GYRO TECHNOLOGY IN THE OIL AND GAS INDUSTRY

Ben Hawkinson, SDC

Steve Mullin Gyrodata

SPE WPTS Meeting, May 2014

Precision Wellbore Placement

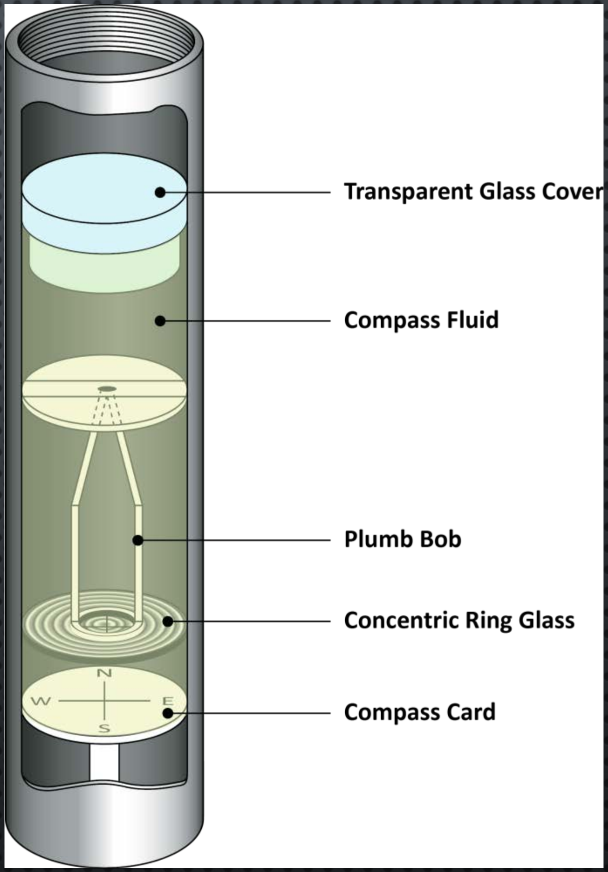
Early Survey Technology

PHOTO MECHANICAL DEVICES – 1930's

A camera unit takes a picture of a compass card. The plumb bob position changes depending on the inclination and direction.

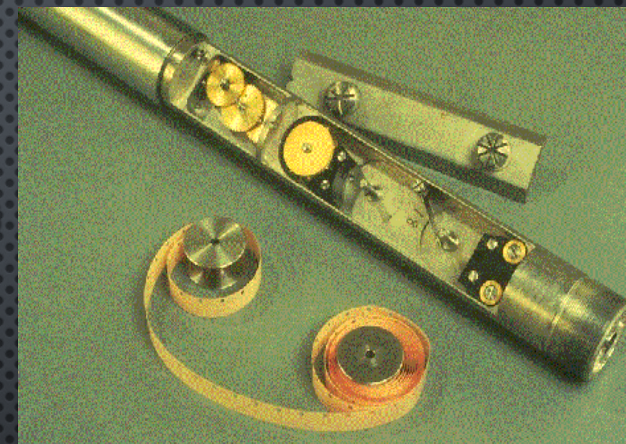
Adaptations led to the ability to take multiple camera shots.

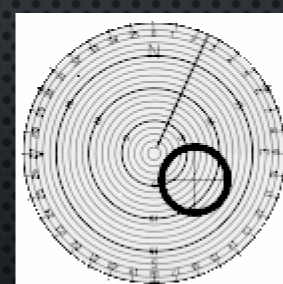
The multishot survey was born.



1930'S

- Surface Oriented to "known" foresight
- Free Gyro
- Drift Error: 0.5° - 2.5° degrees/ 15 minutes
- Accuracy Limitation
  - 1° - ? degrees Azimuth
  - Operator Dependent
- Error: 1° - ? degree

