Modeling Options for Current Energy Converter Systems and Associated Challenges

Marine and Hydrokinetic Instrumentation, Measurement & Computer Modeling Workshop

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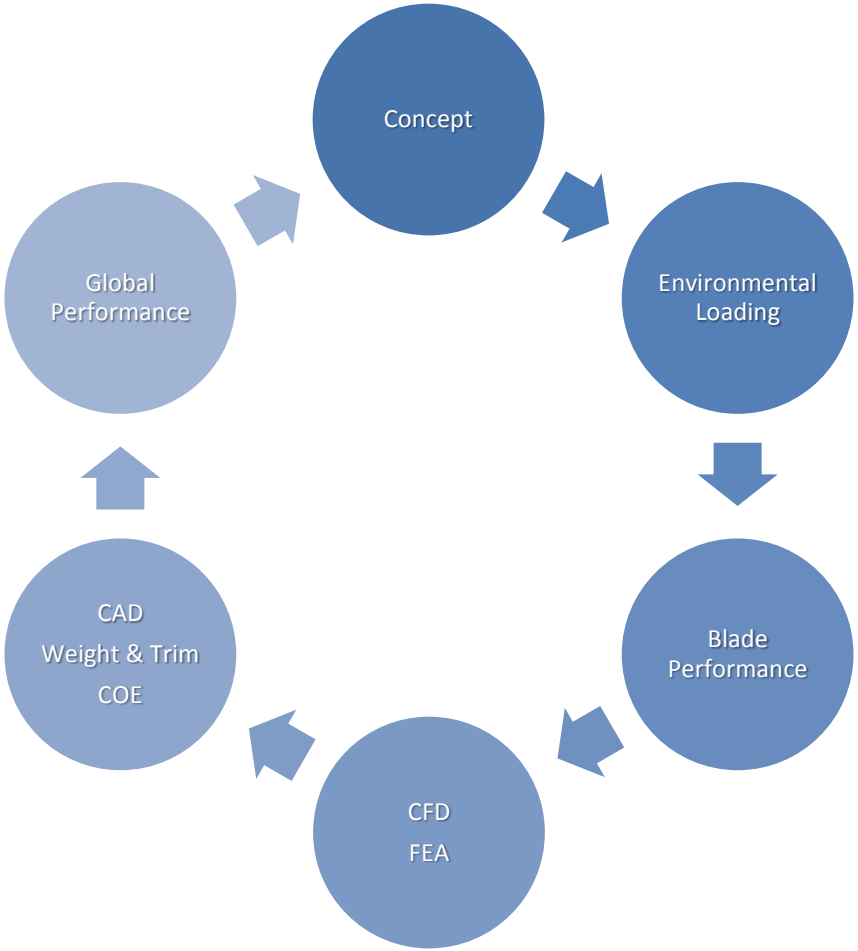
Objectives

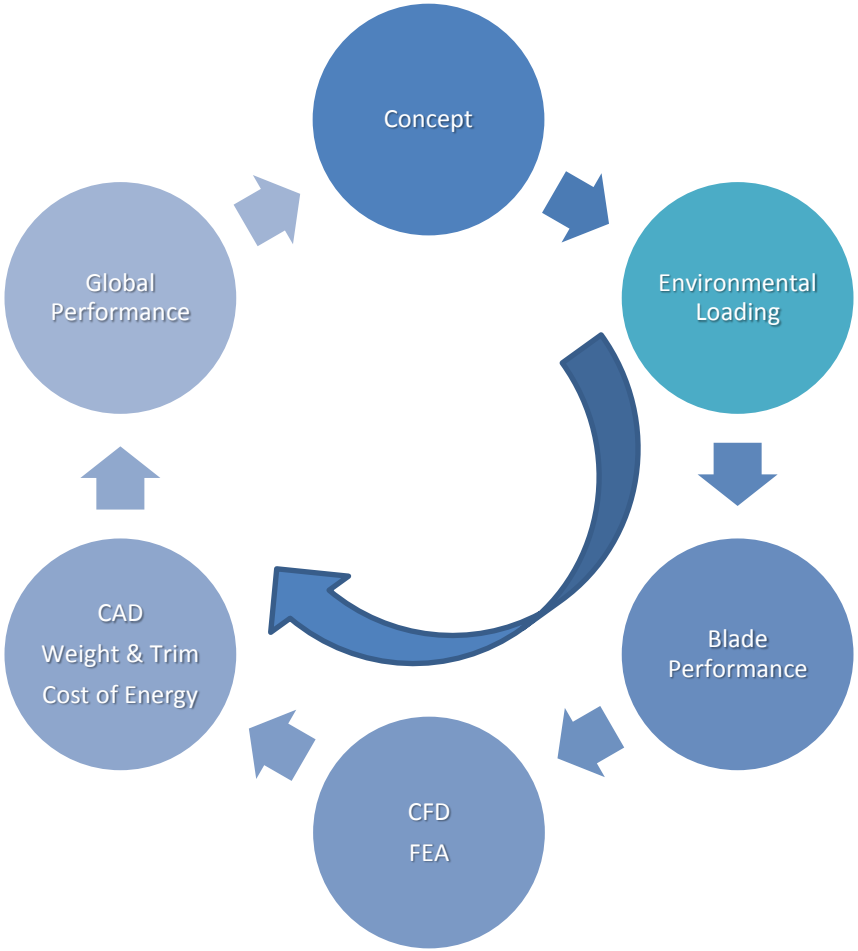
→ Current converter modeling process

→ Challenges with existing techniques

→ Opportunities for improvement

Modeling Process




Concept
Environmental Loading
Blade Performance
CFD
FEA
CAD
Weight & Trim
Cost of Energy
Global Performance

