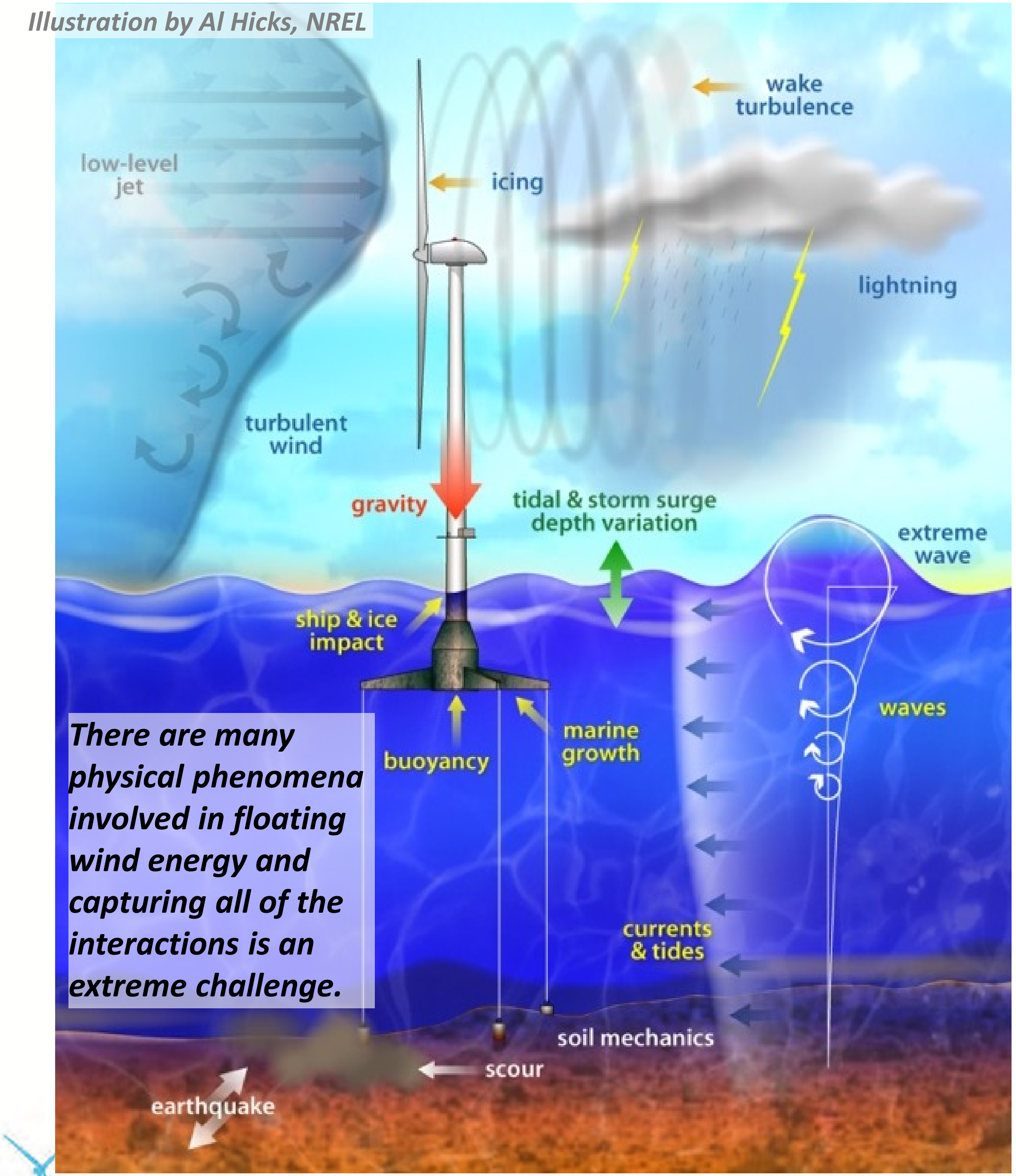
Source: Boeing

System Integration: Block Island Wind Farm



Source: Deepwater Wind

Some Degree of Vertical Integration May Aid Optimization Process

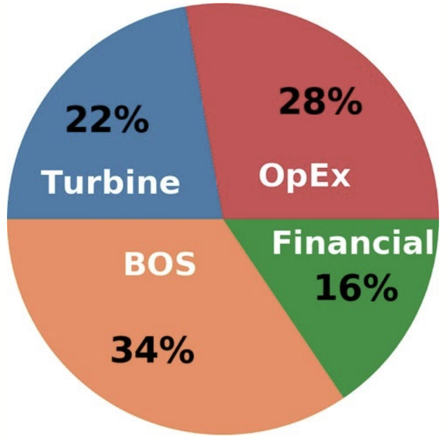


Physical and economic complexities make the floating challenge well-suited to system-focused solutions

Floating Wind LCOE Breakdown

Source: Mone et al. (2017)

78% of LCOE does not come from the turbine (but is impacted by its design)
**BOS: balance of station*