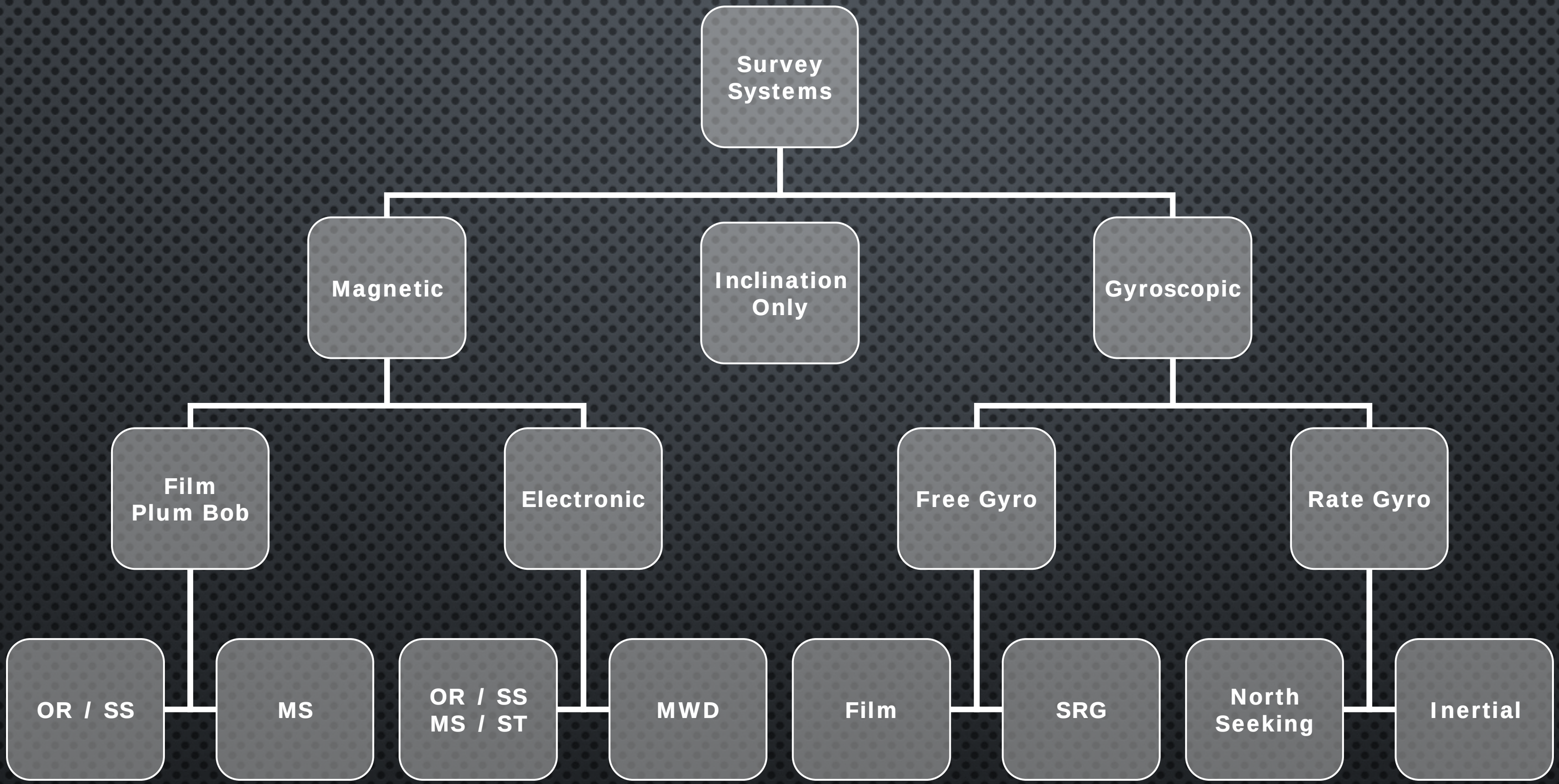




Modern Day

