Industry Steering Committee on Wellbore Survey Accuracy

Collision Avoidance Lexicon

2017

An understanding of collision avoidance terminology requires an understanding of position uncertainty terminology. This lexicon therefore includes the terminology of both subjects, segregated for ease of reference.

The use of *italics* in the definition indicates a word or phrase that is included elsewhere in the lexicon.

The lexicon is extensive, but it is not exhaustive. It focuses on words and phrases that are unique to this discipline, particularly those that are specific to the more widely used well planning computer programs. Except where necessary to support other definitions, it intentionally avoids providing definitions of mathematical functions that can be found elsewhere, in more authoritative texts.

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Collision Avoidance Work Group

POSITION UNCERTAINTY

Word/Phrase/Symbol	Definition
μ	Greek letter mu, symbol for *mean* of a distribution.
ρ	Greek letter rho. *Correlation coefficient*.
σ	Greek letter *sigma*, symbol for *standard deviation* of a distribution.
Along hole axis	The axis that is aligned with the local wellpath orientation, positive with increasing measured depth. In some software this phrase may be used to label the *along hole uncertainty*.
Along hole uncertainty	The projection of the *EOU* onto the *along hole axis*.
Bias	Non-zero *mean* of an error distribution; or displacement of the center of the *ellipsoid of uncertainty* from the corresponding point on the nominal wellpath.
cdf	*Cumulative distribution function.*
Central Limit Theorem	The sum of a large number of independent *random* variables is approximately normally distributed. This theorem is used to justify the assumption that tool errors, which result from a number of *error terms*, may be modelled using a *normal distribution*. However, the theorem is less applicable when the error budget is dominated by a few terms, so the assumption of normality should always be treated with caution.
Confidence interval	A range of values within which the value of a variable is expected to fall with a particular probability. The associated probability is the *confidence level*. Values of the confidence interval are often described in terms of the corresponding *confidence level*, e.g. "95% confidence interval".
Confidence level	The probability value associated with a *confidence interval*. Often expressed as a percentage, e.g. "95% confidence level".
Confidence limits	The upper and lower bounds of a *confidence interval*.
Correlated	Applied to two or more variables, showing a tendency to take values which depend on each other. Two variables that are correlated will have a non-zero *correlation coefficient*. Where the sense is not stated, it is liable to be assumed to mean *Positively Correlated*. In SPE 67616, an *error term* which is expected to take on the same value under different conditions (e.g. at a different *survey station*, in a different *survey leg*, or in a different well).
Correlation coefficient	A number between -1 and +1 which indicates the degree of correlation between two variables. The correlation coefficient is positive for variables which are dependent, zero for independent or *uncorrelated* variables, and negative for variables which tend to move in opposite directions.
Covariance	The covariance between two sets of data X and Y is calculated as $\text{cov}(X, Y) = 1/n \cdot \Sigma_{i=1}^{n}[(x_i - x_m) \cdot (y_i - y_m)]$, where x_i and y_i are the *i*th of n elements in the data sets X and Y with means x_m and y_m respectively. Covariance is related to the *correlation coefficient* ρ_{xy} by $\text{cov}(X, Y) = \sigma_x \cdot \sigma_y \cdot \rho_{xy}$, where σ_x and σ_y are the *standard deviations* of X and Y respectively.

POSITION UNCERTAINTY (continued)