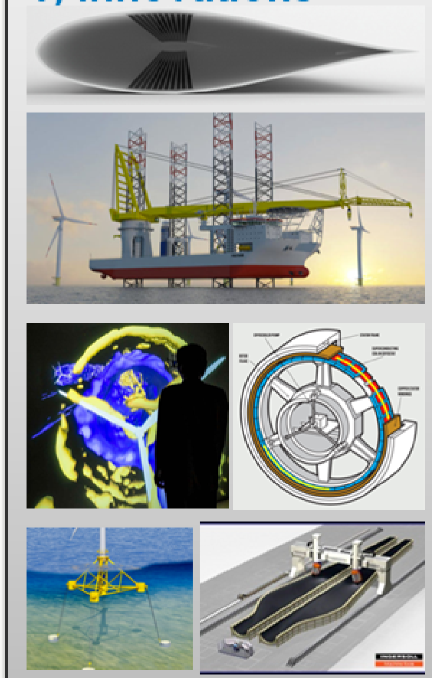
Given the complexity of:

- **Physics** – aerodynamic and hydrodynamic loading on a compliant structure
- **Logistics** – manufacturing, operational expenditures (OpEx), installation, and assembly
- **Economics** – over 50 types of costs are impacted.

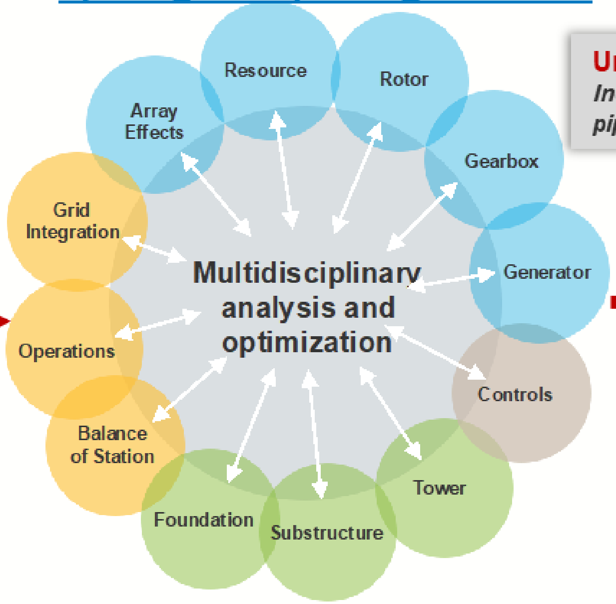
A multidisciplinary, systems-focused approach is needed!

MDAO looks for new pathways toward LCOE reduction by leveraging system interactions and coupling

