

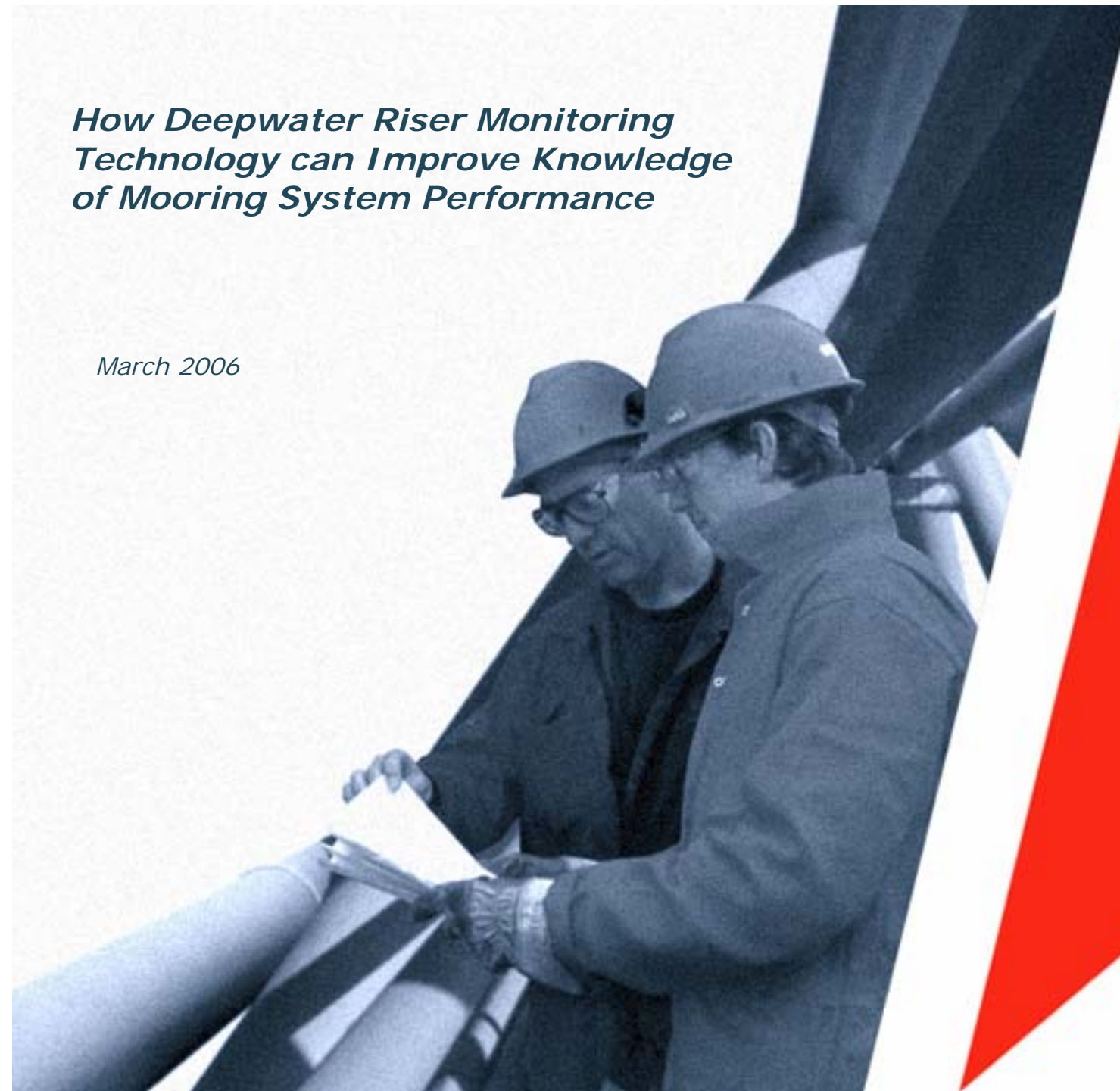


***ACTEON***

***LINKING SEABED TO SURFACE***

*How Deepwater Riser Monitoring  
Technology can Improve Knowledge  
of Mooring System Performance*