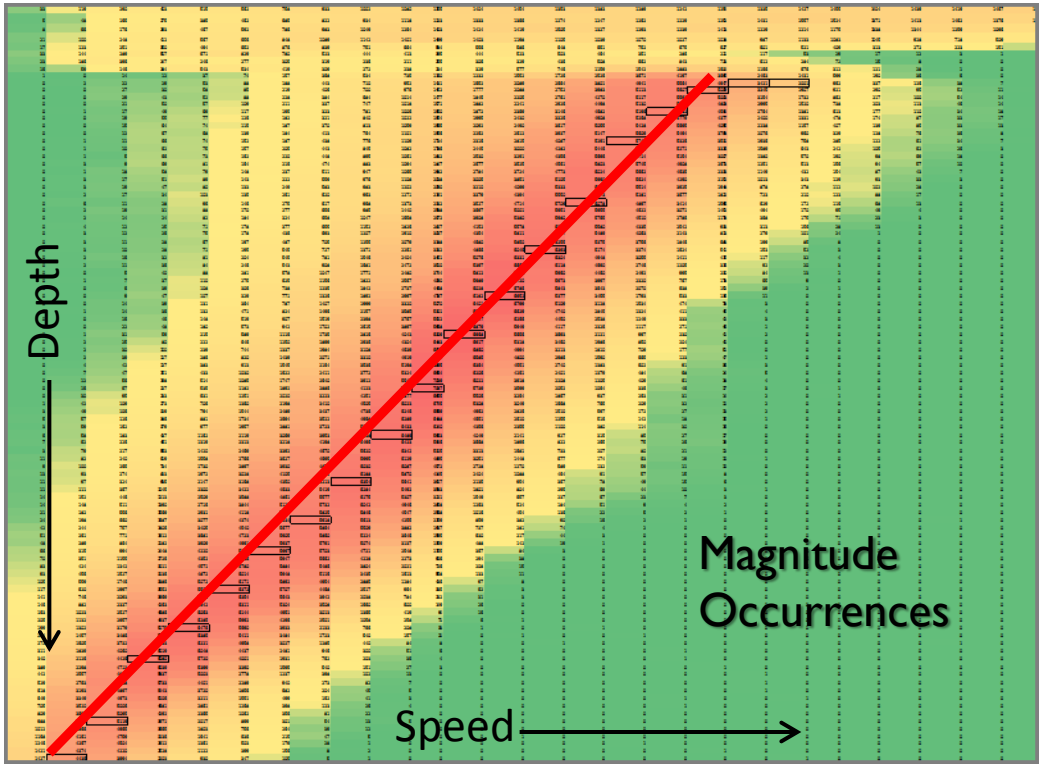
Environmental Loading - Resource

Objective:

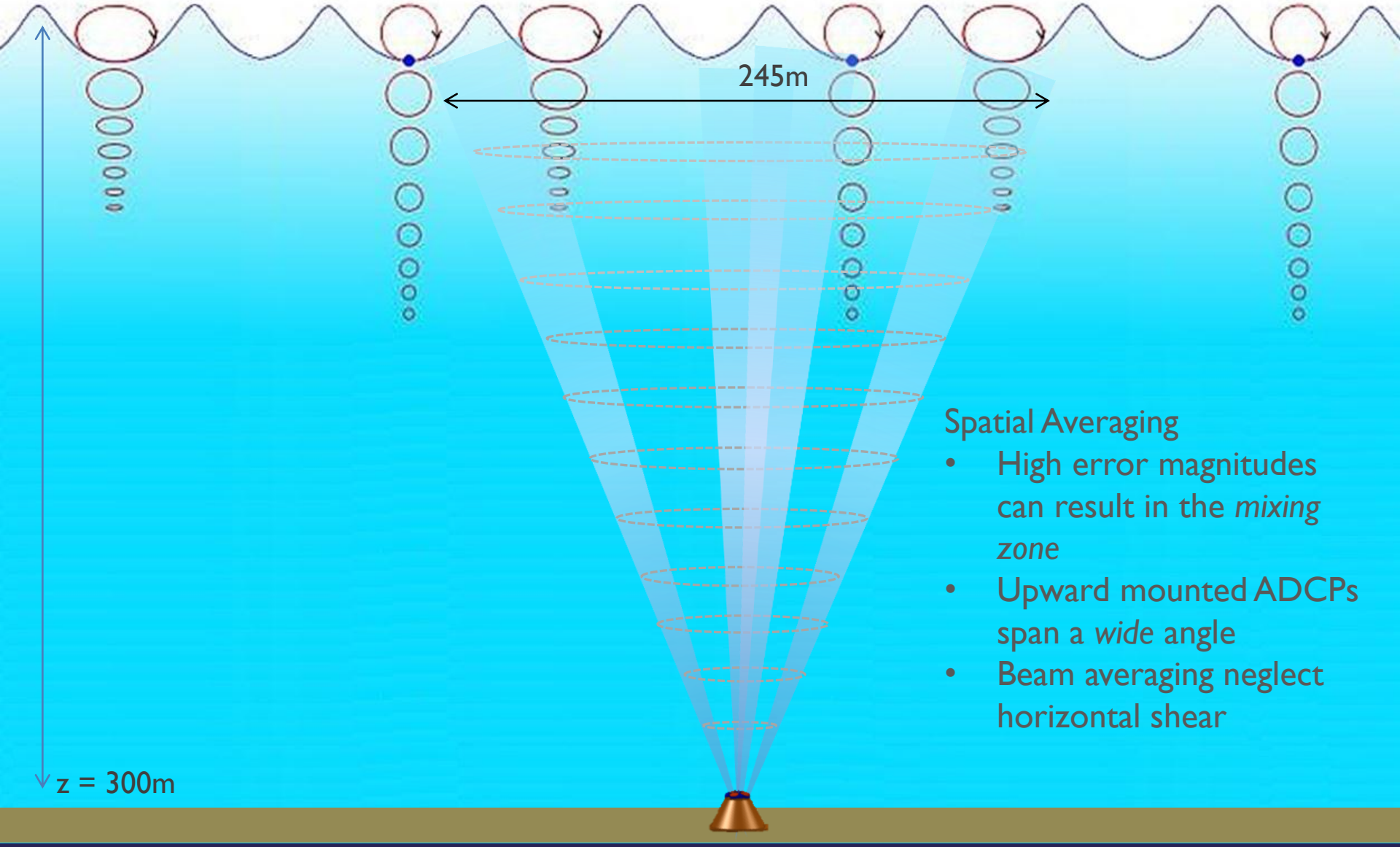
To outline inputs for operating envelope, and environmental conditions for installation, operations & maintenance.