1) Innovations

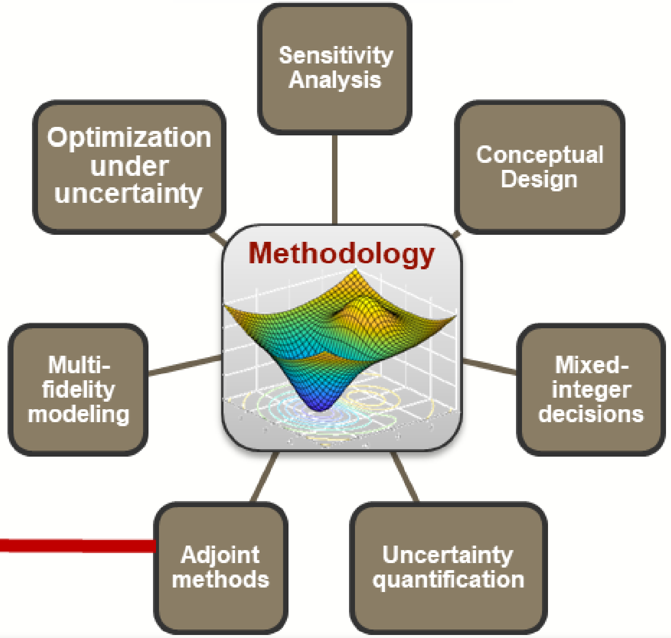


2) Integrated paradigm: MDAO



Uniqueness
Industry can be too stove-piped for an MDAO approach

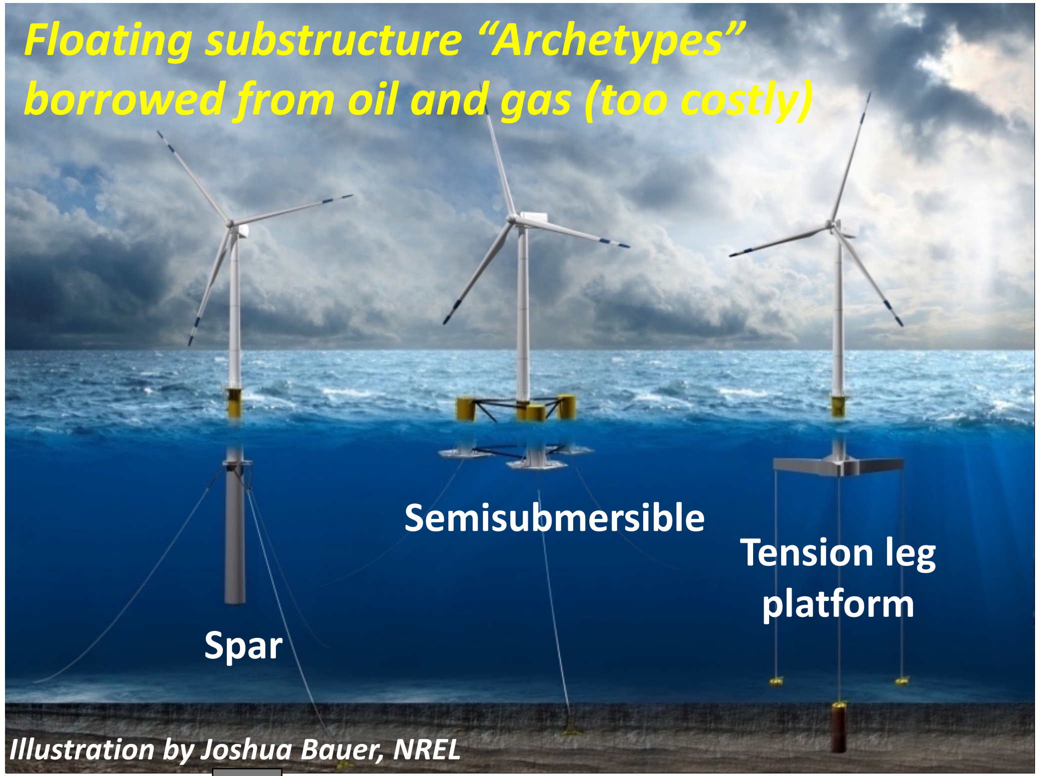
3) Methodology



4) Cost-benefit tradeoffs

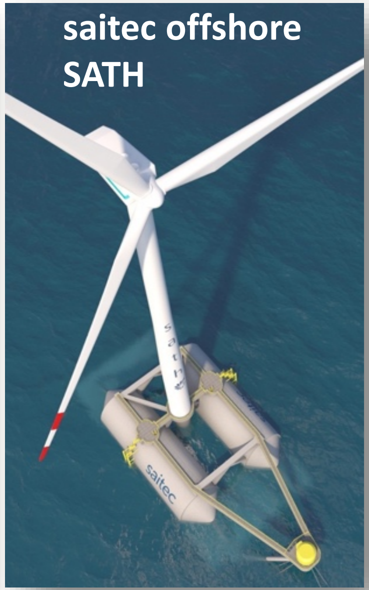
Research
Combine wind industry knowledge, aerospace best practices, and NREL innovations

For floating offshore turbines, there is a wild world of possibilities to explore

