Survey Error Distributions and Wellbore Collision Probabilities

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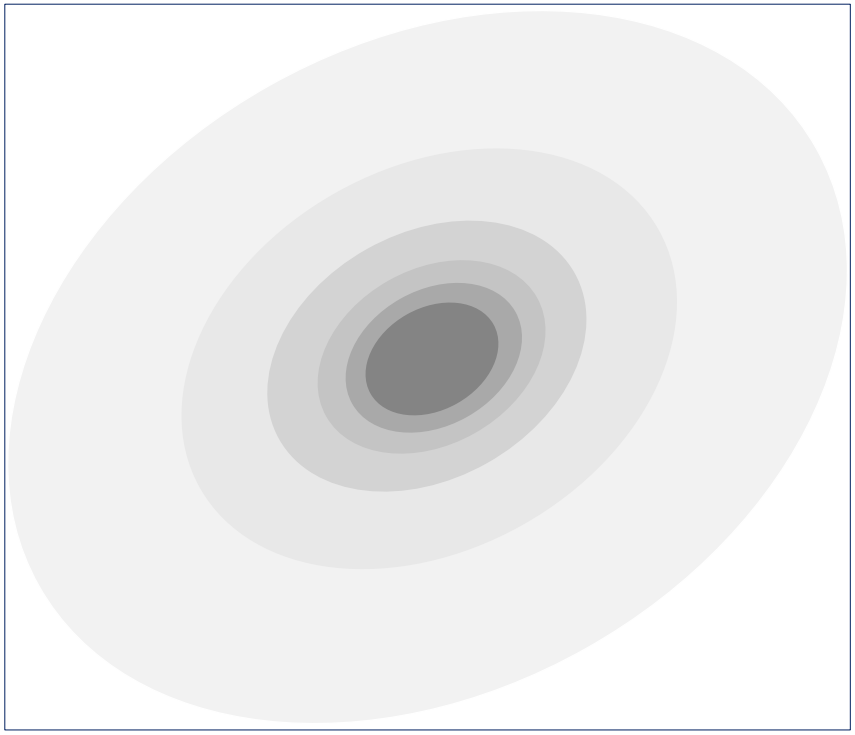
WELLPOS

Outline

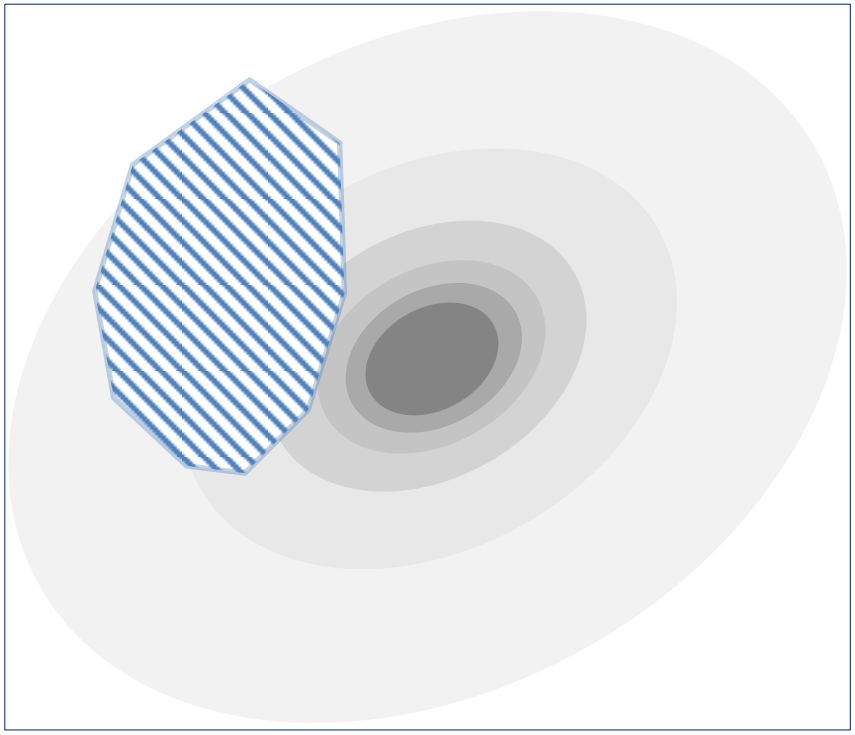
- Wellbore Geometries and Collisions
- Wellbore Separation Requirements
- Probability Distributions
  - normal distributed data
  - empirical survey data
- Comparison of Collision Probabilities
- Conclusions

