



## **OPERATIONS**

# **The Use of Safety Moorings in DP Operations**

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## On the use of "safety mooring" in DP applications



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**Kongsberg Maritime**

# Background

- Relative DP operation
  - Fixed structure
  - Floating structure
- Need to improve safety of operation
  - Blackout
  - Drive-off
  - Drift-off
- Mooring alternatives
  - To sea bed
  - Via support vessel
  - Safety hawser



# Relative Positioning

## Free floating vessel

- ROV vessels
- Platform Supply Vessels
- Accommodation vessels
- Diving vessels
- Construction vessels

## Vessel "connected"

- Shuttle tanker loading
- Heavy lifting



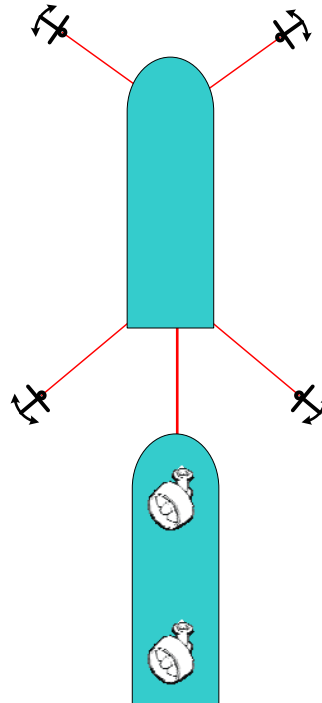
# Configurations

From bad ...



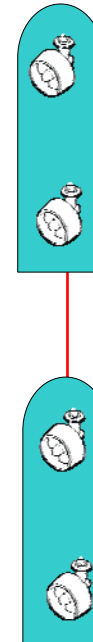
Case #1

... to worse ...



Case #2

... to disaster



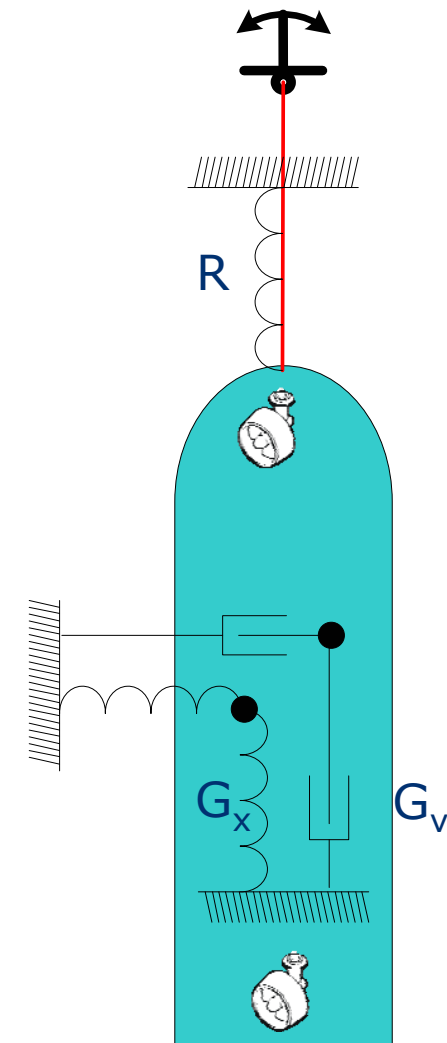
Case #3

# Basic problem

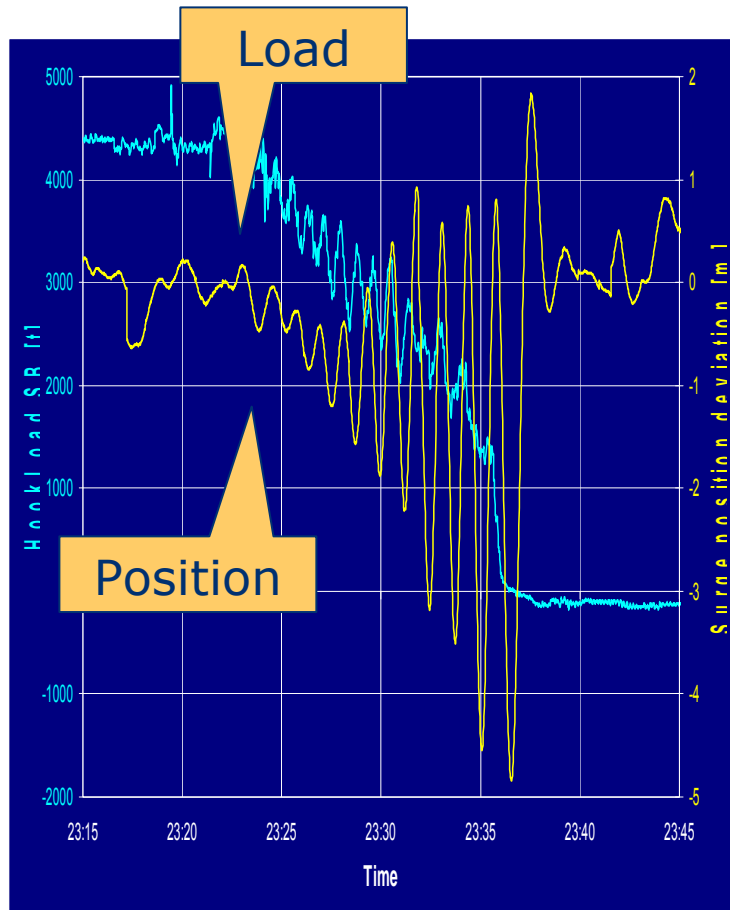
- Mooring force is unknown
- Mooring restoring stiffness unknown
  - May be high
- Relationship restoring – damping violated
  - May be fixed if mooring known

$$G_v = 2\xi\sqrt{m(R+G_x)}$$

- DP and mooring may “fight” each other
- Relative DP
  - Reference may move
- Special “anchor assist” functionality available
  - Can not change physics .