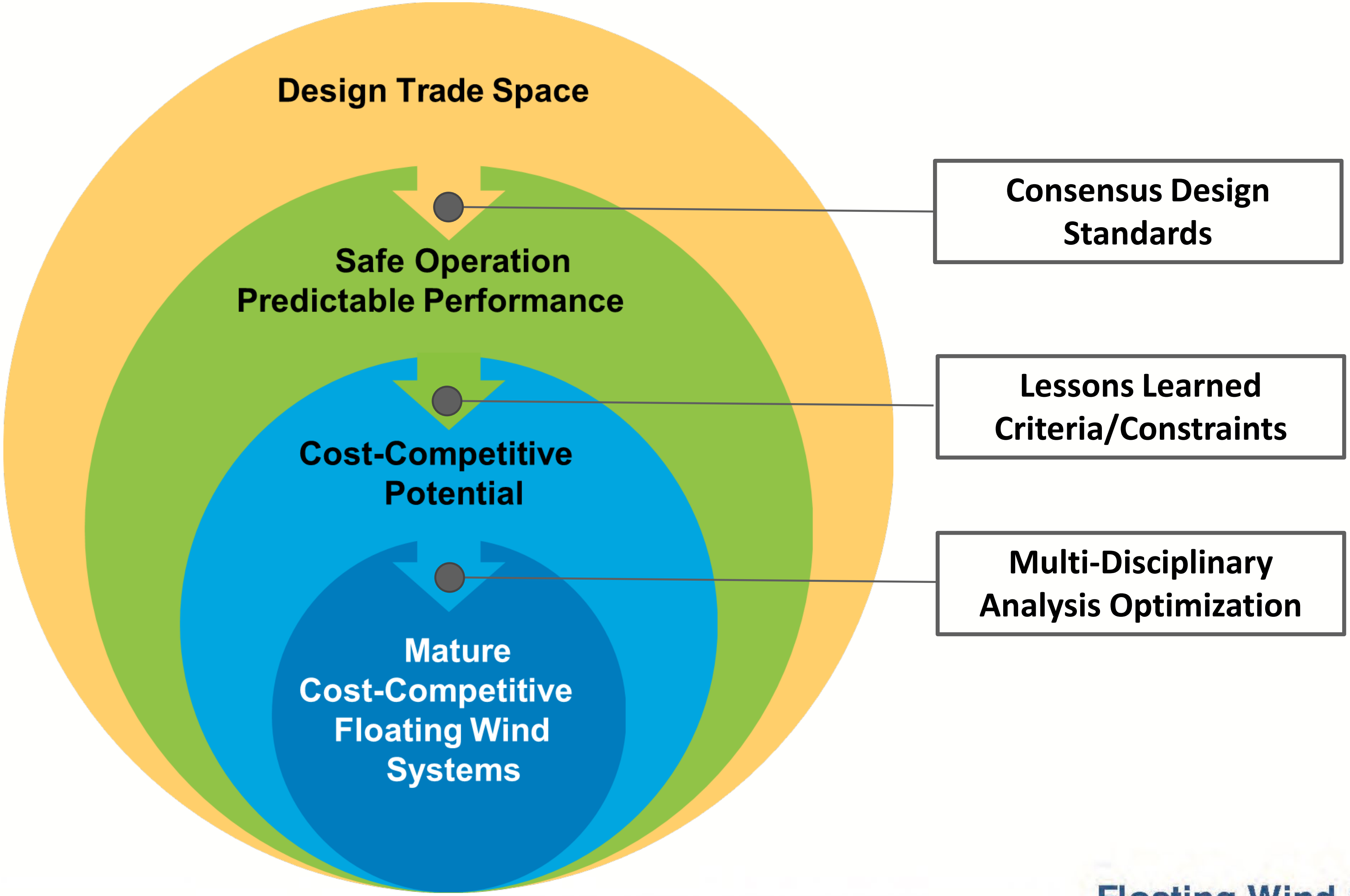


Integrated Design paradigm to find new solutions that minimize lifetime costs

(only some will be successful)



Floating Wind Cost Optimization Framework



Narrow the tradespace using lessons learned from experience

- Minimize motion
- Low center of gravity
- Industrialization
- Scalability
- Manufacturability
- Site Independence
- Deployability
- Maintainability
- Corrosion Control
- Decommissioning

Taking assembly into account in the design

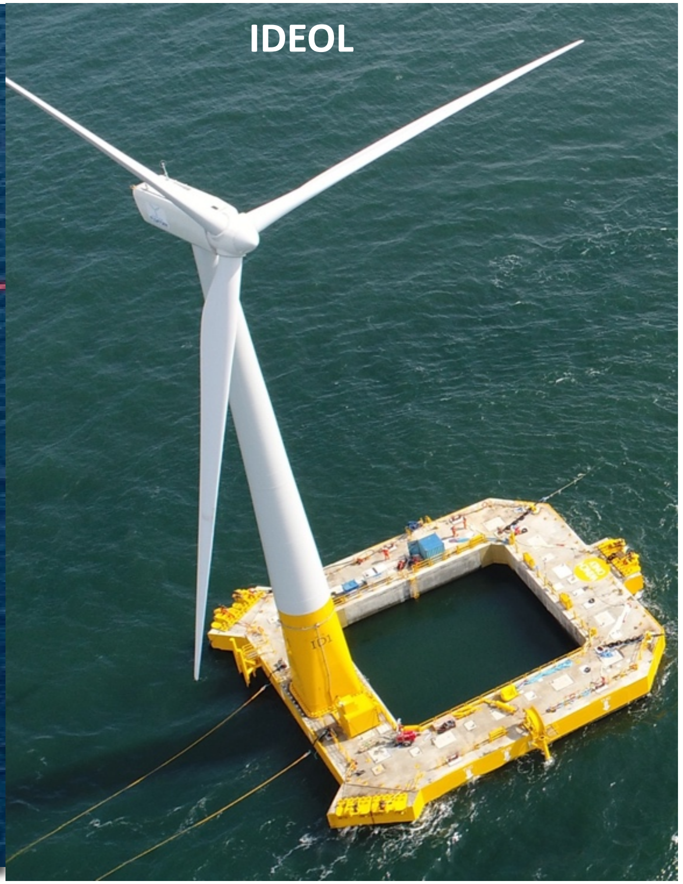
Source: GICON

Small draft allows for:

- **Wide port availability**
- **Quayside assembly that minimizes costly specialized vessel and labor hours at sea**
- **Usage of land-based crawler cranes (cheapest option).**

Off-center turbine alleviates crane boom and loading requirements

Principle Power Inc WindFloat



IDEOL

Taking transport and installation into account in the design

Turbine and Platform

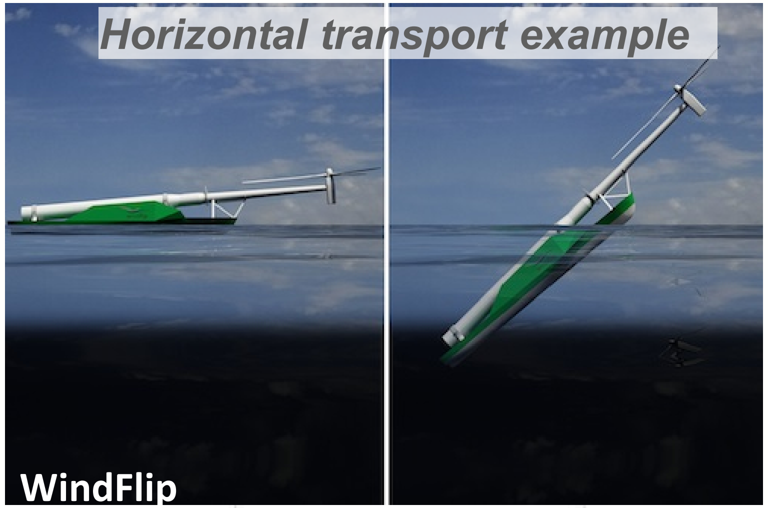
- Towable designs eliminate need for customized vessels
- Horizontal transport of turbines would open up new solutions

