A DESIGN-OF-EXPERIMENTS BASED APPROACH TO ENGINEERING A ROBUST MOORING SYSTEM FOR A SUBMERGED ADCP

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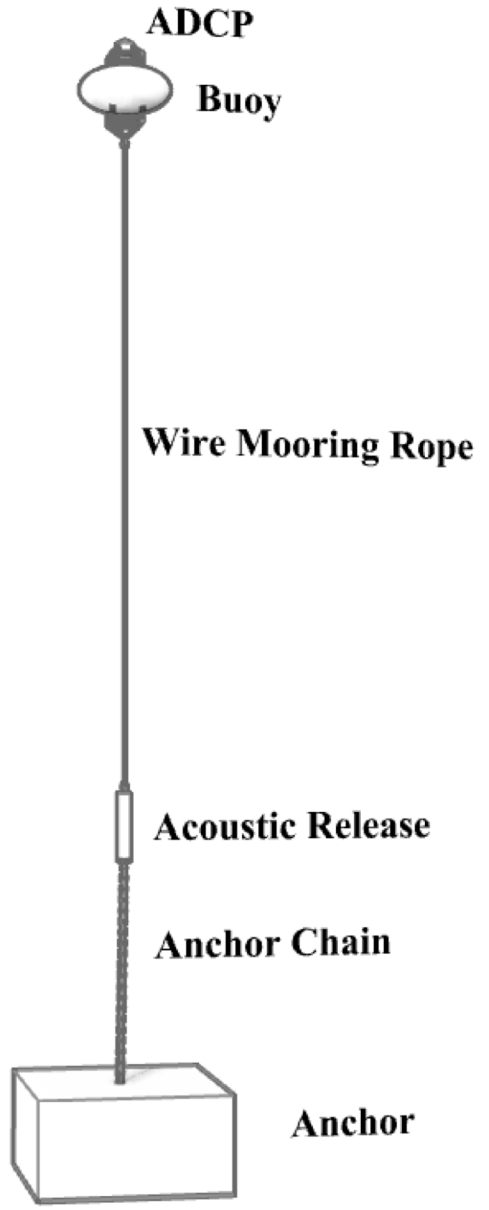
Mooring Design Objectives

Objectives:

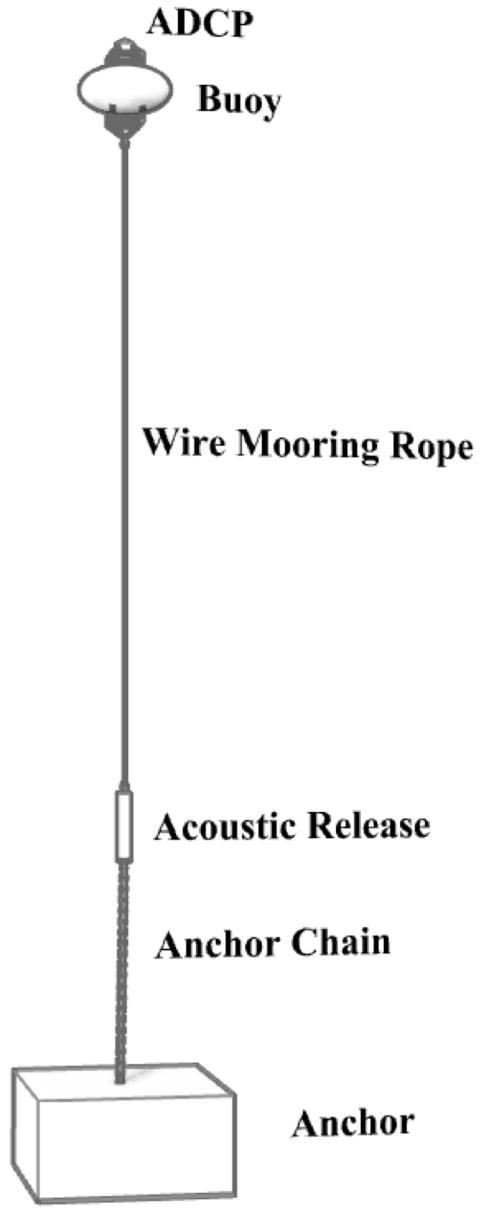
1. Maintain wire rope safety factor
2. Maintain anchor chain safety factor
3. Prevent anchor sliding
4. Minimize ADCP knockover
5. Minimize ADCP pitch
6. Recover acoustic release independently
7. Minimize capital cost



(Not to scale)

Initial Design

Wire Load Safety Factor	2.87 ✓
Chain Load Safety Factor	3.19 ✓
Anchor Sliding	0.002 ✓
ADCP Pitch	8 ✓
ADCP Knockover	24.8 X
Acoustic Release Recovered?	Yes ✓
Cost	?