- General Characteristics of Current *resource*
  - Mixed layer zone
  - Mean, maximum, minimum
  - Weibull distribution → AEP
  - Turbulence → Fatigue

Current Magnitude as Function of Depth



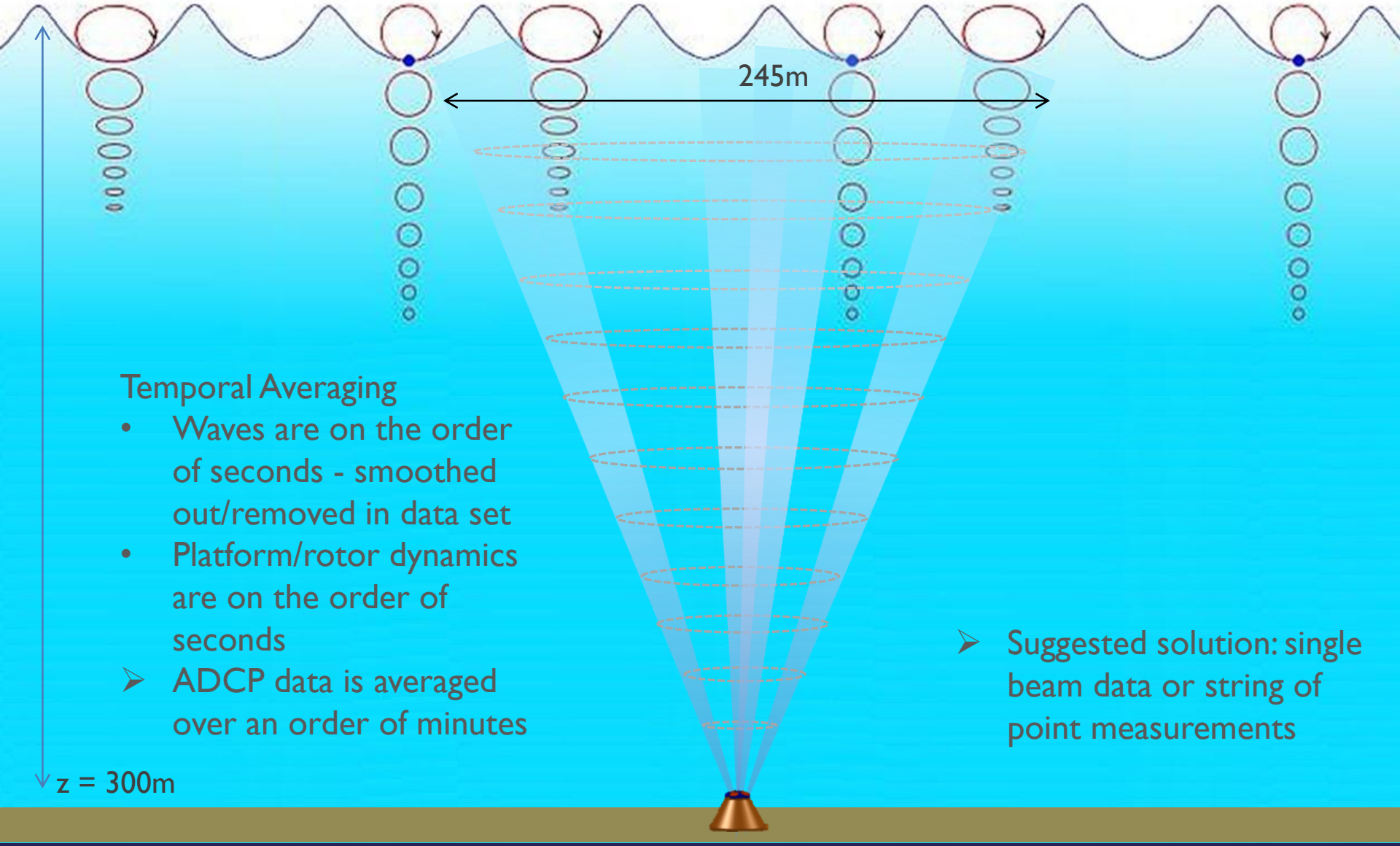
➢ Challenge – Spatial Averaging



Spatial Averaging

- High error magnitudes can result in the *mixing zone*
- Upward mounted ADCPs span a *wide* angle
- Beam averaging neglect horizontal shear

➢ Challenge – Temporal Averaging



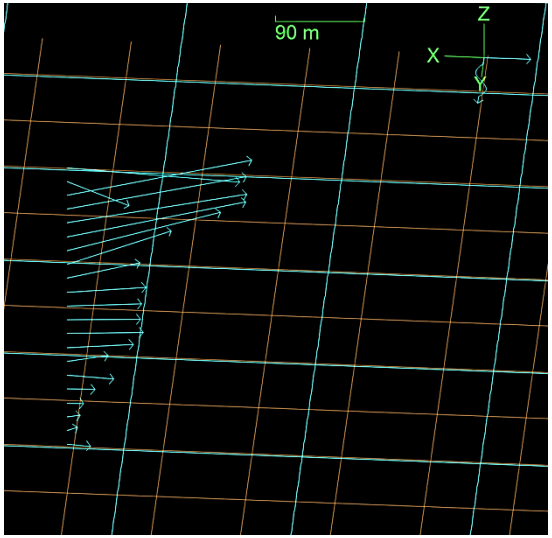
Temporal Averaging

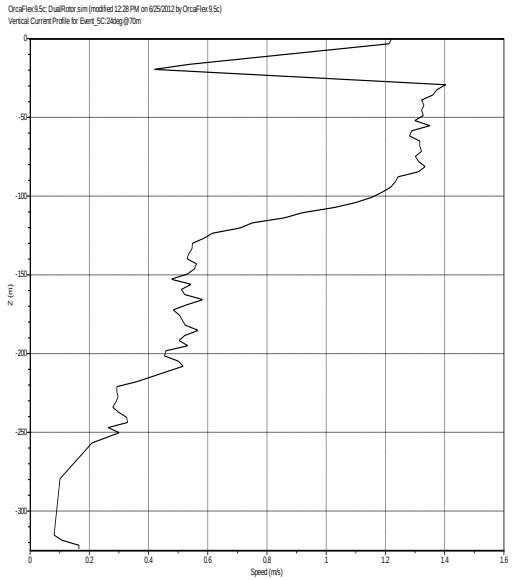
- Waves are on the order of seconds - smoothed out/removed in data set
- Platform/rotor dynamics are on the order of seconds

