Lessons Learnt from RAPID Mooring WB4 partial collapse

5th UK Moorings Workshop

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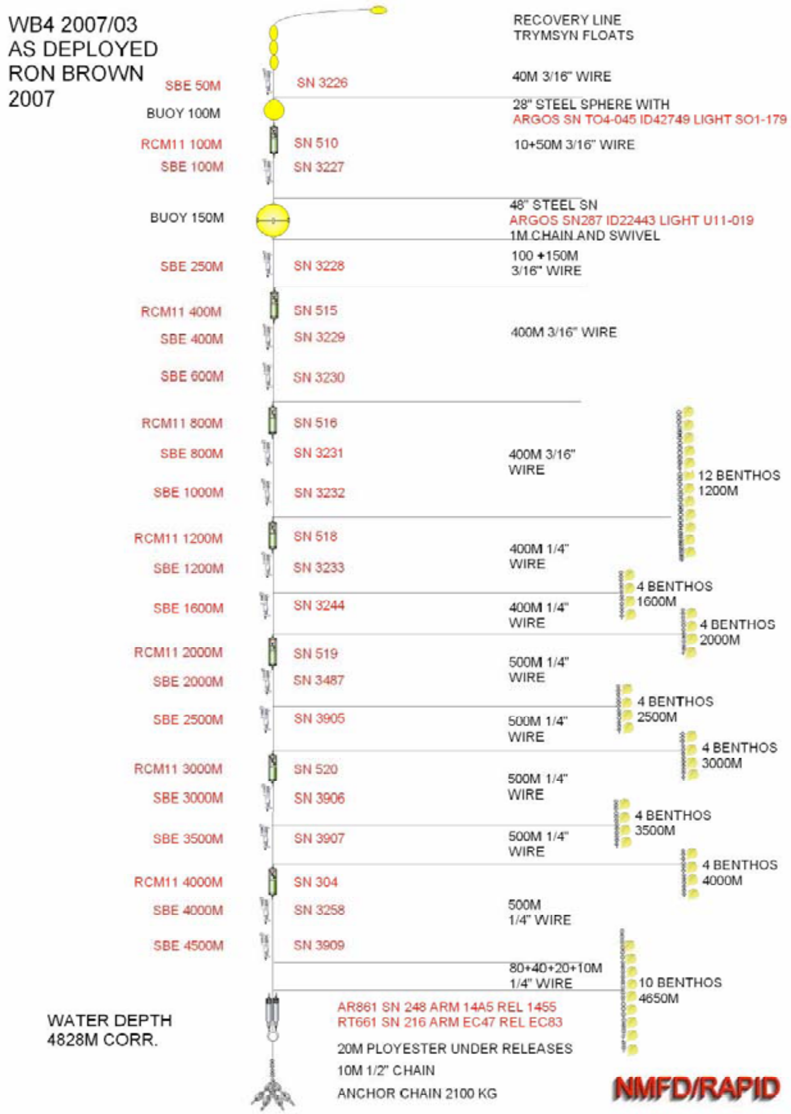
Outline

- WB4 Mooring aims and configuration
- What went wrong
- Initial findings
- Evidence
- Most likely cause
- Lessons learnt

Rayner, D., Brito, M.P., Cunningham, S., Griffiths, G. and Stevenson, P., 2008. *Investigation as to the cause of the partial collapse of the 26° N mooring wb4_4_200703*. National Oceanography Centre Southampton, 35pp. (National Oceanography Centre Southampton Research and Consultancy Report, 57).