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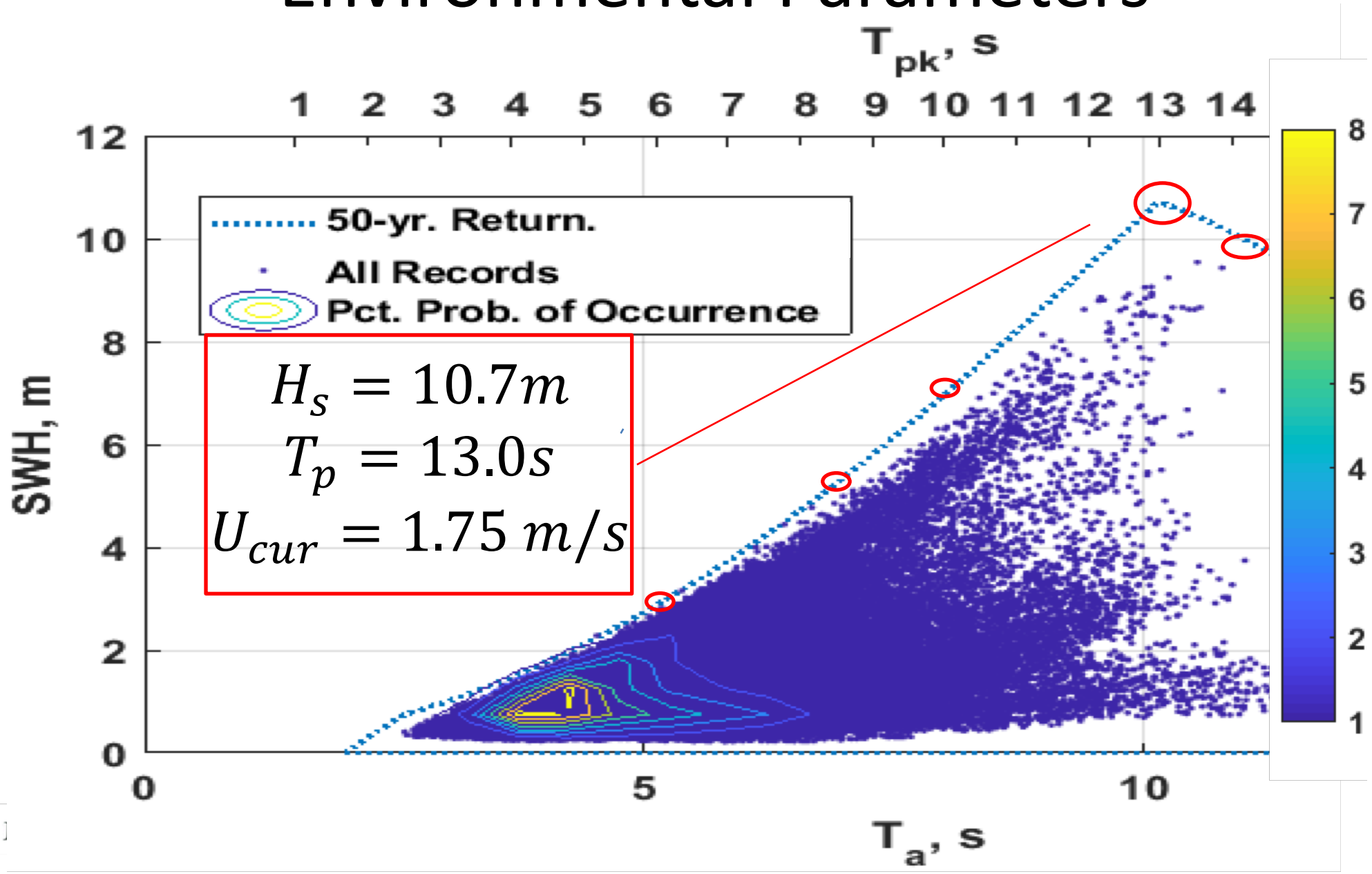
Hypothesis