➢ ADCP data is averaged over an order of minutes

➢ Suggested solution: single beam data or string of point measurements

➢ Challenge – Modeling Current

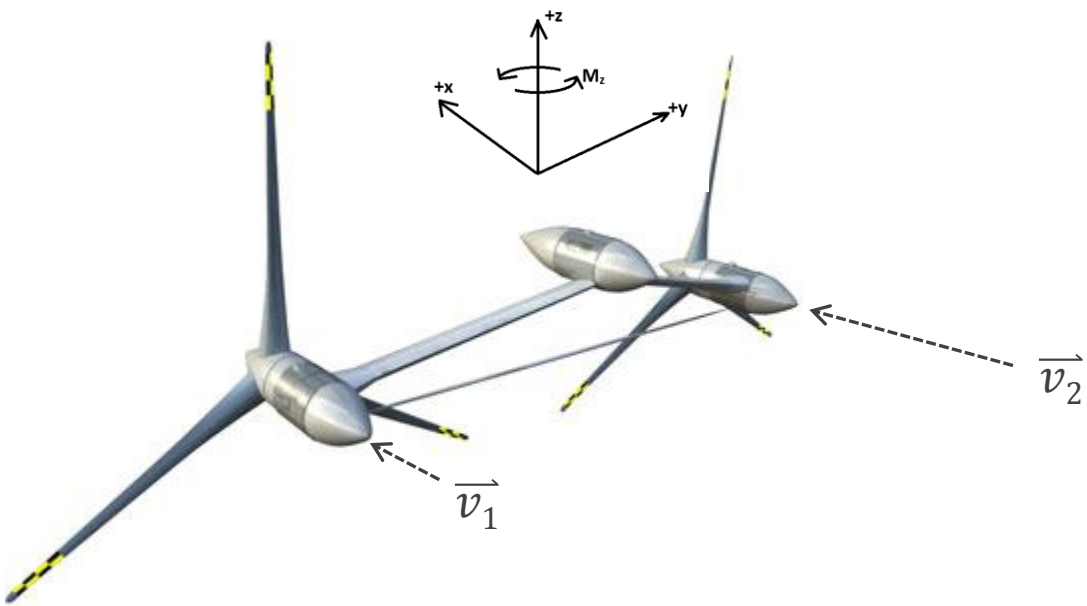




Modeling Challenges – *Current Profiles*

- Uniform velocity is assumed at all x,y locations
- Horizontal shear presents instability problems for multi-rotor systems or multiple platforms experience different velocities
- Within OrcaFlex & Stability codes, a *horizontal recursion factor* can be applied at all depths, to modify the profile horizontally

Environmental Loading – Events



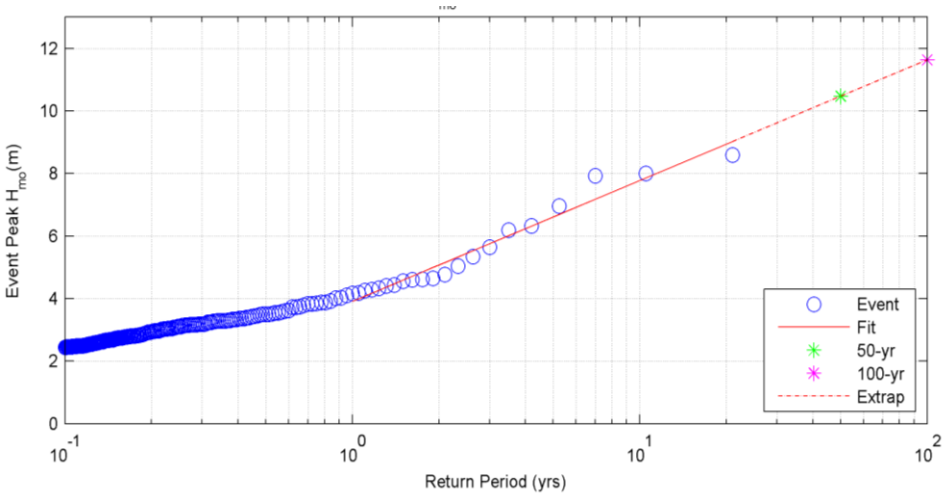
- Additional events that can impact the resource
  - Spin-off Eddies
  - Internal waves
  - *Horizontal sheer → platform instability*

➢ Challenge – Surface Waves

- Surface *wave data* is available for buoys from the NBDC, but only in sparse locations for Florida
- Predictions from US Army Corps provide additional locations
  - Planning Installation & maintenance
  - *Hindcasts* for 100yr return periods

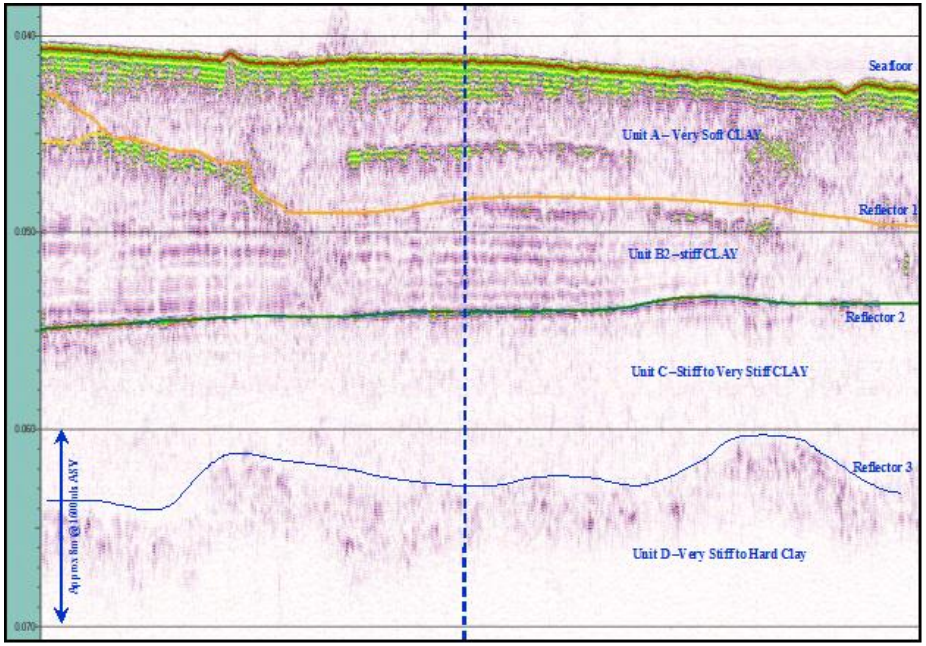
➢ Opportunities for under/over-prediction of loading

