OPERATIONAL WELLBORE SURVEY GROUP

December 04, 2023

Jonathan Lightfoot
Sub-Committee Chair

Agenda

- Mission & Anti-Trust
- Brand and Scope
- 2024 Meetings and Events
- Probability of Collision (Mohamed Elshabrawy & Jerry Codling)
- Projection Ahead Case Study (Marc Willerth)
- Unconventional Pad Surface and Intermediate Steering for Safe Separation
- Open Discussion

Attendees on December 4th

1. Jonathan Lightfoot – Oxy
2. Mohamed Elshabrawy – Shell
3. Todd McKenzie - Shell
4. Ayush Raj Srivastava - ExxonMobil
5. Pete Clark – Chevron
6. Kevin Sutherland - Chevron
7. Dalis Deliu – ConocoPhillips
8. Bill Allen – bp
9. Marianne Houbiers – Equinor
10. Nicholas Robertson – bp
11. Hans Dreisig – Total

1. Adrian Ledroz - Gyrodata
2. Michael Calkins – HilCorp
3. Jerry Codling – Halliburton Landmark Graphics
4. Marc Willerth – H&P Technologies
5. Jamie Steward – Baker Hughes
6. Darren Aklestad – slb
7. Nasikul Islam – AI Driller
8. Jon Bang – Gyrodata

Our Mission

To promote practices that provide confidence that reported wellbore positions are within their stated uncertainty.

Anti-Trust Statement

We are meeting to help develop and promote good practices in wellbore surveying necessary to support wellbore construction which enhance safety and competition.

The meeting will be conducted in compliance with all laws including the antitrust laws, both state and federal. We will not discuss prices paid to suppliers or charged to customers nor will we endorse or disparage vendors or goods or services, divide markets, or discuss with whom we will or will not do business, nor other specific commercial terms, because these are matters for each company or individual to independently evaluate and determine.

2024 Brand

OWSG: Operational Wellbore Survey Group

Operators, OEMs, Service Partners & Interested Parties

Scope: Case Studies and Operational Practices - Implementation

Schedule: Meetings every other month

OWSG Chair – Jonathan Lightfoot (Position Open)

2024 Meetings

1. February 6th
2. March 26th
3. May 28th
4. July 23rd
5. September 24th
6. November 26th

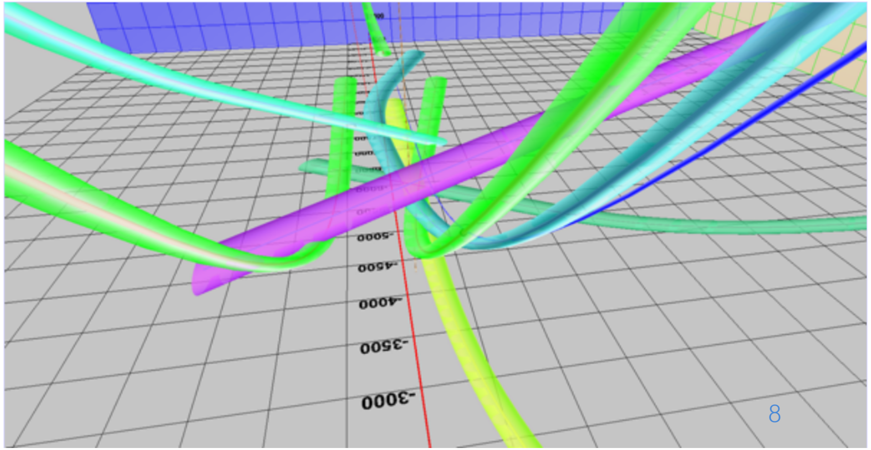
Probability of Collision – Introduction

Collision Avoidance – why?

- The consequences of an unplanned intersection with an existing well can range from financial loss, asset damage, to a catastrophic blowout and loss of life. Failure to manage collision risk has led to well control incidents in the industry.