Rigorous Design Methodologies

State-of-the-art Numerical Modeling

Efficiently design a robust, effective, and affordable mooring system for a deep-water ADCP

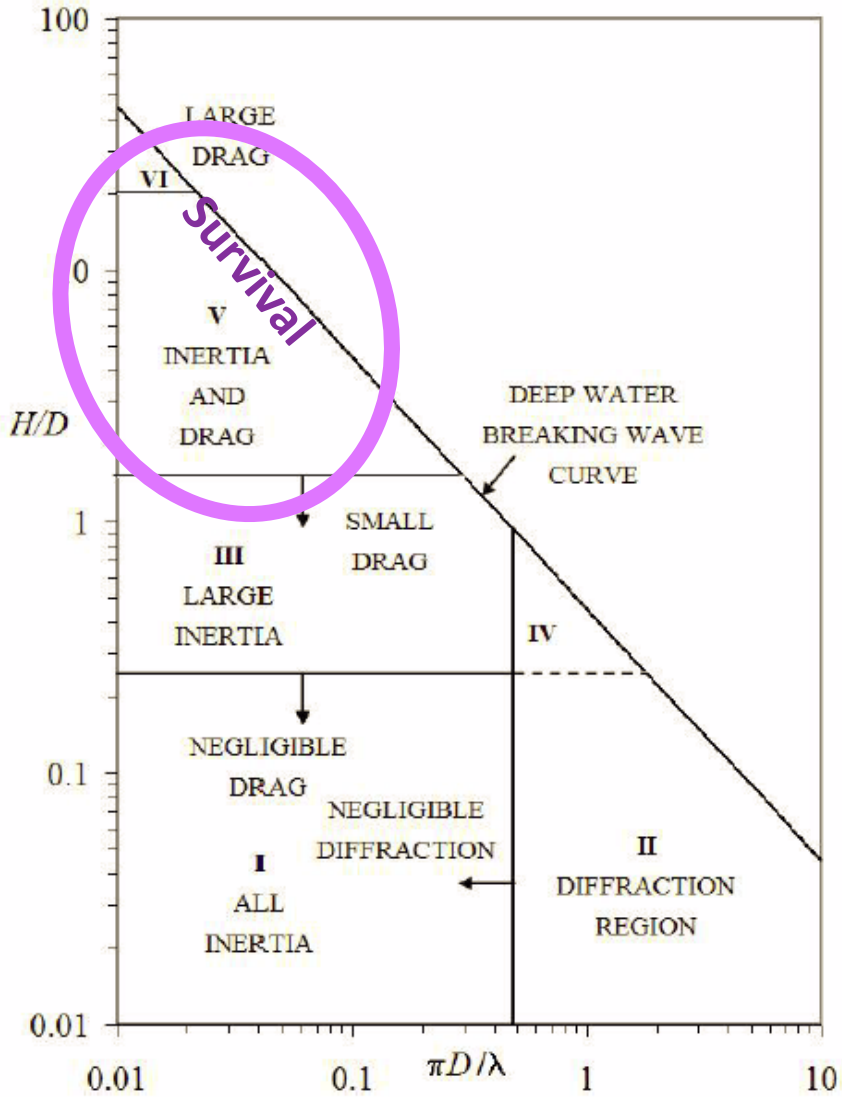
Environmental Parameters



$$H_s = 10.7m$$
$$T_p = 13.0s$$
$$U_{cur} = 1.75\ m/s$$

Dynamic Numerical Model

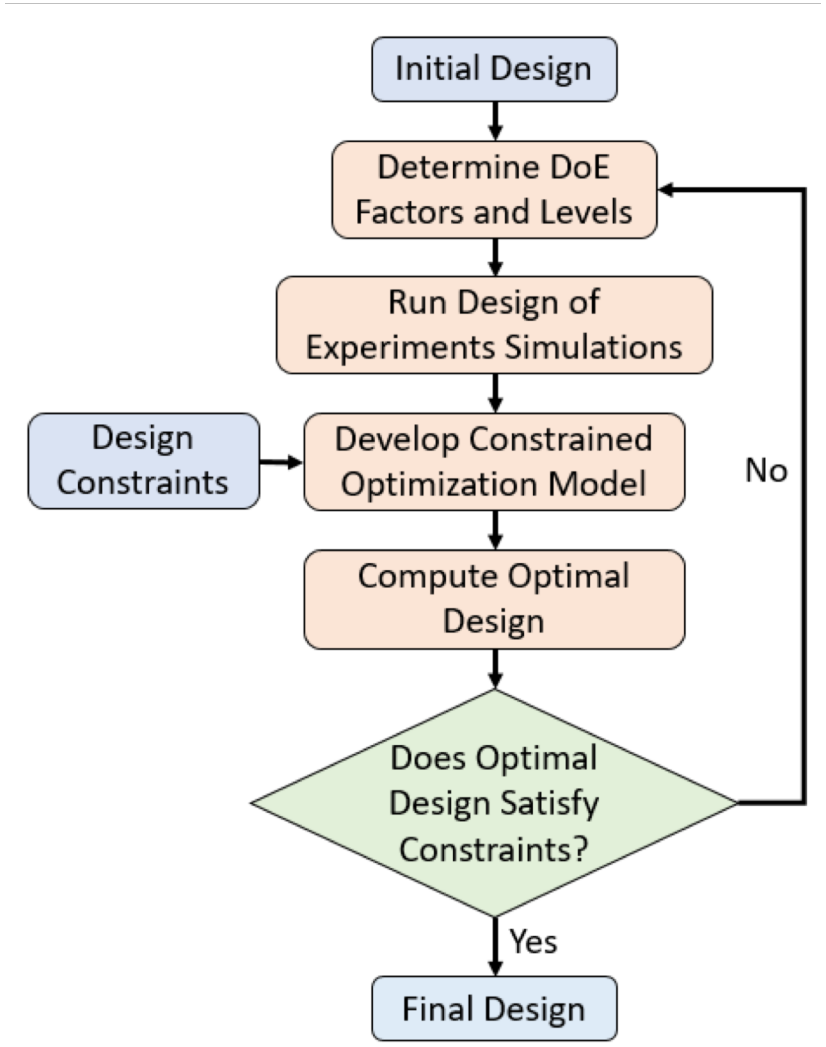
- Low-diffraction regime (Morison-style hydrodynamics)
- FEA of mooring system
- Nonlinear Lagrangian formulation



(Chakrabarti, 1987)