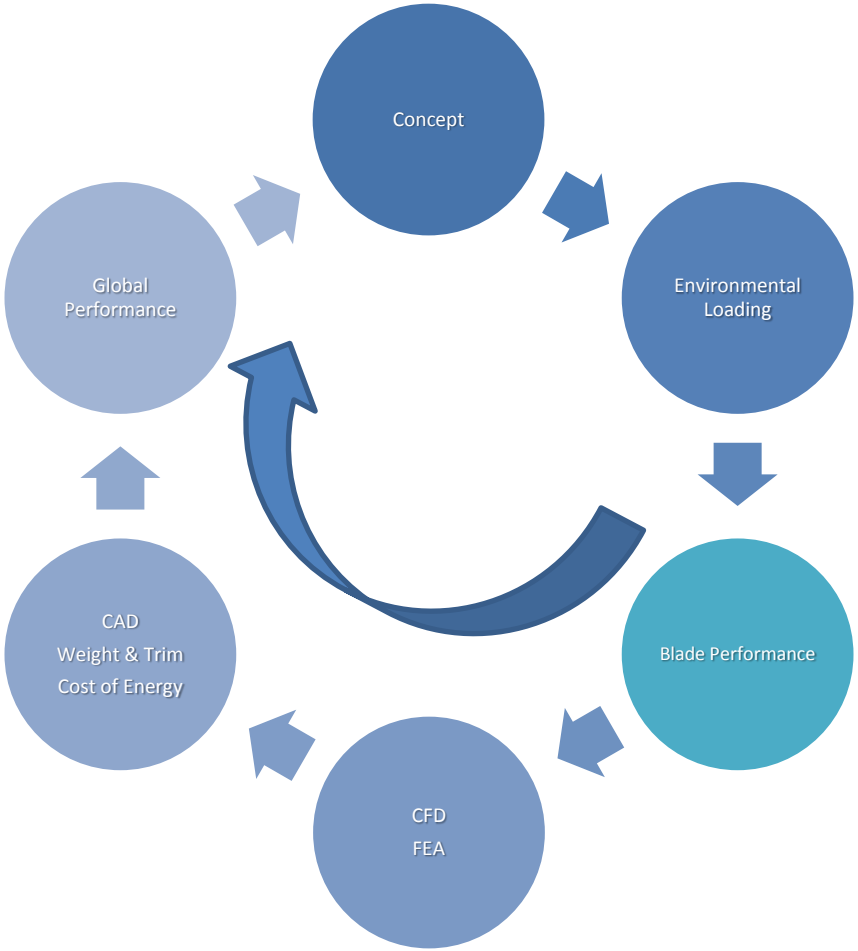
2010		Average Period (s)													
		0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 6	6 - 7	7 - 8	8 - 9	9 - 10	10 - 11	11 - 12	12 - 13	13 - 14
Wave Height (m)	0 - 0.5	0	0	5	117	147	38	5	0	0	0	0	0	0	0
	0.5 - 1	0	0	1	738	1929	1497	504	67	0	0	0	0	0	0
	1 - 1.5	0	0	0	220	2229	1390	482	125	0	0	0	0	0	0
	1.5 - 2	0	0	0	2	1338	1559	420	130	15	0	0	0	0	0
	2 - 2.5	0	0	0	0	302	1347	372	63	41	1	0	0	0	0
	2.5 - 3	0	0	0	0	22	820	249	58	38	8	0	0	0	0
	3 - 3.5	0	0	0	0	0	316	219	57	31	9	0	0	0	0
	3.5 - 4	0	0	0	0	0	35	161	56	49	9	0	0	0	0
	4 - 4.5	0	0	0	0	0	3	86	19	42	8	0	0	0	0
	4.5 - 5	0	0	0	0	0	0	46	15	11	3	0	0	0	0
	5 - 5.5	0	0	0	0	0	0	10	20	6	0	0	0	0	0
	5.5 - 6	0	0	0	0	0	0	0	5	4	2	0	0	0	0
	6 - 6.5	0	0	0	0	0	0	0	0	0	4	0	0	0	0
	6.5 - 7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7 - 7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7.5 - 8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8 - 8.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8.5 - 9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9 - 9.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9.5 - 10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10 - 10.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10.5 - 11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11 - 11.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11.5 - 12	0	0	0	0	0	0	0	0	0	0	0	0	0	0



➢ Challenge - Geotechnics

- Geotechnics
  - Limited knowledge of soil type & thickness
  - Parametric sub-bottom profiling can be used to scan the area
  - Requires coring to validate - an expensive procedure
  - Anchor options may vary based on the site location
  - ➢ Anchoring presents a cost "bogie" → COE modeling

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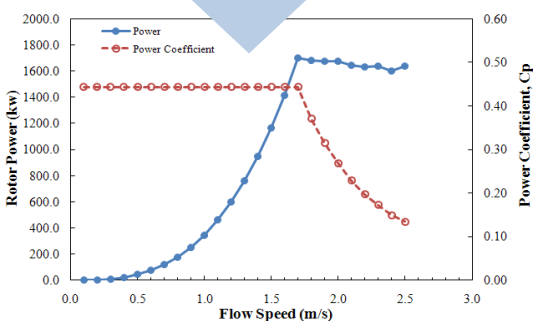
➢ Challenge – Blade Performance

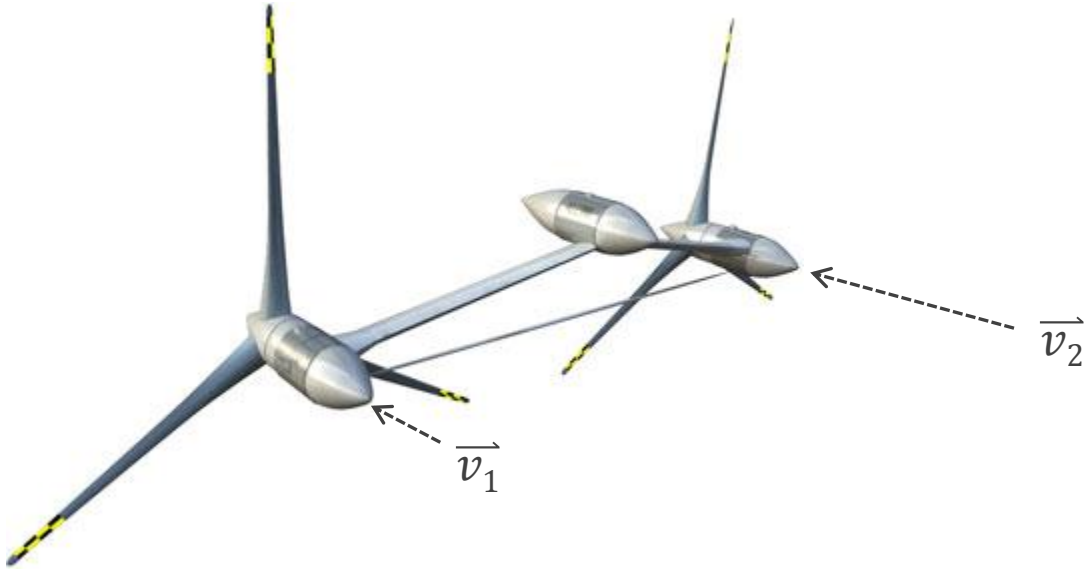
- NREL *design codes* were designed for aerodynamic purposes
- Neglect added mass effects, cavitation effects

