Wellbore Positioning Past, Present and Future.

Len Duncan

44th General Meeting
September 22nd, 2016
Glasgow, Scotland, UK

Wellbore Positioning Technical Section

The Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA)

Speaker Information

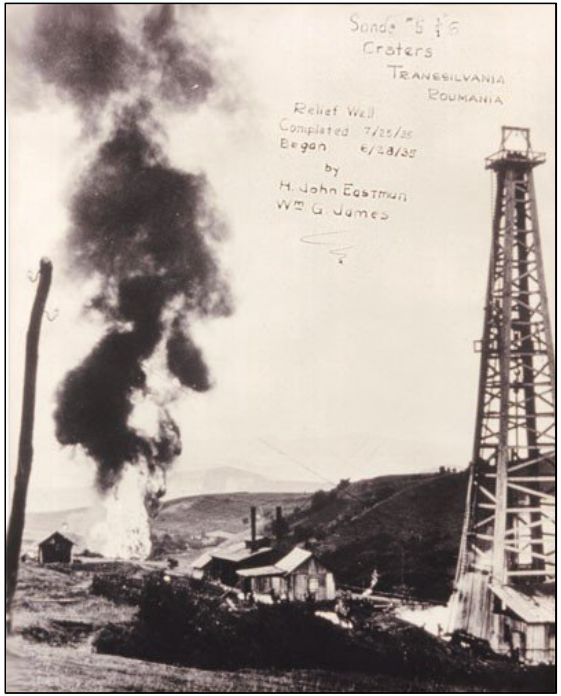
- Len Duncan
- Wellbore positioning, past, present and future
- September 22nd 2016.
- Magvar/Surcon

Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

20's thru 70's

- Earliest survey systems developed in late 1890's for Diamond Mine applications. Used acid bottle variations until first gyro system developed by Elmer Sperry in the 30's for oilfield applications.
- John Eastman seen here with early Gyro System.



Photos taken by Angus Jamieson

Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

20's thru 70's

- Drift Indicators
- Photo Mechanical Free Gyro Systems
- Photo Mechanical Compass Systems
- Wireline Steering Tools
- Systems used then were very operator dependent.

Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

1933 Acid Bottle Survey

Hobbs, New Mexico

Active Offset Well

Error Tool Code Anyone?

Hobbs, New Mexico
January 16, 1933.

Mr. S.G. Sanderson
Box 661
Tulsa, Oklahoma.

Dear Sir:

Following are the acid bottle slope tests run on D.W. Hardin No. 2 after cement and plug had been drilled on the 8-1/4" casing, and also the hole bailed dry of water. Also, I am showing herein the tests run at 250 feet intervals while the well was being drilled.

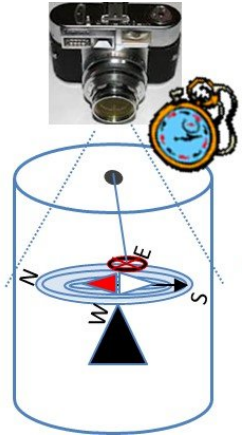
Depth	Degrees Off	250 feet Intervals and Method	
1000'	1	1/2	Acid Bottles
1250'	2	1	" "
1500'	5/8	1-1/4	" "
1750'	5/8	1-1/4	" "
2000'	1-1/4	5/8	" "
2250'	0	5/8	" "
2500'	5/8	1-1/2	" "
2750'	1	5/8	" "
3000'	3-3/4	2-1/4	Hughes Outfit
3250'	7	1-1/2	" "
3500'	10-1/2	1-1/2	" "
3750'	10-1/2	2	" "
4000'	10-3/4		

I might state that in making the complete test with acid bottles that a 3" acid bailer was run inside the 8-1/4" casing for the reason that we had no larger bailer to run.