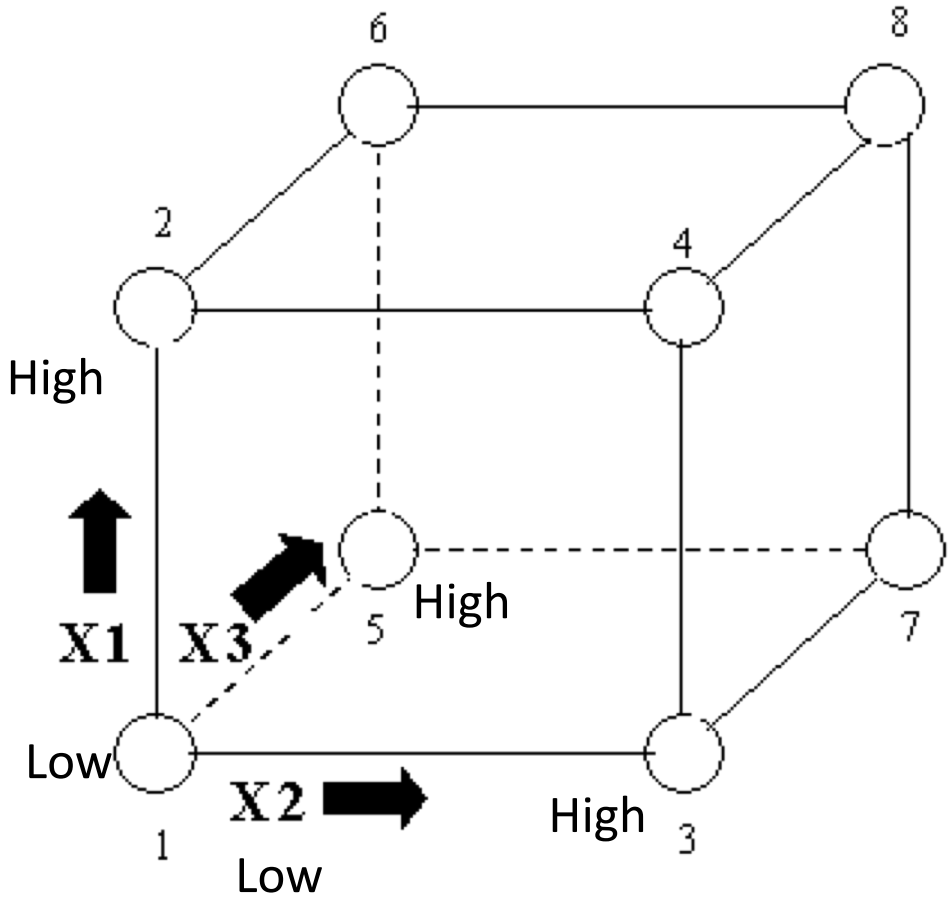
Design Approach—Overview

1. Specify objectives
2. Specify input ranges
3. Quantify sensitivities using numerical model
4. Assemble and solve optimization model from sensitivities
5. Check result