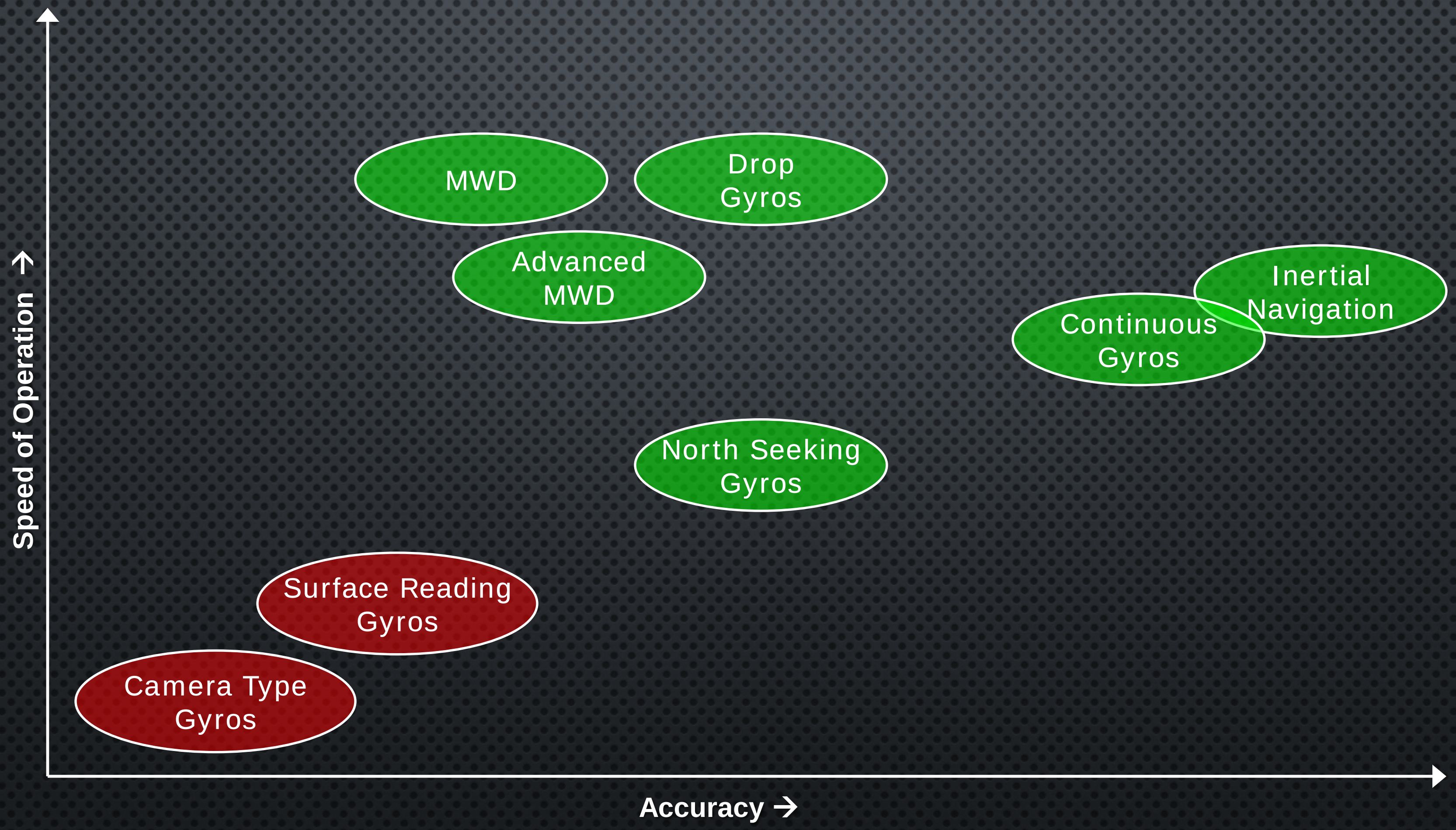
- North Seeking Rate Gyro
- MWD
- LWD
- GWD

