Offshore Wind Turbines: Extreme Wind/Wave Risk and Regulatory Needs

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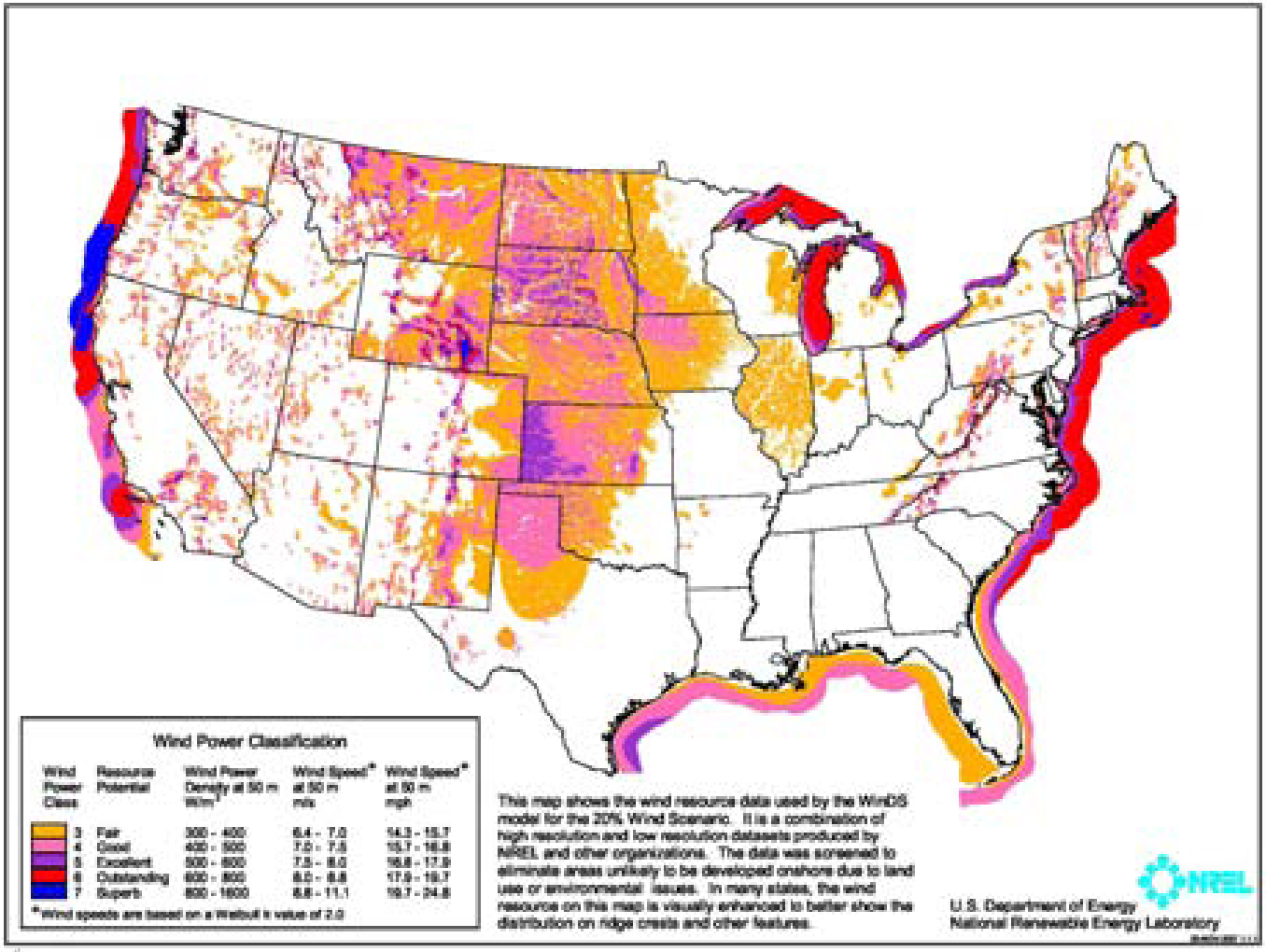
Introduction