*March 2006*



**ACTEON**



## *Criticality of Riser and Mooring Systems*

- There are typically two critical systems that link the seabed to the surface, in floating drilling and production facilities:
  - Riser systems, which are critical in terms of hydrocarbon containment
  - Mooring Systems, which are critical in terms of facility station-keeping
- Riser and Mooring System design is built around complex mathematical analyses, based on numerous assumptions
- Designs are quite often marginal with respect to strength and fatigue, particularly in deeper water
- Achieving confidence in the adequacy of the analytical response predictions is key to ensuring integrity of Risers and Moorings
- Deepwater experience and operational data is relatively limited

## *Riser and Mooring System Analysis*



- The accuracy of analysis results is dependant upon:
  - The ability of the software to adequately solve the problem (software solution capability) and correctly model complex boundary conditions
  - The accuracy of the assumptions inherent within the computer models (e.g. waves and currents, drag coefficients, inertia coefficients, damping parameters, etc)
  - Accuracy of design assumptions regarding vessel motions, environmental data, produced fluids etc
- The above assumptions are subject to considerable degrees of uncertainty, any of which may have a dramatic effect on the accuracy of predictions
- This can lead to over-design (and probably higher than necessary cost), or under-design (and possible failure)



## *Riser and Mooring System Loads*

- Loading on risers and moorings may comprise a complex combination of:
  - Drag loads due to currents, varying through the water column
  - Drag and Inertia loads due to waves
  - Wave Frequency vessel motions (first order motions)
  - Slow drift vessel motions (second order motions)
  - Wind Forces
  - Vortex Shedding
  - Thermal loads
  - Pressure loads
  - Etc
- One of the key inputs to any mooring or riser analysis is environmental wind, wave and current data
- This will typically be based on statistical analysis of available weather information
- This environmental data will be a key analysis input and may require a large number of load cases to be considered
- The actual conditions that do occur may well be somewhat different to the predicted data, used in the design process
- There is significant volume of evidence to indicate that we are not particularly capable in predicting environmental data (e.g. the 2005 hurricanes in the GOM)

## *Riser and Mooring System Considerations*

- Significant considerations may include:
  - Vessel motions
  - Wear
  - Corrosion (global and pitting)
  - Effects of sour service on weld performance
  - Structural overload
  - Fatigue endurance uncertainty (e.g. weldments, stress concentrations, S/N curves, connectors, fracture performance etc)
  - Fairing and strake performance (VIV Suppression)
  - Fabrication quality and ability to detect significant defects
  - Installation damage
  - etc

## *Local and Global Response Monitoring*



- Monitoring of Riser and Mooring Systems has three objectives:
  - To establish if the actual local responses occurring in the field, for known combinations of loading, are within those predicted by analyses (KPI – Key Performance Indicators)
  - To collect data that allows the global response to be determined and correlated with predictions, and the data to be fed into integrity management processes
  - Determine and log the accumulation of fatigue damage with time, and ensure that the fatigue capacity of the systems are not exceeded
- Riser and mooring system response is complex
- Responses at critical locations are often difficult to accurately predict
- Preferred Monitoring approach
  - Monitor local response at key locations in the system
  - Determine predicted global response using analytical domain
  - From global response determine predicted response at critical locations
  - Compare critical location response with analytically derived Key Performance Indicators