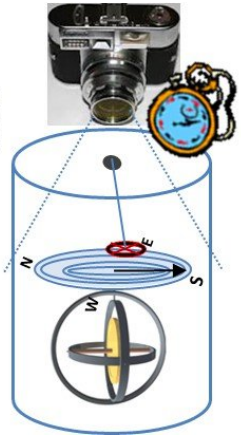
Yours very truly,

CCC/vac

Punched Disk



Camera Based Magnetic

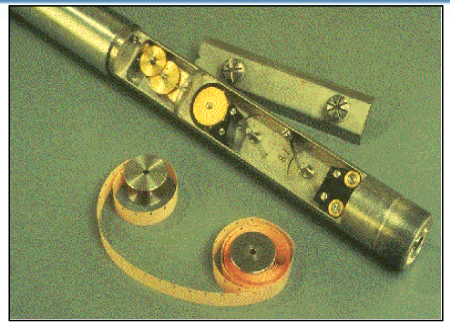


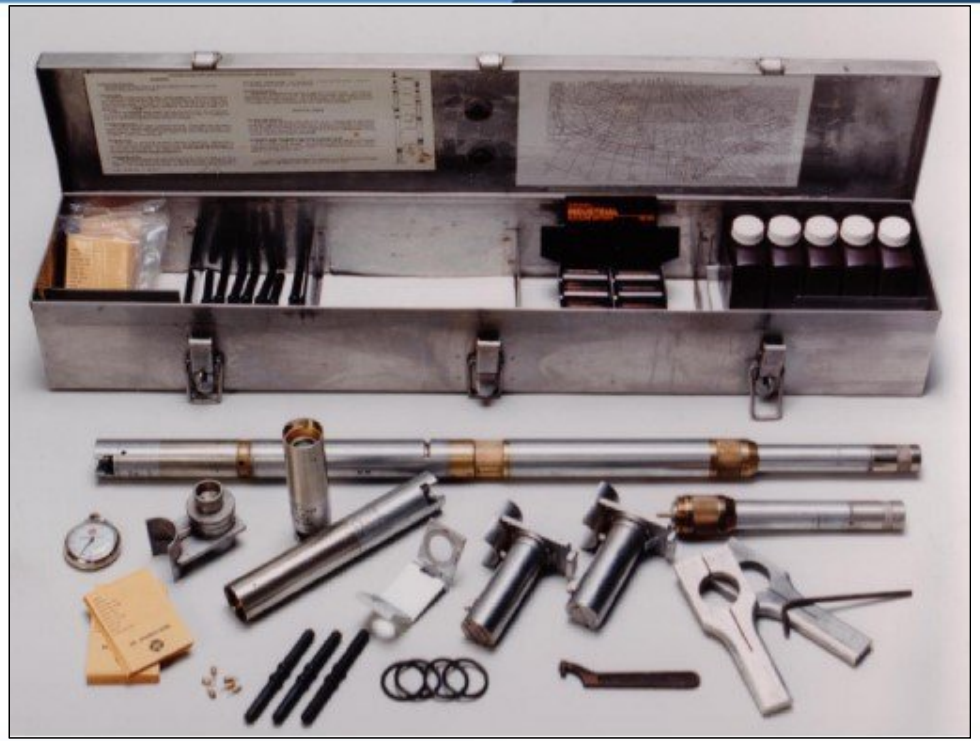
Camera Based Gyro

Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

Free Gyros

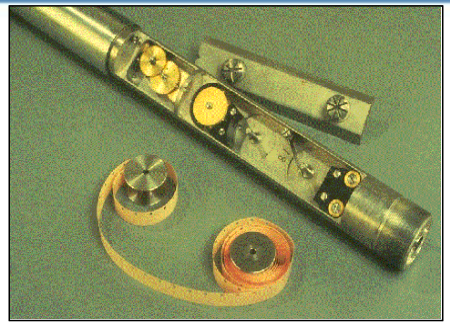


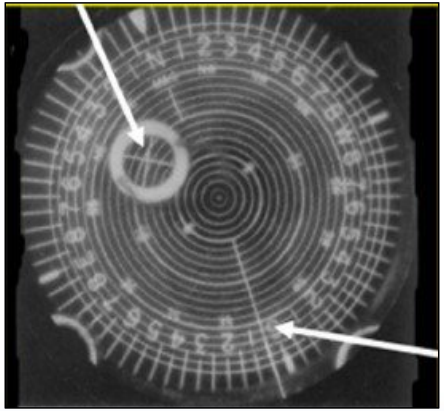


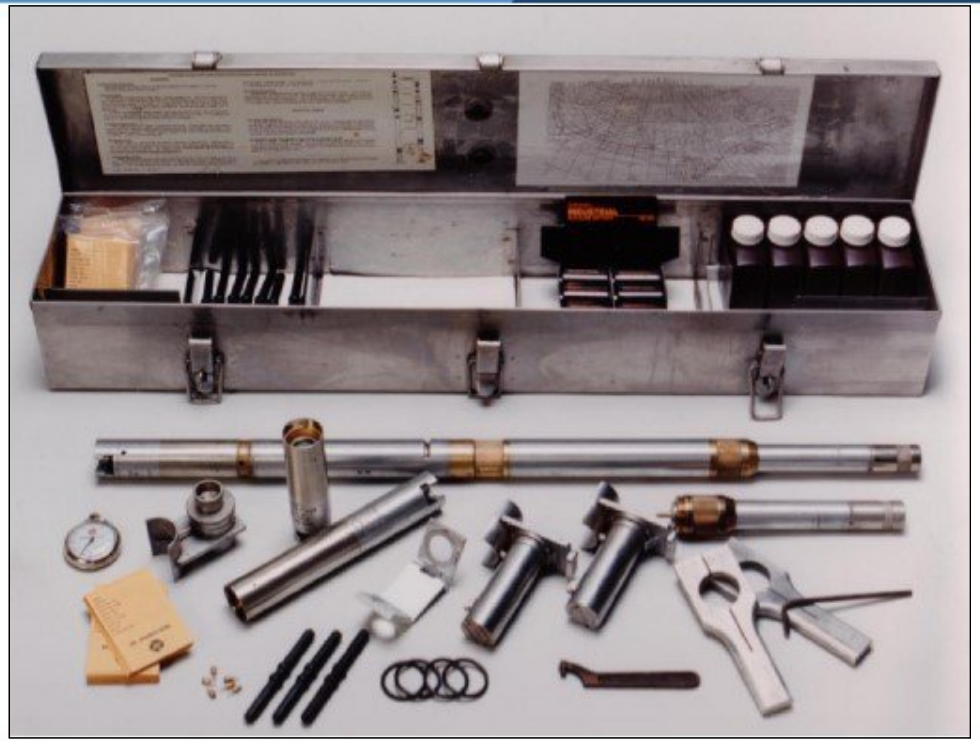
Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