- MMI executing a Joint Industry Project on comparing IEC design guidelines for offshore wind turbine to API offshore platform guidelines
  - Guideline comparison for design aspects covered
  - Reliability assessment using both
    - For generic structure at a site
    - For generic structure at multiple offshore sites using local metocean risk
    - For two specific offshore wind turbine designs (monopile and multi-pile) at multiple offshore sites using local metocean risk
- Will offer stakeholders insights into inherent target reliabilities of API and IEC guidelines

Offshore Wind Energy Potential



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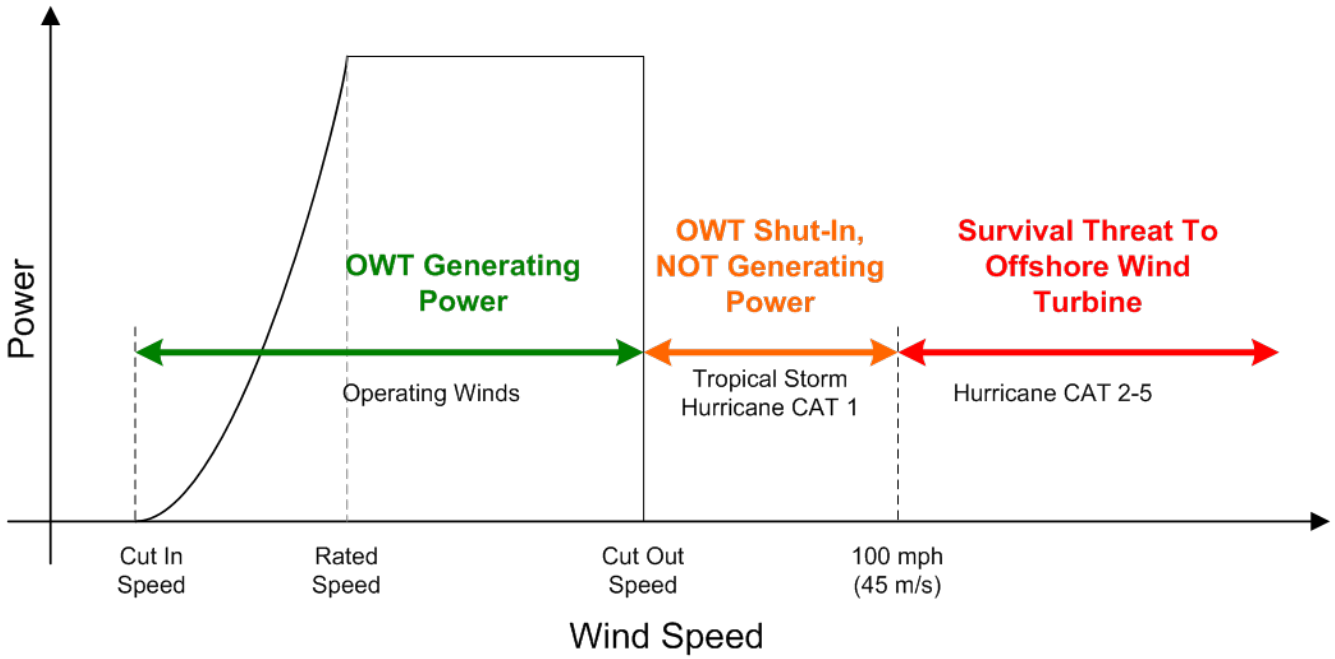
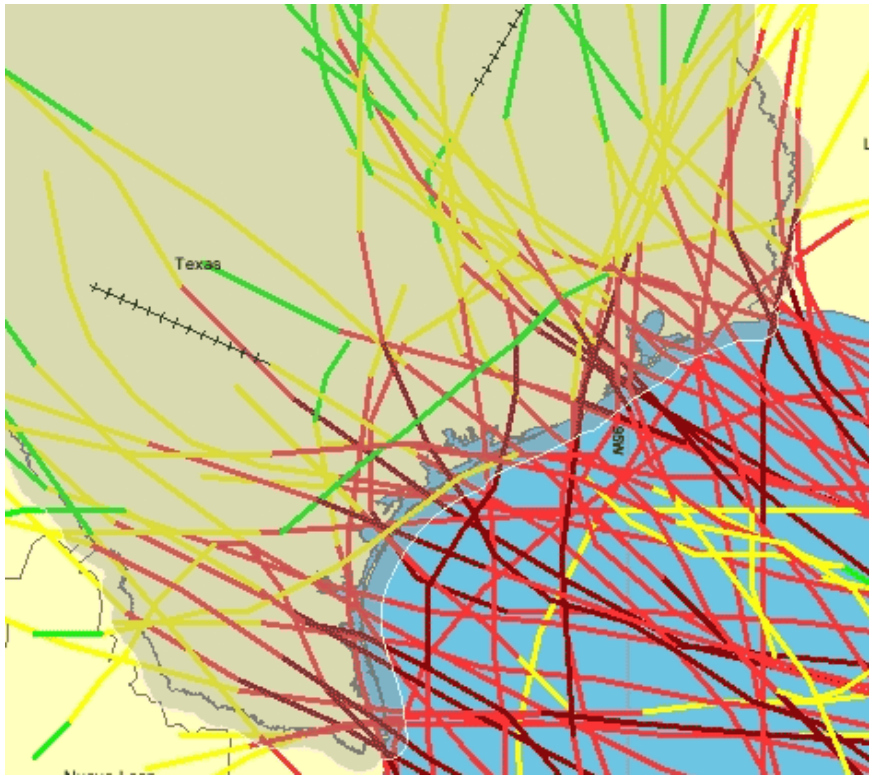
Wind: Source of Power & Threat