Probability Density



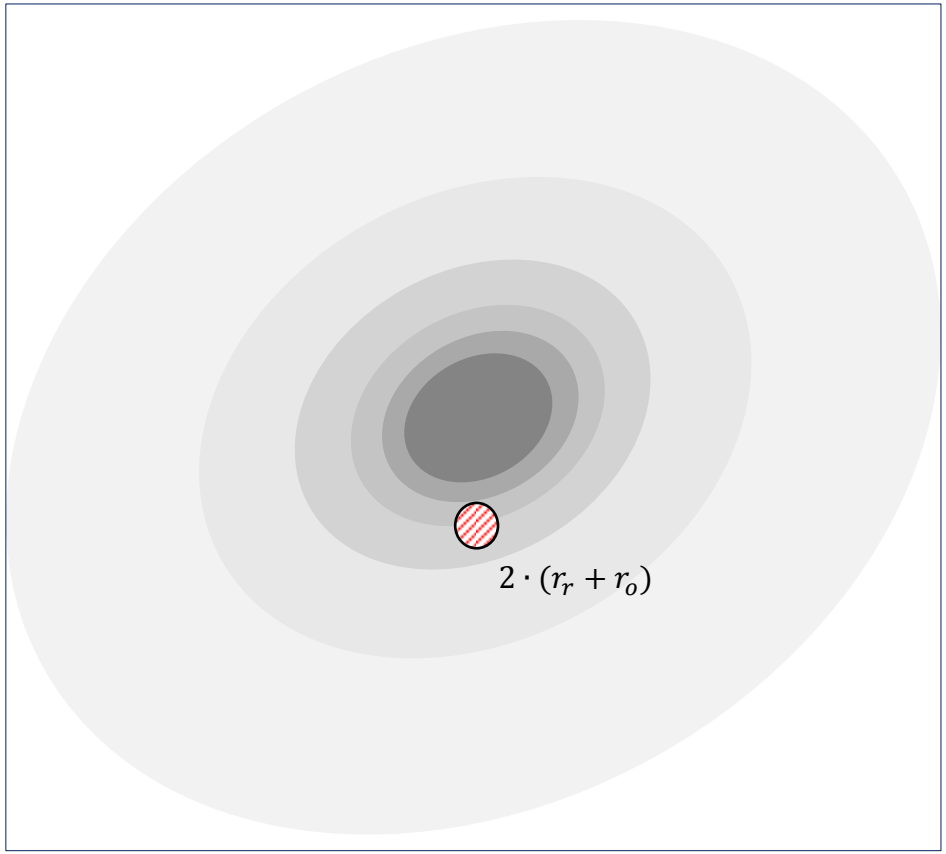
The Probability Density of the relative wellbore positions is illustrated by the concentric ellipses/ ellipsoids.

Collision Probability

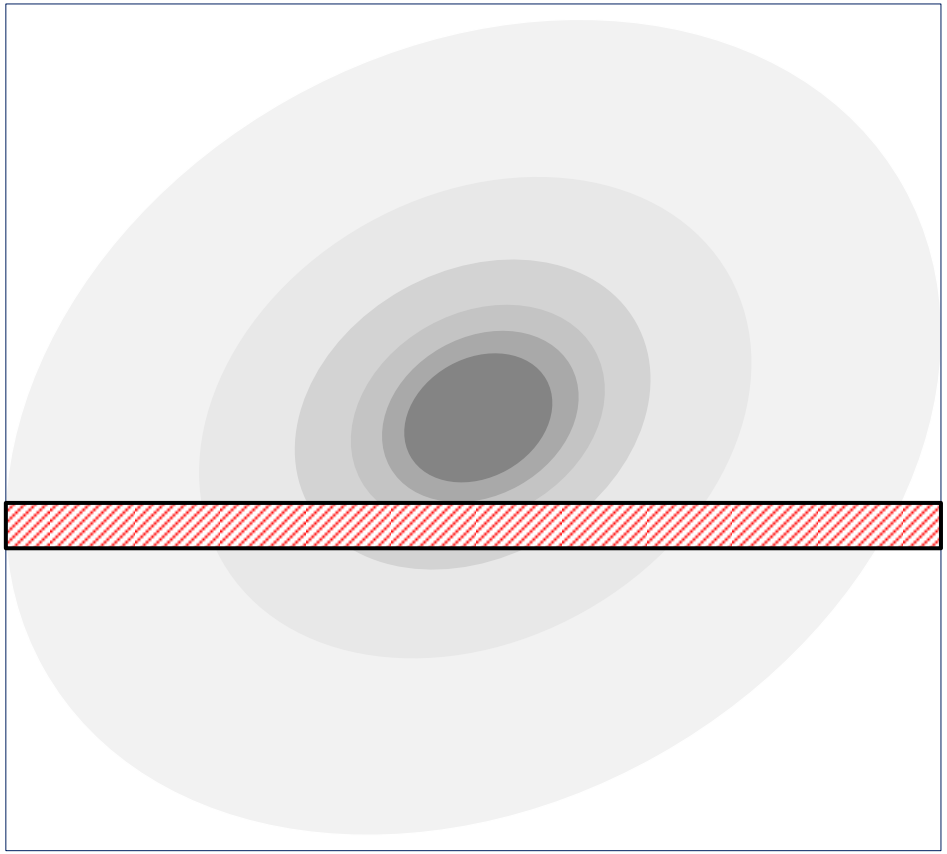


The Collision Probability is the probability density integrated over the appropriate area/ volume of the probability density.

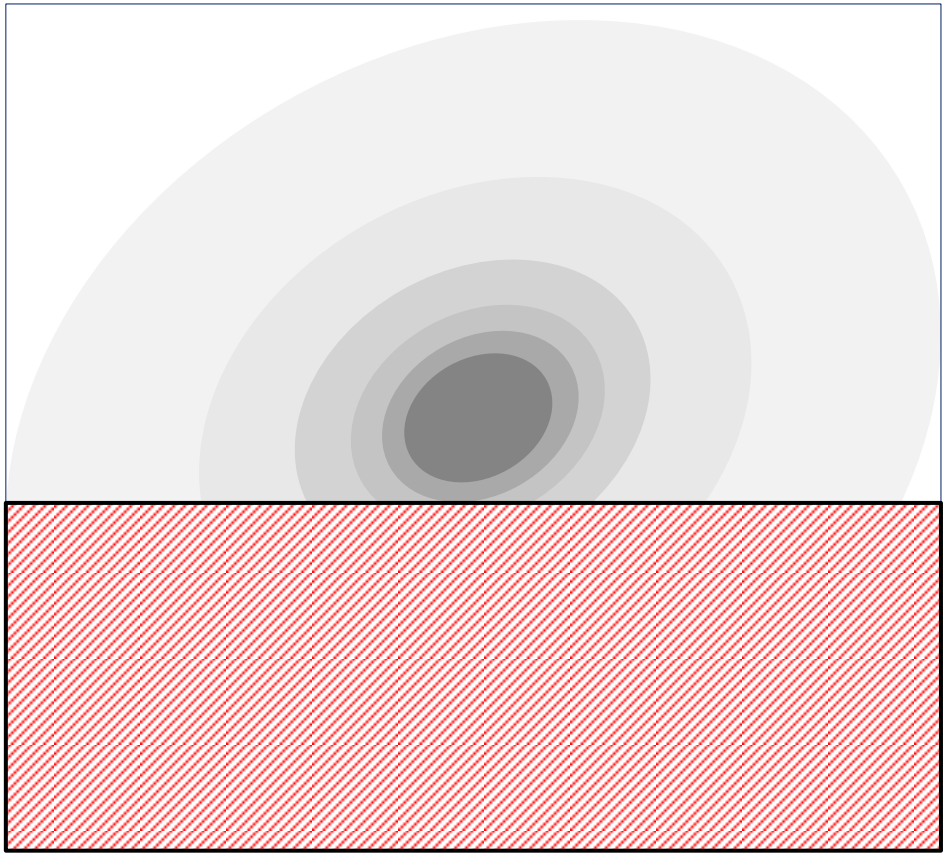
Parallel wellbores (head-on)