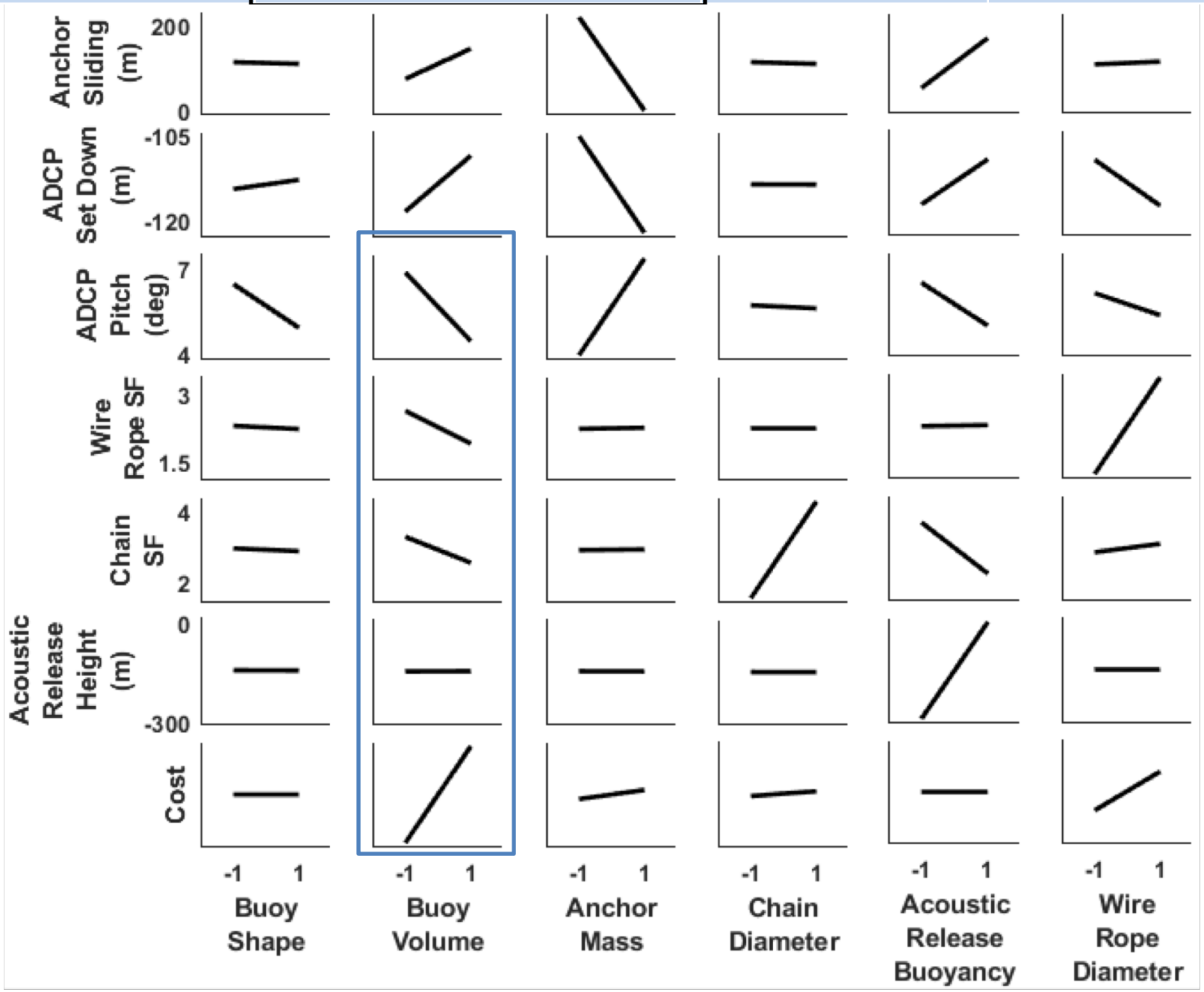
Design Approach—Design of Experiments

Design Factor	Upper Limit	Upper Limit
Reserve Buoyancy Shape	Spherical	Elliptical
Reserve Buoyancy Lift	2,800 N	3,900 N
Anchor Mass	600 kg	1,500 kg
Chain Diameter	6 mm	10 mm
Acoustic Release Buoyancy	0.02 m^3	0.237 m^3
Wire Rope Diameter	6 mm	10 mm



(Adapted from NIST, 2018)

