# Design & Installation Improvements to Improve Reliability

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# Preface

- Every location is different.
- Every rig is different.
- Evaluate each situation.

- Available technology
- Maturing technology
- Evolving practices
- Risk management
- Impact management

# State of the Industry

- API RP-2SK
  - Mooring line tension FOS
  - Anchor guidelines
  - Analysis methods
- 10-Year Hurricane
- >10-Year Survivability

# Field Choices

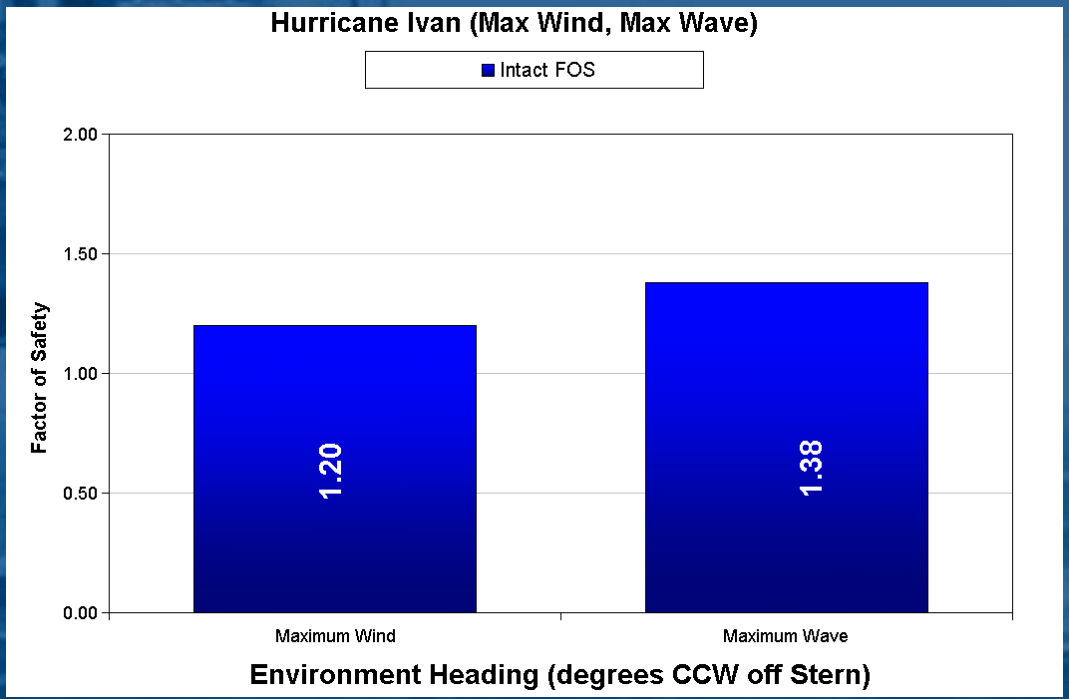
- My Field:
  - Time of year?
  - Pipelines / umbilicals?
  - Other structures?
  - Seafloor conditions?
  - Well program?
  - Shallow hazards?
- My MODU Mooring
  - Conventional system?
  - Anchor change?
  - Preset mooring(s)?
  - Buoyed lines?
  - Synthetic inserts?
  - Probable break point?

# MODU Mooring Failure

- Fairlead Break
  - Components fall to the seafloor
  - Vessel yaw influences leeward line failure
  - Rig floats free, limited seafloor impact
- Anchor Failure
  - Anchor drags in soil
  - Limited vessel yaw
  - Excess loading leads to anchor failure with continuous drag
  - Rig drifts free trailing anchor lines with anchors on the seafloor

# Survivability by Design?

- Can MODU Moorings Survive Hurricane Ivan Events?