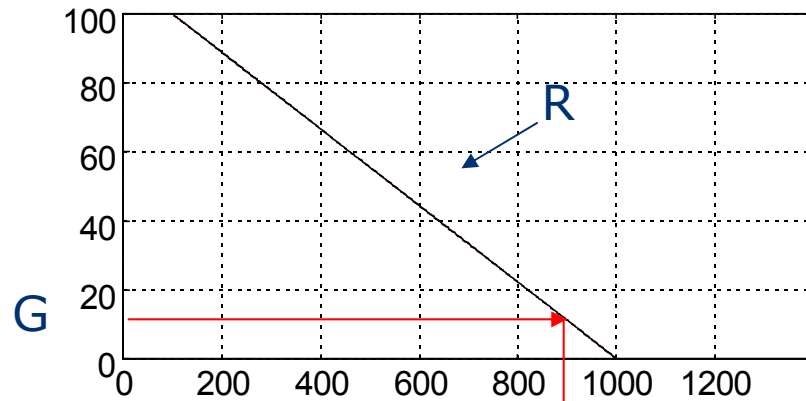
# Heavy lifting



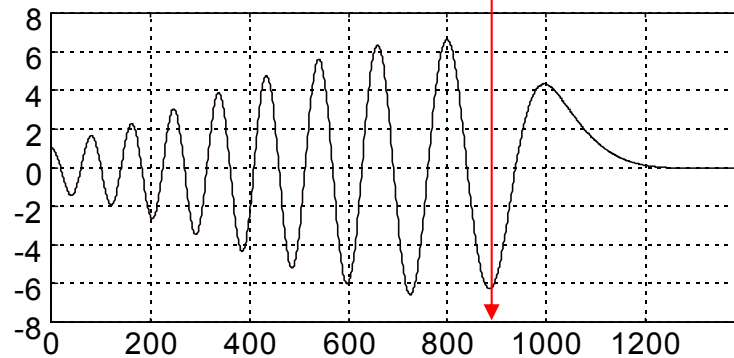
- Oscillations due to interconnection
  - Too large DP bandwidth
  - Relative position measurements do not help
  - Special severe when lifting to moored structure
- Very different from free floating bodies

# Mooring and DP

## Mooring stiffness

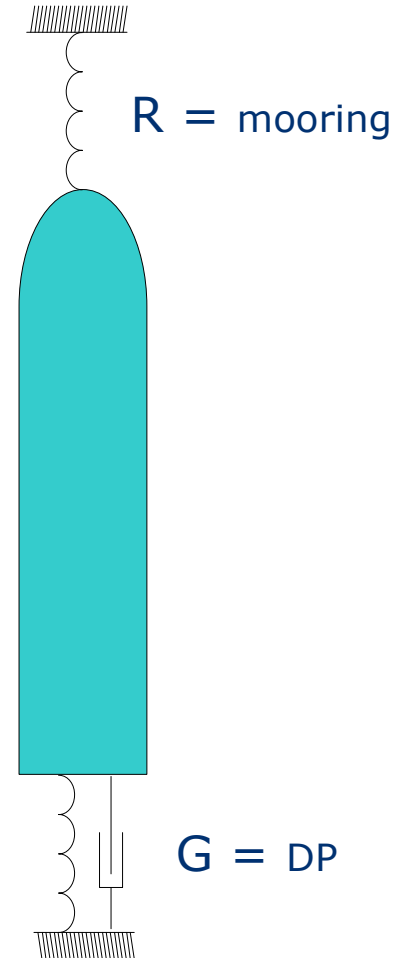


## Motion



Time

OK when  
 $R \leq G$

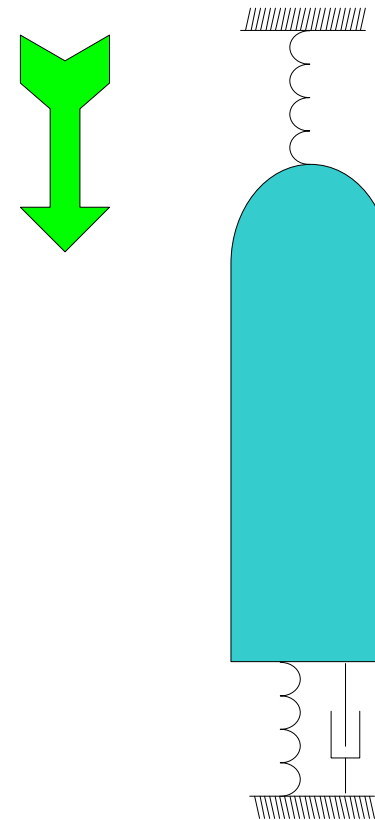




# Case #1

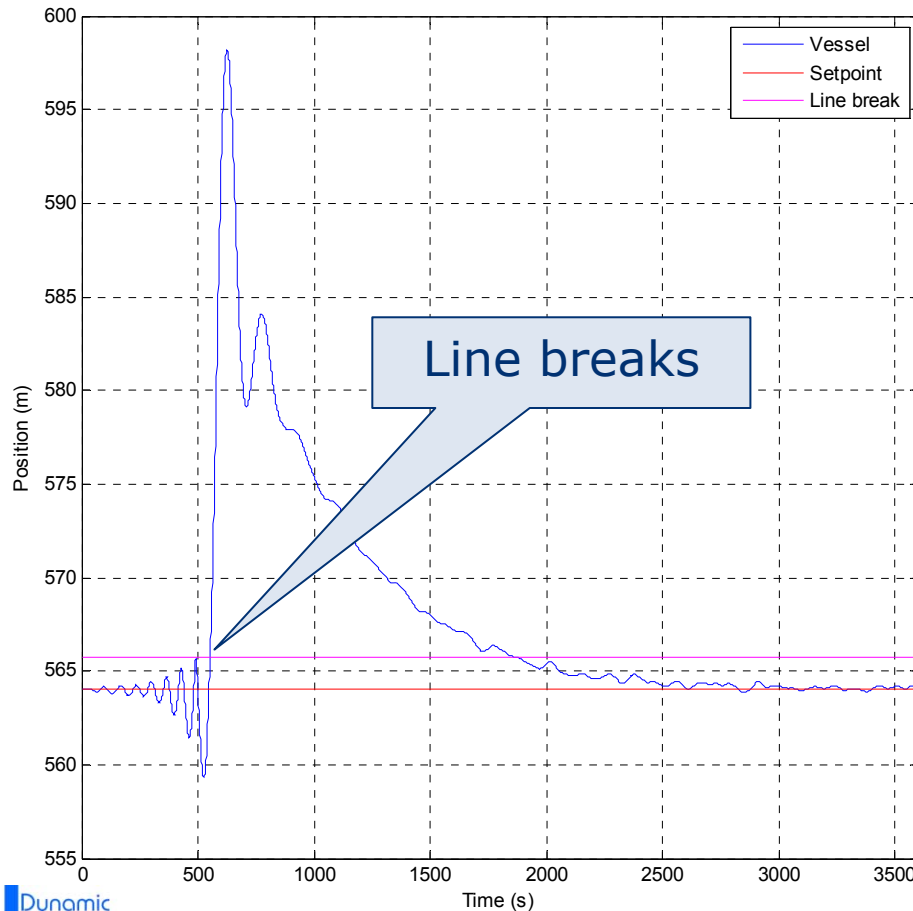
## Fixed mooring

- Mooring must be pre-tensioned to assure stability and avoid collision if blackout
  - Define minimum restoring stiffness
  - Define maximum restoring stiffness
  - Offsetting by thrusters (if needed)
  - Stiffness is generally unknown
- Stability problem if mooring stiffness exceeds DP stiffness
- Anchor dragging severe problem
- Line break disaster