## *Monitoring System Specification and Design*



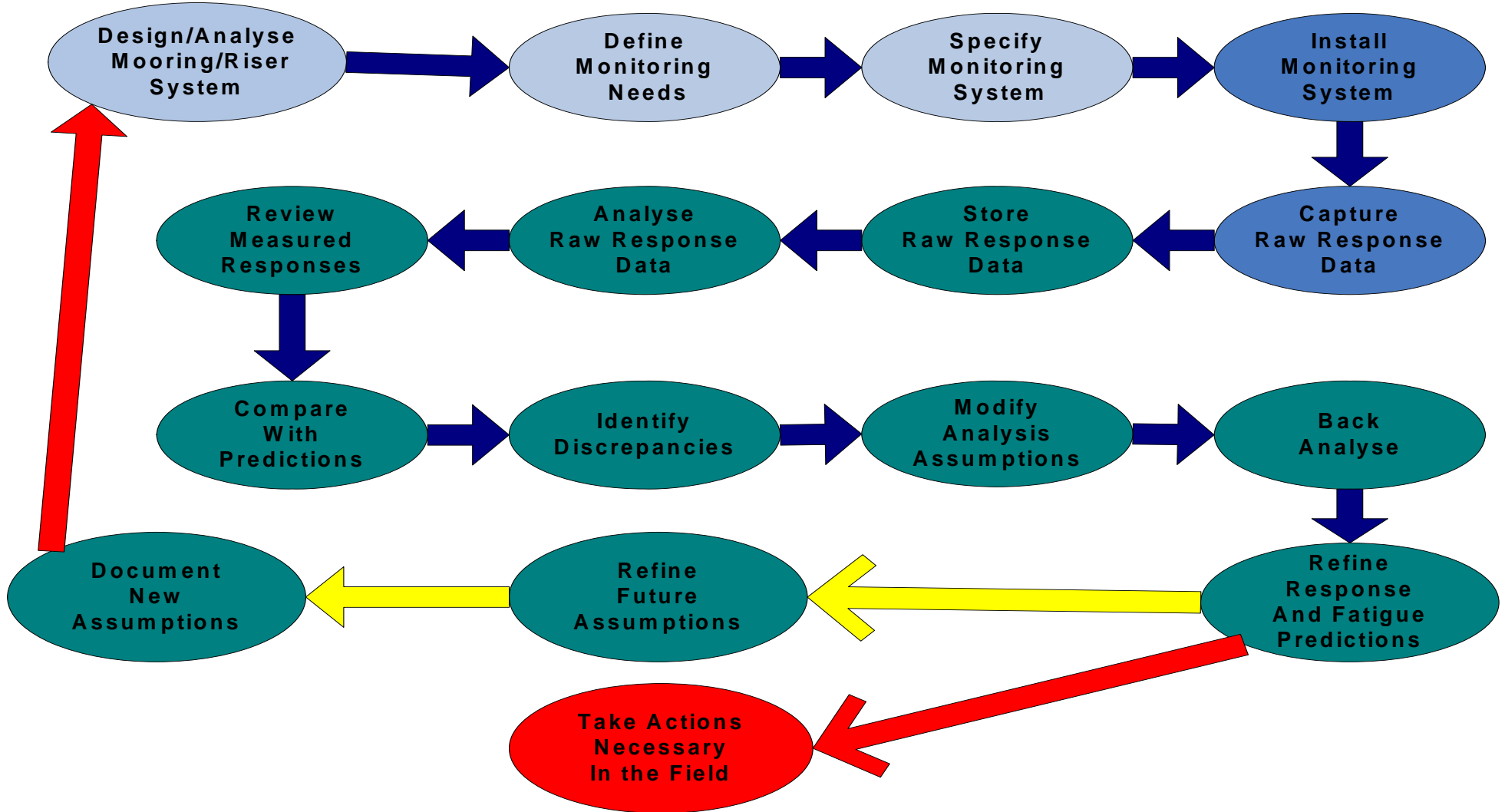
- In order to gain benefit from a riser (or mooring) monitoring system, it must be suitable for the intended purpose
- To achieve this the following must be clearly understood:
  - Structural design and hardware in the system to be monitored
  - Expected responses of system to be monitored
  - Aims of the monitoring system
- Monitoring system design must ensure that:
  - Sufficient data is captured at the appropriate locations, so that global response can be determined
  - Not interfere with operations/installations or itself impact the global response
  - Suitable storage and/or transmission method(s) are included
  - Data processing methods (to extract responses from recorded information) are clear and achievable



## *Monitoring Similarities*

- In many respects, mooring and riser analyses and responses are similar
- Consequently, many of the measuring, data processing and back-analysis methods can be common
- Riser monitoring is now becoming more commonplace and routine
- A range of monitoring equipment, and data processing techniques, have been developed for riser systems
- There is no reason why monitoring could not be similarly commonplace on mooring systems.