Orthogonal wellbores

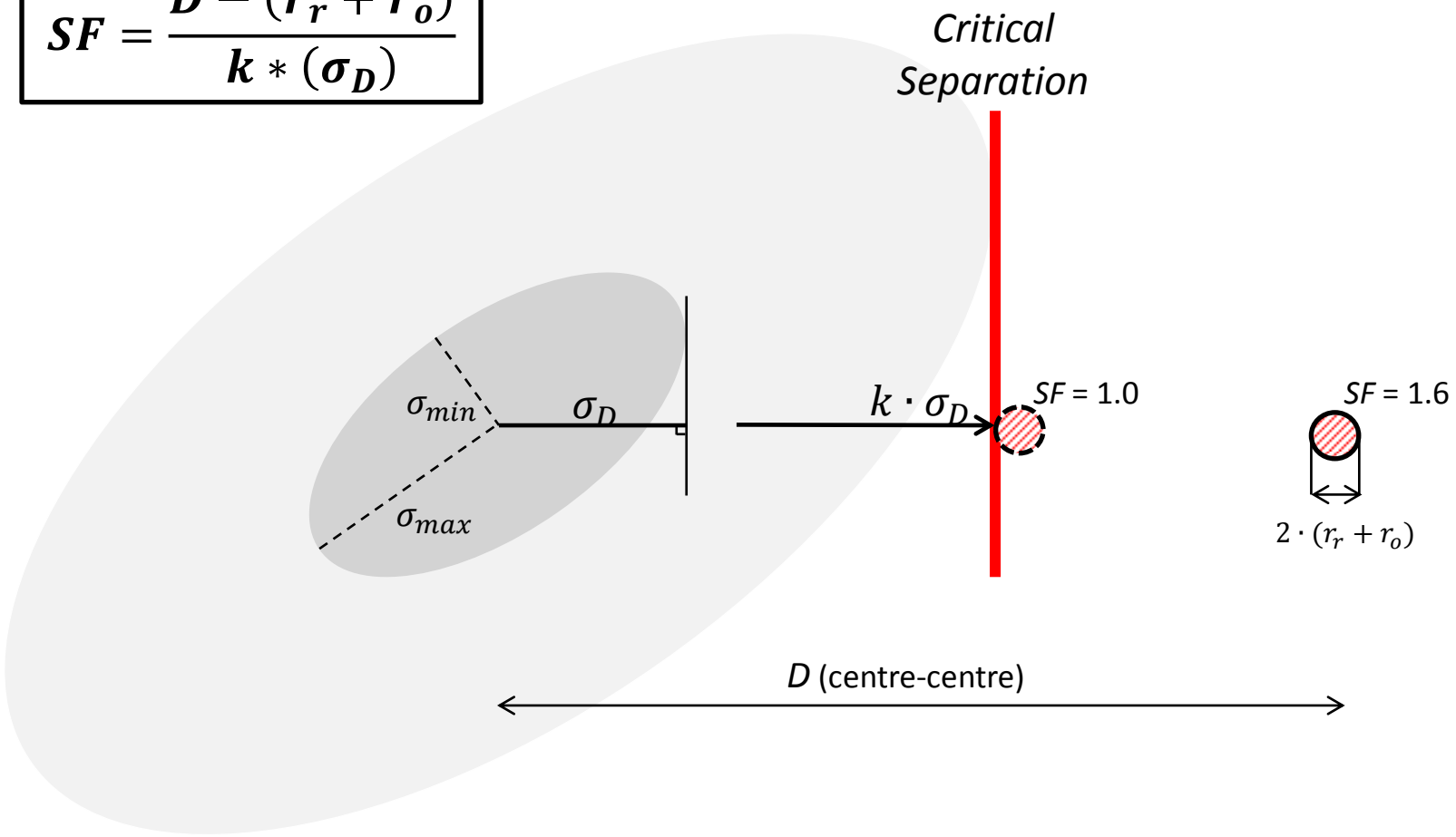


Hazardous zone



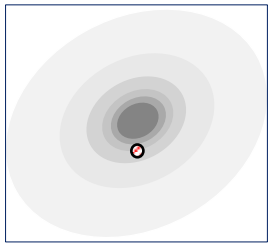
Separation requirement: SF ≥ 1.00
Minimum Allowable Separation Distance

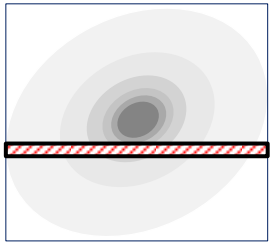
$$SF = \frac{D - (r_r + r_o)}{k * (\sigma_D)}$$