Word/Phrase/Symbol	Definition
Covariance matrix	A matrix made up of variances and *covariances* for the components of a vector. In wellbore positioning we are concerned with a position vector having three components (*rH*, *rL*, *rA*) or (*rN*, *rE*, *rV*). The 3 by 3 *covariance matrix* associated with *positional uncertainty* contains the *variances* σ_i^2 and the *covariances* $\sigma_i \cdot \sigma_j \cdot \rho_{ij}$, where σ_i and σ_j are the *standard deviations* of the uncertainties in the directions corresponding to the *i* and *j* vectors, and ρ_{ij} is the *correlation coefficient* by which they are related.
Cumulative density function	*Cumulative distribution function.*
Cumulative distribution function	The cumulative distribution function $F(x)$ of a distribution is the probability that a *random* variable sampled from that distribution takes on a value less than or equal to the argument *x*.
Dependent	Statistically dependent. Rarely used alternative to *Correlated.*
EOU	*Ellipsoid of uncertainty* or *ellipse of uncertainty.*
Ellipse major axis	The larger of the two *principal axes* of the ellipse formed when an ellipsoid is projected onto a defined plane (e.g. horizontal, or perpendicular to wellbore).
Ellipse minor axis	The smaller of the two *principal axes* of the ellipse formed when an ellipsoid is projected onto a defined plane (e.g. horizontal, or perpendicular to wellbore).
Ellipse of uncertainty	The area produced by projecting an *ellipsoid of uncertainty* onto a defined plane.
Ellipsoid Major axis	The largest of the three *principal axes* of an ellipsoid.
Ellipsoid Minor axis	The smallest of the three *principal axes* of an ellipsoid.
Ellipsoid of uncertainty	For a point specified by its co-ordinate position, the volume encompassed by the point's *position uncertainty* defined at a specified number of *standard deviations* or *confidence level*.
Error ellipse	*Ellipse of uncertainty*.
Error ellipsoid	*Ellipsoid of uncertainty*.
Error model	A group of *error terms* which define the performance of a survey system over a *survey leg*.
Error term	A measurement error which is a component of an *error model*, along with its associated *correlation coefficients* and *weighting function*.
Error vector	The error in *survey station* position resulting from a particular survey *error term* (per SPE 67616).
Full axis	Equivalent to the diameter of an ellipse or ellipsoid, as opposed to *half* or *semi axis*.
Gaussian distribution	*Normal distribution.*
Global	SPE 67616 *propagation mode* definition: *Correlated* across all *survey stations*, all *survey legs*, and all wells.
Gross error	Often used as a subjective description of relatively large errors, but also used to describe the occurrence of errors from a source not accounted for in the model, or of a magnitude greater than the *error model's* 3 *sigma* value. Also used to describe any "off design" event, such as incomplete database of offset wells. Occurrences of such gross errors can lead to well collisions.

POSITION UNCERTAINTY (continued)

Word/Phrase/Symbol	Definition
Half axis	Equivalent to the radius of an ellipse or ellipsoid, as opposed to *full axis*.
High side axis	The axis that is normal to the *along hole axis* in the vertical plane, positive upwards. In some software this phrase may be used to label the *high side uncertainty*.
High side uncertainty	The projection of the *EOU* onto the *high side axis*.
HLA	The "high side - lateral - along hole" right-handed coordinate system.
Horizontal Phi	Angle from north reference to *horizontal semiminor axis.* Same as *minor axis azimuth.*
Horizontal semimajor axis	Radius of the largest axis of the *ellipse of uncertainty* in the horizontal plane. Same as *major semi axis* and *semi-major error*.
Horizontal semiminor axis	Radius of the smallest axis of the *ellipse of uncertainty* in the horizontal plane. Same as *Minor semi axis* and *semi-minor error*.
Independent	Statistically independent. Rarely used alternative to *Uncorrelated.*
Instrument performance model	The set of *error term* values that define a survey tool's performance, for use within a specified *error model*.
IPM	*Instrument performance model.*
Lateral axis	The axis that is normal to the *along hole axis* in the horizontal plane, positive to the right when viewed looking downhole. In some software this phrase may be used to label the *lateral uncertainty*.
Lateral uncertainty	The projection of the *EOU* onto the *lateral axis*.
Major axis	Either an *ellipse* or *ellipsoid major axis*.
Major semi axis	Radius of the largest axis of the *ellipse of uncertainty* in the horizontal plane. Same as *horizontal semimajor axis* and *semi-major error*.
Mean	Average of a set of numbers; or center of a symmetrical distribution.
Minor axis	Either an *ellipse* or *ellipsoid minor axis*.
Minor axis azimuth	Angle from north reference to *minor semi axis*. Same as *horizontal phi.*
Minor semi axis	Radius of the smallest axis of the *ellipse of uncertainty* in the horizontal plane. Same as *horizontal semiminor axis* and *semi-minor error*.
Negatively correlated	Having a *correlation coefficient, ρ,* where $-1 \leq \rho < 0$
NEV	The "north - east - vertical" right-handed coordinate system.
Normal distribution	Distribution of a variable in which the probability density of a particular value x is given by the *pdf* $1/[\sigma \sqrt{(2 \cdot \pi)}] \cdot \exp[- (x - \mu)^2/(2 \cdot \sigma^2)]$ Most error models, if not all, assume that errors are normally distributed. This is not a well founded assumption although the *central limit theorem* provides some support for it.
pdf	*Probability density function.*
Per-well	*Well by well.*