3.6MwTurbine cut out speed: 27 m/s = 60 mph

Past Hurricanes near Coast



Cate-gory	Winds (mph)	Winds (m/s)
TS	39-73	17-33
1	74-95	33-42
2	96-110	43-49
3	111-130	50-58
4	131-155	59-69
5	156+	70+

NHC

Category 3-5 storm track
Category 1-2 storm track
Tropical storm track
Tropical depression track
Subtropical storm track
Subtropical depression track
Extratropical storm track
Tropical low track
Tropical wave track
Tropical disturbance track

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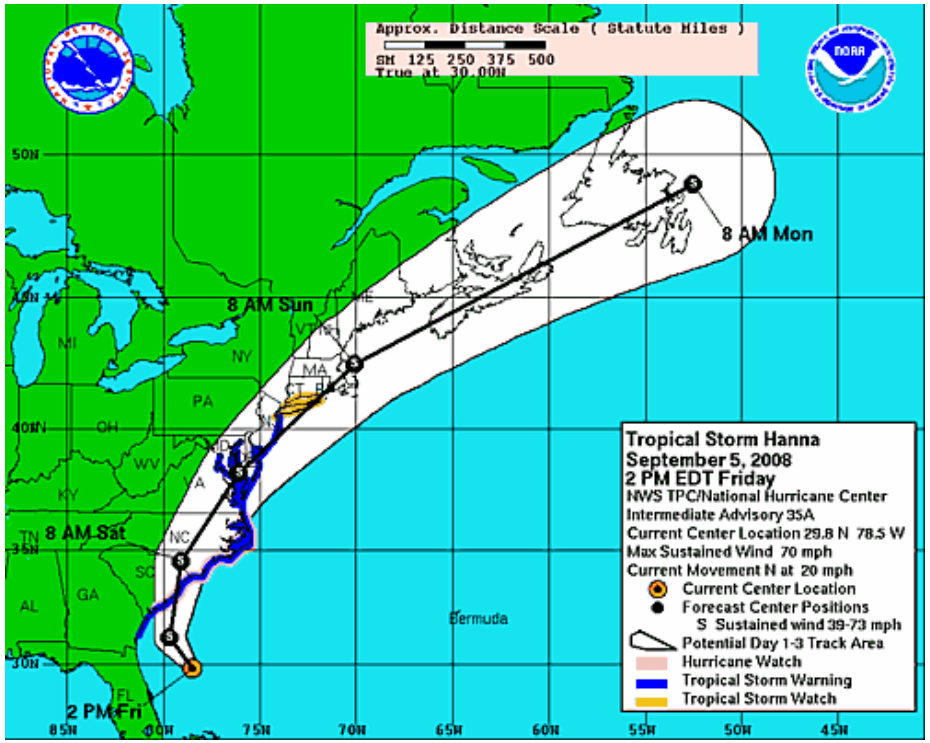
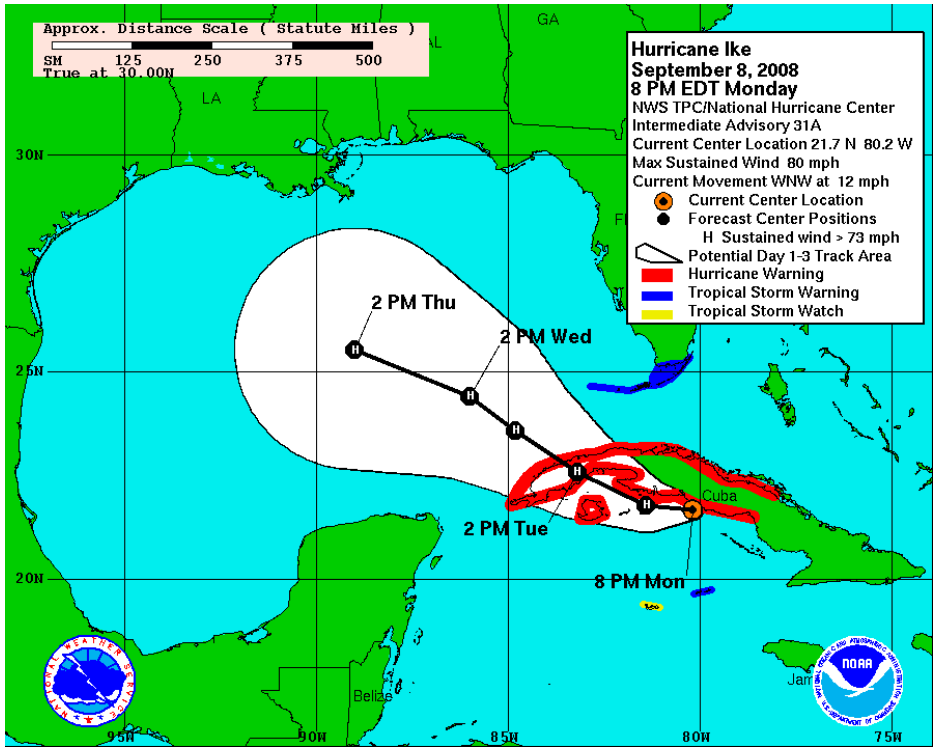
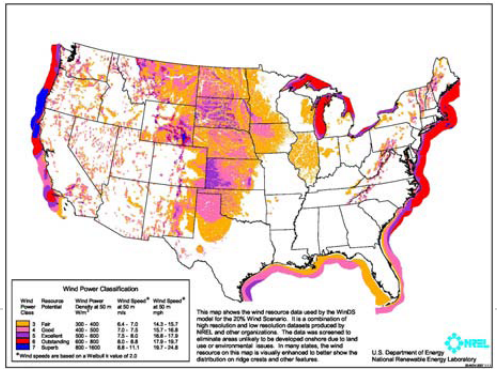
Recent Hurricanes Hanna, Ike







Risk to coastal infrastructure

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What Risk Threshold to Adopt?