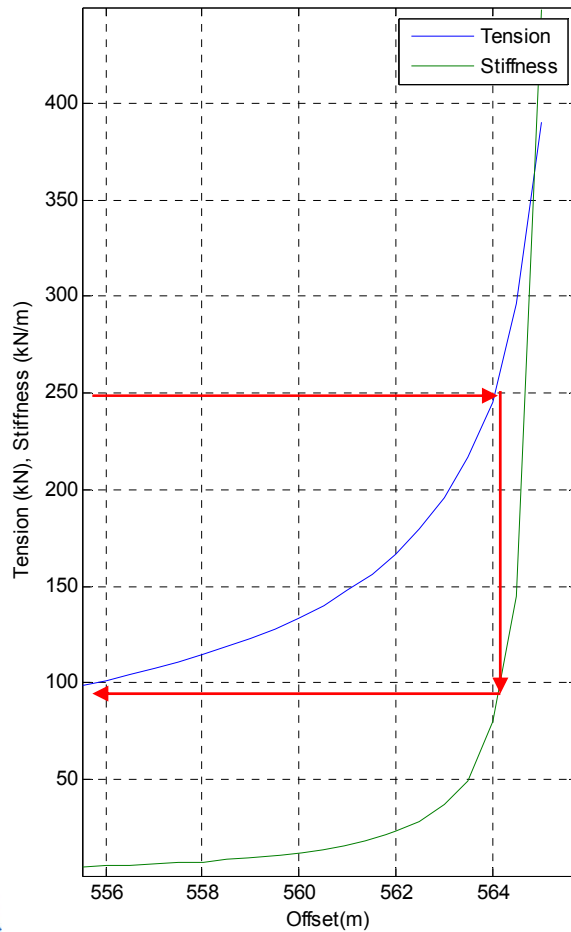
# Case #1

## Single anchor moored - Disaster



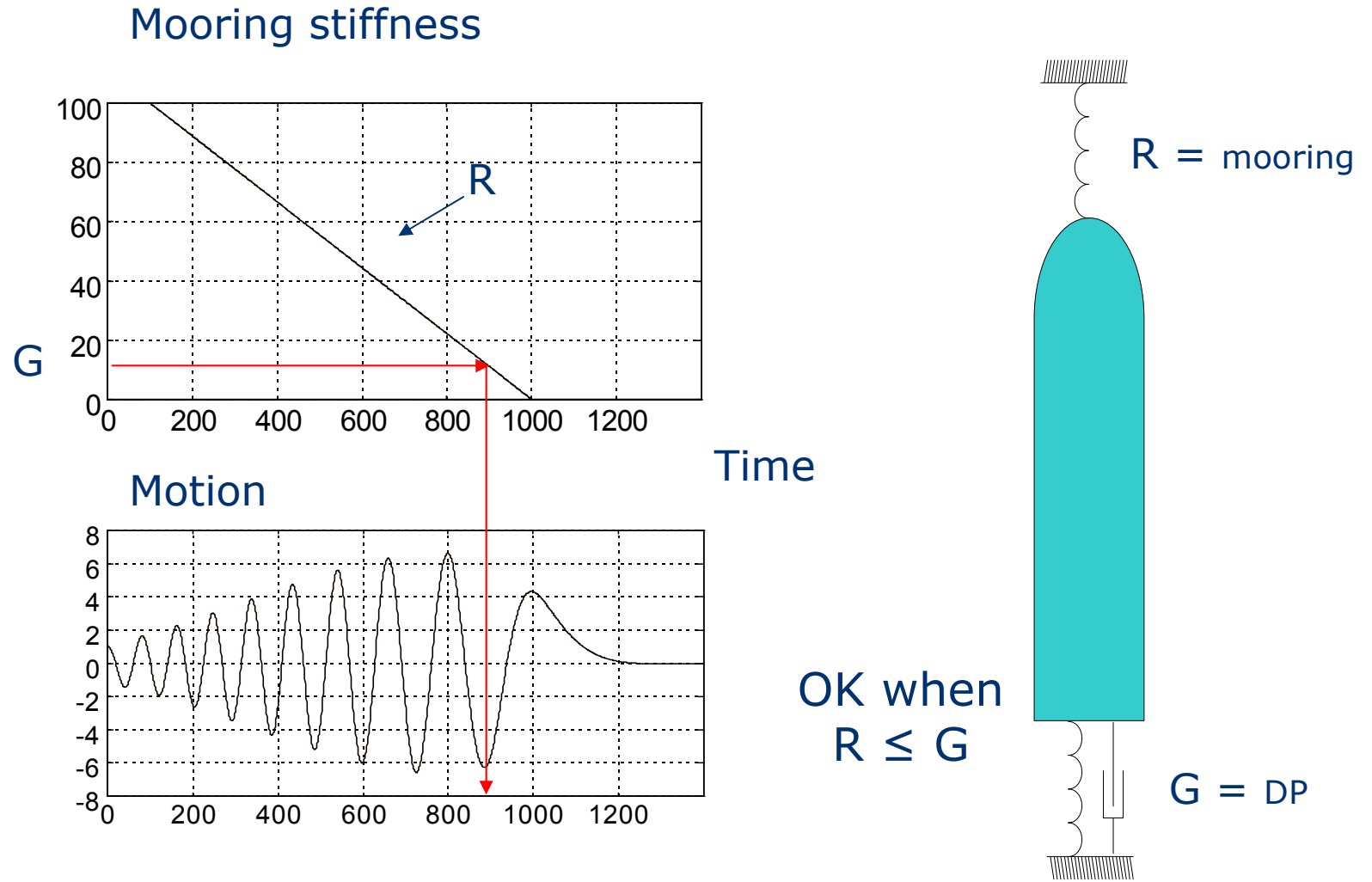
- Wire mooring
  - Diameter 66 mm
  - Length 600 m
  - Depth 200m
- Environmental forces 250 kN
- DP set-point at equilibrium
- Explanation:
  - Disturbance excite mooring
  - DP pumps energy into the system
  - Mooring stiffness too high, or needs much quicker DP control and thruster response