# Monitoring Approach



## Recent/Current Monitoring Programs

- Steel Catenary Risers
  - Agip Allegheny, 600m GoM (x2)
- Drilling Risers
  - BP Sakalin 100m
  - BP Algodual, Brazil, 1300m
  - BP Rebecca and Reki, Brazil, 1000m
  - BP Schiehallion, WoS, 360m
  - BP Svinoy and Assynt, Faroes, 1000m
  - Total Donggalla HP Drilling Riser 1800m
  - Thunder Horse Enterprise (1800m)
  - Atlantis DDII (1800m)
  - Thunder Horse PDQ (Underway)
- Top Tensioned Risers (Production)
  - BP Holstein (1800m)
  - Conoco Magnolia
  - BP Mad Dog
- Completion Risers
  - BP Thunder Horse Enterprise CWOR1 (1800m)
  - BP Thunder Horse PDQ CWOR2 (1800m) (Underway)



## *What has been learned (so far) from riser monitoring?*

- A number of conclusions relating actual to predicted responses – typically project specific – very useful for analysis calibration
- Design tools can overestimate fatigue damage, possibly by between 10x to 100x
- Identification and successful resolution of serious issues arising through design/installation phases
- Rapid confirmation of system integrity following (possibly unexpectedly) extreme storm events
- Data fed into optimised (and therefore cost effective) Integrity Management programs
- Increased confidence in ongoing riser integrity



## *How can System Responses be measured ?*

- Strain Measurement - Strain gauges, Fibre Optic gratings, Fibre Optic curvature mats, etc. Main issues are
  - Location on pipe surface – interface issue with coatings
  - Reliability – sealing, bonding fatigue, wire damage, calibration
- Riser Flexjoint/Balljoint angles – applicable to drilling risers
- Motion Measurement - Accelerometers, Inclinometers, Angular Rate
  - Non intrusive, corrosion resistant, easy to seal/install
  - Highly reliable
  - Cost effective
  - Small weight and size – possible to deploy and recover by ROV



## *Preferred Data Gathering Options*

- “Simplistic” Methods, using stand alone motion measurement data loggers
  - No online data
  - Data non synchronised
  - ROV recovery required
  - Onshore data processing
  - Lowest costs and simplest interface
  - Good for fatigue monitoring
- Comprehensive Online Monitoring
  - Online data and offshore processing
  - Data synchronised or partially synchronised
  - Installation impact – needs to be fitted when system installed
  - Highest cost
  - Rapid use of data e.g. after a storm
  - Assistance with operational decisions

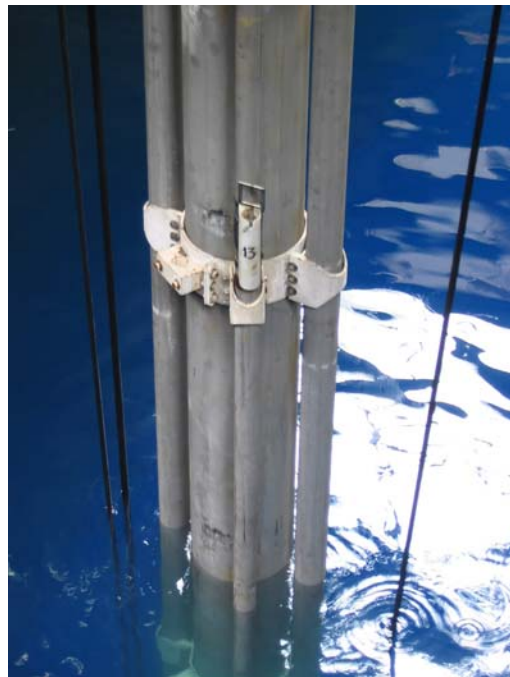
## *Stand Alone Instrumentation – Main Issues*

- Lowest cost solution
- Rapid mobilisation
- Minimum offshore impact
- Provides essential data
- 2H Capability / Scope
  - Pre-analysis
  - Appropriate sensor selection
  - Optimised monitoring plan
  - Riser interface design
  - Installation & offshore support
  - Data and signal processing
  - Reporting and Conclusions