Mooring and Anchors

- Gravity anchors simplify anchor installation and mooring line connection
- Built-in winches simplifies installation and may eliminate specialized vessels

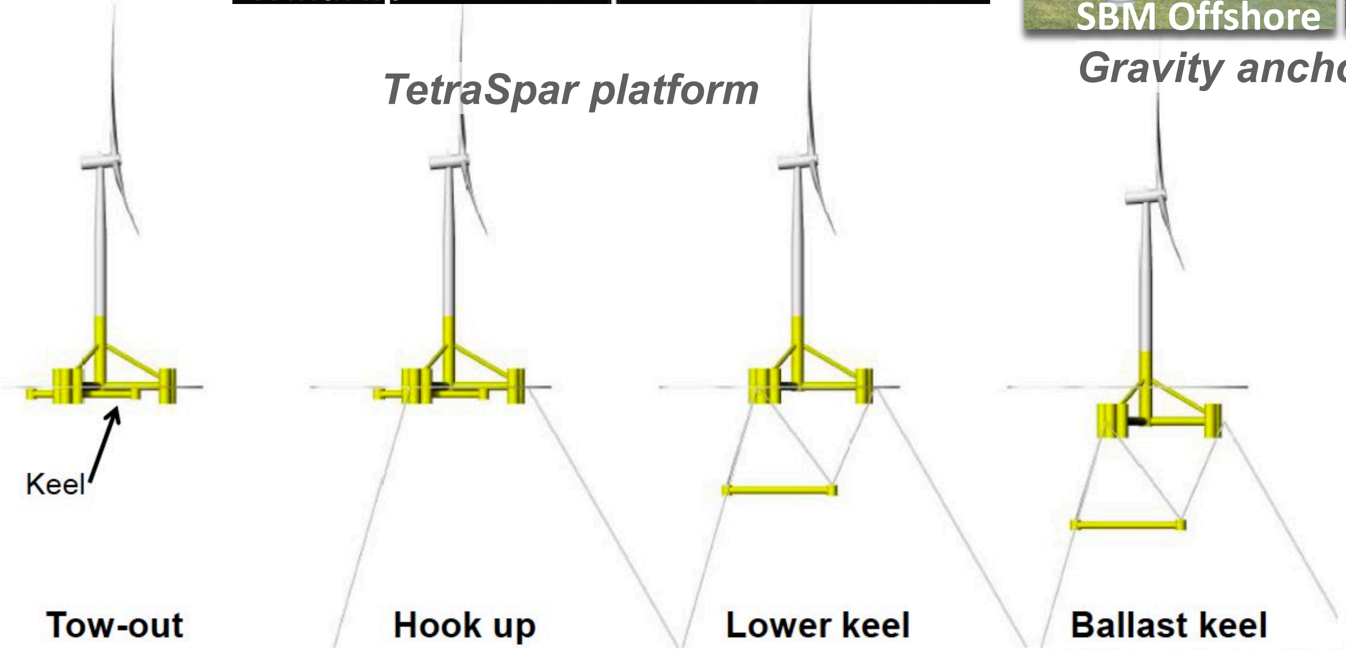
Hybrid Designs

- Allow for easier installation by changing configuration between tow-out and installed