WB4 Mooring

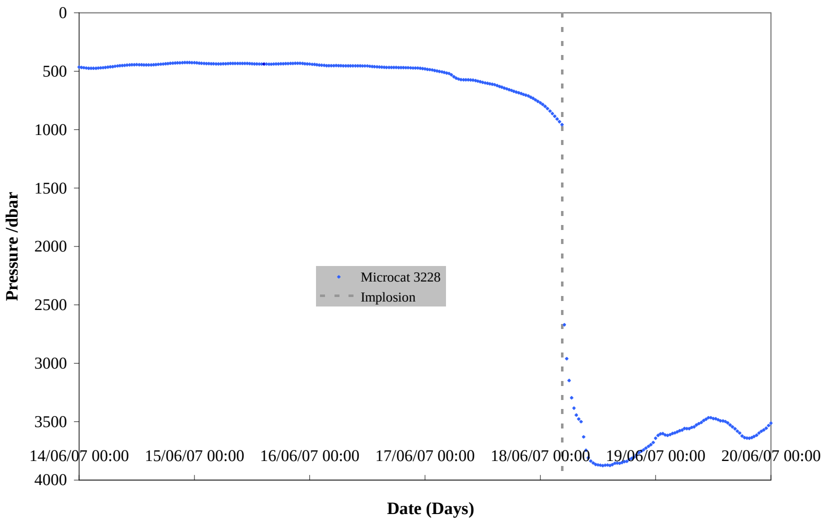


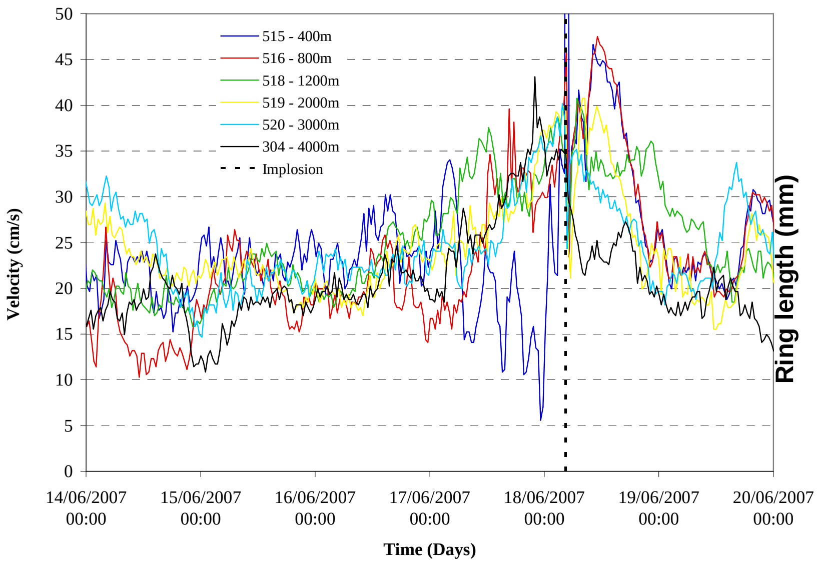
❑The wb4_4_200703 was deployed in Spring 2007 from the RV *Ronald H. Brown* cruise RB0701.

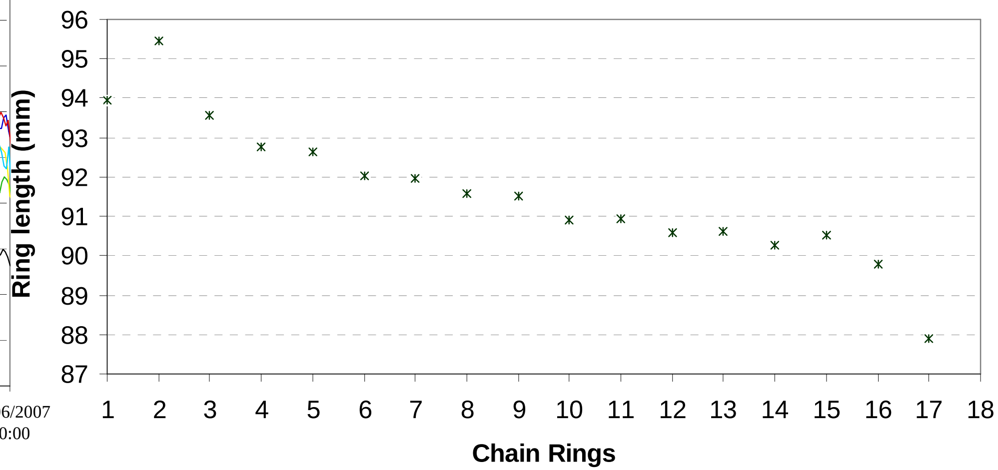
❑The main support buoyancy – a 48-inch-diameter steel sphere – imploded approximately three months after deployment (deployed 31/3/07, imploded 18/6/07), causing a partial collapse of the mooring.