Free Gyros





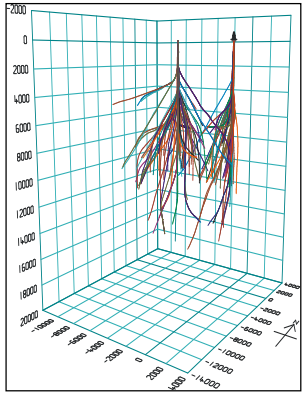


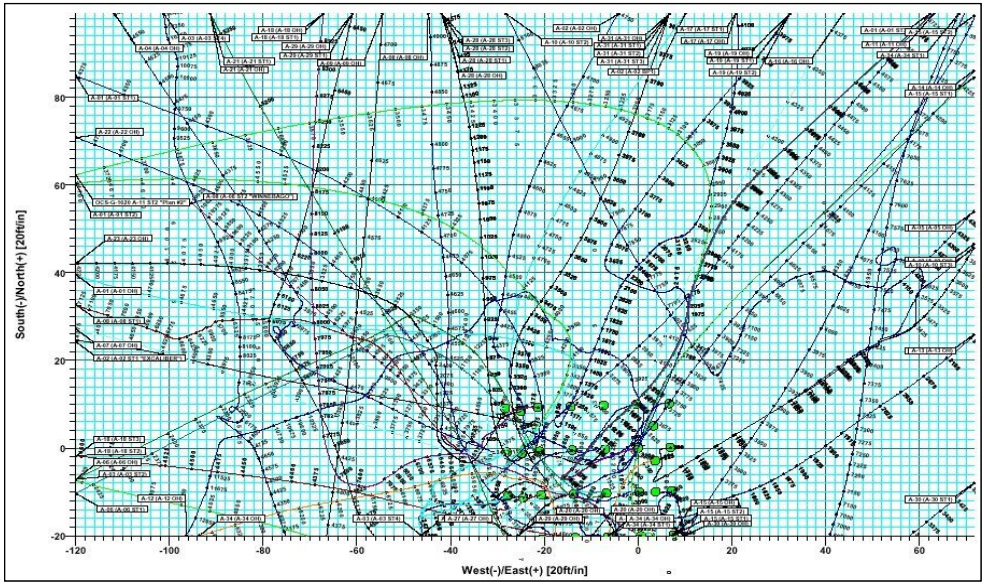
Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

50's thru 80's

- The challenges then were as demanding, if not more so than modern day with many high density platforms under Dev.
- Anti collision was more a case of fingers crossed and check for cement over the shakers !
- The wells were where the surveys said they were !