- With congested platforms and high density of wells drilled in our assets, especially brown fields, collision risks are of a great significance.

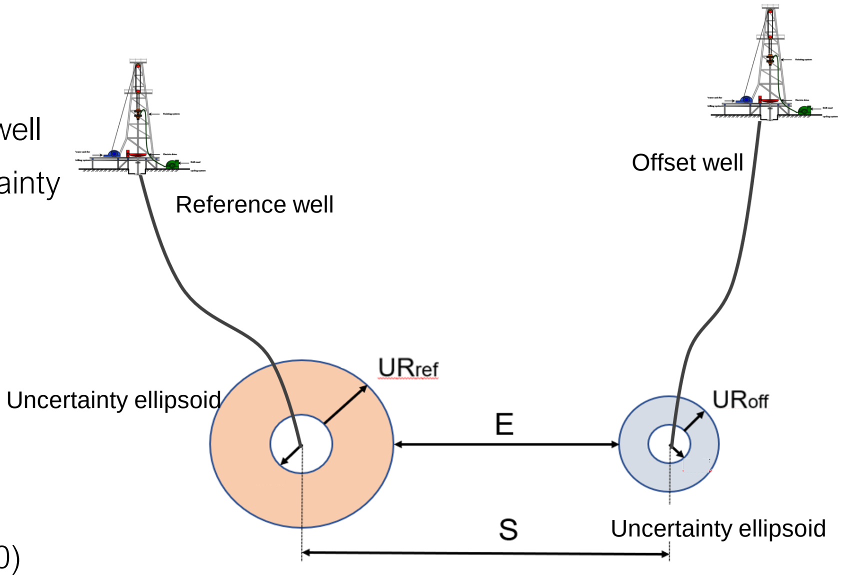
Reference: SPE-184730-Well-Collision-Avoidance Management and Principles



Separation Factor in simple terms

1. Determine the distance "S" from the reference well to the offset well
2. Determine the minimum distance "E" between the survey uncertainty ellipsoids
3. And determine the separation factor or clearance factor

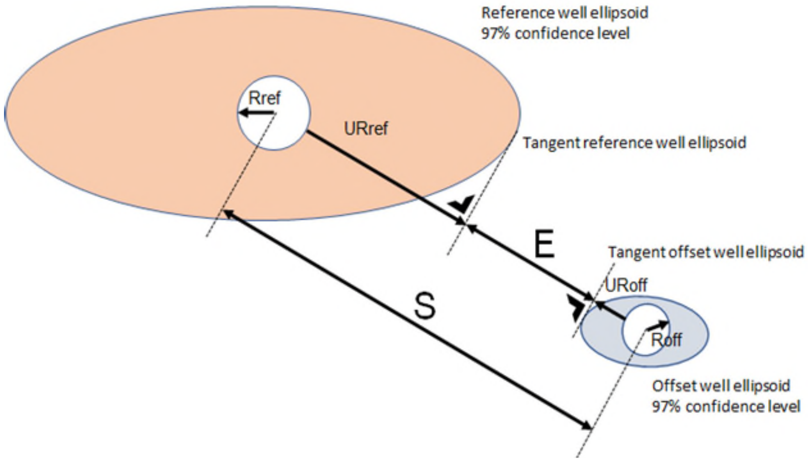
$$SF = S/(S-E)$$



Key facts to know about SF:

- > 1.0 when they have a positive inter-boundary separation (E>0)
- = 1.0 when the ellipses of uncertainty touch (E=0)
- < 1.0 in case of a potential collision, where the ellipses of uncertainty overlap (E<0)

Separation Factor details



For a more conservative SF:

1. 3D scan for min C-C centre in 3D space
2. IB separation using Pedal Curve method, tangent to edge of ellipses
3. Account for TBR
4. Apply 3-sigma confidence level (97%)