Gravity anchors example

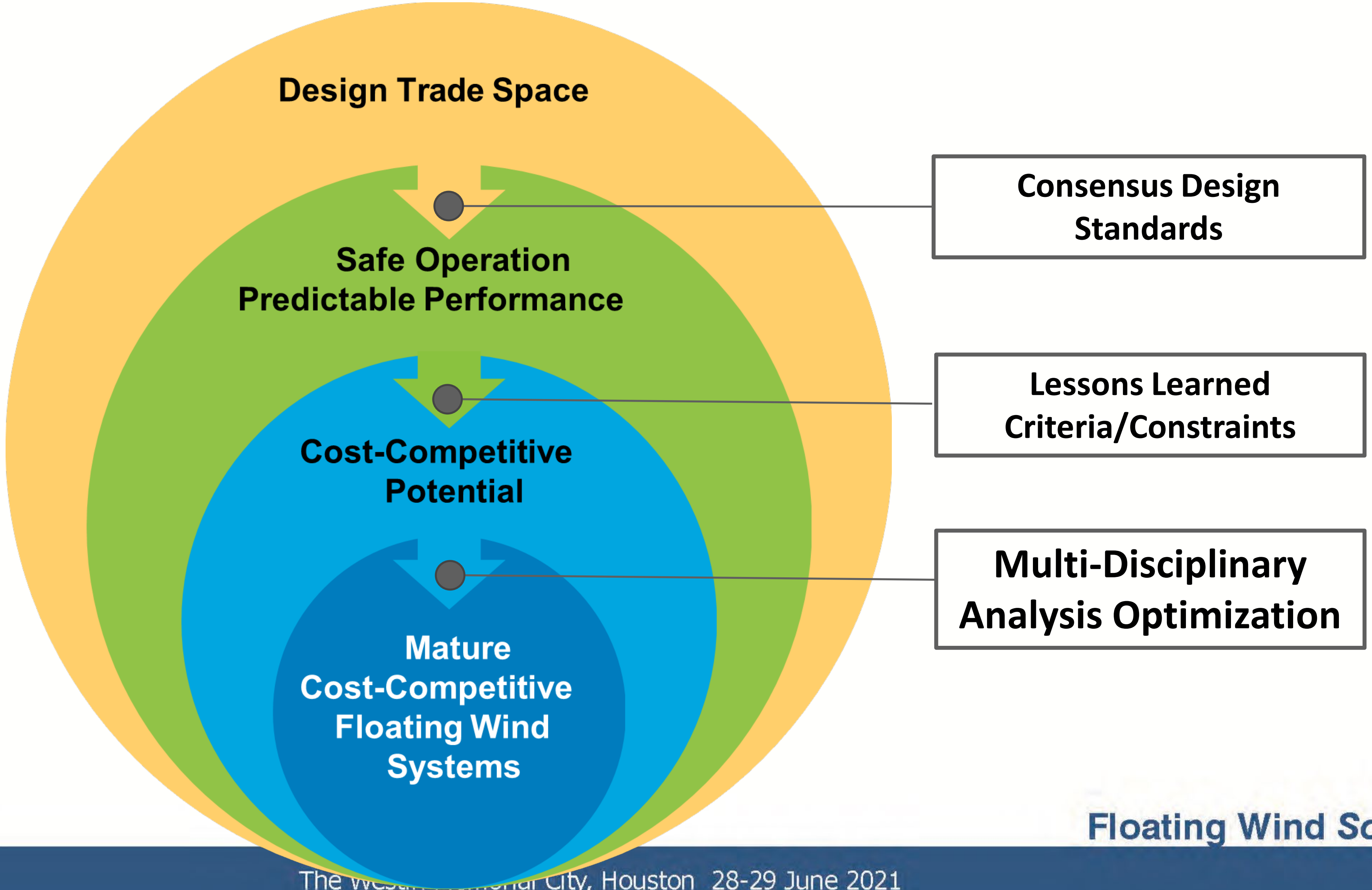
TetraSpar platform



Source: Stiesdal Offshore Technology A/S

Floating Wind Solutions

Mature Cost-Competitive Floating Wind Systems Can Be Achieved Through MDAO System Optimization Tools

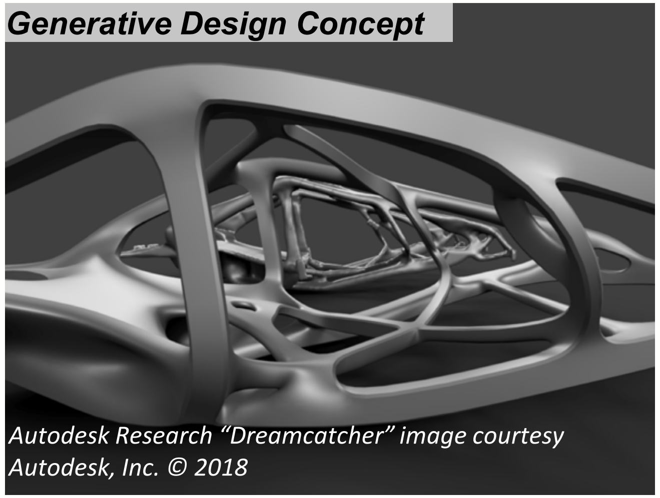


Many innovations offer improvement with a cost premium: Need to consider cost-benefit trade-off to system

- **Every component has a pathway to weight reduction**
  - Different materials or manufacturing
  - Advanced technology innovations
- **Opportunities are commonly more expensive per kilogram, but require fewer kilograms**
  - Difficult trade-off to make intuitively
- **Requires a system-level tool to determine sensitivities and make cost-benefit trade-offs.**