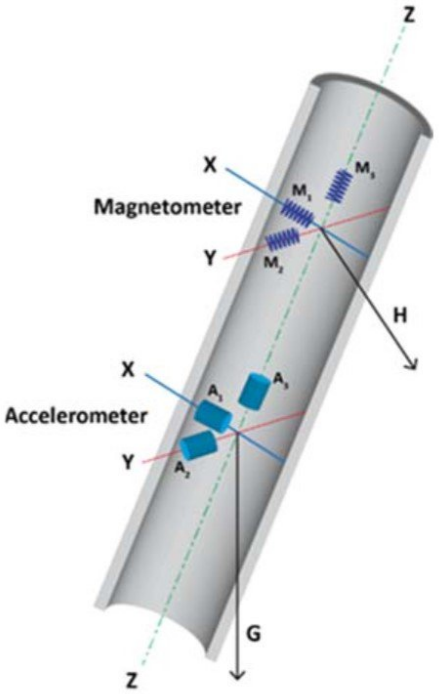
Offshore Gulf of Mexico

Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

1977 1st Surface Recording Gyros

- Accelerometers replace mechanical plumb bobs.
- Resolvers track gyro orientation.
- Significantly more accurate and faster. Kick off time reduced from 3-4 days to <1 day.
- Ability to do cluster shots to eliminate effect of bent sub in low angle scenarios.
- Increased confidence for D/D



Wellbore Positioning
Past, Present and Future

1977 1st Surface Recording Gyros

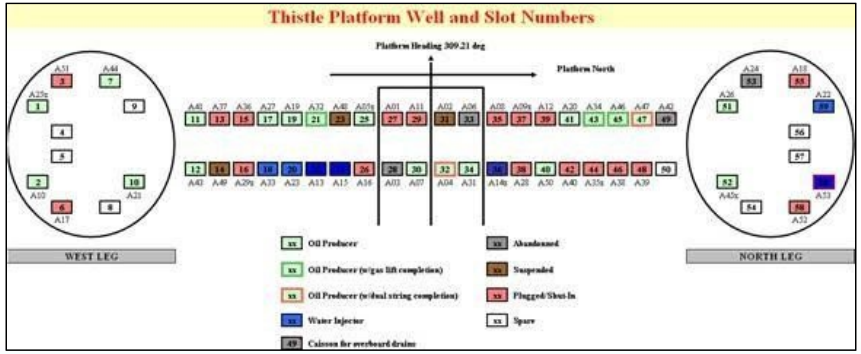
Data converted to pulse train downhole, sent to surface via w/l and decoded at surface back to realtime GTF, INC and AZM.

Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

1977 1st Surface Recording Gyros

- System developed per a request from a Major operator who was setting the largest offshore structure in the North Sea at the time, a twin derrick 60 slot jacket.
- There was concern about slot layout and well separation and the ability to nudge surface hole without spending days taking photo gyro single shots.



Wellbore Positioning
Past, Present and Future

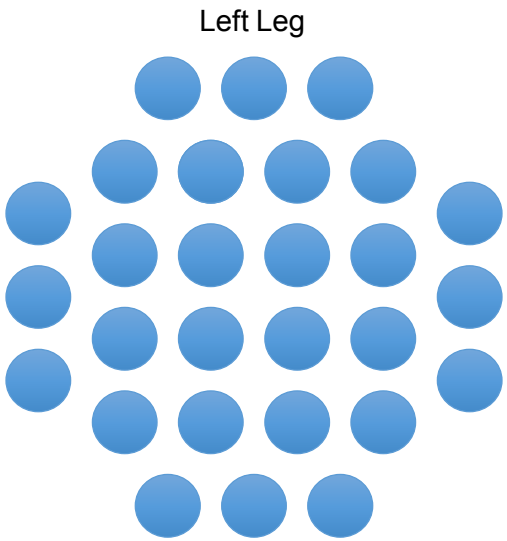
1977 1st Surface Recording Gyros

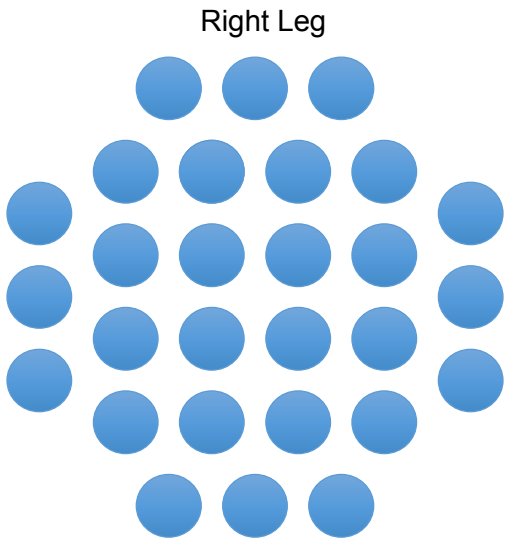
- At the same time, another Major Operator had just set two twin Derrick Platforms in the area and was faced with the same challenges.
- In this case, there were 21 slots each side on one and 20 slots each side on the other.