Available Survey Technology

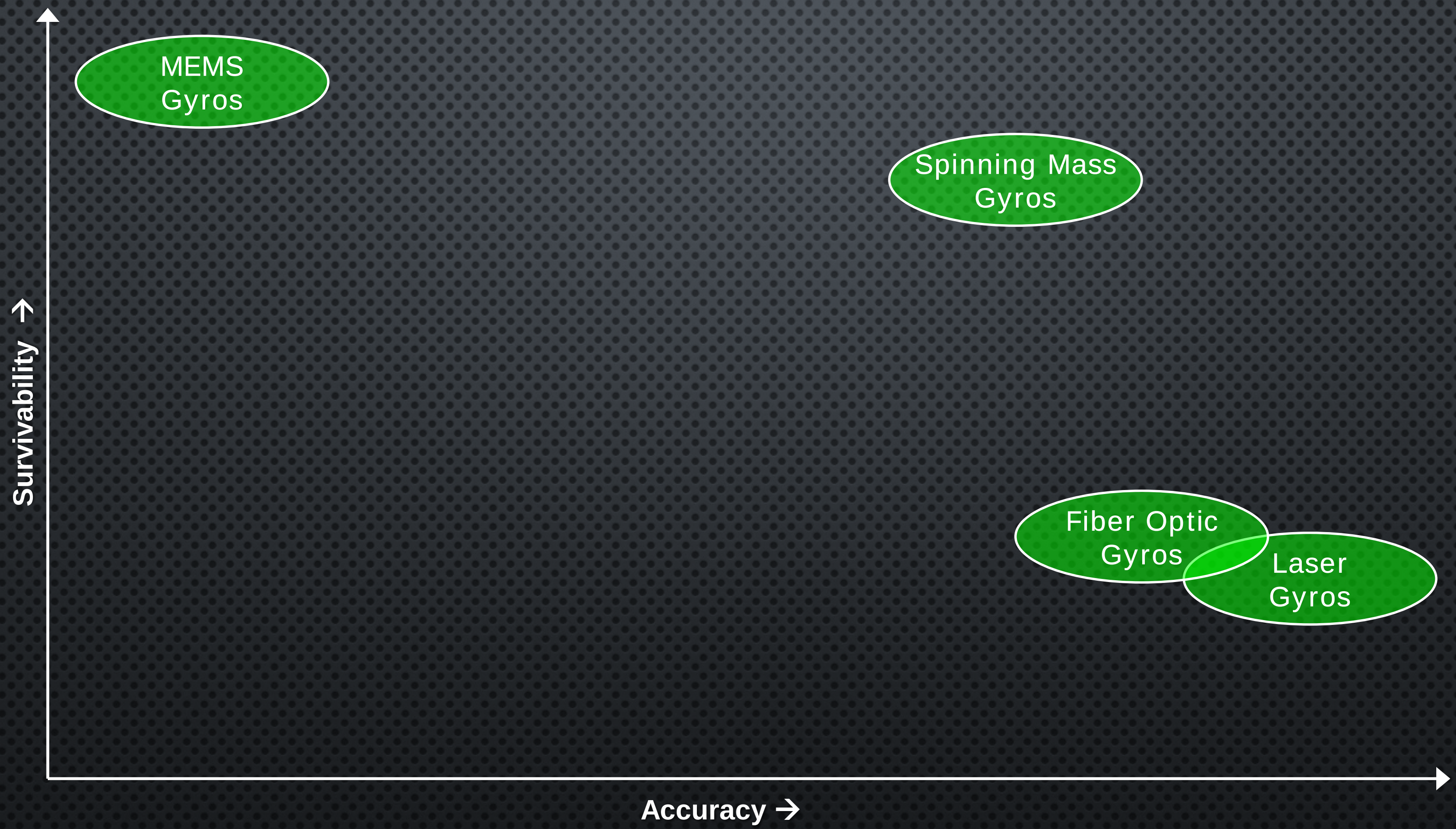


OR = Orientation   SS = Single-Shot   MS = Multi-Shot   ST = Steering Tool   SRG = Surface Readout Gyro
MWD = Measurement While Drilling

Accuracy Vs. Speed



Accuracy Vs. Survivability



MEMS Gyro's

Measurement Science and Technology

Measurement Science and Technology > Volume 23 > Number 2

Using a MEMS gyroscope to measure the Earth's rotation for gyrocompassing applications

L I Iozan[1], M Kirkko-Jaakkola[2], J Collin[2], J Takala[2] and C Rusu[1]

Show affiliations

L I Iozan *et al* 2012 *Meas. Sci. Technol.* 23 025005. doi:10.1088/0957-0233/23/2/025005

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Abstract

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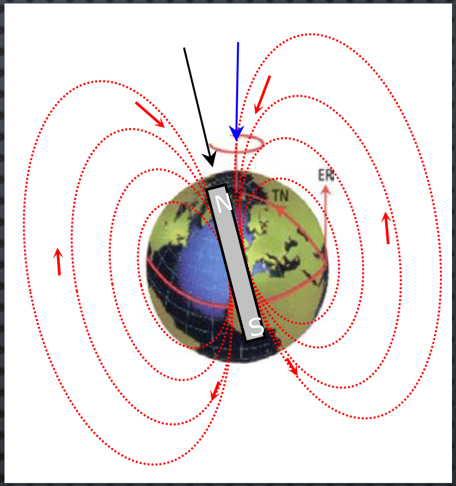
Survey Sensor Datum's

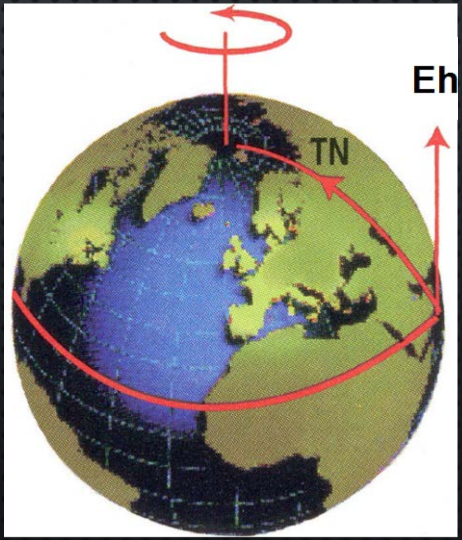
Earths Magnetic Field

- Datum moving (diurnally & general drift)
- Solar effects
- Local anomalies (SPE 56699)
- Magnetic drilling environment
  (Drill pipe, casing, mud - SPE71400)



Earths Rotational Field

- North referencing gyros
- Detects earths rotational 'rate'
- Does not vary
- Perfect reference