5.7.2.3 *Separation Factor (SF)*

The Separation Factor is given by

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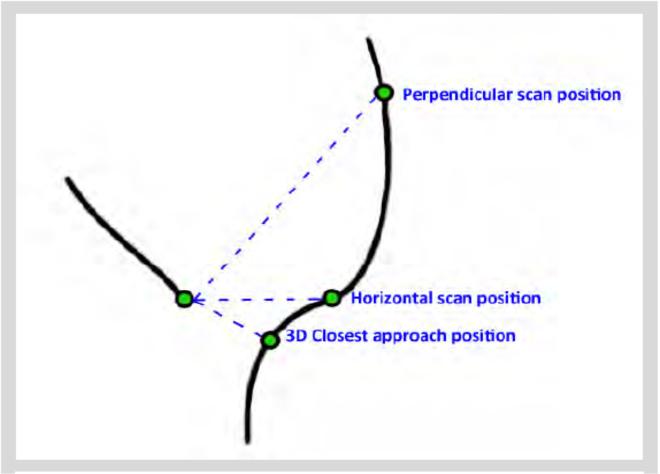
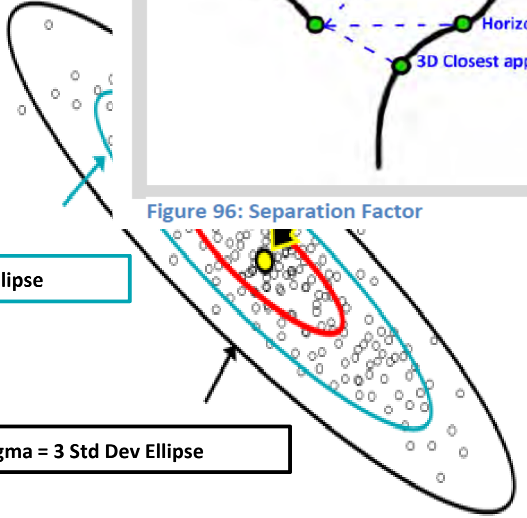


Figure 96: Separation Factor

ters areas at a shallow well



2 Sigma = 2 Std Dev Ellipse

3 Sigma = 3 Std Dev Ellipse

Introducing probability of collision

20.6.1 Difference between Separation Factor and Probability Based Rules

A separation factor based rule is purely geometric whereas a probability based rule relates to actual risk. For example, take two different uncertainty situations which both calculate a separation factor of 1.0. In the first case two 12-1/4" wellbores have uncertainty envelopes which are hundreds of feet across. In the second case the uncertainty envelopes only have a radius of one foot from each well centre. Clearly the second case has a much higher probability of being an actual collision than the former.

Rules merely using reported separation factor numbers will not distinguish between these two cases.

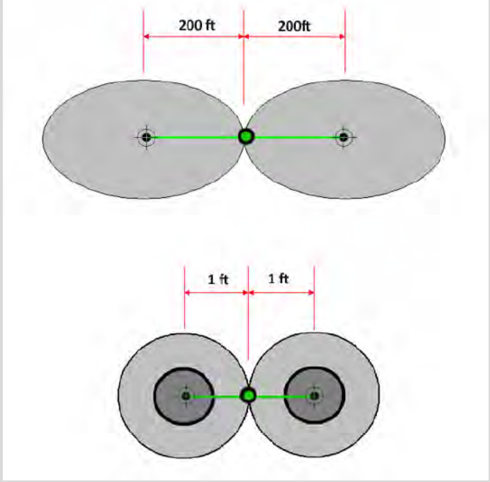


Figure 102: The uncertainty envelopes for two calculation methods

Offset Design
Survey Program:
Offset Site Error: 0.00 m
Offset Well Error: 0.00 m