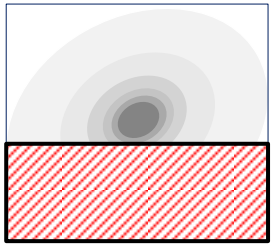


Collison Probability

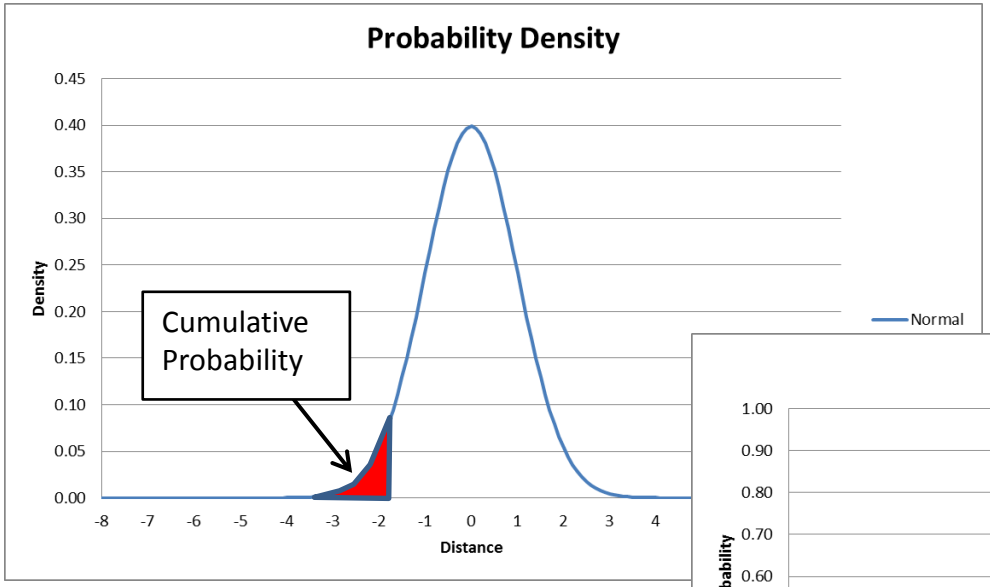
- Collision Probability is dependent of the survey error characteristica
  - Relative Position Accuracies
  - Probability Density
  - Cumulative Probability