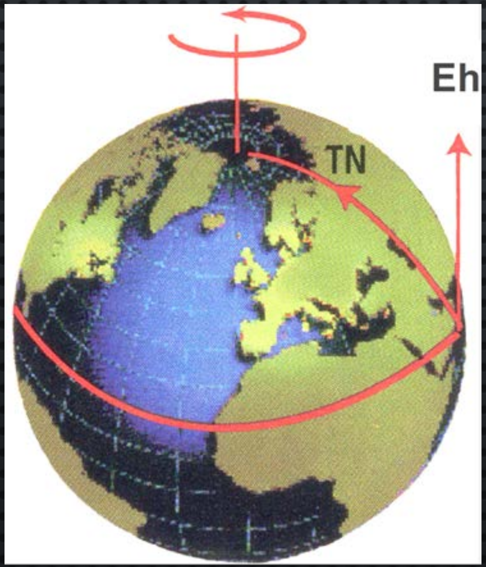
Earths Gravity Field

- Latitude correction equation (RGF30)

North Seeking Theory

Earths rotational rate = (360°/24hr)+(360°/365.25dys/24hr)= **15.041 degs/hr.** This is constant for any position on the globe and can be defined as consisting of a horizontal and vertical component. However, these individual components are not constant and are dependant on the Latitude.

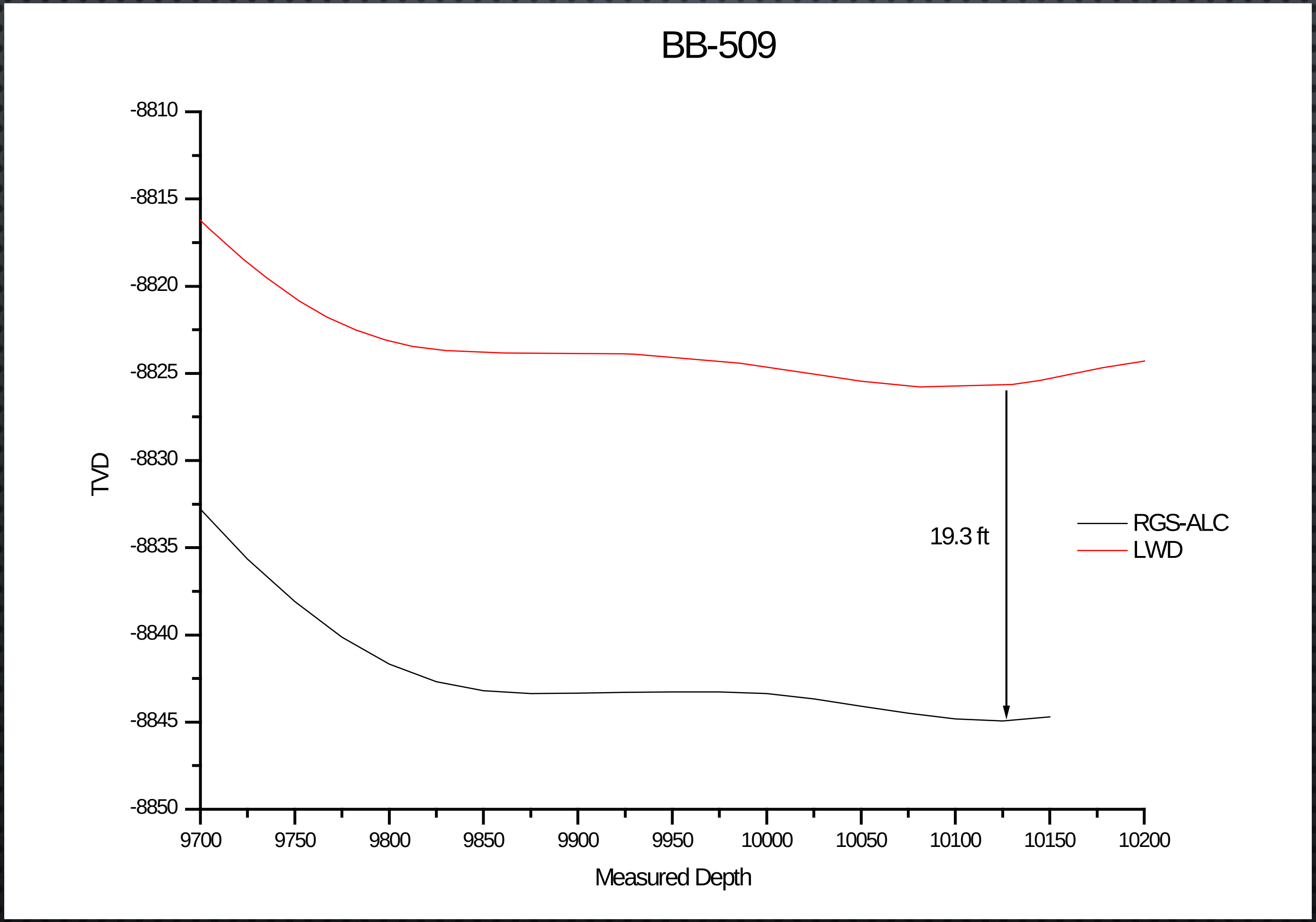
The horizontal component (Eh) = 15.041 x Cosine Lat. (Houston 29.83°N, Eh = 13.05)