Reference Measured Depth (m)	Reference Vertical Depth (m)	Offset Measured Depth (m)	Offset Vertical Depth (m)	Semi Major Axis Reference (m)	Semi Major Axis Offset (m)	Distance Between Centres (m)	Distance Wall-Wall Distance (m)	Distance Between Ellipses (m)	Minimum Separation (m)	Separation Factor	Risked Separation Factor	Probability of Collision	Warning
475.00	474.94	472.42	472.38	0.88	1.04	3.67	3.09	0.22	3.45	1.063	0	1 in 401	SURVEY PROJECTION REQUIRED
500.00	499.93	497.45	497.40	0.90	1.11	3.82	3.24	0.25	3.57	1.069	0	1 in 416	SURVEY PROJECTION REQUIRED
525.00	524.92	522.44	522.39	0.90	1.17	4.24	3.66	0.56	3.68	1.153	0	1 in 607	SURVEY PROJECTION REQUIRED
550.00	549.86	547.39	547.34	0.91	1.23	5.18	4.60	1.39	3.79	1.367	0	1 in 1,533	SURVEY PROJECTION REQUIRED
575.00	574.73	572.31	572.25	0.92	1.29	6.86	6.28	2.97	3.89	1.764	0	1 in 7,689	SURVEY PROJECTION REQUIRED
600.00	599.61	597.11	597.06	0.93	1.34	8.64	8.06	4.65	3.99	2.164	0	1 in 35,428	

Offset Design
Survey Program:
Offset Site Error: 0.00 m
Offset Well Error: 0.00 m