# Case #1 Stiffness



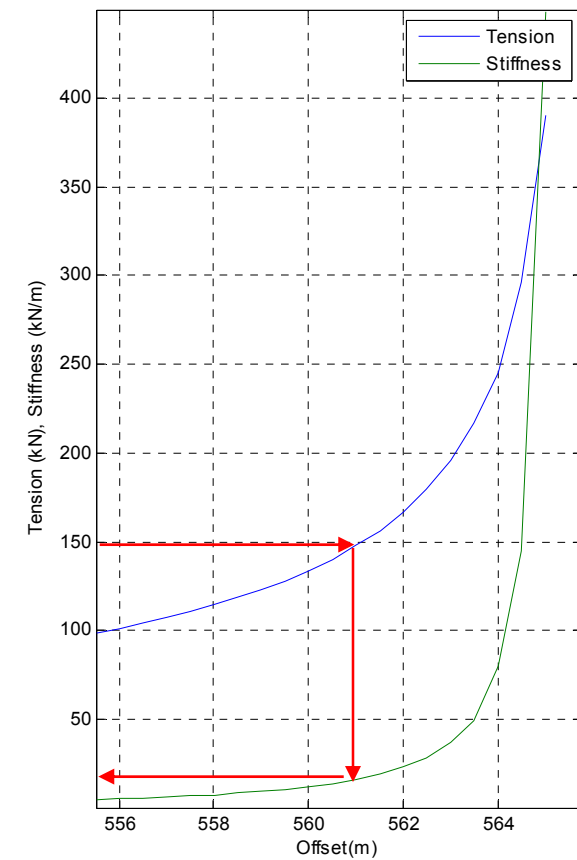
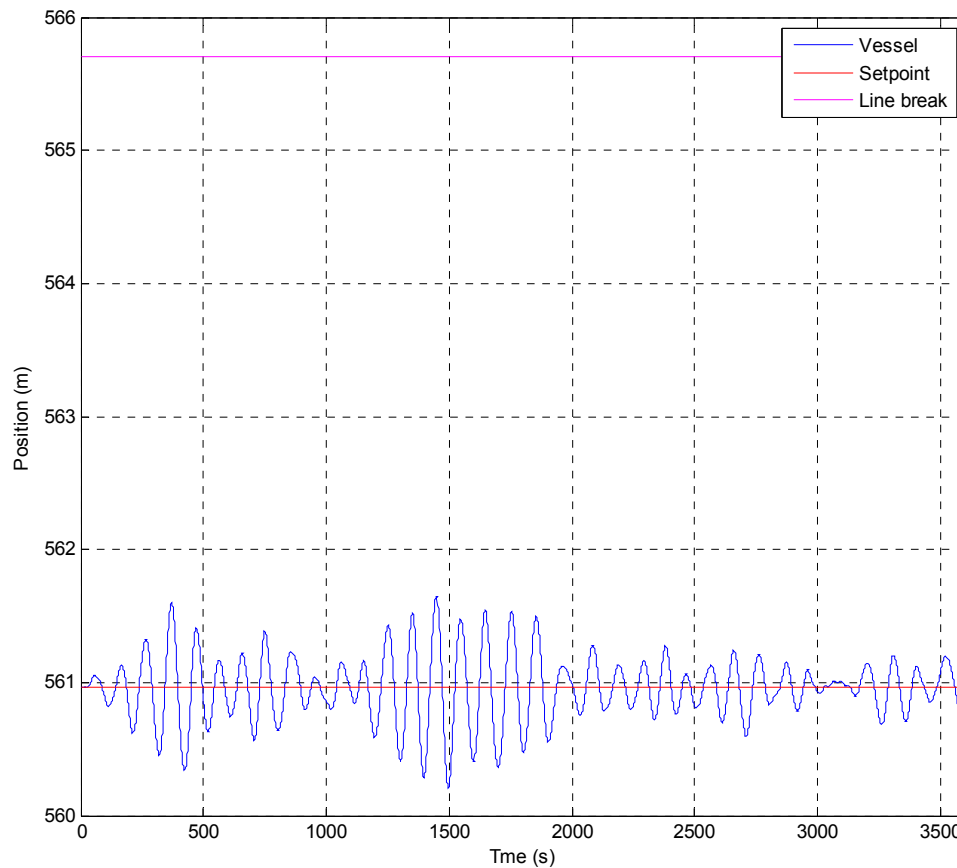
- Mooring stiffness 100kN/m
- DP stiffness 30 kN/m