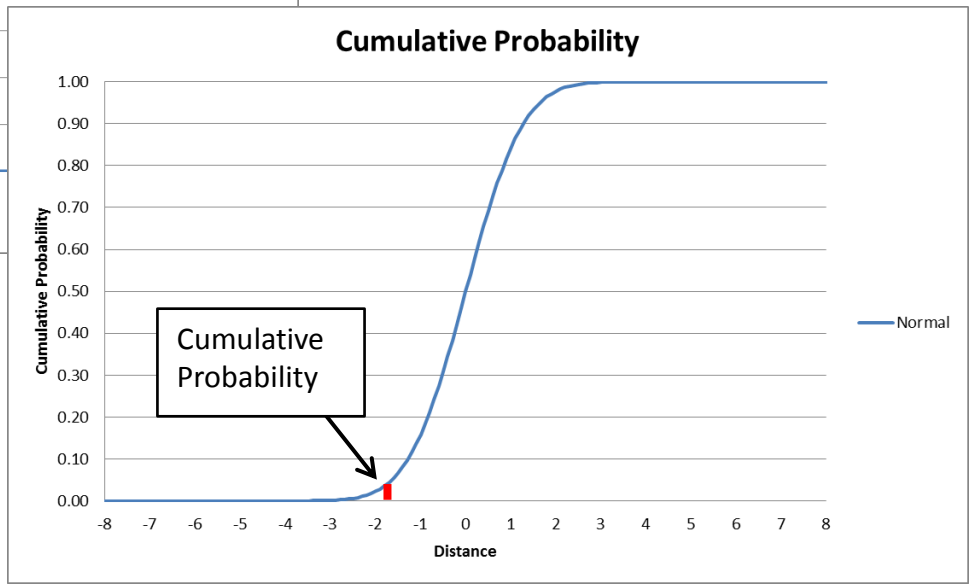






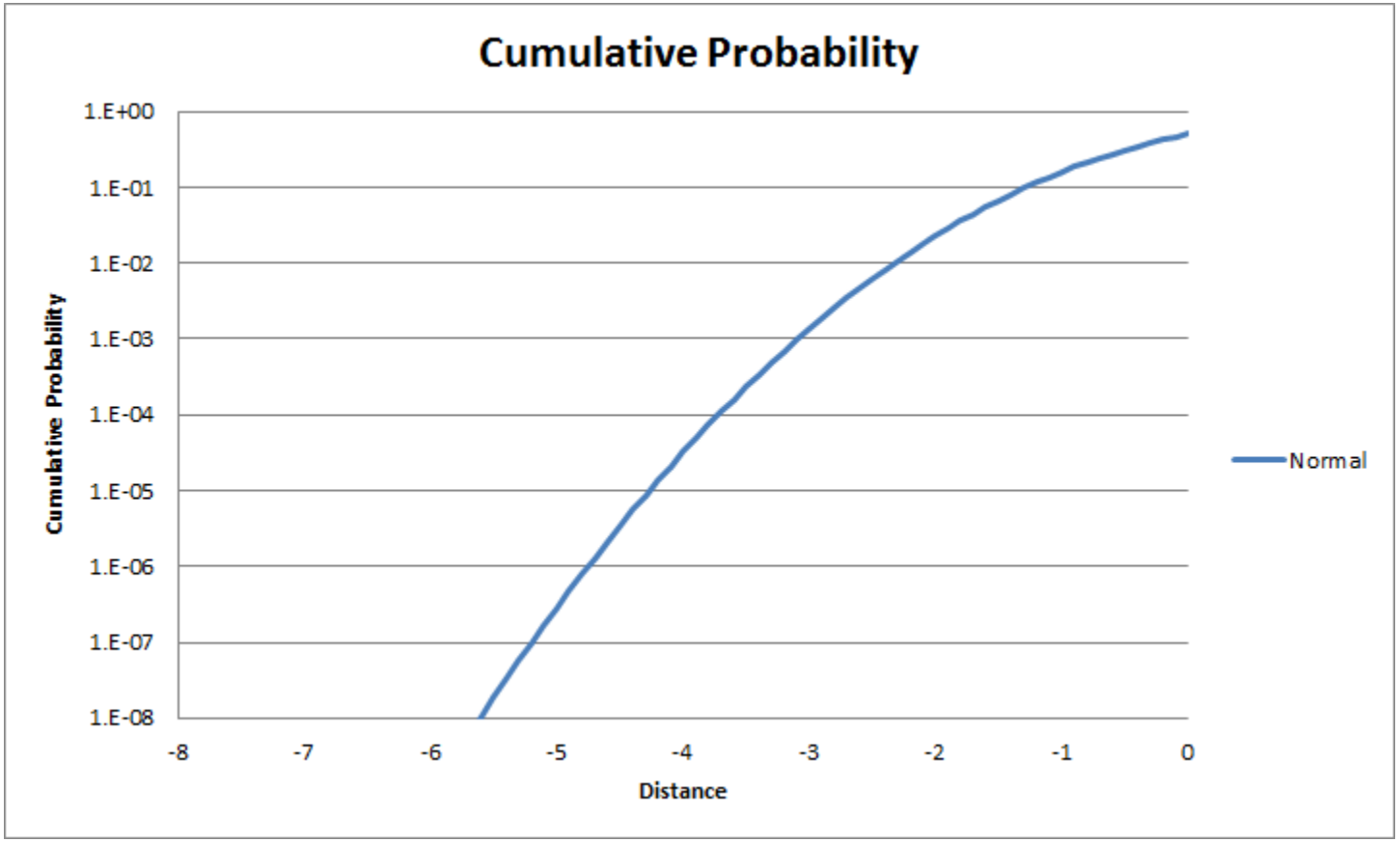
Cumulative Probability





$$P(X \leq x)$$

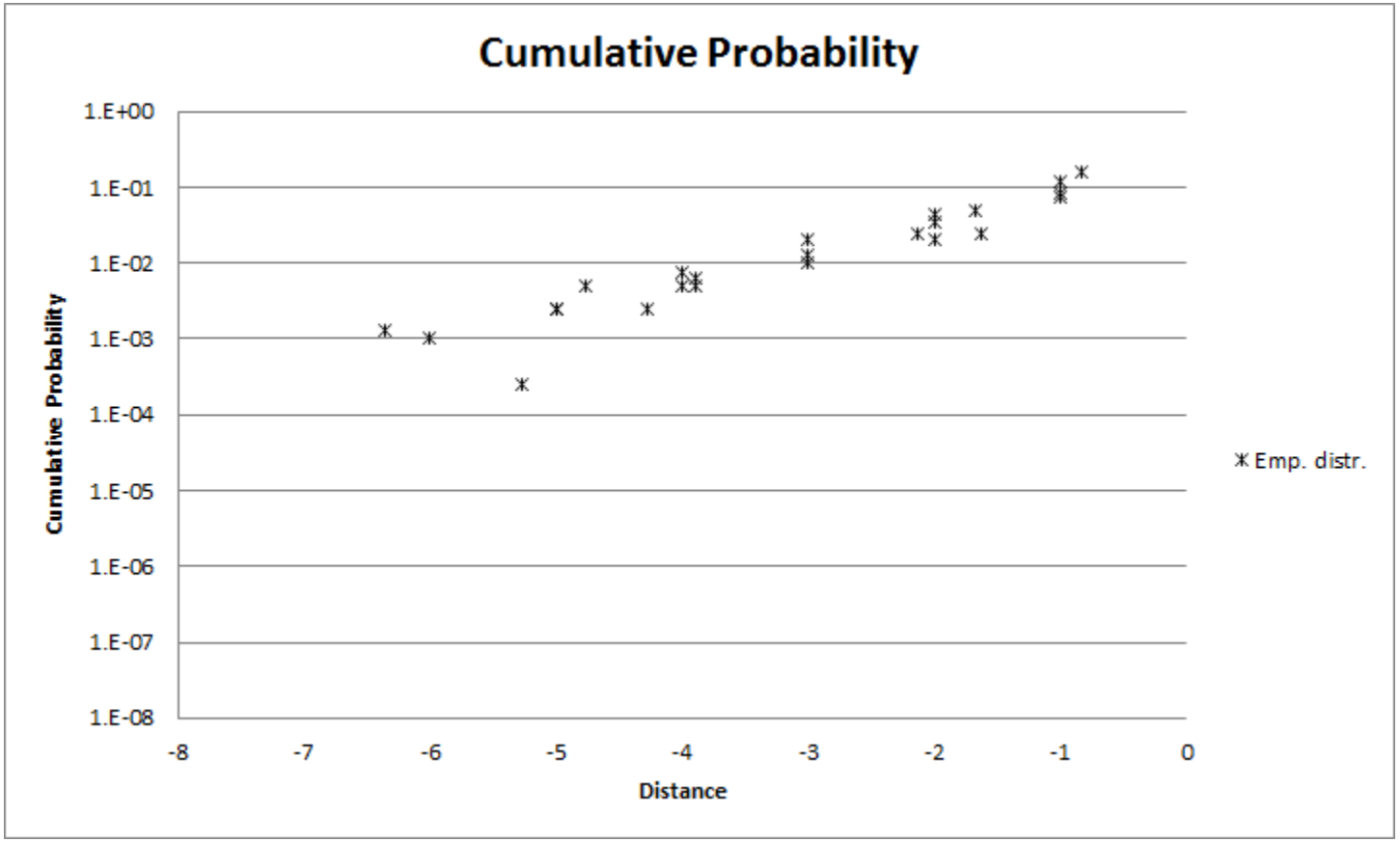
Normal distribution – N(0,1)