# Typical Drilling Riser Monitoring

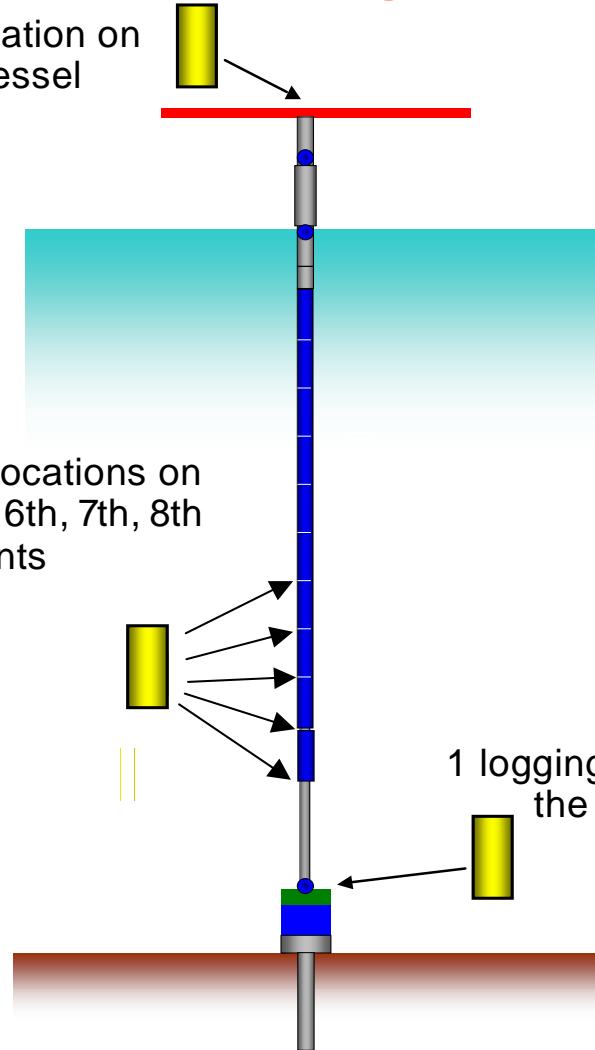
1 logging location on the Vessel



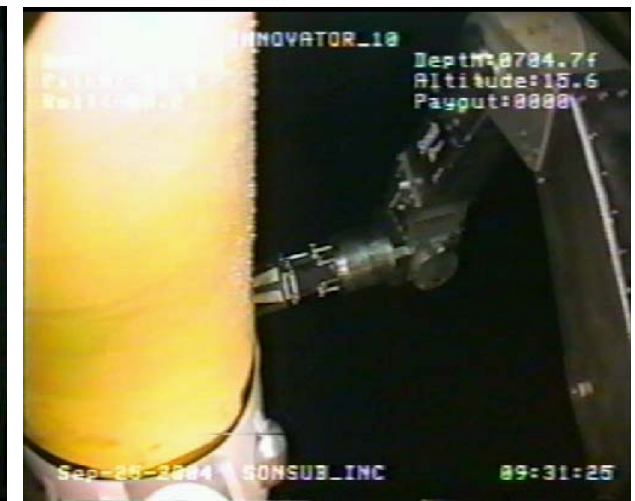
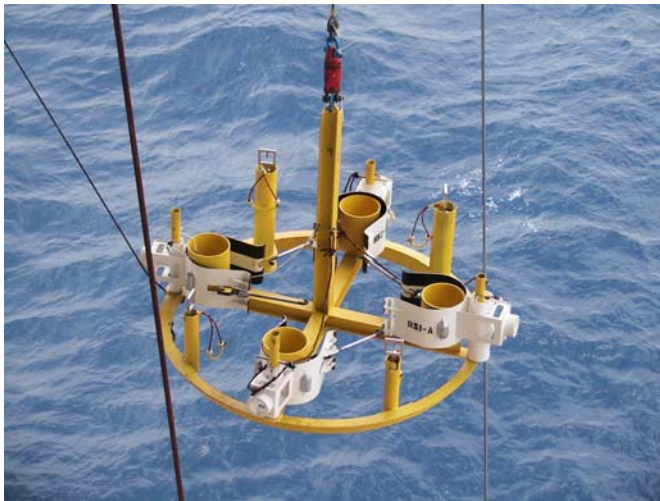
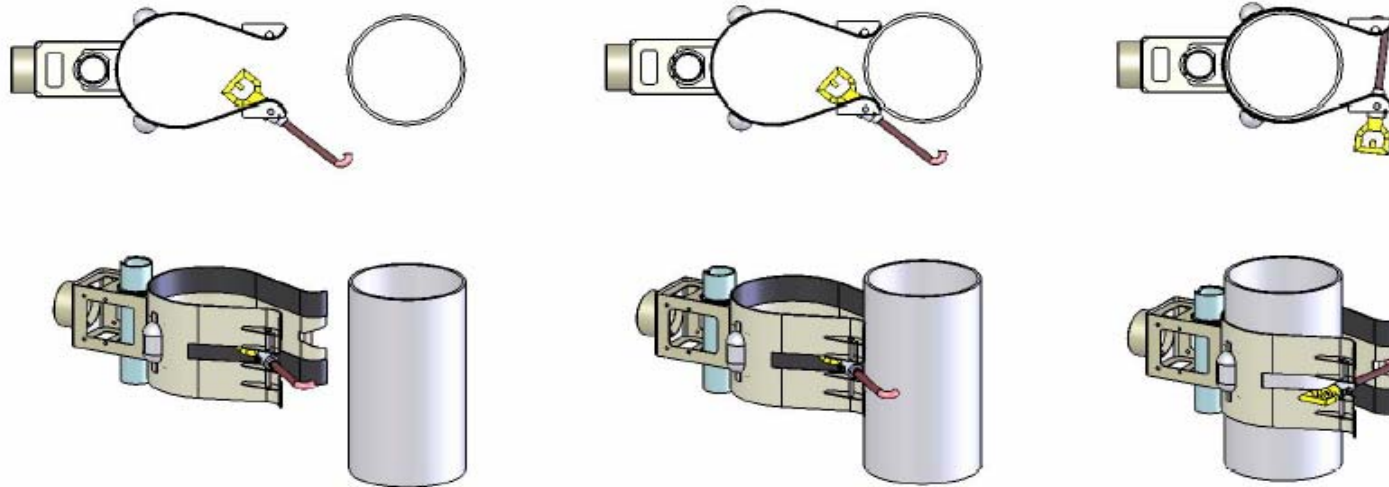
5 logging locations on the 4th, 5th, 6th, 7th, 8th joints