Reference Measured Depth (m)	Reference Vertical Depth (m)	Offset Measured Depth (m)	Offset Vertical Depth (m)	Semi Major Axis Reference (m)	Semi Major Axis Offset (m)	Distance Between Centres (m)	Distance Wall-Wall Distance (m)	Distance Between Ellipses (m)	Minimum Separation (m)	Separation Factor	Risked Separation Factor	Probability of Collision	Warning
625.00	594.67	626.27	594.40	1.32	1.31	59.60	59.26	55.52	4.08	14.625	0	< 1 in 1E+9	
650.00	619.44	651.16	619.17	1.39	1.37	62.15	61.81	57.89	4.27	14.568	0	< 1 in 1E+9	
675.00	644.13	675.94	643.82	1.45	1.43	64.93	64.59	60.49	4.44	14.618	0	< 1 in 1E+9	
700.00	668.75	700.62	668.37	1.49	1.50	68.55	68.20	63.96	4.58	14.953	0	< 1 in 1E+9	
725.00	693.27	725.56	693.17	1.51	1.56	73.02	72.67	68.32	4.70	15.530	0	< 1 in 1E+9	
750.00	717.65	750.50	717.97	1.53	1.63	78.17	77.83	73.35	4.82	16.204	0	< 1 in 1E+9	
775.00	741.86	774.88	742.21	1.56	1.69	84.13	83.78	79.18	4.95	16.991	0	< 1 in 1E+9	
800.00	765.86	798.86	766.04	1.59	1.76	90.96	90.62	85.88	5.08	17.892	0	< 1 in 1E+9	
825.00	789.61	822.44	789.47	1.62	1.83	98.70	98.42	93.55	5.15	19.160	0	< 1 in 1E+9	
850.00	813.08	845.81	812.70	1.66	1.89	107.36	107.08	102.07	5.28	20.323	0	< 1 in 1E+9	
875.00	836.22	868.96	835.74	1.71	1.94	116.88	116.60	111.47	5.41	21.600	0	< 1 in 1E+9	
900.00	859.01	891.84	858.51	1.75	2.00	127.25	126.97	121.71	5.54	22.963	0	< 1 in 1E+9	
925.00	881.41	914.05	880.62	1.81	2.06	138.44	138.16	132.77	5.67	24.405	0	< 1 in 1E+9	
950.00	903.38	935.06	901.54	1.87	2.11	150.57	150.29	144.77	5.80	25.960	0	< 1 in 1E+9	
975.00	924.89	956.18	922.58	1.93	2.16	163.59	163.31	157.66	5.93	27.589	0	< 1 in 1E+9	
1,000.00	945.91	976.84	943.16	2.00	2.21	177.42	177.15	171.37	6.06	29.283	0	< 1 in 1E+9	
1,025.00	966.41	996.81	963.05	2.08	2.26	192.06	191.79	185.88	6.19	31.047	0	< 1 in 1E+9	
1,050.00	986.34	1,015.91	982.09	2.16	2.31	207.51	207.23	201.20	6.31	32.888	0	< 1 in 1E+9	
1,075.00	1,005.69	1,035.04	1,001.15	2.26	2.35	223.71	223.44	217.28	6.43	34.773	0	< 1 in 1E+9	
1,100.00	1,024.42	1,053.52	1,019.56	2.36	2.40	240.62	240.35	234.07	6.56	36.699	0	< 1 in 1E+9	
1,125.00	1,042.50	1,071.29	1,037.27	2.47	2.44	258.22	257.94	251.54	6.68	38.665	0	< 1 in 1E+9	
1,150.00	1,059.91	1,088.48	1,054.41	2.58	2.48	276.48	276.20	269.68	6.80	40.658	0	< 1 in 1E+9	
1,175.00	1,076.62	1,104.85	1,070.71	2.71	2.52	295.37	295.09	288.45	6.92	42.692	0	< 1 in 1E+9	
3,425.00	2,409.00	3,124.76	2,433.01	9.32	11.60	295.18	294.99	265.54	29.64	9.959	0	< 1 in 1E+9	
3,450.00	2,409.00	3,131.20	2,432.34	9.28	11.71	271.17	270.97	241.31	29.86	9.081	0	< 1 in 1E+9	
3,475.00	2,409.00	3,137.09	2,431.81	9.24	11.81	247.18	246.98	217.11	30.06	8.222	0	< 1 in 1E+9	
3,500.00	2,409.00	3,142.98	2,431.37	9.20	11.91	223.23	223.03	192.96	30.27	7.375	0	< 1 in 1E+9	
3,525.00	2,409.00	3,148.99	2,431.04	9.17	12.01	199.33	199.13	168.85	30.47	6.541	0	< 1 in 1E+9	
3,550.00	2,409.00	3,155.14	2,430.81	9.13	12.11	175.49	175.29	144.80	30.68	5.719	0	< 1 in 1E+9	
3,575.00	2,409.00	3,161.54	2,430.68	9.10	12.22	151.73	151.54	120.83	30.90	4.910	0	< 1 in 1E+9	
3,600.00	2,409.00	3,168.54	2,430.60	9.07	12.35	128.07	127.88	96.94	31.13	4.114	0	1 in 129,032,312	
3,625.00	2,409.00	3,175.58	2,430.55	9.05	12.47	104.55	104.35	73.22	31.33	3.337	0	1 in 13,056,917	
3,650.00	2,409.00	3,182.65	2,430.53	9.02	12.59	81.28	81.08	49.84	31.45	2.585	0	1 in 1,268,133	
3,675.00	2,409.00	3,189.77	2,430.55	9.00	12.71	58.56	58.37	27.28	31.28	1.872	0	1 in 120,152	SURVEY PROJECTION REQUIRED
3,700.00	2,409.00	3,197.04	2,430.56	8.98	12.84	37.39	37.19	7.54	29.85	1.252	0	1 in 12,581	SURVEY PROJECTION REQUIRED
3,725.00	2,409.00	3,204.42	2,430.56	8.97	12.97	22.56	22.36	0.56	22.00	1.026	0	1 in 3,815	SURVEY PROJECTION REQUIRED,

