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Methods for Evaluation of Wellbore Collision Probability in Critical Close-Proximity Regions

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Background

Background: Separation factor (SF)

- SF is the commonly used parameter for monitoring collision risk between wells.
- SF = Ratio of distance D_0 and the uncertainty on the distance $k\sigma_s$

$$SF = \frac{D_0 - (R_{ref} + R_{offs} + S_m)}{k\sqrt{\sigma_s{}^2 + \sigma_{pa}{}^2}}$$

SPE-WPTS recommended rule (k=3.5) for HSE-risk wells (SPE-187037-PA)

- Many definitions and flavours (definition of σ_s; choice of k; modifying parameters)
  - From negligible to profound differences (SPE-200475-PA).
  - Possible misunderstandings in communication.

Background (continued)

- SF is used to monitor safe distance (SF >= 1);
  determine when to apply cautionary actions (SF approaching 1);
  determine when to stop drilling / change plans (SF = 1)
  - What do these numbers mean with respect to risk of collision?
  - Does an SF value imply the same near surface as downhole?
- Common approach: first find point pair, then apply uncertainties
  - May miss most crucial point pair => underestimating the risk.
  - SF is a 1D parameter => limitations with respect to complex well geometries.
- Still, collisions happen relatively infrequently (SPE-184730-PA)
  - Is SF unnecessarily conservative?

Critical close-proximity regions

- Tentative definition: 'The sections of both wellbores where special actions are required to ensure safe drilling'.
    - 'Close-proximity' depends on both geometric distance and position uncertainty.
    - Define by specific SF value?

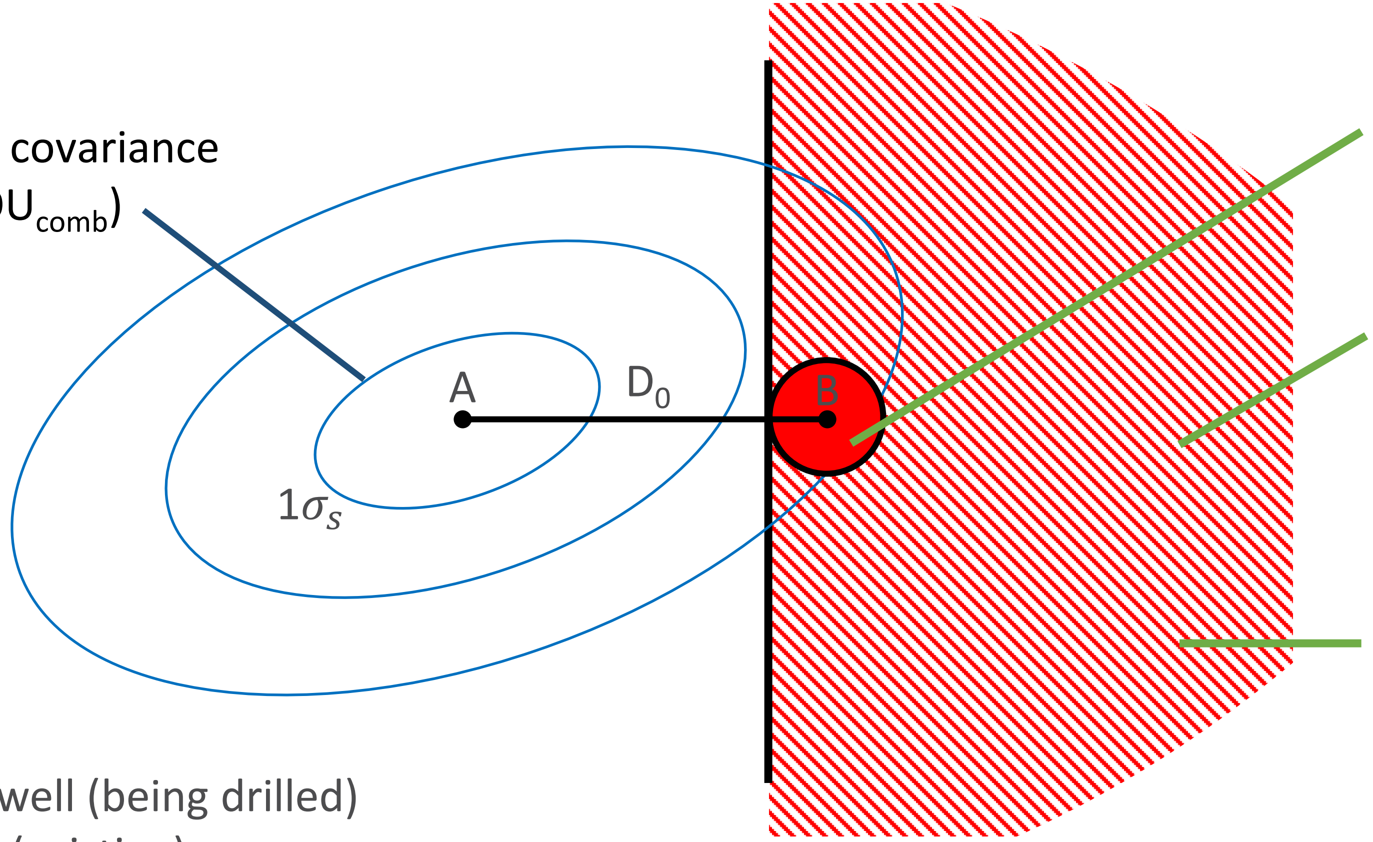
- High accuracy needed: Interpolation
    - More computations.
    - SF still possible.