1 logging location on the LMRP

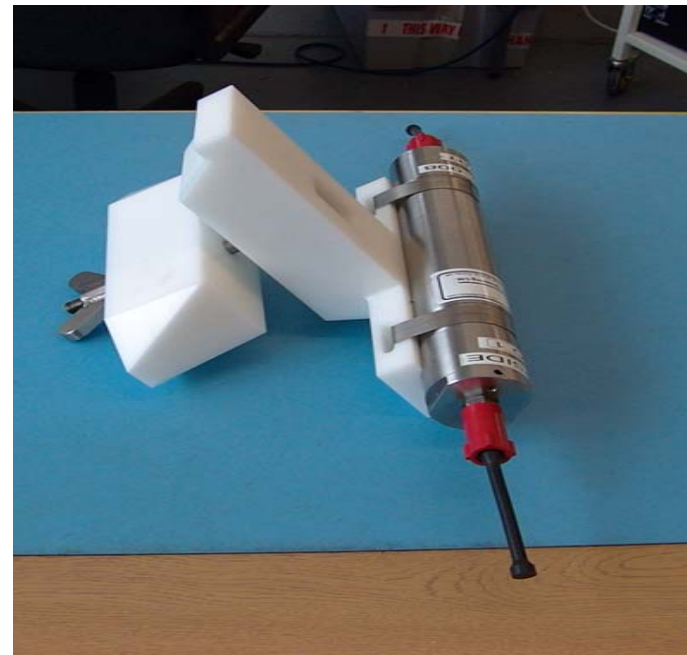
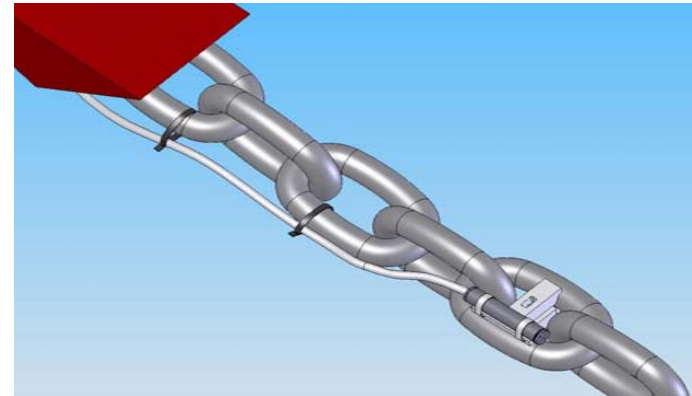