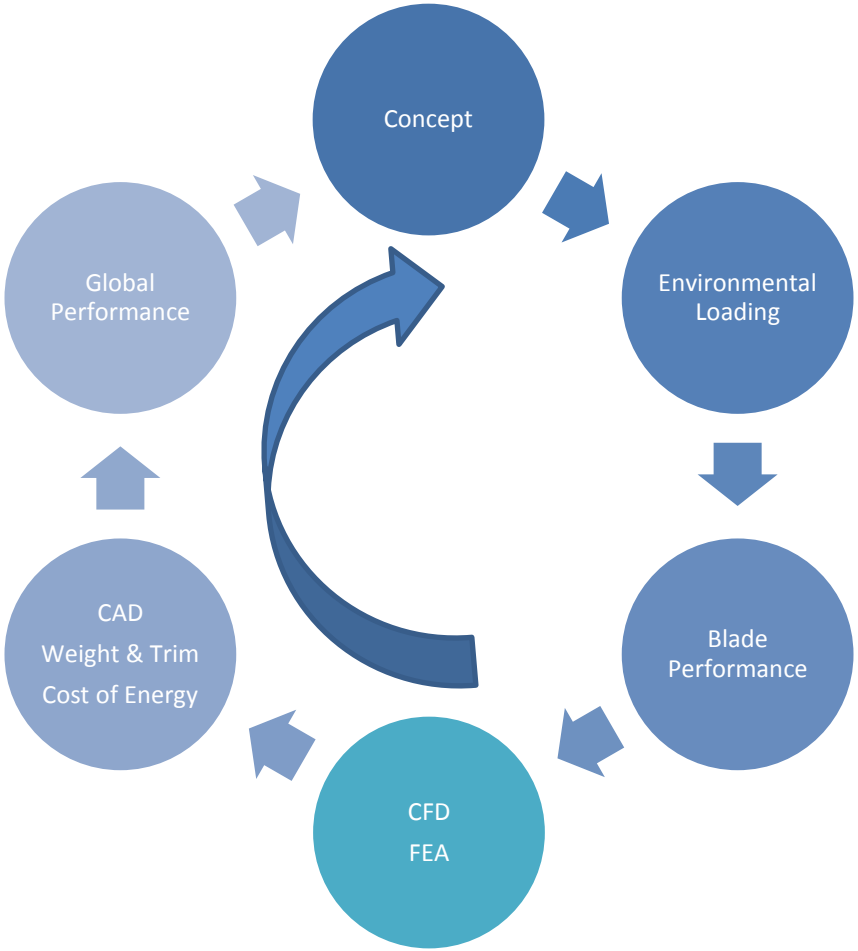
Resource → Harp_Opt *Rotor Design* → WT_Perf *Rotor Performance*



➢ Challenge – Blade Performance

- Traditionally, the blade performance models were developed for rotors mounted on piles, where platform motion is minimal
- To accurately model the energy production for ocean current devices, the platform orientation and motion should be included in the AEP calculations

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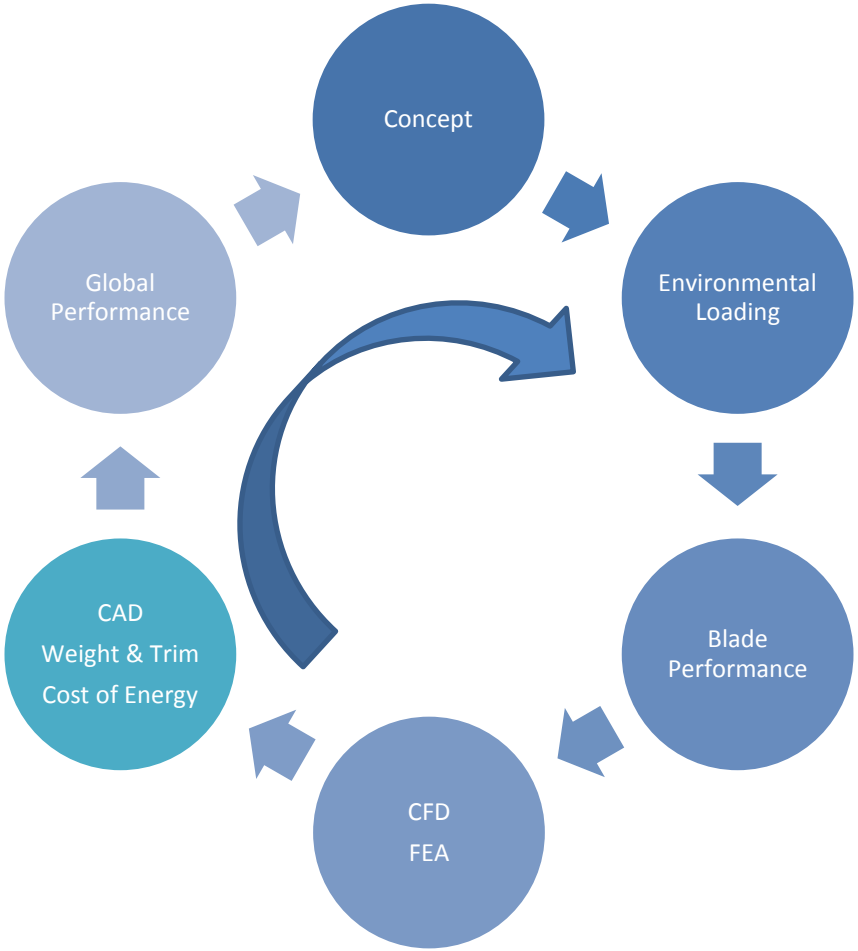
➢ Challenge – CFD/FEA

OBJECTIVE:

To determine the hydrodynamic and structural loading requirements for rotor and platform design.