# Mooring and DP



# Case #1

## Single anchor mooring – On the limit

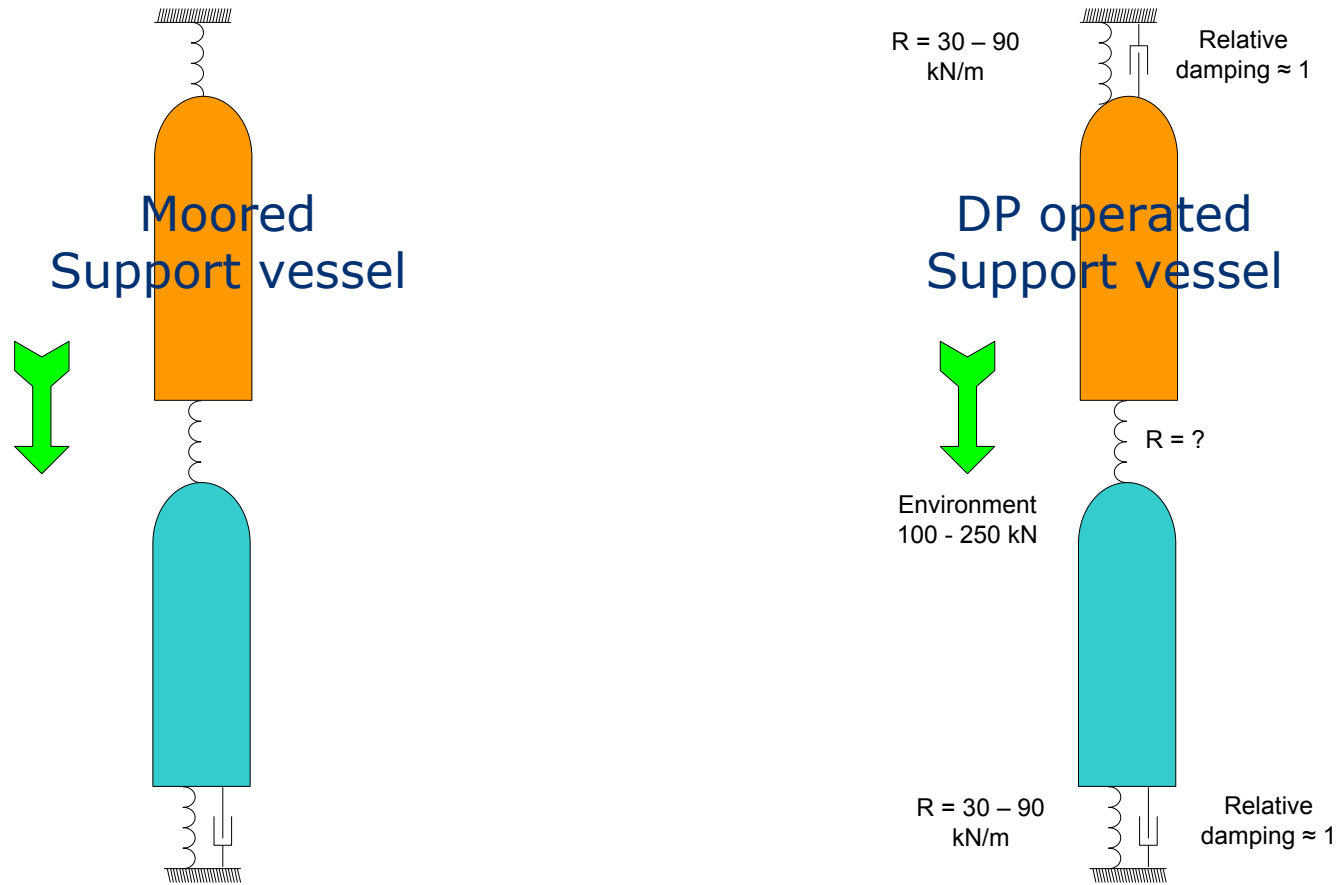


- Environment 150 kN

- Mooring stiffness
- DP stiffness

20 kN/m  
30 kN/m

# Vessel to vessel mooring



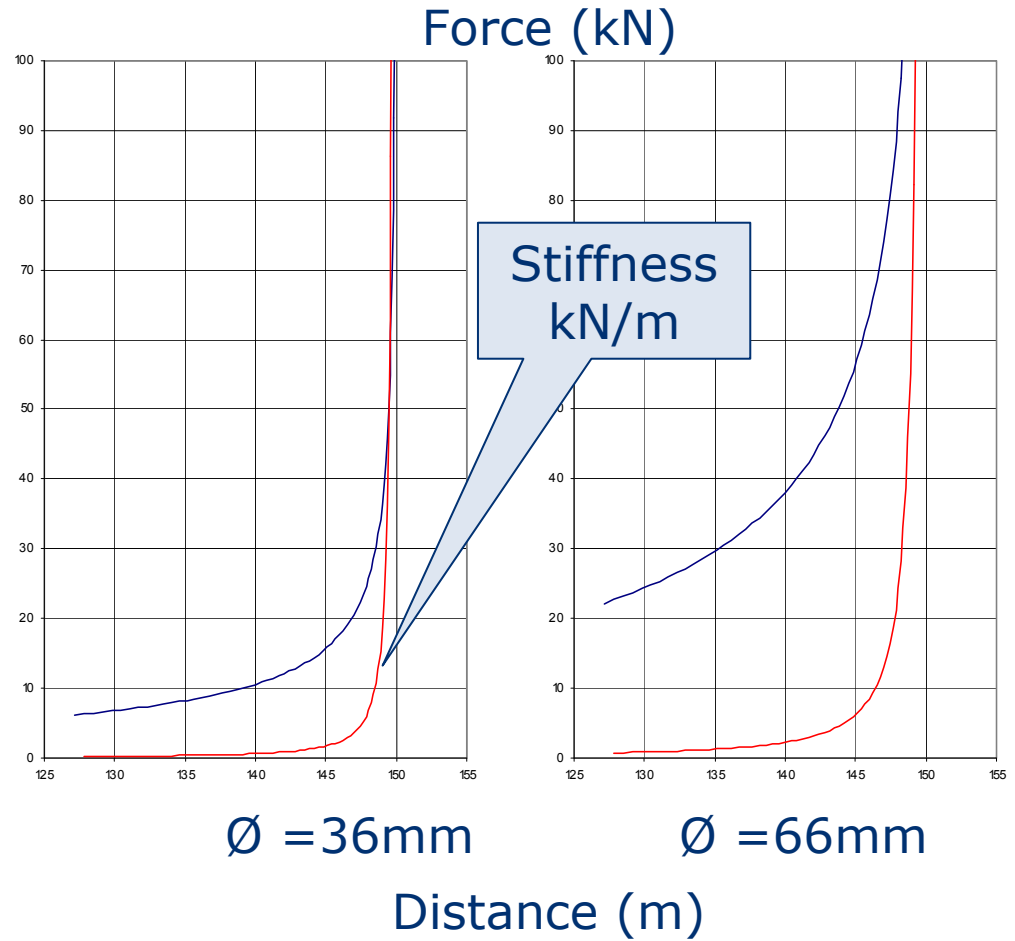
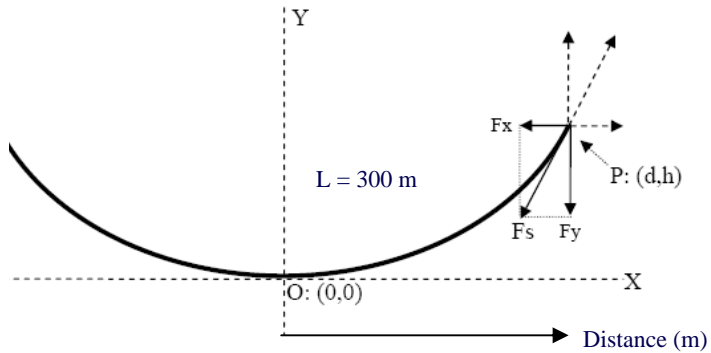
$R = 500 - 1000$   
 $\text{kN/m}$