Design of Experiments: Main Effects



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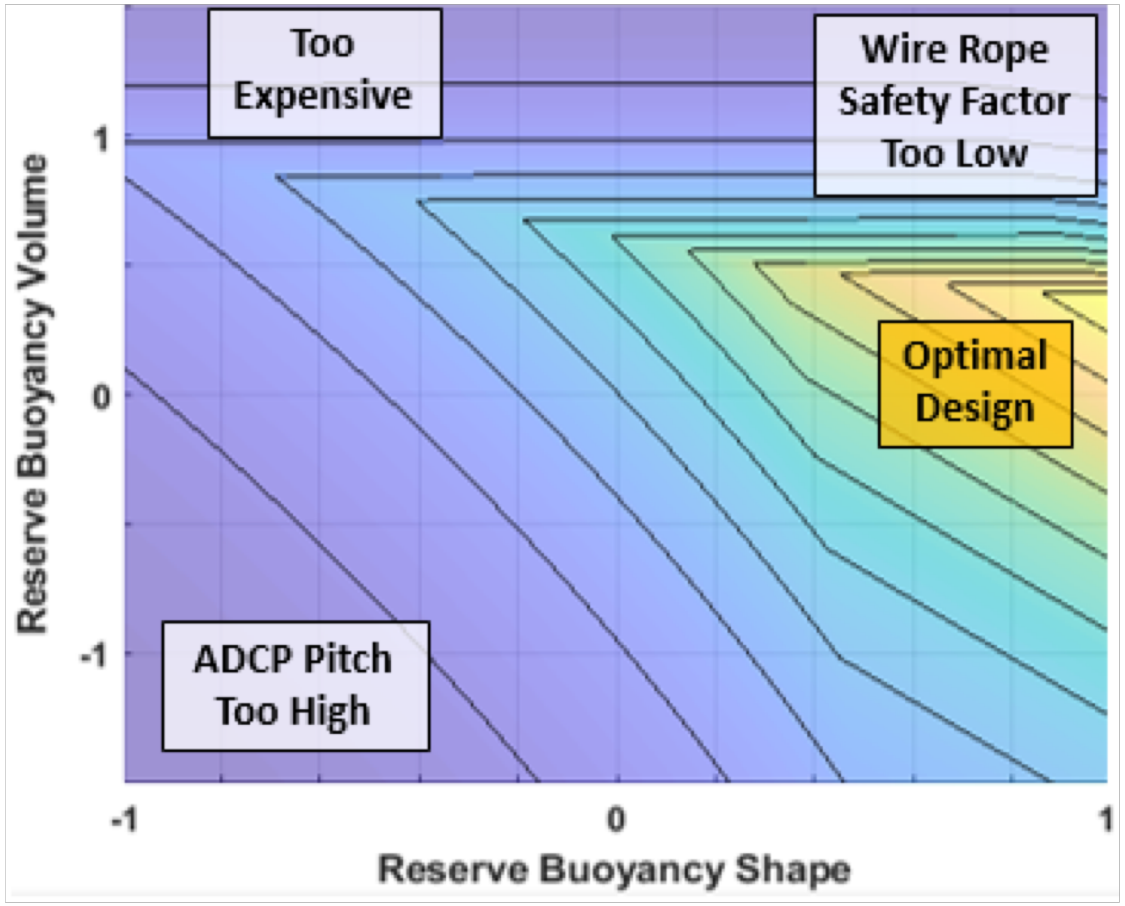
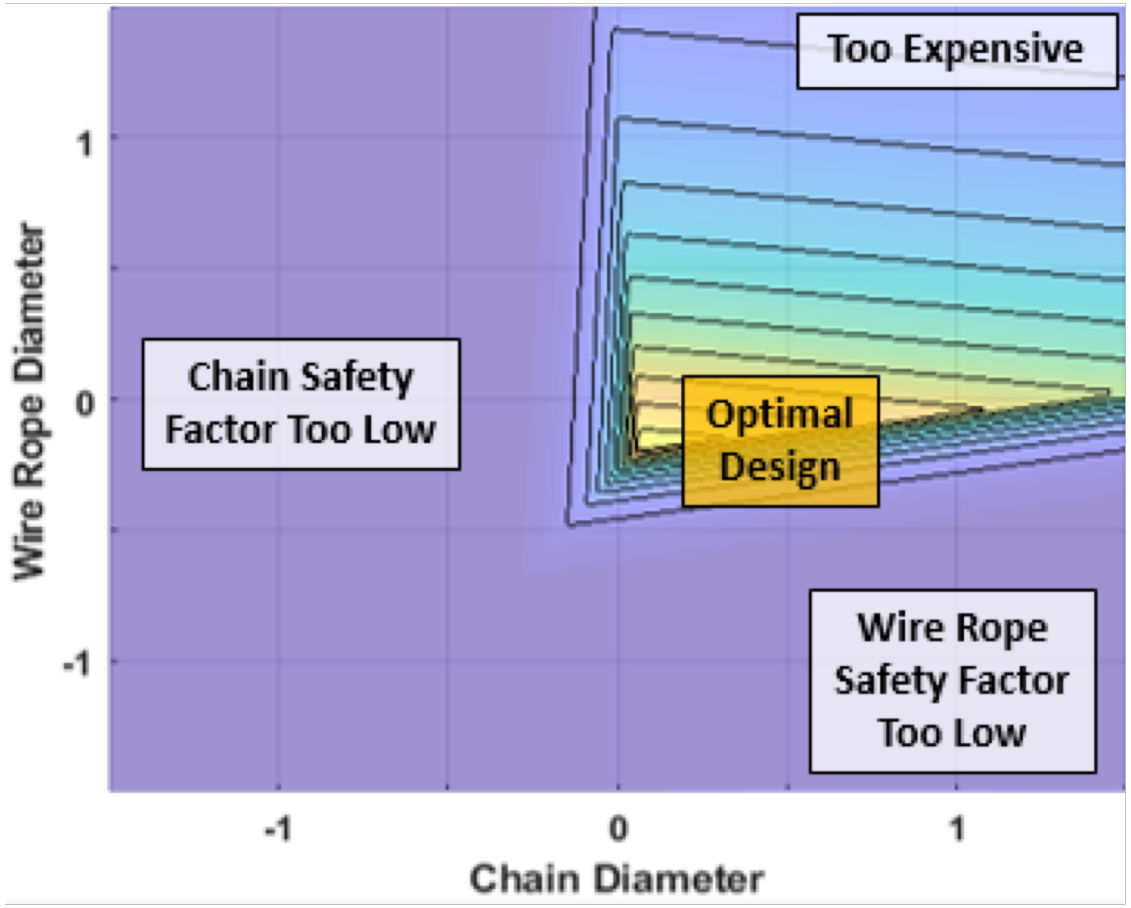
Design of Experiments—Level Setting





Results

Objective	Initial Design	Optimized Design	
Wire Load Safety Factor	2.87 ✓	2.95 ✓	
Chain Load Safety Factor	3.19 ✓	2.53 ✓	
Anchor Sliding	0.002 ✓	0.06 ✓	m
ADCP Pitch	8 ✓	9 ✓	deg.
ADCP Knockover	24.8 X	12.4 ✓	m
Acoustic Release Recovered?	Yes ✓	Yes ✓	
Cost	100% ?	84% ✓	

Conclusion

Combining dynamic numerical modeling with efficient design techniques from other industries yielded a improved performance while decreasing costs.