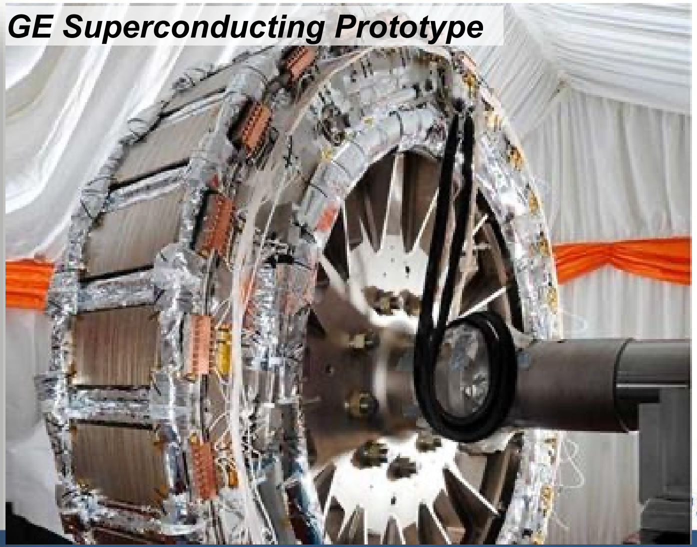
No-tower design

Generative Design Concept



Ming Yang 2-bladed downwind

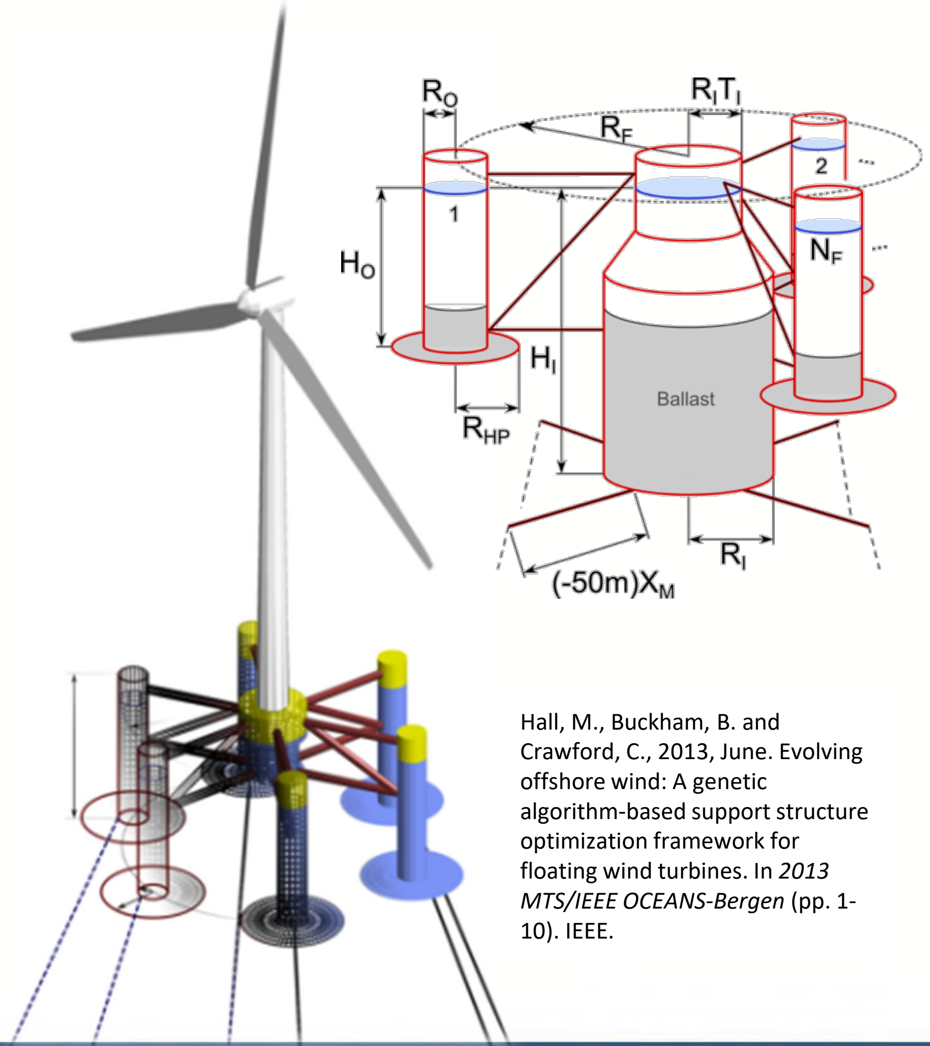
GE Superconducting Prototype



Component optimization has been done, but cannot yet fully optimize a floating turbine + platform + system