# Vessel to vessel mooring

- Catenary

$$d = \frac{L^2 - h^2}{2h} \ln\left(\frac{L+h}{L-h}\right)$$

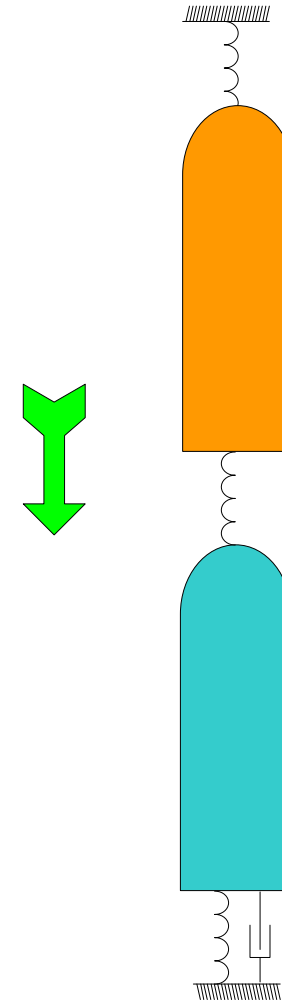
$$F_x = \frac{w(L^2 - h^2)}{2h}$$



# Case #2

## Moored to moored support vessel

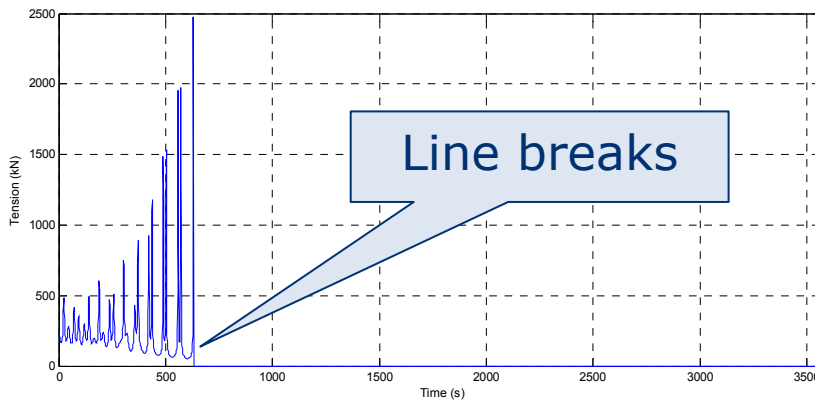
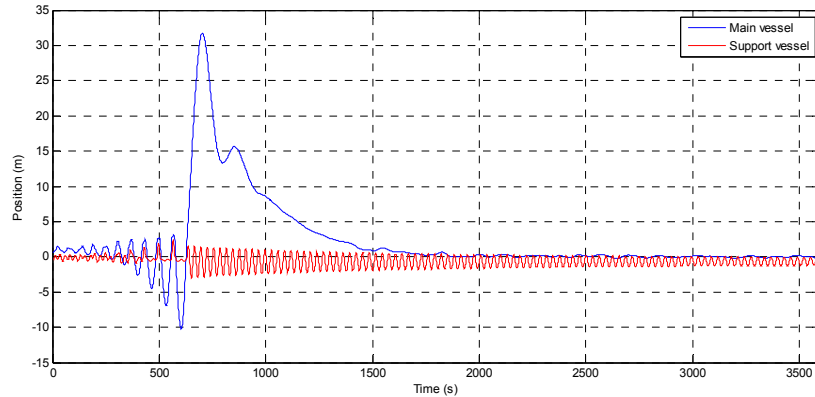
- Mooring must be pre-tensioned to assure stability and avoid collision if blackout
  - Define minimum restoring stiffness
  - Define maximum restoring stiffness
  - Offsetting by thrusters (if needed)
  - Stiffness is generally unknown, but high
- Stability problem
- Anchor dragging severe problem
- Anchor line break disaster





# Case #2

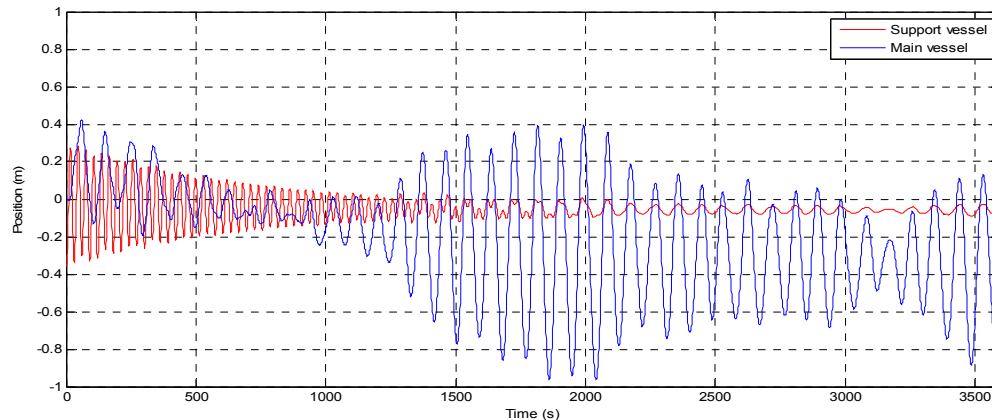
## Moored to moored support vessel - Disaster