POSITION UNCERTAINTY (continued)

Word/Phrase/Symbol	Definition
Position uncertainty	An estimate of the uncertainty associated with a point on the wellpath, either planned or actual, based on the planned or actual survey method. The output of a survey tool *error model* is fully defined by a *covariance matrix*, but normally reported as an *EOU*.
Positional uncertainty	*Position uncertainty*.
Positively correlated	Having a *correlation coefficient, ρ,* where $0 < ρ ≤ 1$
Principal axis	The longest or shortest axis through the center of an ellipse. For an ellipsoid, the longest or shortest axis, or the axis normal to these two.
Probability density function	The derivative of the *cdf*: the probability that a *random* variable *x* is in any particular interval [*a*, *b*] is the integral of the *pdf* from *a* to *b.*
Propagation mode	The degree of correlation between the values of an error at different *survey stations*; described as *Random*, *Systematic*, *Well by Well*, or *Global* in SPE 67616.
PU	*Position uncertainty*.
Random	A variable with unknown value, selected from a known or assumed probability distribution. SPE 67616 *propagation mode* definition: *Uncorrelated* between different *survey stations*.
s.d.	*Standard deviation.*
Semi-axis	Equivalent to the radius of an ellipse or ellipsoid, as opposed to *full axis*.
Semi-major error	Radius of the largest axis of the *ellipse of uncertainty* in the horizontal plane. Same as *Horizontal semimajor axis* and *Major semi axis*.
Semi-minor error	Radius of the smallest axis of the *ellipse of uncertainty* in the horizontal plane. Same as *Horizontal semiminor axis* and *Minor semi axis*.
sigma	*Standard deviation*.
Standard deviation	A statistical measure of the dispersion or spread of a distribution, obtained by extracting the square root of the *variance*.
Standard normal distribution	A *normal distribution* with *mean* equal to zero and *standard deviation* equal to 1.
Survey leg	A group of directional measurements taken with a single tool, either in a single run or over several runs during which the operating conditions are assumed to be constant.
Survey program	The types and sequence of survey instruments to be used in a well. It will normally be presented as a listing or table and will include information such as the depth interval that each survey tool will be run in, the required survey frequency, corrections to be applied, contingencies and also the *error model* to be assigned to each *survey leg*. The *survey program* should be designed to ensure that all of the well's directional objectives are met.
Survey station	A point in the wellbore at which a directional measurement is made.
Systematic	*Correlated.* SPE 67616 *propagation mode* definition: Correlated across all stations within a *survey leg*, *uncorrelated* between different *survey legs*.