Reference: ISCWSA-UHI Introduction to Wellbore Positioning

Probability of Collision: Jerry Codling

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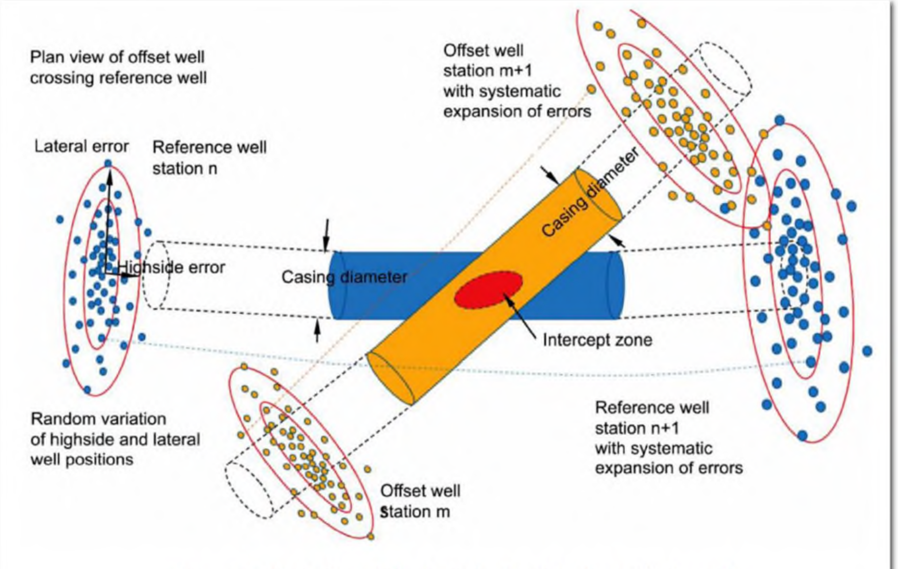

Figure 2—Illustration of Monte Carlo simulator for well intercept.

IADC/SPE-189654-MS

Probability of Wellbore Intercept Made Easy

Jeremy Codling, Halliburton

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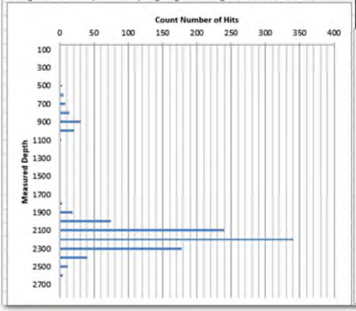
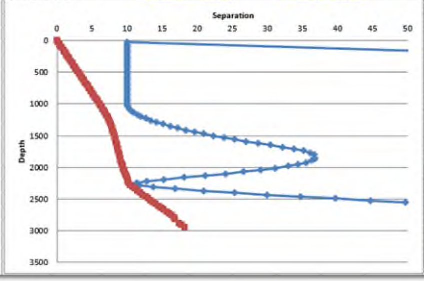
Test monte carlo simulation for wellbore interceptions at high angle								Random	Sigma	Casing	Total	Count	Hits	Misses	Probability	
Student T	Yes	Wrong Sid	Yes					0.1	3.5	0.0127	100000	100000	1570	98430	1.570%	Hits
MD	INC	AZI	TVD	NS	EW	EHIGH	ELAT	ROT	ALH	CAS	TFO		14551	85449	14.551%	Wrong Side
2280.00	85.00	180.00	1856.72	-789.57	0.00	10.46	28.97	0.00	11.65	30	246.73	DIST				
2280.00	83.31	189.52	1867.72	-782.37	-0.46	10.51	28.32	0.12	12.17	30	66.44	11.30423		Run Simulator		
Convergen	1.69	-9.47	9.62	deg		4.236592	11.57507			0.762						
					Pedal	10.76452										
Sigma	Sigma value for highside and lat errors				Peripheral	8.166776										
Casing	To convert from diameters in inches to length units															
Total	Number of samples in Monte Carlo simulation															
Student T	Use Student T distribution (default is Gaussian)															
Wrong Si(	Calculate probability of going on 'wrong side' of other well															

	Pedal	Normal	Student6	Peripheral	Normal	Student6
	0.98	0.84	0.82	1.29	0.90	0.88
	1.12	0.87	0.85	1.48	0.93	0.90
Separation Factor	0.28			0.37		
Expected probability		31	33		35	37
of collision		3.25%	3.00%		2.86%	2.71%
Expected probability		6	5		10	8
of wrong side		16.37%	18.26%		9.84%	12.21%