❑This collapse meant that no measurements were made shallower than approximately 1600m for nine months of the mooring deployment.

Initial findings







Hypothesis

48” sphere imploded first

- Design currents – unexpected knockdown
- The site was deeper than expected
- Shortening of the chains
- The mooring may not ever be completely upright

Design currents

Maximum depth and knockdown experienced by 48" steel sphere for different design scenarios

Design	Current profile							
	As used in original design		Strongest measured by WB4_4_200703		Maximum from historical data		At minimum knockdown of WB4_4_200703	
	Max depth (m)	Knock-down (m)	Max depth (m)	Knock-down (m)	Max depth (m)	Knock-down (m)	Max depth (m)	Knock-down (m)
As intended	464.1	277.3	357.0	170.2	627.6	440.7	187.1	0.2
As deployed	526.0	302.0	452.9	228.9	814.6	590.7	224.2	0.3
As recovered	545.8	321.0	471.5	246.6	856.5	631.7	225.2	0.3

Shortening the moorings wires

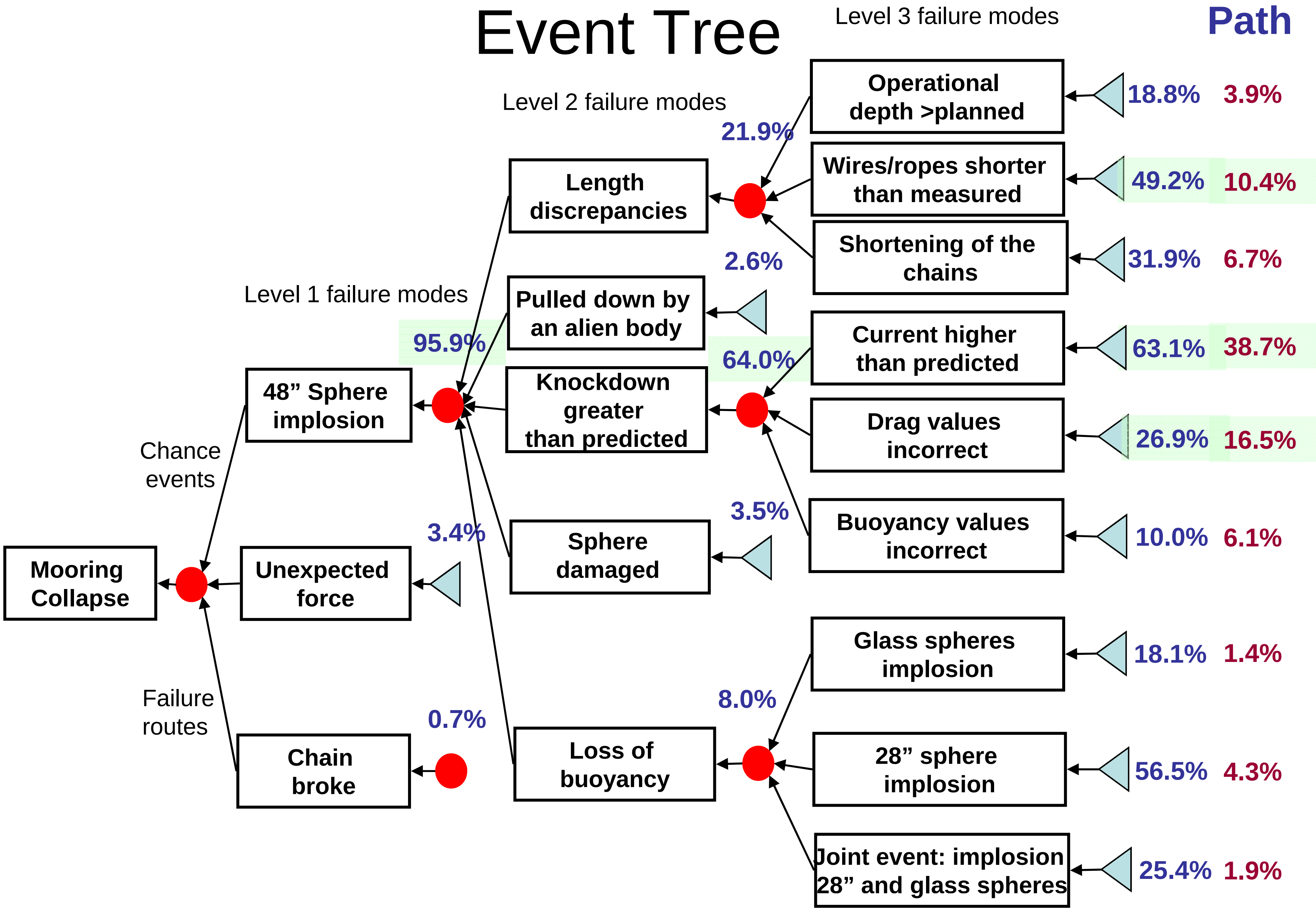
Sphere	Design	Current profile							
		As used in original design		Strongest measured by WB4_4_200703		Maximum from historical data		At minimum knockdown of WB4_4_200703	
		Max depth (m)	Knock-down (m)	Max depth (m)	Knock-down (m)	Max depth (m)	Knock-down (m)	Max depth (m)	Knock-down (m)
28”	As deployed	498.9	278.4	431.9	211.4	791.4	570.9	222.0	0.2
	As recovered (3 glass lost)	517.9	296.5	449.7	228.3	832.0	610.6	221.7	0.3
48”	As deployed	557.2	275.0	492.7	210.6	852.1	570.0	282.4	0.2
	As recovered (3 glass lost)	576.3	293.3	510.6	227.6	892.7	609.7	283.3	0.3
	As recovered (3 glass lost) plus assume loss of 28” sphere	615.4	330.9	570.5	283.6	1026.9	742.5	287.3	2.8