References and Additional Slides

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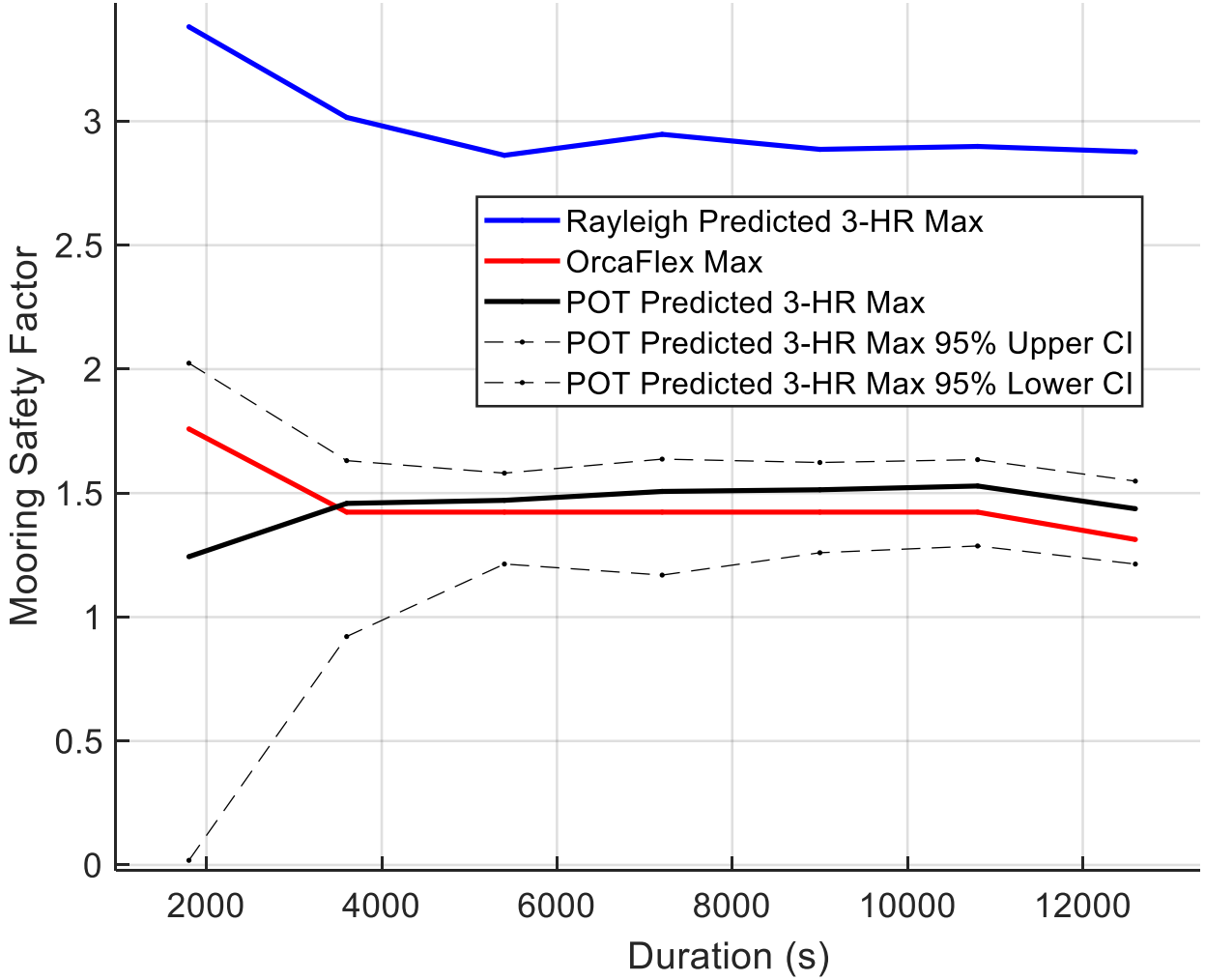
Results—Design Parameters

Design Parameter	Initial Design	Optimized Design
Reserve Buoyancy Shape	Spherical	Elliptical
Reserve Buoyancy Lift	0.603	0.49 N
Anchor Mass	1,500	1,694 kg
Chain Diameter	10	8.1 mm
Acoustic Release Buoyancy	0.237	0.18 m^3
Wire Rope Diameter	10	7.6 mm

Design Method—Sensitivity



Results	Traditional Catenary	
Criteria	Design Wave	Gen. Pareto Dist.
Buoy Load Safety Factor	3.2	0.9
Pitch Factor	4	0.6

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