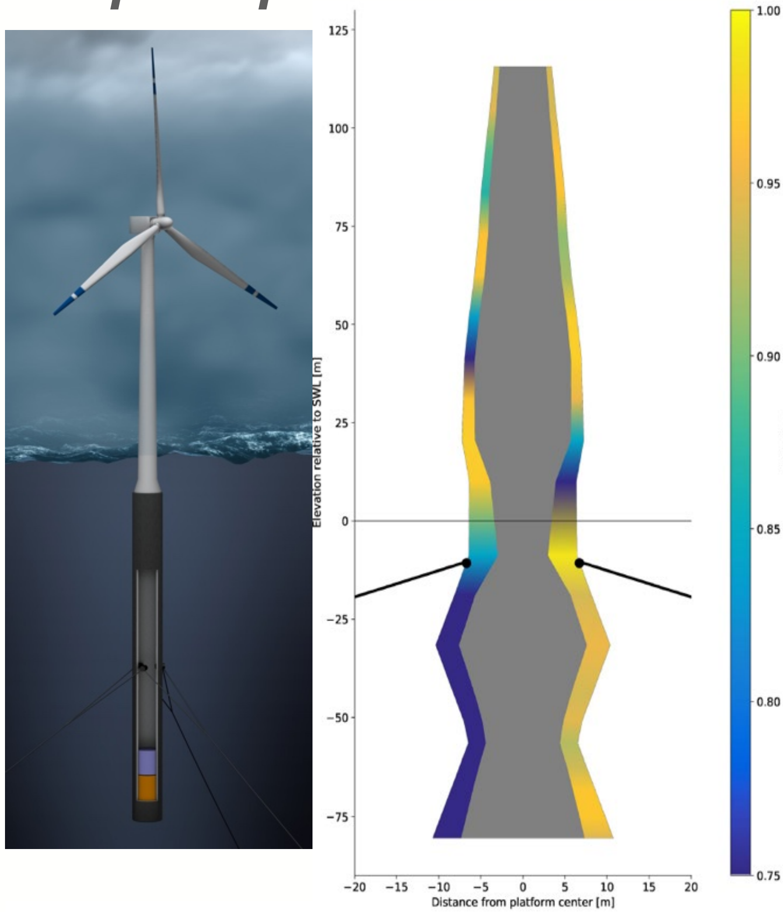
15-MW Reference Wind Turbine

Semi Optimization



Hall, M., Buckham, B. and Crawford, C., 2013, June. Evolving offshore wind: A genetic algorithm-based support structure optimization framework for floating wind turbines. In *2013 MTS/IEEE OCEANS-Bergen* (pp. 1-10). IEEE.

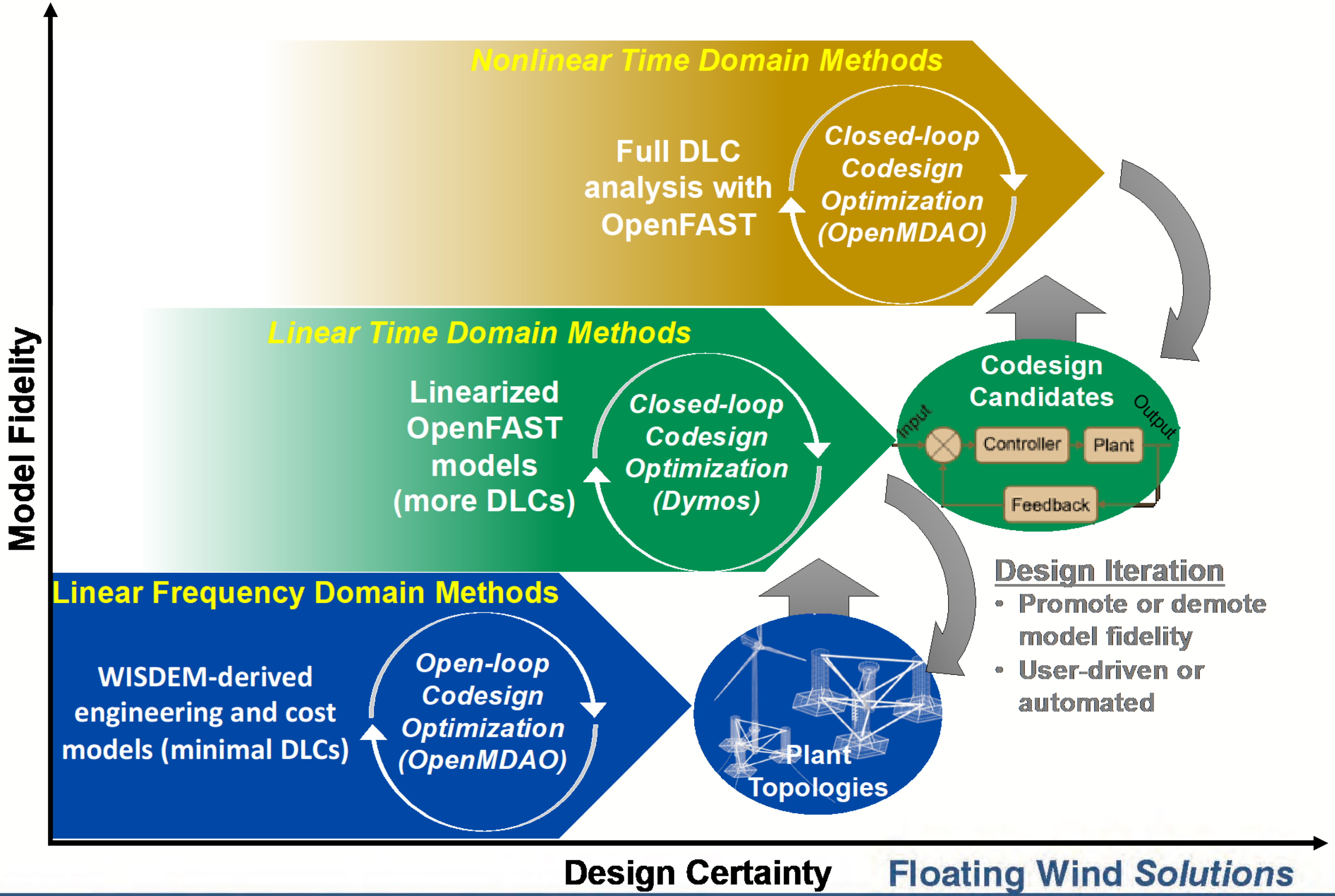
Spar Optimization



Hegseth, J.M., Bachynski, E.E. and Martins, J.R., 2020. Integrated design optimization of spar floating wind turbines. *Marine Structures*, *72*, p.102771.

ARPA-E ATLANTIS WEIS Project: Multifidelity Optimization

- **ATLANTIS: Controls Co-Design for FOWT**
- **NREL: Wind Energy with Integrated Servo-control (WEIS)**



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Thank You!

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