- Gulf of Mexico metocean risk being revisited
- The 100-year wave few years ago may no longer be so
  - Indications: In Central Gulf, threat may be much higher (→ 100-year wave height much larger)
- Strategy
  - Decide risk/reliability threshold to adopt for US
  - Devise design "recipe" that ensures threshold or better
- High investment, new technology warrant design to higher risk threshold

Reliability via Recipe

- Metocean conditions – use defined hazard
  - E.g., use an X-year wave, wind, current, etc.
- Design structure with strength and load per recipe (i.e., use implicit safety factors)
  - Implies achievement of target reliability
- Check Reserve Strength (ratio of collapse to design load)
  - High reserve strength implies higher reliability
  - Redundancy in system generally contributes to higher reliability
- 100- or 50-year wave/wind design alone does NOT achieve target reliability

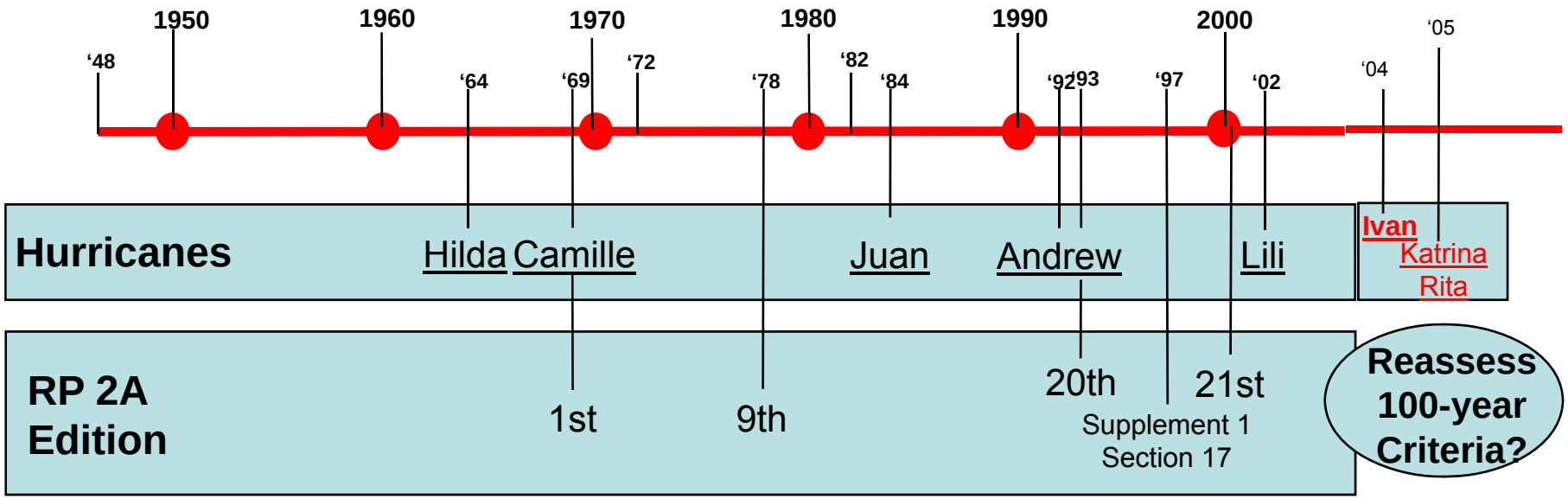
MMS Specific Issues/Concerns

- **50 Year vs. 100 Year Return Periods**
  - **US offshore facilities generally use 100-year (is current public perception of structural safety)**
- **US offshore environmental risk different than North Sea and different in NE US vs. GoM**

- **Fundamental need: Ensure that offshore turbines can withstand extreme storm/hurricane conditions**

Background to API RP-2A

- 1st edition 1969 (WSD) → 21st edition today
- Used to design > 7000 structures!