It can be observed that this **horizontal component** of the Earths spin vector is always pointing to geographic North,
i.e.   **it is a perfect True North reference.**

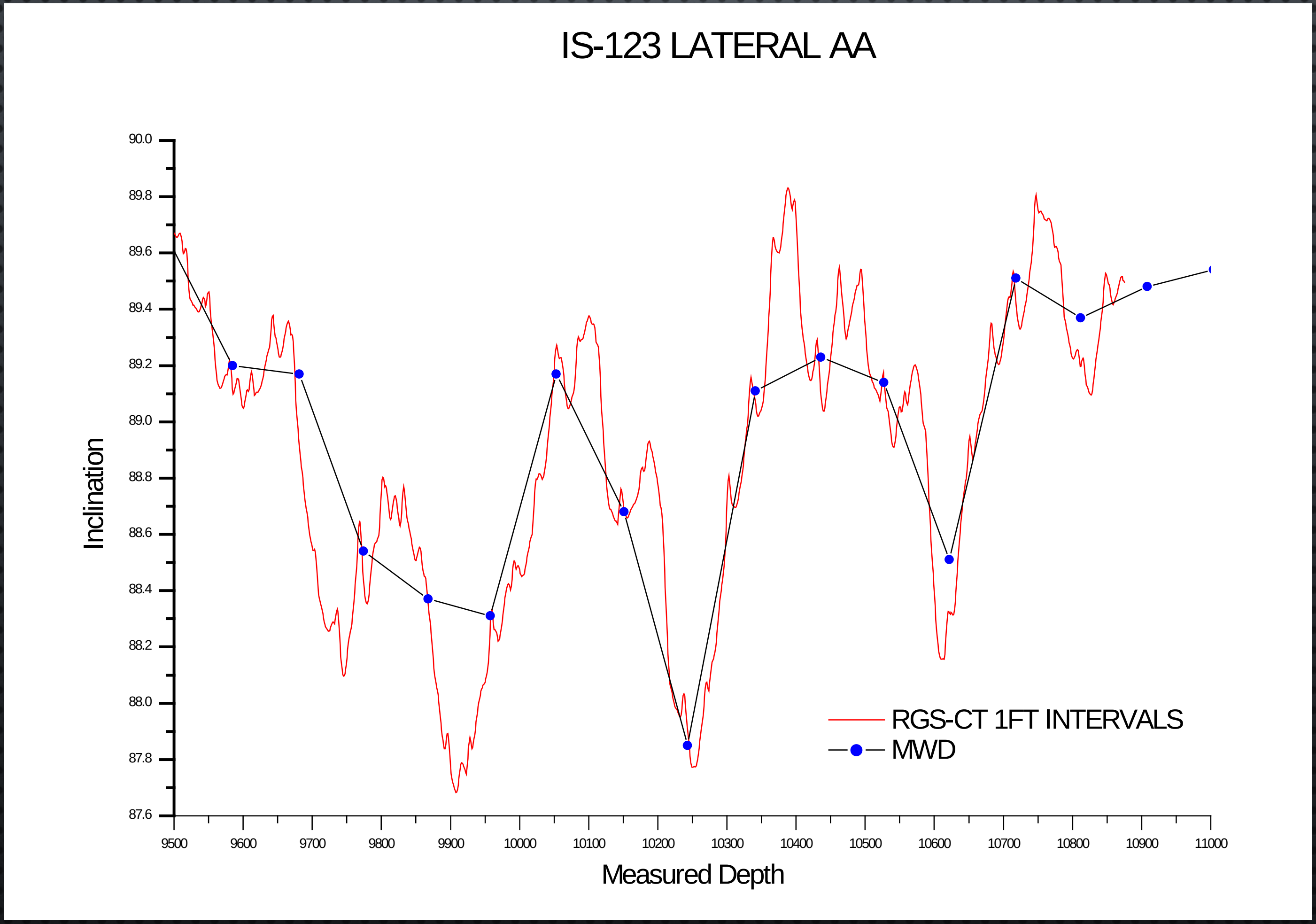
It is the accurate measurement of the horizontal earth rate vector that is the basis for all North Seeking gyroscopes. In gyro compass mode the tool is held stationary at each required survey depth and the survey data is calculated independently at each point. This method is commonly referred to, as **Gyro Compassing**.