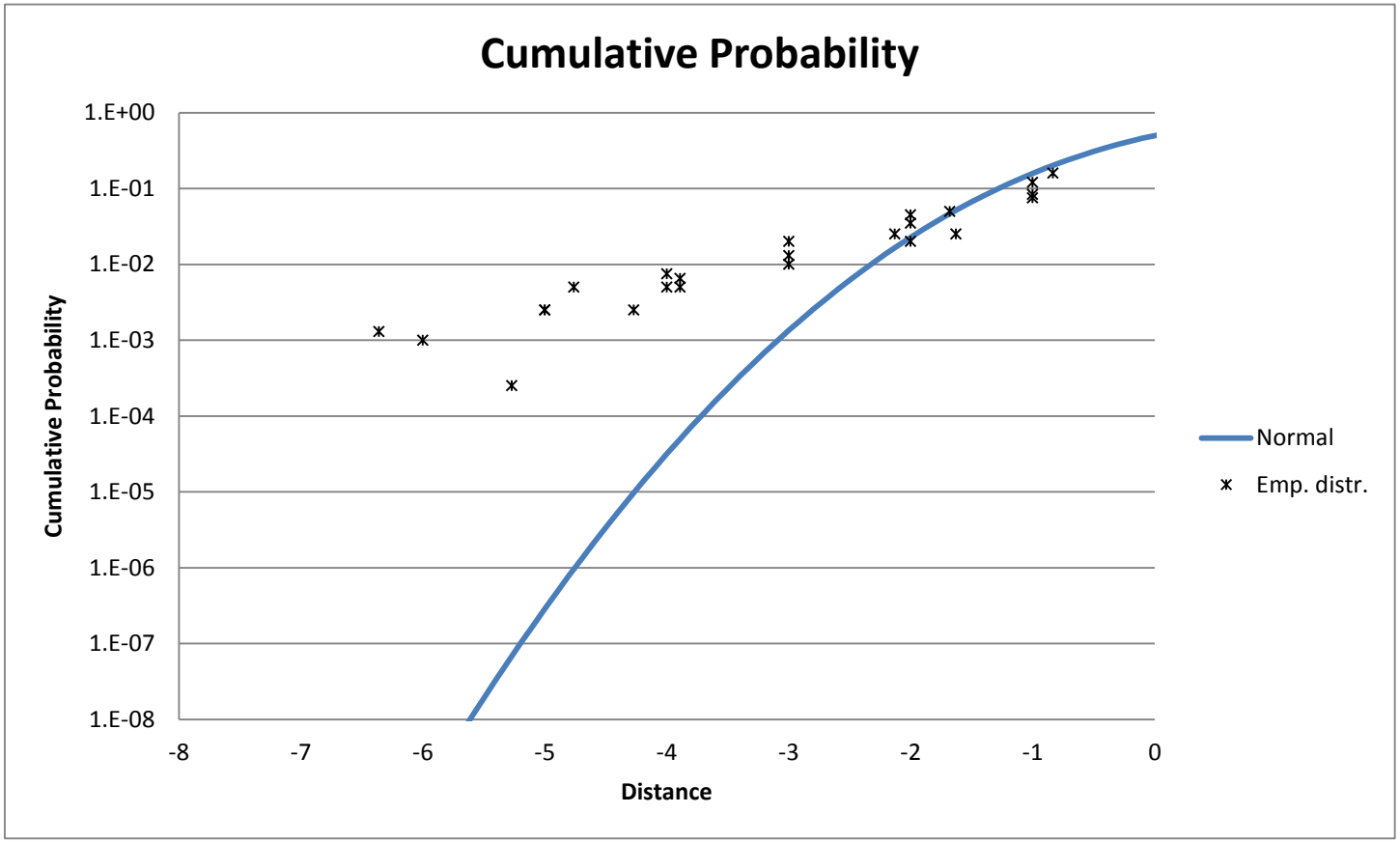
Empirical Data

- Codling, J. (2010): *"Tail Heavy Distributions & Confidence Levels for Directional Survey Measurements"*. Presented (slides) at 31st ISCWSA meeting March 2010.
- Macmillan, Susan; Grindrod, Steve (2010): *"Confidence Limit Associated With Values of the Earth's Magnetic Field Used for Directional Drilling".* SPE paper 119851, SPE Drilling & Completion, June 2010
- Nyrnes, Erik; Torkildsen, Torgeir; Nahavandchi, Hossein (2005): *" Error Properties of Magnetic Directional Surveying Data",* SPWLA 46th Annual Logging Symposium, June 2005.
- Torkildsen, T.; Sveen, R.H.; Bang, J. (1997): *"Geomagnetic Reference"*, Report no. 1 and 2. IKU Petroleum Research 32.0897.00/01/97 and 32.0897.00/02/97.
- Williamson, H. S. (1998): "*Towards Risk-Based Well Separation Rules"*. SPE paper 36484, SPE Drilling and Completion, March 1998.