## ROV Installed Loggers and Brackets – BP Holstein/Mad Dog

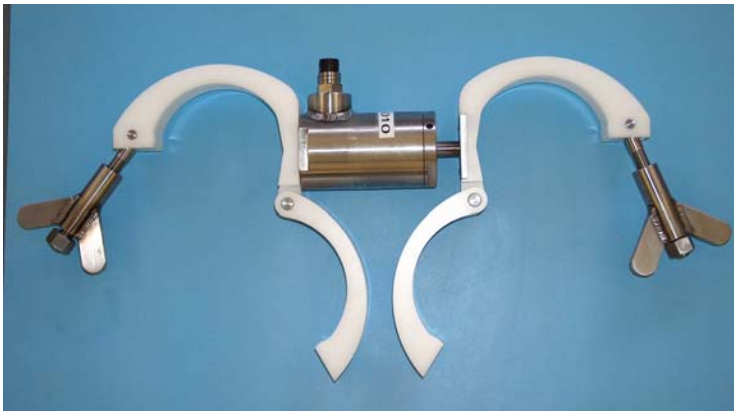
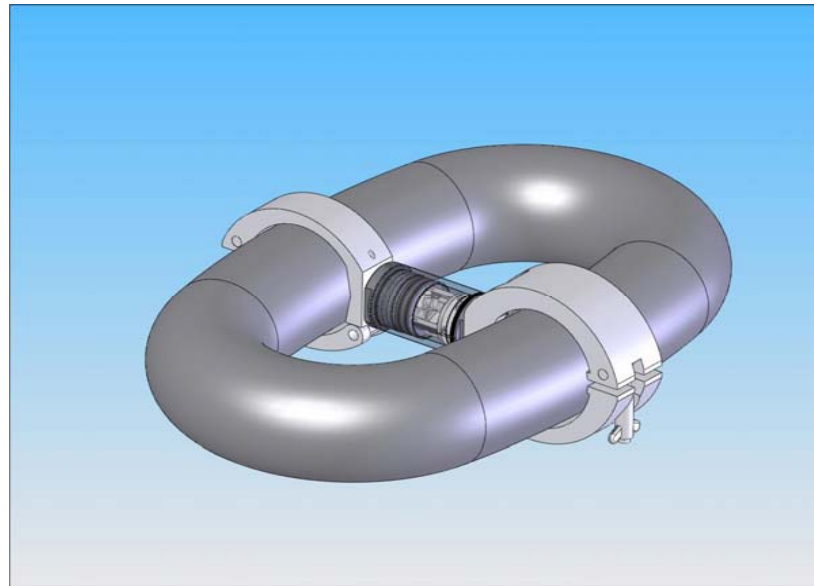


## Mooring Chain Angle Monitoring

- Ease of diver attachment
- Angle measured using accelerometer
- ADXL203
- Angle resolution  $<0.1\text{deg}$
- Tension resolution typically 1-2Te
- Instrument error  $<0.5\%$
- System error  $\sim 0.5\%$  (due affect of waves)
- Total error  $\sim 1\%$  (for 95% seastates)
- Worst case error  $<5\%$  (averaged min/max)
- Catenary or taut leg



# Mooring Chain Dynamic Tension Monitoring





## Summary

- The benefits of riser monitoring are starting to be realised, these being:
  - Unexpected responses have been discovered and understood, resulting in improved analyses
  - Responses have been correlated to back-analyses, reducing assumption uncertainty for future work
  - Cases of overload, which might have gone undetected, have been identified
- If monitoring programmes are to be successful, then:
  - The monitoring needs to be well planned and implemented
  - The response(s) to be monitored must be well defined and understood
  - The monitoring equipment needs to be capable of capturing the required responses
  - The storage and/or transmission capabilities of the monitoring system must be adequate
  - Data processing requirements need to be identified, planned and resourced into the project
  - Back-analysis requirements need to be identified, planned and resourced into the project
  - Conclusions from the back-analysis results need to be well documented, communicated and incorporated into future work



## *Summary (cont'd)*

- Much of the experiences from riser monitoring could be equally well applied to mooring monitoring
- Riser monitoring equipment and techniques are available, and are becoming increasingly field proven
- Such techniques and equipment could equally well be applied to mooring monitoring
- Mooring monitoring could become a more routine operation, in the same way that riser monitoring is becoming more routine at the present time
- The benefits that mooring monitoring would produce are:
  - Verification of present analysis methods
  - If present methods cannot be verified, new methods could be developed
  - Improved predictions of extreme responses
  - More reliable mooring systems
  - Ability to “predict” when mooring maintenance is necessary