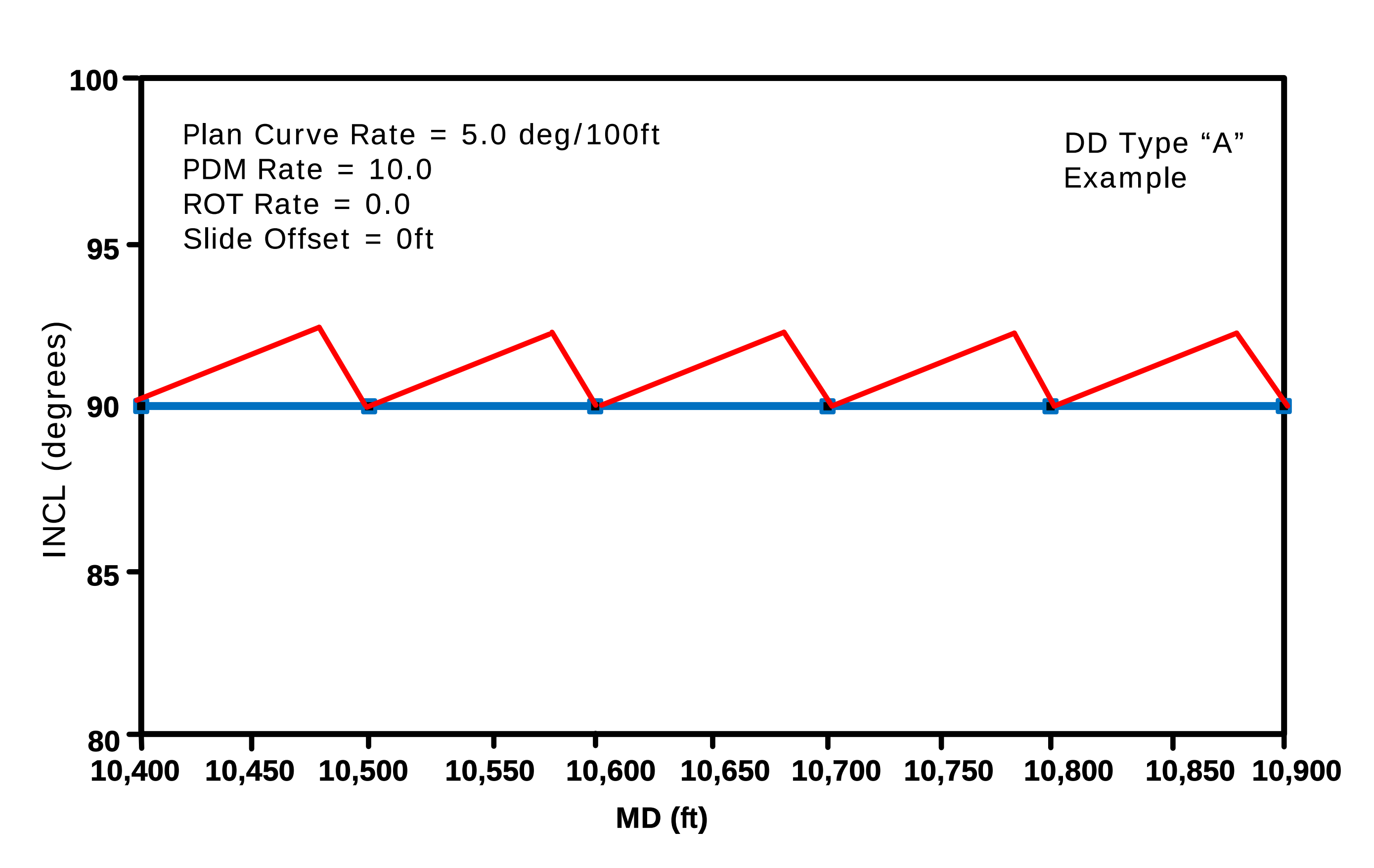
Depth Error



BB-509
-8810
-8815
-8820
-8825
-8830
-8835
-8840
-8845
-8850
TVD
9700
9750
9800
9850
9900
9950
10000
10050
10100
10150
10200
Measured Depth
19.3 ft
RGS-ALC
LWD