Wellbore Positioning
Past, Present and Future

1977 1st Surface Recording Gyros

- Slots were typically 6 - 8 ft. center to center.



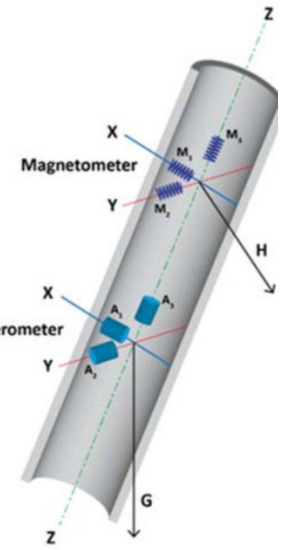


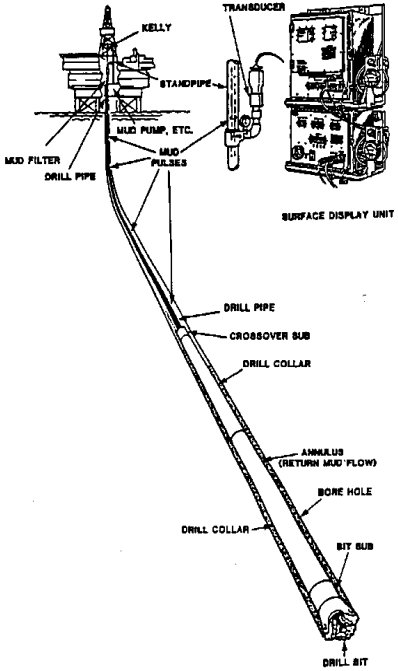
Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

1978 1st MWD Systems Deployed.

- Magnetometers replace mechanical compasses.
- Accelerometers replace angle units.
- Data converted to binary and sent to surface as pulses.
- Real time readout on rig floor
- Display gives D/D Tool Face, Inc. and Azm.
- Significant time reductions in open hole sections.



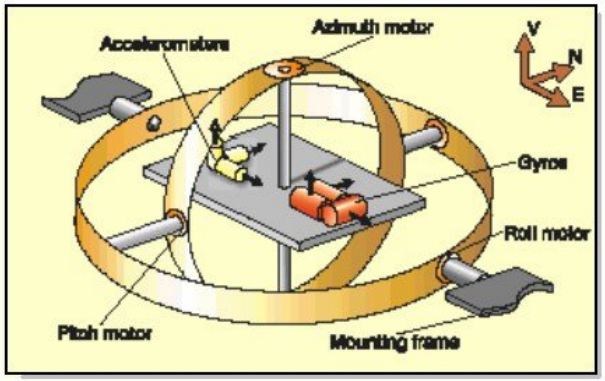


Wellbore Positioning
Past, Present and Future

1978 1st Full Inertial Platform FINDS Tool.

- 3 Gyro Full Inertial Platform giving extremely high accuracy.
- Run in a 10 ¾”OD casing.
- Physical size and weight restricted operations on many projects and ultimately was removed from service.

Gimball Mounted Inertial Platform



Wellbore Positioning
Past, Present and Future

1981 1st N. Seeking Gyro Systems.

Game changing technology eliminating sighting errors and significant increase in accuracy.

Less operator dependent than older systems.

Used for kick off and definitive casing/drill pipe surveys.

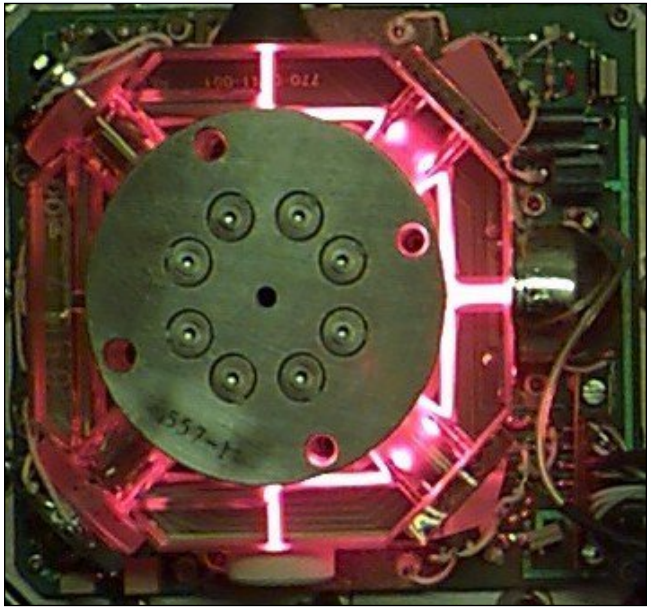
Uses earths spin rate as ref.