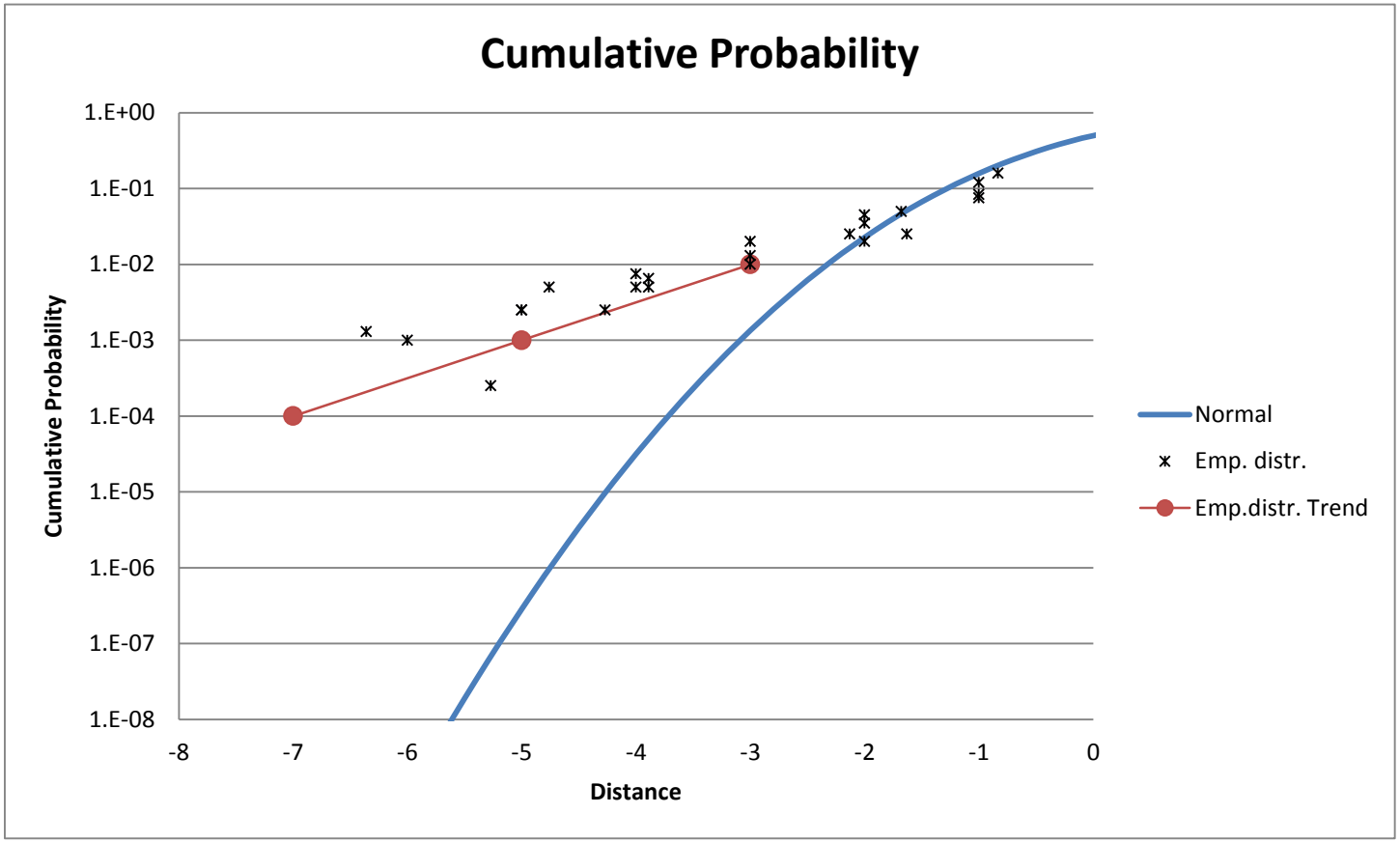
Empirical Data Distribution



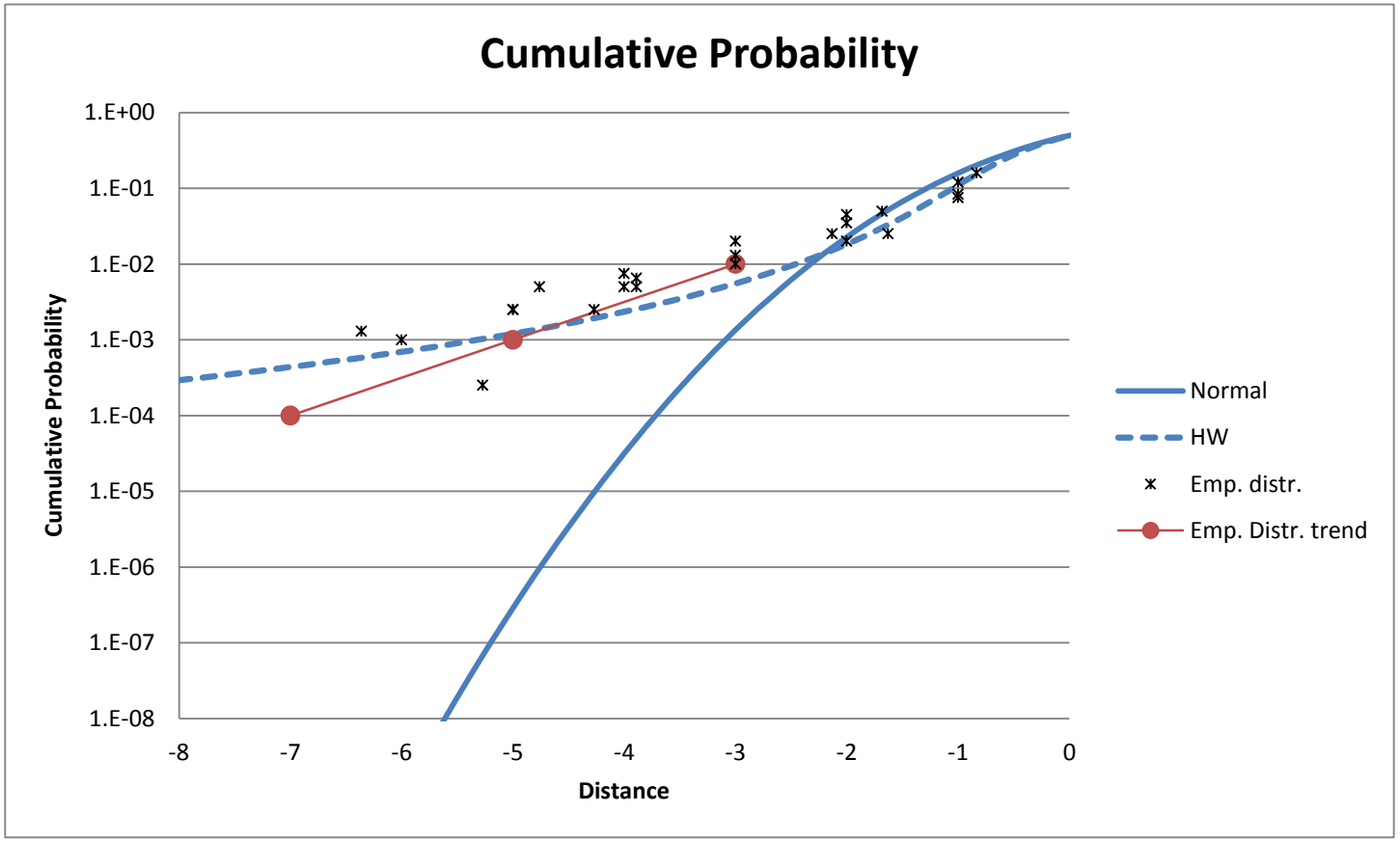
Empirical data and Normal distribution



Empirical data trend



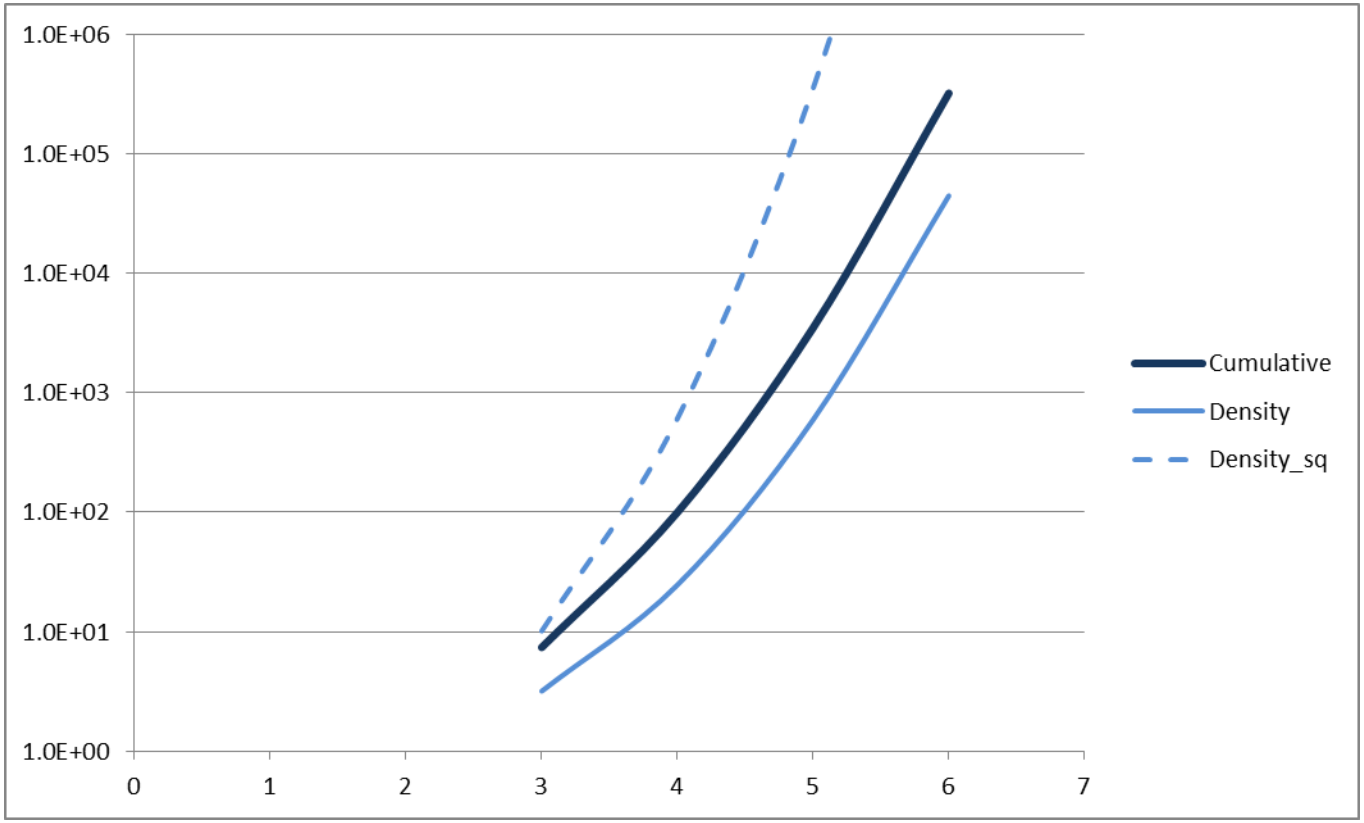
“Candidate” Distribution by Hugh Williamson (HW)



Comparison of Cumulative Probabilities

Distance	Normal Distribution	Empirical Data	Mult. Factor
3.0	0.0013499	0.0100000	**7**
4.0	0.0000317	0.0031623	**100**
5.0	0.0000003	0.0010000	**3489**
6.0	0.0000000	0.0003162	**320296**

Comparison of Probabilities Multiplication Factors



Conclusions

- The probability densities for survey data are more «heavy-tailed» than Normal distributed data:
  - errors > 3σ, ~ 10 times more frequent
  - errors > 4σ, ~ 100 times more frequent
  - errors > 5σ, ~ 1000 times more frequent
- If collision probability matters, distributions derived from survey data should be introduced in the probability estimations.