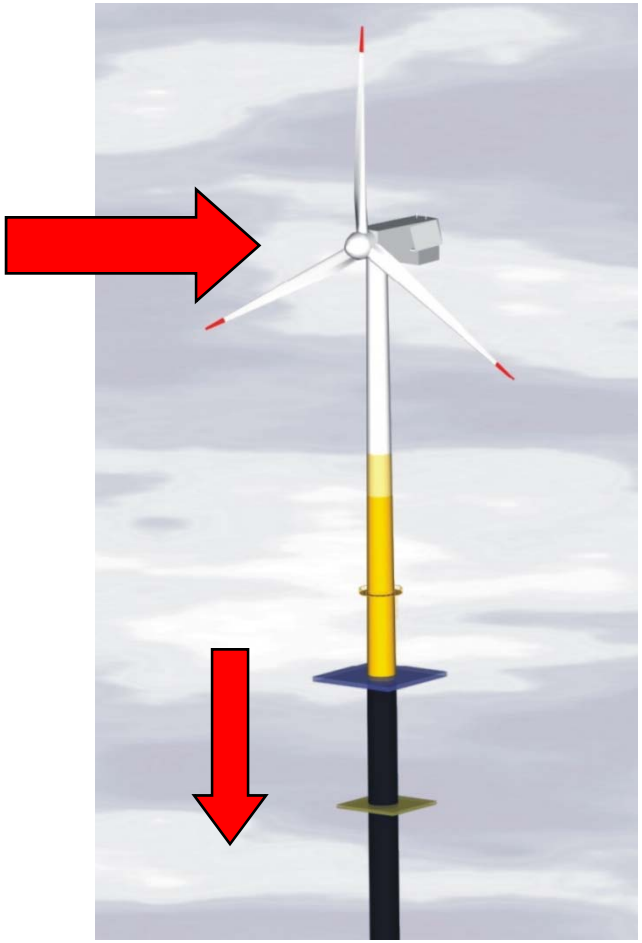


Approach of API RP-2A

- Targeted at offshore oil & gas structures
- Design procedures for structure & foundation
- Methods to calculate loads & structural capacity
- Provides wind & wave data for continental U.S.

API RP-2A does not address…

- Turbine-specific design load cases
- Wind fatigue loading
- Soil-structure interaction for large diameter piles
- Grouted connections carrying significant moment load



Approach of IEC 61400-3

- Comprehensive set of design load cases for turbine support structure
- Uses a Partial safety factor format
- Does not address structural capacity
- Does not provide regional environmental data
- Refers to other codes for turbine machinery & design checks

External conditions: Sea states

	API RP-2A	IEC 61400
Wave height return period	100 years	nominally 50 years
Wave theories	Same: Stokes 5th & Stream function	
Breaking waves	No guidance	Spilling & plunging
Storm surge	Specified for GoM	Required, not given
Current profiles	Tidal	Tidal, wind & surf
Current velocities	Partially specified	Specified

External conditions: Wind

	API RP-2A	IEC 61400
Averaging period	3s, 5s	3s
Reference height	10m	Hub height
Shear profile	Log	Exponential
Turbulence	Log law	Exponential law
Turbulence	1 point, 1 component	Various 3 component
Gust specification	Stochastic	Stochastic & Determ.

Japanese Experience

Miyako region – All 7 turbines failed in typhoon Maemi(2003) (Gust 74.1 m/s)

NOTE:

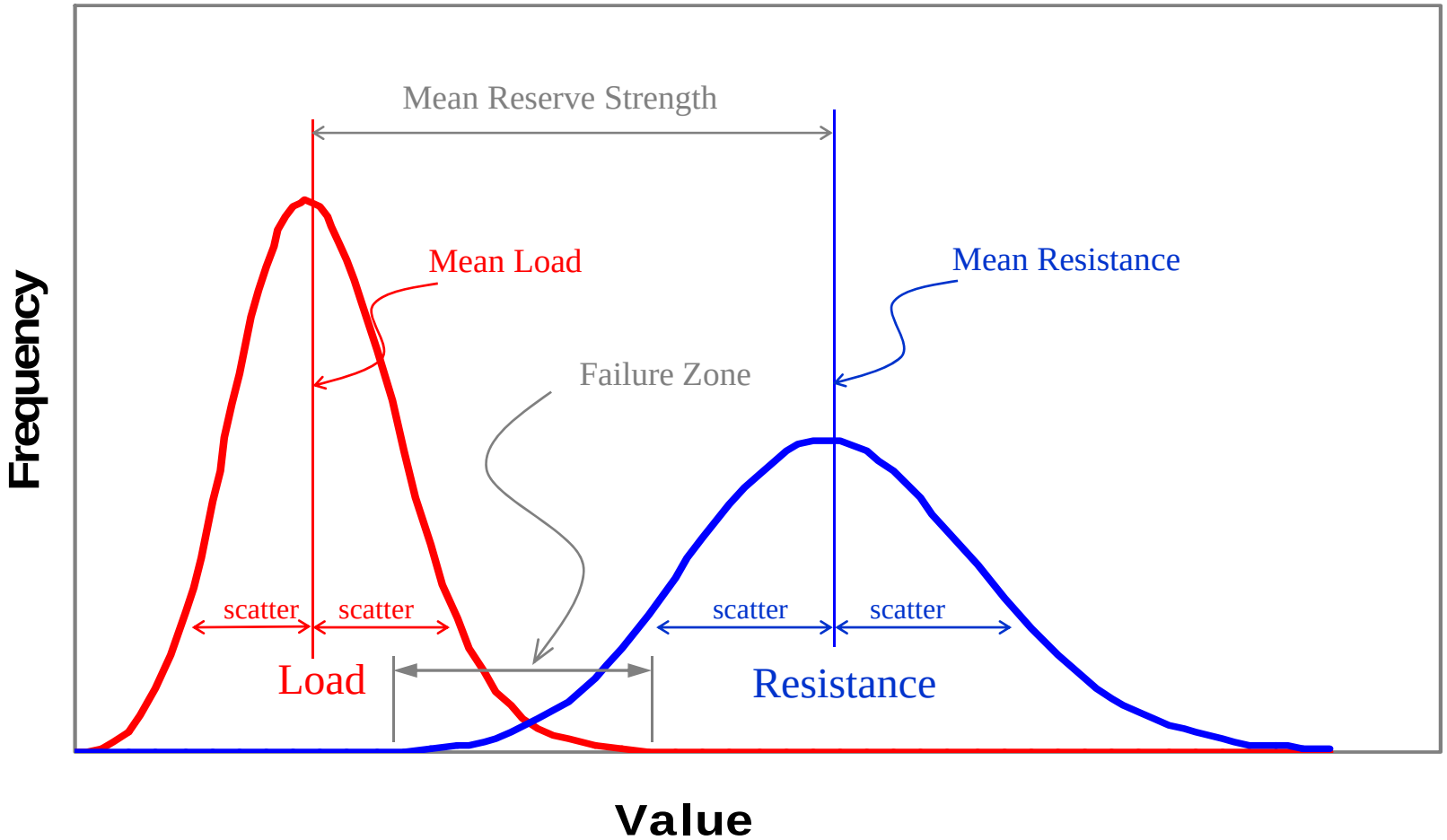
•Turbine failure rate in Japan is 3 times that of Denmark

•Gust winds experienced about 7 times larger than IEC guidelines

Source: Suguro (MHI)

Formulation of Structural Reliability

(Elementary case)