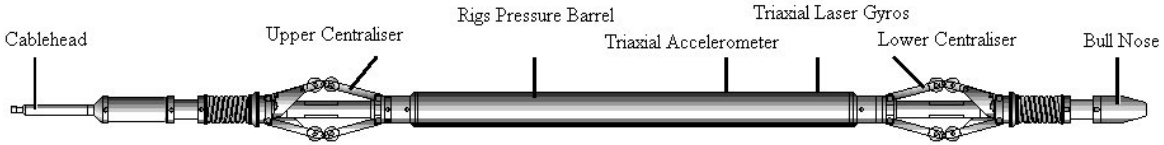
Still had to be stopped at survey stations for data acquisition..

Wellbore Positioning
Past, Present and Future

1985 1st Ring Laser Inertial Gyro RIGS Tool

- Uses laser path instead of spinning wheel.
- Very high Accuracy.
- Run in a 5 ¼" Barrel.
- Limited inventory and costly to service.
- Ultimately removed from Service.





Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

1985 1st Continuous N. Seeking Gyros Systems.

- Major time reduction and increase in accuracy at high angles.

1990's

- Gyro and MWD systems continued to improve but a more formal definition of survey procedures, error models and realistic anti collision calculations were needed.
- Drop Gyro mid nineties, major market shift allowing N.Seeking tools to be dropped in drillpipe and survey on out trip.
- Huge time saver to clients. These tools are still the preferred gyro option today for cost effectiveness.

2000

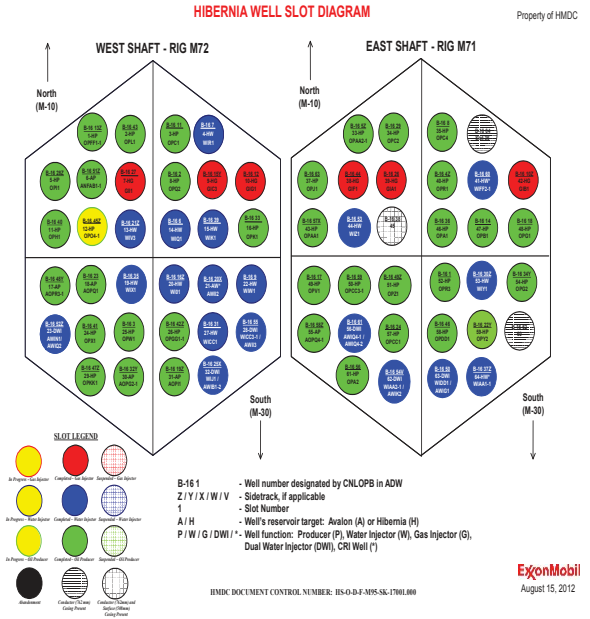
- Gyro MWD systems introduced to further enhance wellbore position accuracy and reduce EOU's in top hole.