# MODU Risk Assessment

- Understand failure
- Quantify probability
- Prudently minimize impact of probable failure method

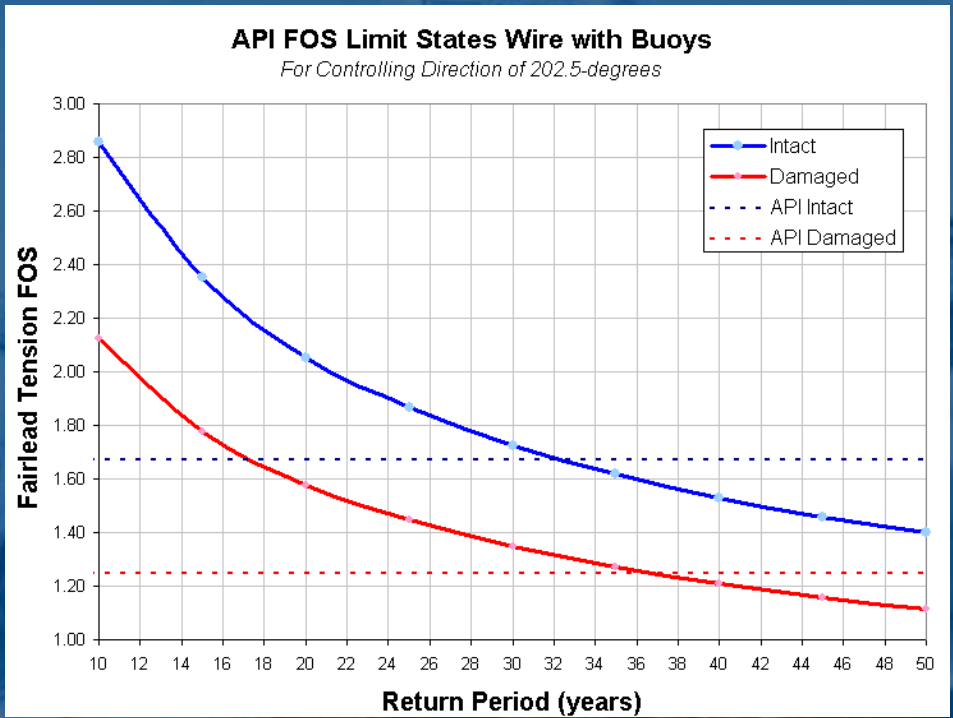
# Pipeline Risk


- Moorings over pipelines?
  - As-is configuration
  - Buoyancy
  - Synthetics
  - Anchor selection
  - Catastrophic failure
- Moorings short of pipelines?
  - Anchor selection
  - Catastrophic failure

# Facility Risk

- Proximity?
- Relative direction?
- Biased mooring system?
- Anchor selection?
- Hold-back systems?

# "Limit State" Analysis




- Quantify system robustness
- Utilize results to determine risk level
- Comparative study with alternate systems / configurations

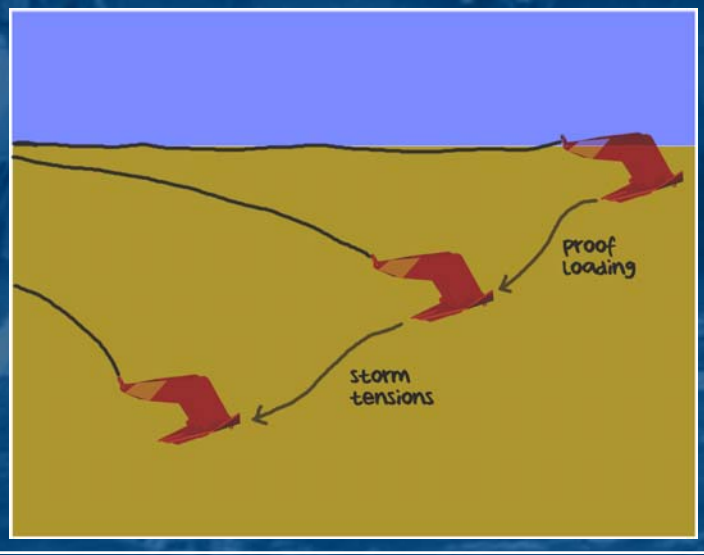
# Anchor Selection

## A pivotal choice

# Conventional Anchors

- 100-year old technology
- Performance well understood
- Capacity limited with size
- Failure with anchor uplift
  - Some residual capacity upon failure
  - Enables load sharing among adjacent mooring lines