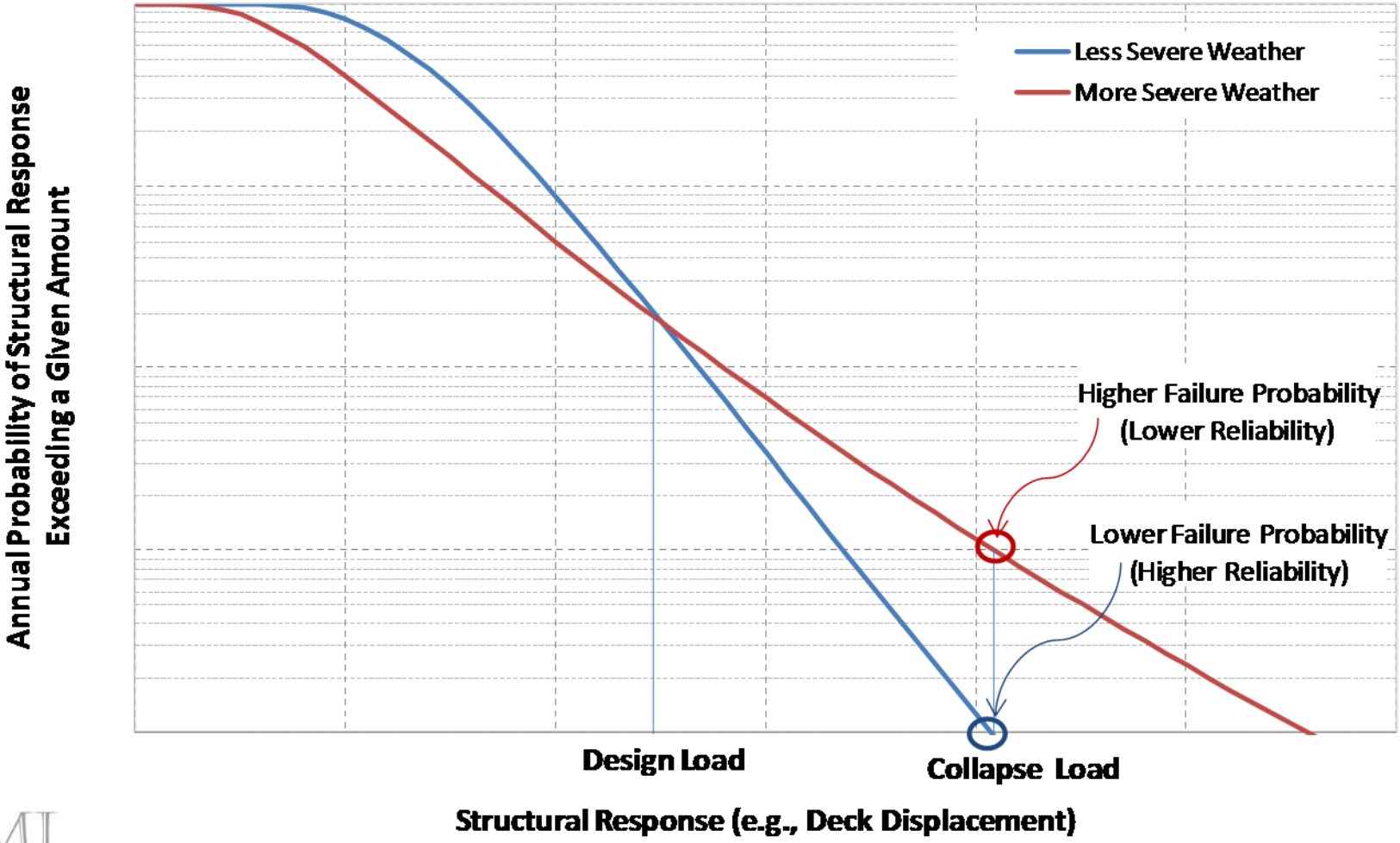


Formulation for General Case

- Reliability = Probability that Strength > Load
- Strength assessment, function of
  - Structure member sizing, load resistance path
  - Redundancy
- Load assessment, function of
  - Metocean (wind, wave, currents) conditions
  - Structure type (transparency to wind/wave)
- Uncertainties in strength & load impact reliability
- Design recipe: Ensure

  "Design" strength > "Design" load

Regional Variation on Reliability



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Summary

- Hurricane threat to offshore wind turbines exist
- Regional variation in threat across US waters
- Different structure types with different redundancies will result in varying reliability
  - Burden on designer to achieve target reliability threshold
- Design guideline recipes contain inherent target reliability
  - Recipe includes X-year wind/wave with use of safety factors
- MMI study underway on use of API and IEC recipes for extreme load reliability assessment