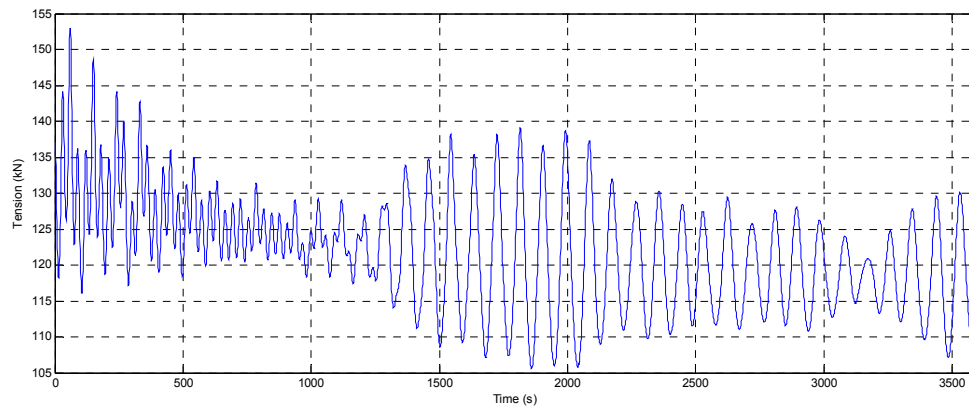
- Wire mooring between vessels
  - Diameter 66 mm
  - Length 300 m
- Environmental forces 250 kN
- Support vessel in equilibrium
  - Four point mooring (symmetric)
  - Diameter 66 mm
  - Length 800 m
  - Depth 200 m
- DP set-point at equilibrium
- Explanation:
  - Same story

# Case #2

## Moored to moored support vessel – On the limit



- Wire mooring
  - As before
- Environmental forces 140 kN
- Support vessel in equilibrium
  - Mooring as before
- DP set-points at equilibrium

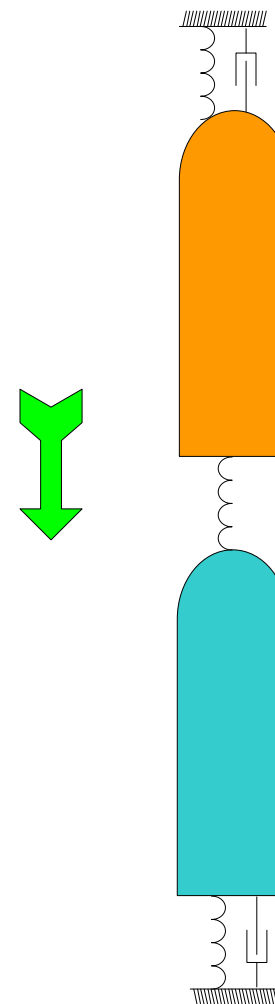


- Explanation:
  - Same story
  - Mooring stiffness matches DP
    - DP 30 kN/m
    - Vessel-vessel mooring 25 kN/m
    - Additional body

## Case #3

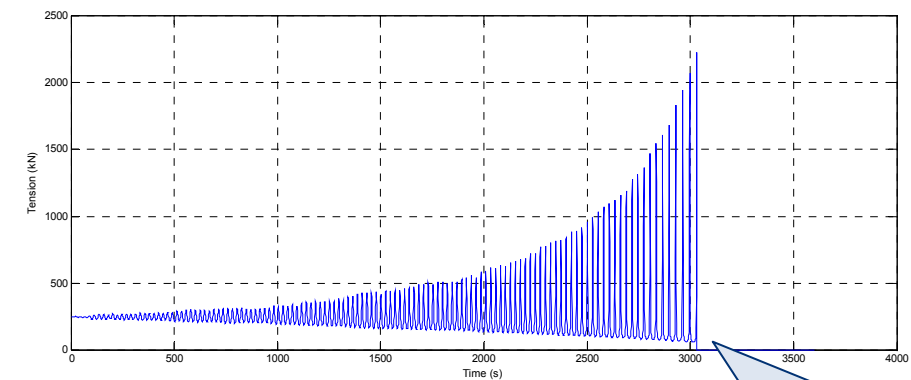
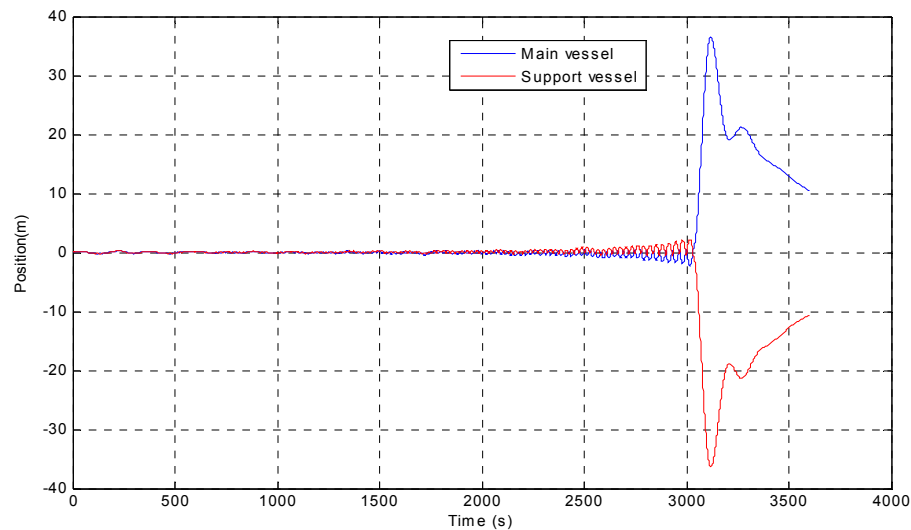
### Moored to DP support vessel

- Mooring must be pre-tensioned to assure stability and avoid collision if blackout
  - Define minimum restoring stiffness
  - Define maximum restoring stiffness
  - Offsetting by thrusters (if needed)
  - Stiffness is generally unknown, but high
- Stability problem
- DP failure support vessel sever problem