- Computational time requires significant processors to evaluate various *flow conditions* in a timely manner

Flow Conditions			Mean Forces			Mean Moments		
AoA	Flow Spe	Rotor	Fx	Fy	Fz	Mx	My	Mz
(deg)	(m/s)	(rpm)	(kN)	(kN)	(kN)	(kN-m)	(kN-m)	(kN-m)
0	0.50	1.27	130	0	0	260	-2	-7
5	0.50	1.27	126	-1	2	247	-20	-7
10	0.50	1.27	128	-1	3	254	-37	-9
15	0.50	1.27	126	0	4	250	-55	-12
20	0.50	1.27	121	0	6	233	-70	-14
25	0.50	1.27	114	0	7	212	-83	-17
0	1.00	2.53	504	-2	0	1,069	0	-24
5	1.00	2.53	0	0	0	0	0	0
10	1.00	2.53	497	0	12	1,054	-163	-36
15	1.00	2.53	490	1	18	1,034	-234	-43
20	1.00	2.53	0	0	0	0	0	0
25	1.00	2.53	0	0	0	0	0	0
0	1.50	3.80	1,111	-4	0	2,397	-6	-54
5	1.50	3.80	1,115	-2	15	2,417	-197	-67
10	1.50	3.80	1,098	0	29	2,373	-364	-81
15	1.50	3.80	1,078	2	39	2,315	-534	-94
20	1.50	3.80	1,037	3	51	2,189	-692	-112
25	1.50	3.80	979	5	62	2,019	-820	-135
0	1.70	2.80	1,289	-6	2	4,526	-27	-29
5	1.70	2.80	1,277	7	25	4,493	-171	38
10	1.70	2.80	1,266	10	40	4,447	-314	129
15	1.70	2.80	1,243	17	58	4,353	-434	204
20	1.70	2.80	1,196	24	75	4,141	-552	265
25	1.70	2.80	1,132	29	90	3,865	-640	304
0	2.00	2.05	1,384	-3	5	7,816	-88	-21
5	2.00	2.05	1,377	23	25	7,758	-217	449
10	2.00	2.05	1,350	46	44	7,547	-344	882
15	2.00	2.05	1,303	69	63	7,164	-495	1,259
20	2.00	2.05	1,224	94	83	6,483	-793	1,429
25	2.00	2.05	1,147	107	102	5,873	-915	1,503
0	2.50	1.85	1,382	0	4	4,593	-132	-27
5	2.50	1.85	1,404	33	5	4,748	-100	700
10	2.50	1.85	1,365	56	14	5,009	-190	1,178
15	2.50	1.85	1,277	82	45	5,124	-506	1,243
20	2.50	1.85	1,262	127	51	5,581	-707	1,675
25	2.50	1.85	1,265	212	46	6,516	-1,388	2,465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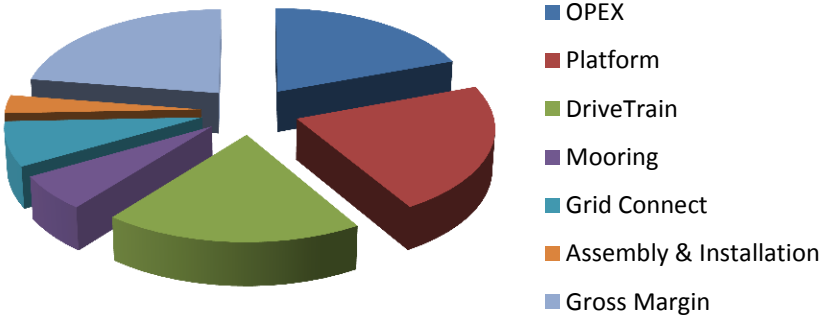
CAD

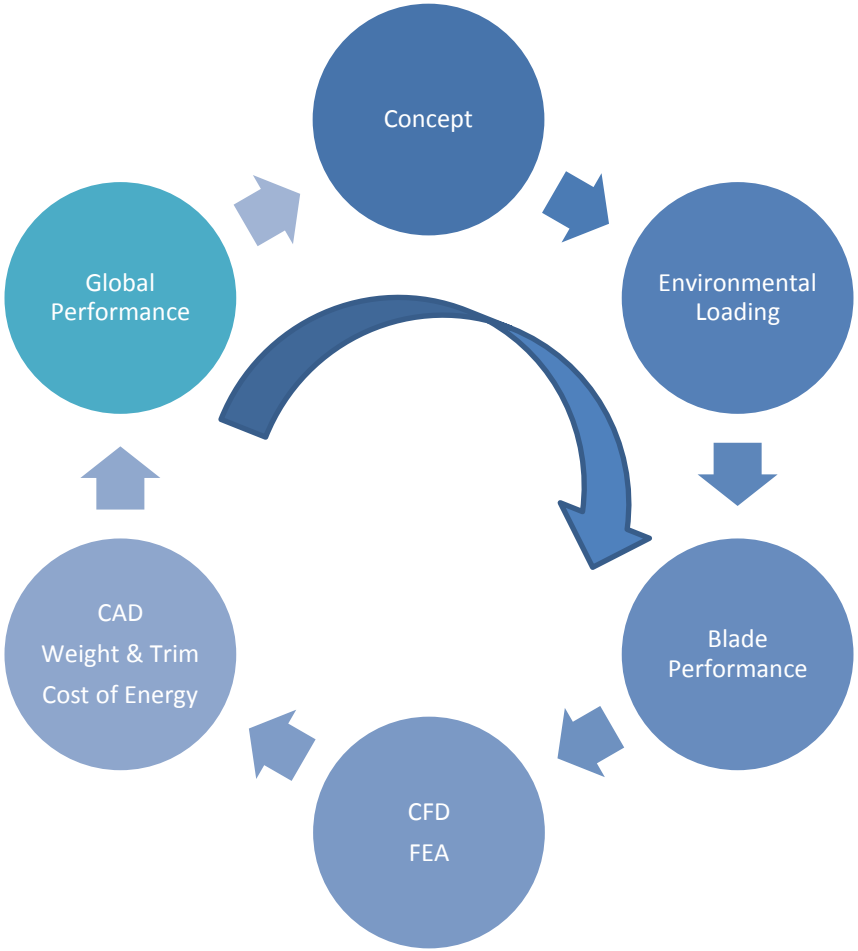
OBJECTIVE:

To arrive at a nacelle and internal design that satisfies mechanical, structural & electrical requirements, and includes robust, reliable off-the-shelf components.