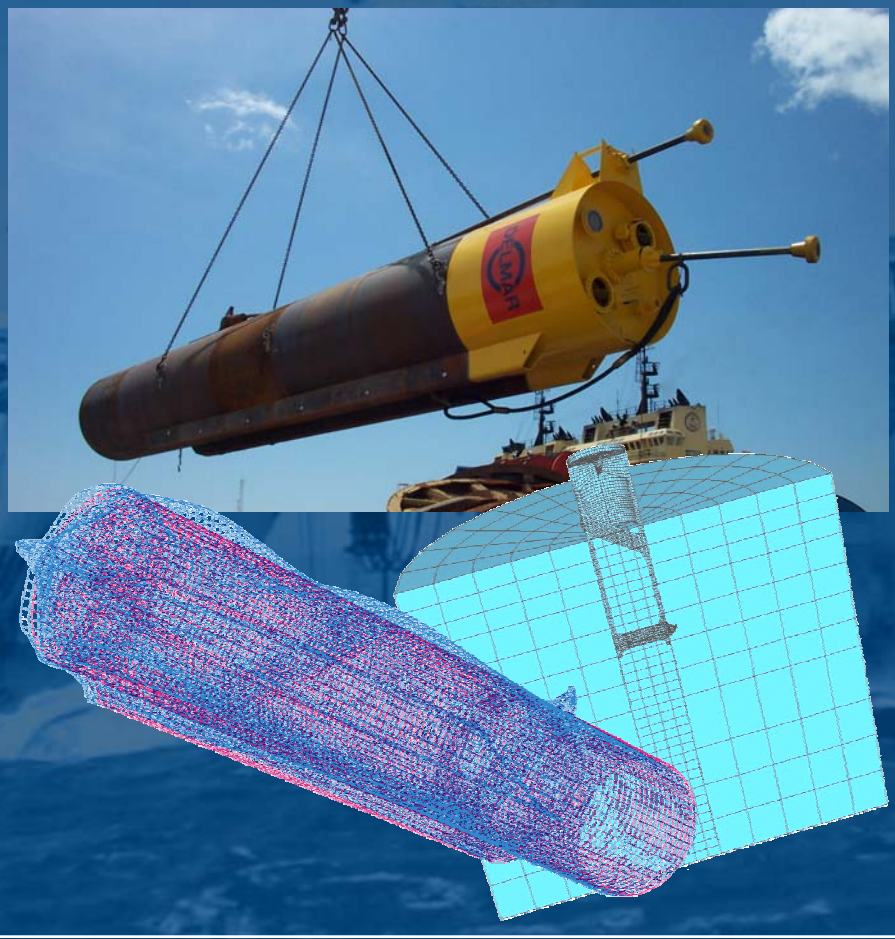
# HHC Drag Anchors




- ~20-year old technology
- Performance well understood
- Large capacity versus size
- Failure with anchor uplift beyond 20-degrees
  - Residual capacity upon failure
  - Enables load sharing among adjacent mooring lines