- Alternative: Probability
    - More fundamental parameter than SF.
    - Unambiguous definition and interpretation: P = 0.001 <=> 1 event per 1000 cases.
    - Flexible (any pdf; any well geometries; any desired interval in both wells) (SPE-184644-PA).

Probability: $P(within\, Vol) = \iiint_{Vol} pdf\ dV$

Same parameters D_0, σ_s, etc. as in SF formula, but different approach => can only expect qualitative correspondence

Combined covariance matrix (EOU_{comb})



Combined diameters of A and B:
∭ Volume => P_{DH} (Direct hit)

Unintentional crossing:
∭ Half-space volume => P_{UC}

$P_{DH} \ll P_{UC}$

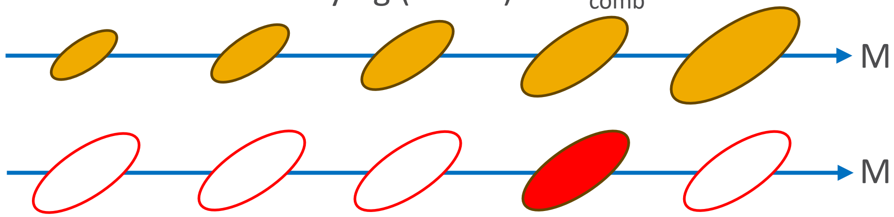
SF relates to ‘being beyond a certain point’; i.e. crossing (P_{UC})
(P_{DH} may be negligible at SF $\approx$ 1)

A = reference well (being drilled)
B = offset well (existing)

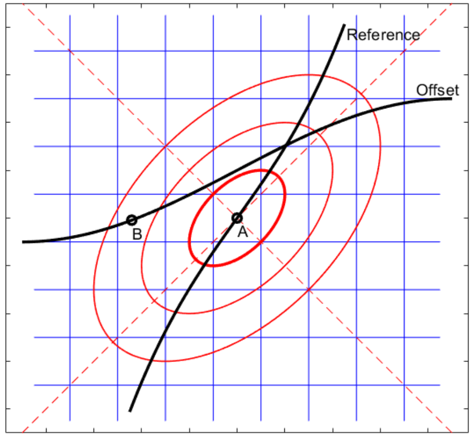
Scope of study: - Compare SF and P_{DH} for critical regions
- P_{DH} calculation options

- Most accurate P_{DH} by:
  - High-resolution (interpolated) data
  - Actual EOU_{comb}; varying along both wells

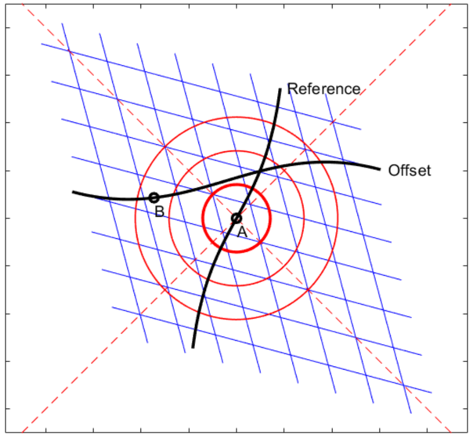
P_{DH} option 1: Use of constant EOU_{comb}: Accuracy?