- Weight & Trim
  - Components and spacing
  - Static stability
  - Associated costs
  - ➢ Installation concepts
  - ➢ Maintenance requirements

- Cost of Energy
  - Design Life (yrs)
  - Capital Costs (CAPEX)
  - Annual Energy Production estimates (AEP)
  - Operations & maintenance
  - ➢ Cost/kW

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Global Performance

Objective:

To arrive at a design that is easy to install, presents minimal opportunity for mooring entanglement, & will endure the harsh environmental loading over the design life.

- Anchor Suitability
- Mooring type: Catenary, taut
- Number of lines required
- Concept of operations
- Dynamic/static stability

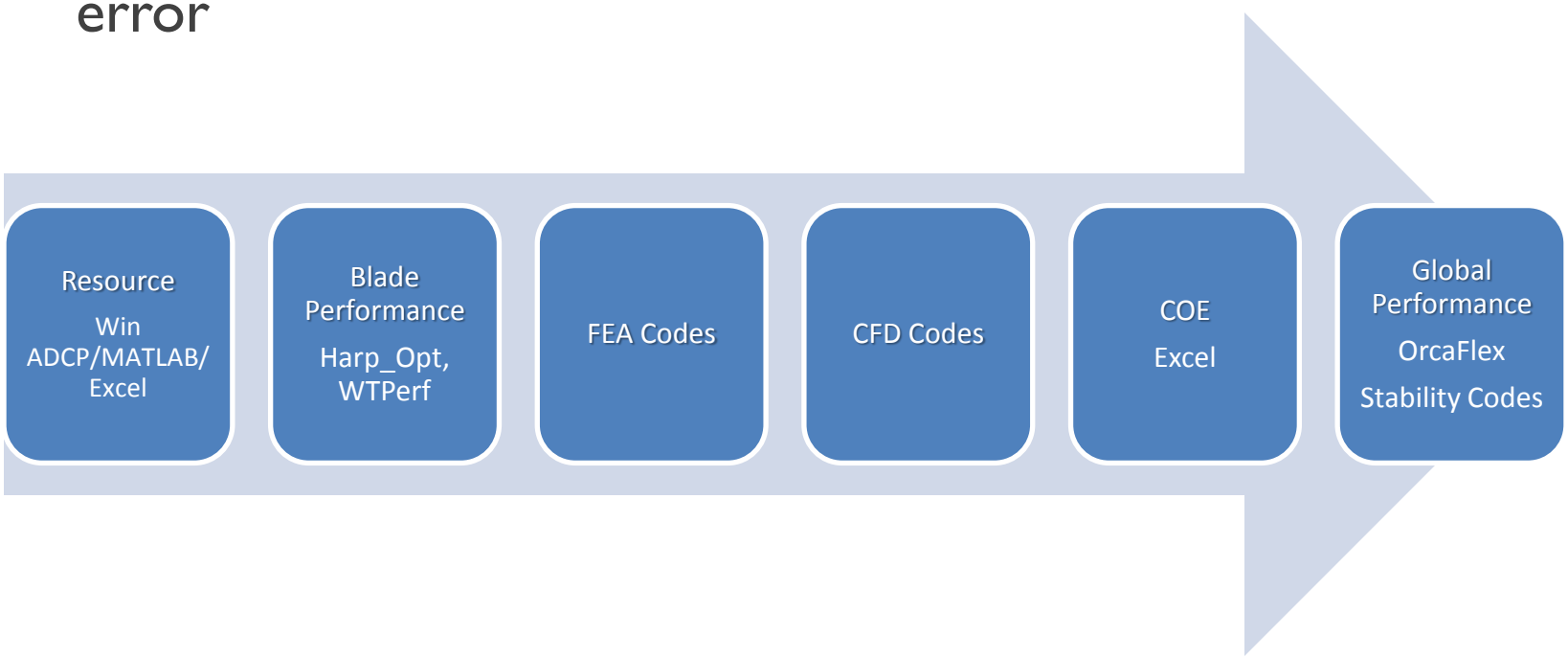
➢ Challenge – Global Performance

- Anchor modeling is neglected
- Modeling the rotor in OrcaFlex is a challenge
- This code does not use blade element momentum theory, therefore induced velocity is neglected

➢ Solution - stability codes or coupled modeling

➢ Summary: Modeling Tools Process

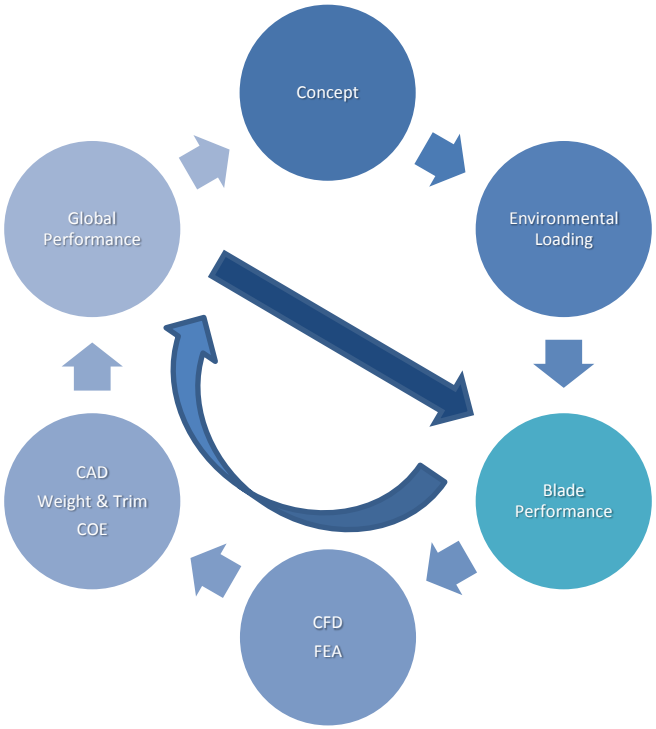
- Piecewise modeling techniques present opportunities for error



➢ Solution: tight design teams & thorough understanding of boundary conditions to optimize power to weight ratios

Summary: Modeling Tools Process

- Modifications in one model can require another design loop



➢ Opportunities for Improvement

- Coupled tool is needed that incorporates
  - Rotor Performance
  - Platform Stability
  - Mooring Dynamics
  - Flutter, Wake effects, …

➢ This tool could more accurately provide AEP estimates

Additional Opportunities of Current Energy Systems

- Finer granularity resource data
- Point measurements with coupled motion sensing
- Public domain geotechnical data
- COE model templates & offshore/wind industry validation

Questions ?

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