MDR	MDO	100	Count	
2203.192	2208.607	200	0	
2066.061	2070	300	0	
2271.755	2277.178	400	0	
2154.966	2160	500	0	
2070	2073.18	600	3	
2084.577	2088.481	700	6	
689.9991	690	800	8	17
2190	2194.215	900	14	0.02%
2219.357	2224.478	1000	31	
2310	2314.908	1100	21	
2355.3	2362.567	1200	2	
2140.162	2144.414	1300	1	
2250	2255.177	1400	0	
2248.733	2255.638	1500	0	
2171.548	2178.079	1600	0	
2190	2196.06	1700	0	
2232.367	2239.119	1800	0	
2265.437	2272.743	1900	3	
2190	2195.301	2000	19	
2190	2195.304	2100	75	
2439.688	2443.406	2200	240	
900	900	2300	341	
2340	2347.257	2400	178	
958.2093	958.2065	2500	40	
2116.535	2120.57	2600	12	
2273.189	2278.608	2700	4	
2303.989	2310	2800	1	
2070	2074.154	2900	0	
1947.323	1950			
2231.168	2235.726			
2396.389	2400			
2274.688	2280			
2184.594	2190			





Probability of Collision – Cont'd

-25 to -20	BLACK	NON-OPERABLE:	Evacuate the zone and or area/country
-16 to -10	RED	INTOLERABLE:	Do not take this risk
-9 to -5	YELLOW	UNDESIRABLE:	Demonstrate ALARP before proceeding
-4 to -2	GREEN	ACCEPTABLE:	Proceed carefully, with continuous improvement
-1	BLUE	NEGLIGIBLE:	Safe to proceed

SEVERITY ↓ / LIKELIHOOD →	Improbable 1	Unlikely 2	Possible 3	Likely 4	Probable 5
Light -1	-1 1L	-2 2L	-3 3L	-4 4L	-5 5L
Serious -2	-2 1S	-4 1S	-6 3S	-8 4S	-10 5S
Major -3	-3 1M	-6 2M	-9 3M	-12 4M	-15 5M
Catastrophic -4	-4 1C	-8 2C	-12 3C	-16 4C	-20 5C
Multi-Catastrophic -5	-5 1MC	-10 2MC	-15 3MC	-20 4MC	-25 5MC

White arrow indicates decreasing risk

Figure 1. HARC Risk Assessment Matrix

AADE-07-NTCE-28

AADE AMERICAN ASSOCIATION of DRILLING ENGINEERS

A Comprehensive Approach to Well-Collision Avoidance

B. Poedjono, Schlumberger; G. Akinniranye, Schlumberger; G. Conran, Schlumberger; K. Spidle, Schlumberger; and T. San Antonio, Schlumberger

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This paper was prepared for presentation at the 2007 AADE National Technical Conference and Exhibition held at the Wyndam Greenspoint Hotel, Houston, Texas, April 10-12, 2007. This conference was sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author(s) of this work.

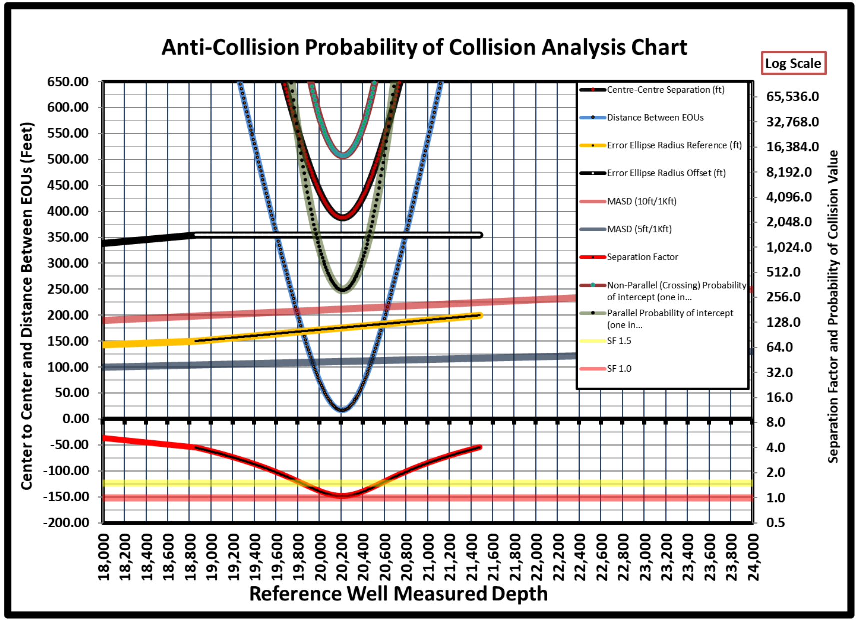
- Improbable
- Unlikely
- Possible
- Likely
- Probable