# Case #3

## Moored to DP support vessel - Disaster

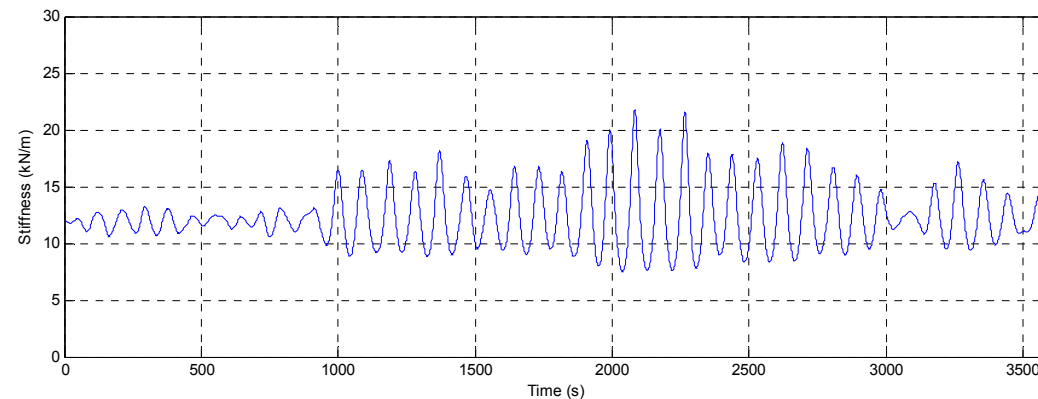
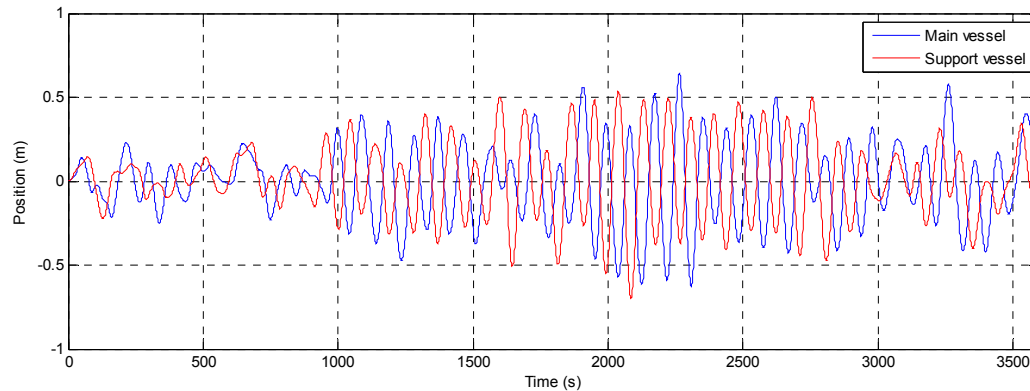


- Wire mooring
  - Diameter 66 mm
  - Length 300 m
- Environmental forces 250 kN
- DP set-points at equilibrium
- Explanation:
  - Same story

Line breaks

# Case #3

## Moored to DP support vessel – On the limit



- Wire mooring
  - Diameter 66 mm
  - Length 300 m
- Environmental forces 70 kN
- DP set-points at equilibrium
  
- Explanation:
  - Same story
  - Mooring stiffness matches DP
    - DP 30 kN/m
    - Mooring 15 kN/m
    - Additional body

# Configurations Summary

From bad ...

... to worse ...

... to disaster

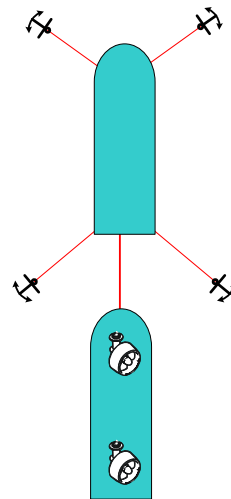
**Environment  
150 kN**

**Environment  
140 kN**

**Environment  
70 kN**



Case #1



Case #2



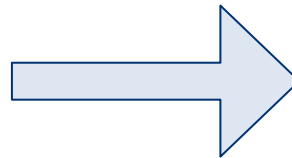
Case #3

# Additional hazards

## Moored to moored support vessel

### Hold-back vessel

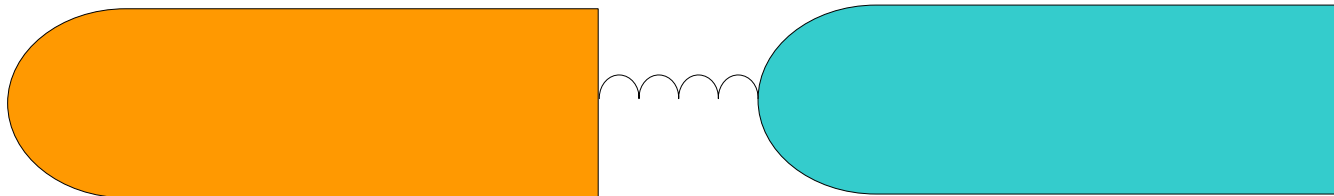
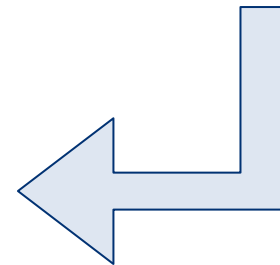
- Drive-off
- Black out
- Positioning instability



### Main vessel

- Positioning instability

- Positioning instability



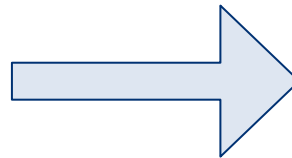
# Additional hazards

## Moored to moored support vessel



### Hold-back vessel

- Drive-off
- Black out
- Positioning instability



### Main vessel

- Positioning instability

- Positioning instability





# Alternative risk control measures IMCA M 185 (2007)

Before considering attaching a hold-back vessel:

- Reschedule operation to a time when principal hazard does not exist
- Wait for environmental conditions
- Use sea bed anchor
- Connect to another moored vessel
- Moor to a fixed facility

## Good enough?

Considerations About the Use of Hold-Back Vessels  
During DP Diving Operations



# Alternative risk control measures

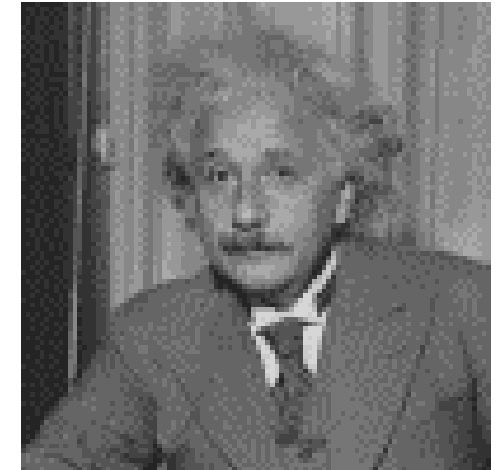
## Good enough advice?

Before considering attaching a hold-back vessel:

- Reschedule operation to a time when principal hazard does not exist
- Wait for environmental conditions

**YOU CAN'T BEAT THE PHYSICS**

**KNOW WHAT YOU ARE DOING**



Considerations About the Use of Hold-Back Vessels  
During DP Diving Operations

Thank you for the attention  
Questions?



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