POSITION UNCERTAINTY (continued)

Word/Phrase/Symbol	Definition
TVD dimension	Dimension from center to TVD extremity of *ellipsoid of uncertainty*.
Uncertainty at a survey station	The *positional uncertainty* associated with the particular point along the hole at which a survey tool made a measurement.
Uncertainty at an assigned depth	The *positional uncertainty* associated with a particular depth along a hole. Differs from *uncertainty at a survey station* in that the depth is precise; i.e. there is no along-hole error at the depth of interest.
Uncertainty model	*Error model*.
Uncorrelated	Applied to two or more variables, showing a tendency to take values which are independent. Two variables that are uncorrelated will have a zero *correlation coefficient*. In SPE 67616, an *error term* which is expected to take different values under different conditions (e.g. at a different *survey station*, in a different *survey leg*, or in a different well).
Variance	A measure of the dispersion or spread of a number of values. The population variance S^2 is calculated by $1/n \cdot \Sigma_{i=1}^{n}(x_i - x_{pm})^2$, where x_i is the *i*th of *n* elements in a population which has a *mean x_{pm}*. The sample variance s^2 is calculated by $1/(n - 1) \cdot \Sigma_{i=1}^{n}(x_i - x_{sm})^2$: the smaller denominator compensates for the fact that the values of a sample from a population are more tightly grouped about the sample *mean x_{sm}* than the population *mean x_{pm}*.
Vertical uncertainty	The projection of an *EOU* onto the vertical axis.
Vertical semi-axis	Half the *vertical uncertainty*.
Weighting function	Per SPE 67616, a three-element vector by which an *error term* value is multiplied to find the corresponding errors in depth, inclination, and azimuth. The function attempts to model the term's response to operational and environmental variables.
Well by well	SPE67616 *propagation mode* definition*: Correlated* across all *survey stations* and all *survey legs* within a well, *uncorrelated* between wells.

The Collision Avoidance section follows.

COLLISION AVOIDANCE

Word/Phrase/Symbol	Definition
3D distance	The shortest distance between the *reference well*, at a particular measured depth, and an o*ffset well*. The vector always intersects the o*ffset well* at right angles.
3D least distance	*3D distance.*
ACR	*Anti-collision Rule*.
ADP	*Allowable deviation from plan.*
Allowable deviation from plan	The distance, measured on the plane of analysis, that the *reference well* can be deviated from the plan while maintaining the *minimum allowable separation distance*.
Anti-collision	Collision avoidance.
Anti-collision diagram	A *travelling cylinder diagram* that includes indication of allowable deviation of the *reference well* from its planned trajectory.
Anti-collision rule	An equation that defines the m*inimum allowable separation distance* between the *reference well* and an o*ffset well* at any specified point along the *reference well*.
Center to center clearance distance	In some software, the distance between the center lines of the *reference well* and an *offset well* on a specified plane.
CF	*Clearance factor*.
Clearance	General term for calculation of distance between *reference* and *offset wells.*
Clearance factor	*Separation factor*.
Closest approach	The distance between a nominated point on the r*eference well* and the nearest point on an o*ffset well*. Calculated along the line originating at the point of interest on the *reference well* and intersecting the o*ffset well* at right angles.
Closing factor	An obsolete term for Statoil's *Separation factor*.
Drilling well	*Reference well*.
Drilling tunnel	The volume that is encompassed by the *tolerance lines* along the *planned well* trajectory.
Factor of separation	*Separation Factor*.
Intersection angle	The angle between the attitude of the *reference well* and the attitude of the *offset well* at their respective analysis positions. An aid in the selection of an appropriate analysis interval.
MAC	Minimum allowable clearance. Same as *MASD* and *MAS*.
Major risk well	A phrase probably coined by BP, for whom the definition is an *offset well* that, if collided with, represents a risk to personnel or the environment. Other users of the term may have a different definition of major risk.
MAS	Minimum allowable separation. Same as *masd* and *MAC.*
masd	*Minimum allowable separation distance.* Same as *MAS* and *MAC.*
Minimum allowable separation distance	A phrase probably coined by BP. For a specified measured depth on the *reference well*, the well separation distance that equates to the no-go criterion of the *ACR*; i.e. the expression of ratio or probability *ACR* criteria as distances.