Maximum depth and knockdown experienced by the 28” and 48” steel spheres for different design scenarios – using the shortened wires design “short2”

Model sensitivity to drag coefficients, buoyancy and currents

	48” Steel Sphere		28” Steel Sphere	
	Design depth (m)	Knock-down (m)	Design depth (m)	Knock-down (m)
25% increase in Drag on the glass spheres	490.1	265.3	428.4	266.2
10% decrease on the glass spheres buoyancy	512.2	286.8	450.3	287.5
25% decrease in glass sphere buoyancy	564.3	337.8	502.0	338.2
5% decrease of the 28” sphere buoyancy	493.2	268.3	431.5	269.2
10% decrease in the 28” sphere buoyancy	496.1	271.0	434.5	272.1
20% decrease on the 28” sphere buoyancy	498.8	273.4	437.4	274.7
20% increase in current plus 5% increase in the 28” sphere buoyancy	889.0	664.0	826.0	664.3
20% increase in current plus implosion of the 28” sphere	1038.7	811.4	-	-
10% increase in current plus implosion of the 28” sphere	661.5	434.2	-	-

Event Tree



Level 3 failure modes
Path
Level 2 failure modes
Level 1 failure modes
Chance events
Failure routes
Mooring Collapse
48” Sphere implosion
95.9%
Unexpected force
3.4%
Chain broke
0.7%
Length discrepancies
21.9%
Pulled down by an alien body
2.6%
Knockdown greater than predicted
64.0%
Sphere damaged
3.5%
Loss of buoyancy
8.0%
Operational depth >planned
18.8%
3.9%
Wires/ropes shorter than measured
49.2%
10.4%
Shortening of the chains
31.9%
6.7%
Current higher than predicted
63.1%
38.7%
Drag values incorrect
26.9%
16.5%
Buoyancy values incorrect
10.0%
6.1%
Glass spheres implosion
18.1%
1.4%
28” sphere implosion
56.5%
4.3%
Joint event: implosion 28” and glass spheres
25.4%
1.9%

Summary of lessons learnt

Technical aspects:

- ➢Wire lengths
- ➢Components specifications, e.g. chain, 48” sphere
- ➢Design currents/Extreme events modelling

Organisational aspects:

- ➢Rigorous system development lifecycle
- ➢V&V of the software design tool. Need for a dynamic tool.
- ➢Fault logging and reporting procedures. Fault database on lessons learnt