P_{DH} option 2: Calculate in Mahalanobis space: Computation time?



EOU_{comb} in physical space (ellipse / ellipsoid)

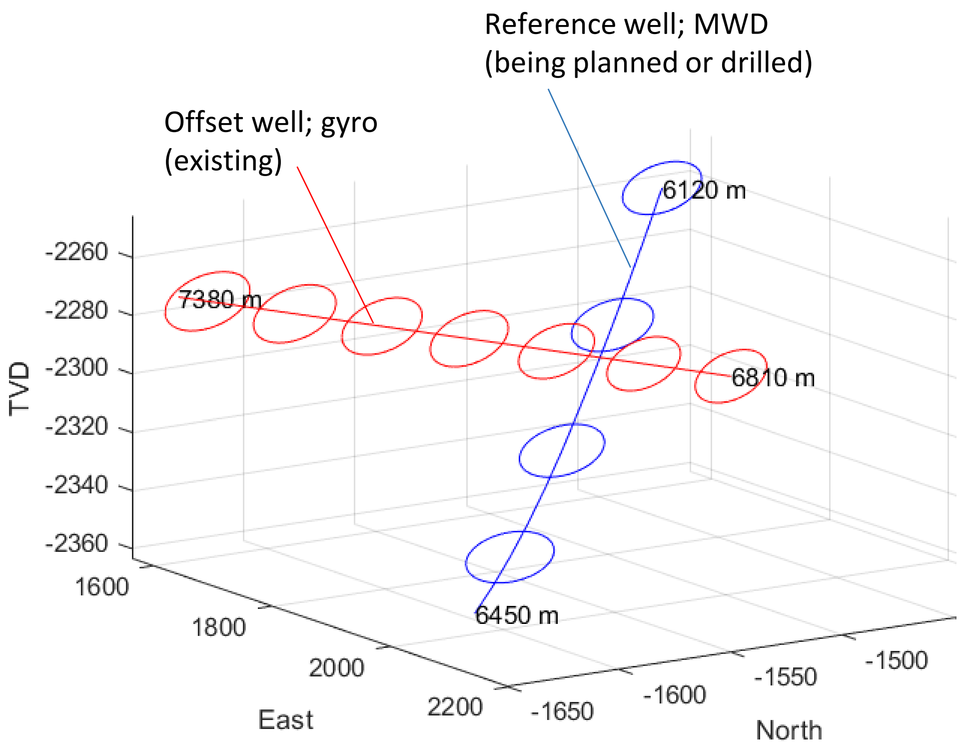


EOU_{comb} in Mahalanobis space (circle / sphere)

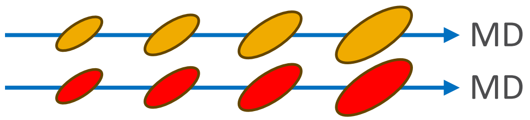
(Mathematically equivalent options)

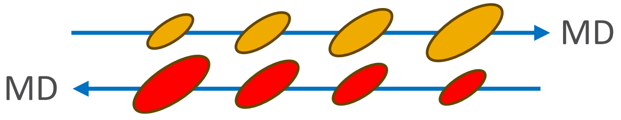
Numeric example

Numeric example



- Synthetic but realistic wellbores; one curved
  - Nearly perpendicular; slightly anti-parallel.