# HHC Drag Anchors

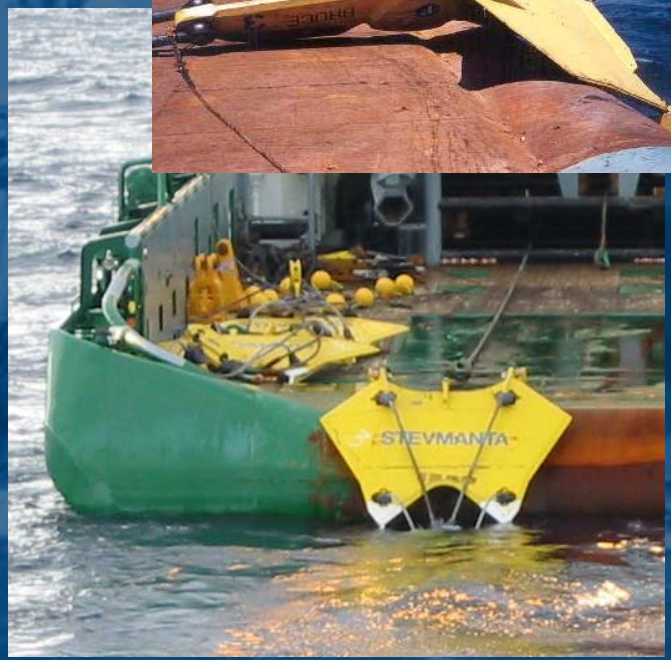
# Suction Pile Anchors



- ~10-year old technology
- Performance understood
- Failure with excess loading
  - No residual capacity upon failure
  - Stationary foundation (no load sharing)
  - Probable failure method is local padeye structural failure

# Suction Pile Failure

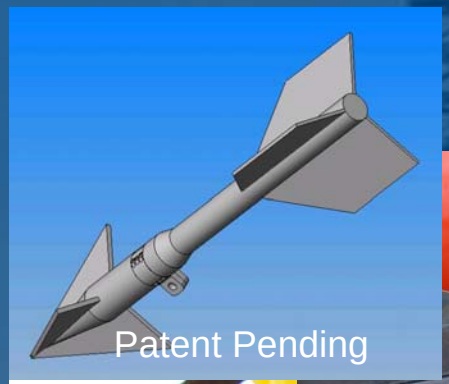
# Vertically Loaded Anchors

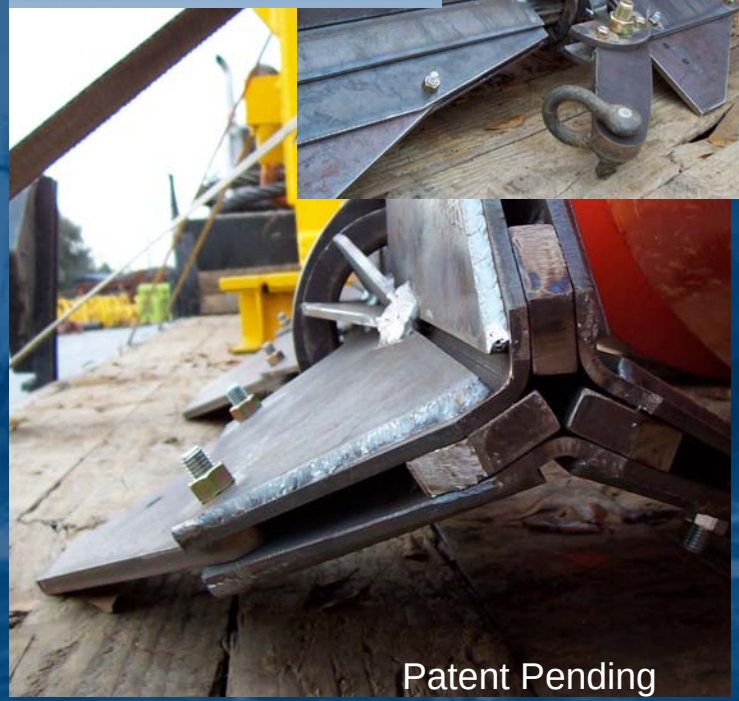



- Maturing technology
- Performance understood
- Failure with excess loading
  - Increasing capacity with load
  - Enables load sharing among adjacent mooring lines
  - Probable failure method is with excessive rotational loading

# Vertically Loaded Anchor

# New Anchors




- Maturing technology
- Performance under evaluation
- Failure with mooring component
  - Increasing capacity with load
  - Enables load sharing among adjacent mooring lines
  - Load arm follows mooring line spread angle

# New Anchors