Continuous Gyro

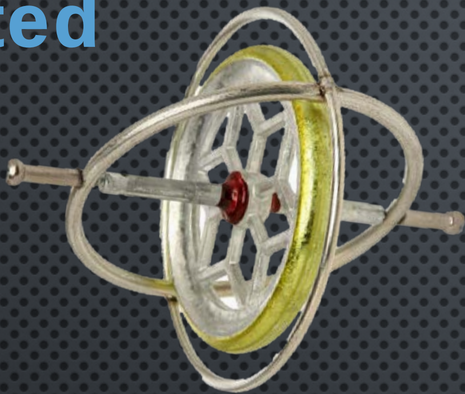




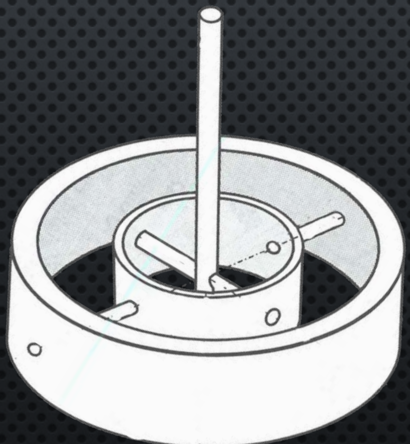
Plan Curve Rate = 5.0 deg/100ft
PDM Rate = 10.0
ROT Rate = 0.0
Slide Offset = 0ft
DD Type "A"
Example
100
95
90
85
80
INCL (degrees)
10,400
10,450
10,500
10,550
10,600
10,650
10,700
10,750
10,800
10,850
10,900
MD (ft)

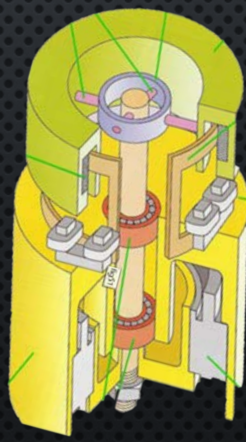
Gyroscope Sensors

Floated



Dynamically Tuned





$$L \approx \omega m r^2$$

Common Gyro Surveying Modes

Mode	North-Seeking	Continuous
Properties Measured	Earth Rotation Vector Gravity Vector	Cross-Axis Tool Rotation
Applications	gyroMWD/GWD Drop Surveys Continuous Init	High Speed Surveying (Wireline, Drop) Continuous gyroTF
Considerations	Tool must be very still to collect a survey	Faster running speeds are better, as drift errors are time-dependent.

Gyro Instrument QA

Since the quality of a gyro instrument is a critical factor in collecting a successful survey, the instrument calibration process must be tightly correlated to the Instrument Performance model.

Sensor Manufacture

Sensor Installation

Factory Calibration

Field Calibration

In-Run Quality Control

Gyrocompass

- Inclination QC is generally the same as with MWD systems
- Comparison against theoretical ERH is the primary QC measure
- Additional measures include gyro output stability and gyro bias stability.

Continuous Surveying

- Zero-velocity drift checks are used to compensate for bias, mass unbalance, and Earth Rate effects
- QC measures ensure that drift variation matches predicted values

Basic Gyrocompass Processing

Data is collected by sampling cross axis rotation rate and acceleration, at positions 180 degrees apart.

Raw

- Raw Gyro Rates (GX_1, GX_2, GY_1, GY_2)
- Raw Accelerations (AX_1, AX_2, AY_1, AY_2)
- Tens to hundreds of readings in each position

Mid

- Gyro Bias (QC Term) (G-Bias X and G-Bias Y)
- Gyro and Accel Phases ($\tan^{-1}(G_Y/G_X)$)
- Gyro and Accel Stability/Noise

Done

- Inclination (normal)
- Azimuth (Gphase – Aphase)
- ERh (G Amplitude)

Running Considerations

1. Casing surveys with proper running gear provide the best directional measurement
2. Use of a CCL or Gamma-Ray for Wireline Correlation ensures measured depth accuracy
3. Pre-and-Post Job Field Calibrations monitor mass unbalance performance
4. Drop Surveys save time by enabling surveys while tripping

10 Questions

1. How are your gyros calibrated, and how often?
2. How do you know they need calibration?
3. What are your QA/QC measures
4. Does your gyro measure Earth Rate, and what should it be?
5. How do you know your tool was working properly on location?
6. What is the experience level of your surveyors?
7. What is the accuracy of your survey tool?
8. Do you have an ISCWSA error model for your survey tool?
9. How do you validate your error model?
10. Where do your sensors come from?