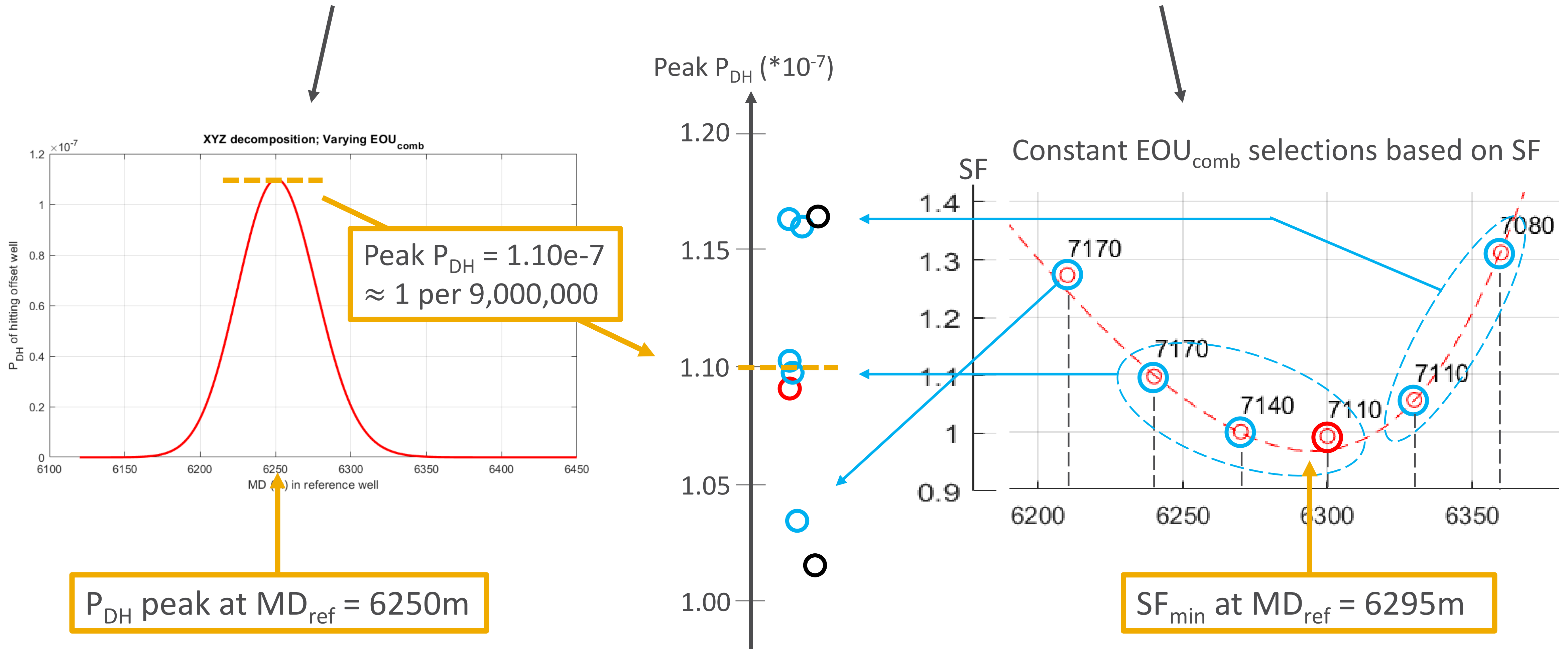


- Surveyed by standard MWD and gyro tools.
- Normal pdfs; uncertainty correlations are neglected.
- Original survey intervals 30 m; interpolated to ~1 m.
- Relative position such that SF $> \sim 1$ (k = 3.5).

Most accurate calculation:

Interpolated; using actual EOUs (=> varying EOU_{comb})

Compared to using a pair of 'representative' EOUs (=> constant EOU_{comb})



Conclusions

Conclusions (1): Comparison of SF versus P_{DH}.

- Various scenarios require various approaches.
  - Trade-off between accuracy and computational efficiency.
- P_{DH} is well suited for critical close-proximity regions:
  - Fundamental definition and interpretation.
  - Accurate results on high-resolution (interpolated) data.
  - Flexible: Any well geometry / pdf shape / analysis interval.
- SF is well suited for safe-distance ‘screening’:
  - More efficient evaluation than detailed P_{DH} calculation.
  - Useful for defining critical region onset.

Conclusions (2): P_{DH} options in critical close-proximity regions

- Accuracy of results is important.
  - High accuracy / high resolution obtained by interpolation along MD.
  - P_{DH} recommended.
- Constant EOU_{comb} cannot be recommended.
  - Difficult to select ‘representative’ pair of EOUs from *a priori* (low resolution) data.
  - Using the two largest EOUs will always be conservative; however, accuracy may be an issue.
- P_{DH} evaluation in physical space versus Mahalanobis space:
  - No significant difference in computation time (NB: limited case study).

Conclusions (3): Further work.

- Define transition from 'safe' distance (use SF) to critical region (use P_{DH}).
  - SF-based criterion.

- Accuracy depends crucially on pdf model.
  - Distances of typically 3-4σ: Using proper pdf (especially tails) is important.

Thank you for your attention

Thanks to Gyrodata and SLB for the opportunity to develop and publish this work.