Wellbore Positioning
Past, Present and Future

Survey Technology Timeline

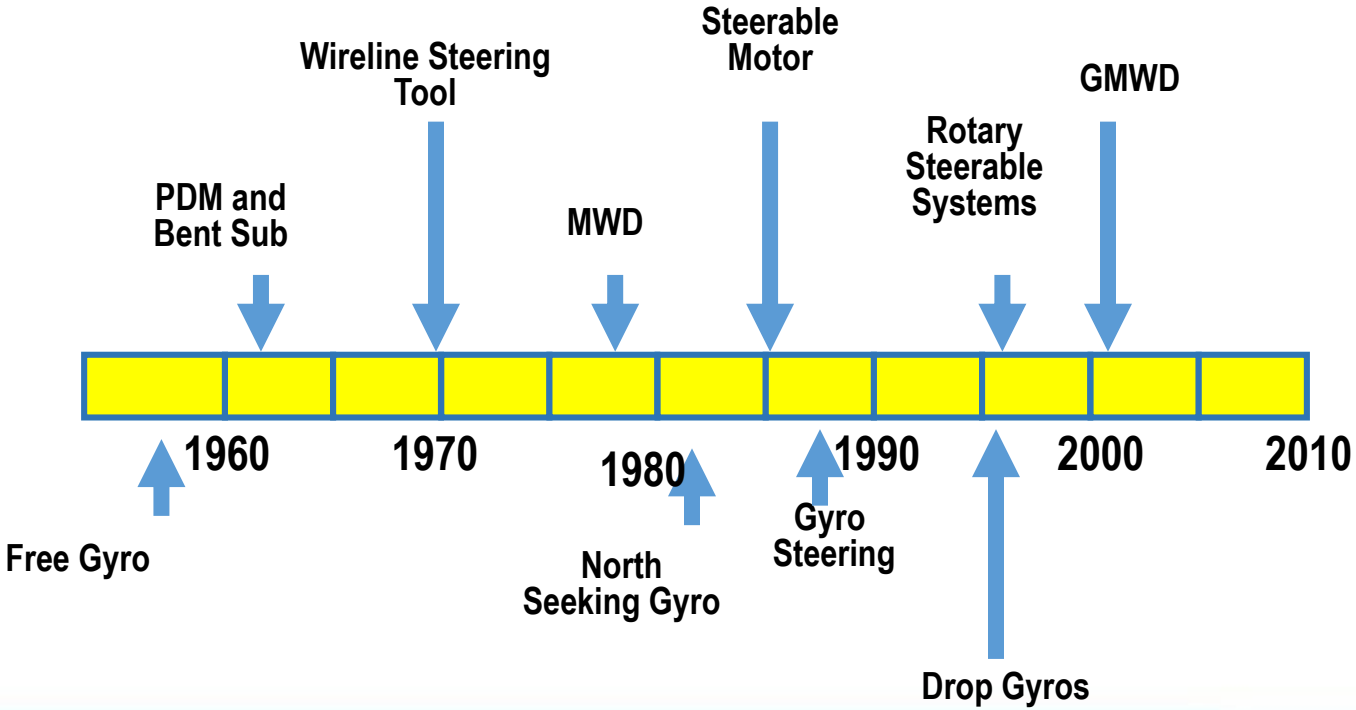
1997 64 Slot Structure

- 20 Years later, an even larger density structure set offshore NFLD.
- 64 Slots. Now all drilled.
- Thanks to higher spec. gyro systems, Gyro MWD and high end MWD Systems, very tight control of well placement was achieved during the Project.



Wellbore Positioning
Past, Present and Future

Survey Technology Timeline



Wellbore Positioning
Past, Present and Future

Error modeling/well planning timeline.

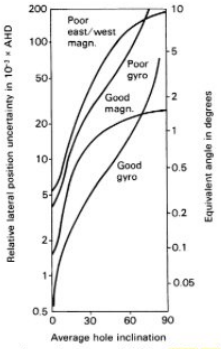


Fig. 9.9. Survey uncertainty using error model (after Wolff and de Wardt; courtesy of the SPE).