COLLISION AVOIDANCE (continued)

Word/Phrase/Symbol	Definition
Minimum distance	In some software, the *closest approach.*
Minor risk well	A phrase probably coined by BP, for whom the definition is an *offset well* that, if collided with, does not represent a risk to personnel or the environment. Other users of the term may have a different definition of minor risk.
No-go area	With respect to the *reference well*, an area on a *travelling cylinder diagram* which is beyond a *tolerance line*.
No-go distance	The radial distance from a position on an *offset well* on a *travelling cylinder diagram* that defines the *no-go area* for that position.
Normal plane	The plane normal to the *reference well* at the depth of interest. The *travelling cylinder* plane.
Object well	*Offset well*.
Offset well	An existing or *planned well* that is to be evaluated for risk of collision with the *reference well*.
Oriented separation factor	Schlumberger *Separation Factor* definition that takes into account the geometry of the *EOU*'s and provides the same probability of collision for a given *OSF* value.
OSF	*Oriented separation factor.*
Pedal curve	The locus of points of the intersection of the perpendicular from the ellipse center with the tangent to the ellipse.
Pedal curve radius	The radius of the *pedal curve* along a line of interest, usually between the points of interest on the *reference* and *offset wells*.
Pedal surface	The locus of the points of intersection of the perpendicular from the *ellipsoid* center with the tangent plane to the *ellipsoid*.
Pedal surface radius	The radius of the *pedal surface* along a line of interest, usually between the points of interest on the *reference* and *offset* wells.
Plane angle	The angle between the wellbore attitude at a point of interest on the *reference well* and the line, lying in the chosen scanning plane, that connects that point to the *offset well.*
Planned well	In this context, sometimes used to refer to the *reference well* before drilling commences.
Projected vector	Vector perpendicular to the *reference* and *offset* wellbore directions at the depth(s) of interest.
Proximity	General term for calculation of distance between *reference* and *offset wells.*
Proximity ratio	*Separation factor*.
QRA	*Quantitative risk assessment*.
Quantitative risk assessment	The identification of all of the possible outcomes of a well collision, the quantification of the consequences of each outcome and the assessment of whether the risk is acceptable.
Reference well	The well being planned or drilled and assessed for risk of collision with *offset wells*.
Risk based rule	An *anti-collision rule* that has probability of collision as its criterion.
Separation distance	In some software, specifically the *center to center clearance distance* minus the casing and/or hole dimensions.

COLLISION AVOIDANCE (continued)

Word/Phrase/Symbol	Definition
Separation factor	A ratio generally defined as well separation distance divided by the combined *position uncertainty* of the *reference* and *offset wells*. There are various definitions of how the numerator and denominator are calculated.
SF	*Separation factor*.
TC	*Travelling cylinder*.
TCR	*Tolerable collision risk*.
Tolerable collision risk	The maximum acceptable probability of collision based predominately on the cost of collision and the cost of reducing the probability of collision.
Tolerance line	A line on a *travelling cylinder diagram,* or other plot, which indicates a maximum allowed displacement of the *reference well* from its plan. Usually the closest allowed approach to an *offset well,* calculated from an *anti-collision rule.*
Travelling cylinder	The *travelling cylinder diagram* or relating to aspects of the diagram.
Travelling cylinder diagram	A graphical representation of the physical relationship of the *offset wells* to the *reference well* in which the planned *reference well* is represented as the centre point of a polar diagram. The position of the *offset wells* and the as-drilled *reference well* are plotted by their polar co-ordinates on a plane normal to the planned *reference well* at the measured depth of interest. The *TC* diagram is normally referenced to map north or highside.
Travelling cylinder distance	The distance between the *reference* and *offset well*, calculated on a plane normal to the *reference well*. The well separation distance plotted on a *travelling cylinder diagram*.