Group discussion

- How do different operators address Probability of Collision in Risk Assessment / MOC process?
- Is there an agreement in the industry on a specific model to calculate Probability of Collison?
- What is the "accepted" threshold for Probability of Collision in non-HSE risk well cases?
- For operators who use Compass, what is the calculation method used in Compass? Any recommended settings for Anti-collision scan?
- Further research / testing recommendations?

Probability of Collision – Chart / Plot

- REPORTS AND CHARTS
- RISKED COST CALCULATIONS
- DISPENSATION FOR NON-HSE RISK OFFSETS
- MASD AND ADP
- INCIDENCE ANGLE OF APPROACH



Projection Ahead Case Study (Marc Willerth)

$$SF = \frac{D - R_r - R_o - S_m}{k\sqrt{\sigma_s^2 + \sigma_{pa}^2}} \quad (1)$$

Parameter	Description
D	The distance between a specified point on the centerline of the reference well and the nearest point on the centerline of the offset well. The point on the reference well is specified first. The point on the offset well is identified as the point of closest approach in 3D space or in the plane normal to the reference well when traveling-cylinder diagrams are being used for collision monitoring (ISCWSA 2013).
R_r	The openhole radius of the reference borehole.
R_o	The openhole radius of the offset borehole.
S_m	The surface margin term increases the effective radius of the offset well. It accommodates small, unidentified errors and helps overcome one of the geometric limitations of the separation rule, described in the Separation-Rule Limitations section. It also defines the minimum acceptable slot separation during facility design and ensures that the separation rule will prohibit the activity before nominal contact between the reference and offset wells, even if the position uncertainty is zero.
k	The dimensionless scaling factor that determines the probability of well crossing.
σ_{pa}	Quantifies the 1-SD uncertainty in the projection ahead of the current survey station. Its value is partially correlated with the projection distance, determined as the current survey depth to the bit plus the next survey interval. The magnitude of the actual uncertainty also depends on the planned curvature and on the actual BHA performance at the wellbore attitude in the formation being drilled. The project-ahead uncertainty is only an approximation, and although it is predominantly oriented normal to the reference well, it is mathematically convenient to define σ_{pa} as being the radius of a sphere.
σ_s	The relative uncertainty at one SD between the two points of interest, derived from their respective positional uncertainties σ_r and σ_o in the direction of D (see Appendix A).

Table 2—Description of the parameters used in the SF equation. SD = standard deviation.

$$SF = \frac{D - R_r - R_o - S_m}{k\sqrt{\sigma_s^2 + \sigma_{pa}^2}}$$

Future Case Study and Discussion Topic

- Unconventional Pad Surface and Intermediate Steering for Safe Separation
  - Recommended Slot Spacing
  - Surface Nudges
  - S-Shaped with 2D Curve vs. Slant with 3D Curves
- DLS Limitations for Artificial Lift (Well Life Cycle)
- Tie-In Practices for Whipstock Sidetracks & Openhole Sidetracks
- Revision 5.x Naming Format for PUMs

Thank you

Next Meeting will be on February 5, 2024.