Standard/Chevron survey error paper

Shell Cones of Uncertainty

ISCWSA

Standard, Prudhoe Bay Survey Errors

Major Service Providers using own Inhouse

1970

1980

1990

2000

2010

Wolf / DeWardt Paper

Sysdrill

Compass

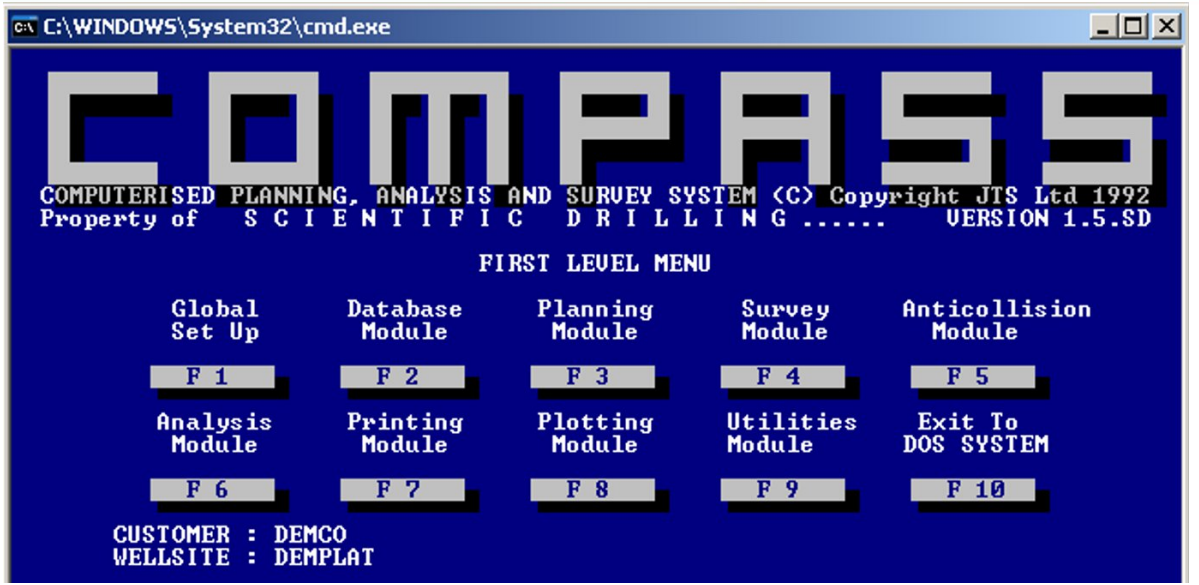
Winsurv

Kellydown ??

Wellbore Positioning
Past, Present and Future

Early Software Development

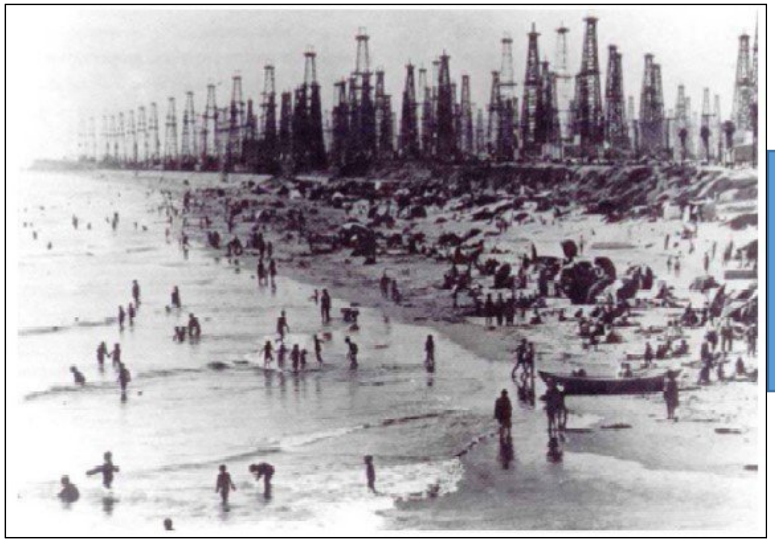
- **1990's – MS-DOS**
- **Directional Well Planning**
- **SURVEY**
- **PLANNING**
- **ANTICOLLISION**
  - ANCILLARY FUNCTIONS
  - UTILITES (LOGOS, ERROR MODELING, FERRANTI SURVEYS, GEOMAGNETIC, ETC...)
  - ANALYSIS
  - PLOTTING (WALLPLOTS, SPIDER, TRAVELING CYLINDER & SMALL 8.5 X 11 DRAWINGS)
  - PRINTING (REPORTS)
  - DATABASE FUNCTIONALITY



Planning & Survey Data - Software Pioneer - Angus Jamieson

Wellbore Positioning
Past, Present and Future

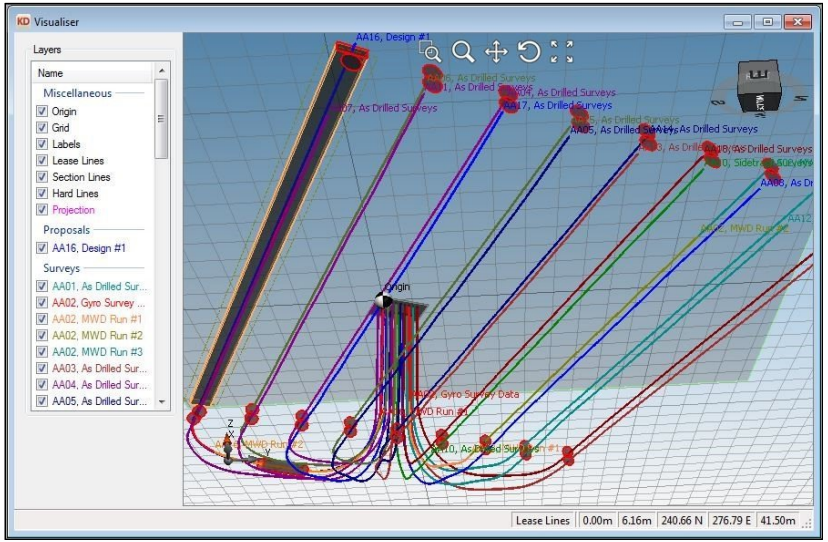
Environmental Challenges



Wellbore Positioning
Past, Present and Future

Error modeling/well planning timeline.

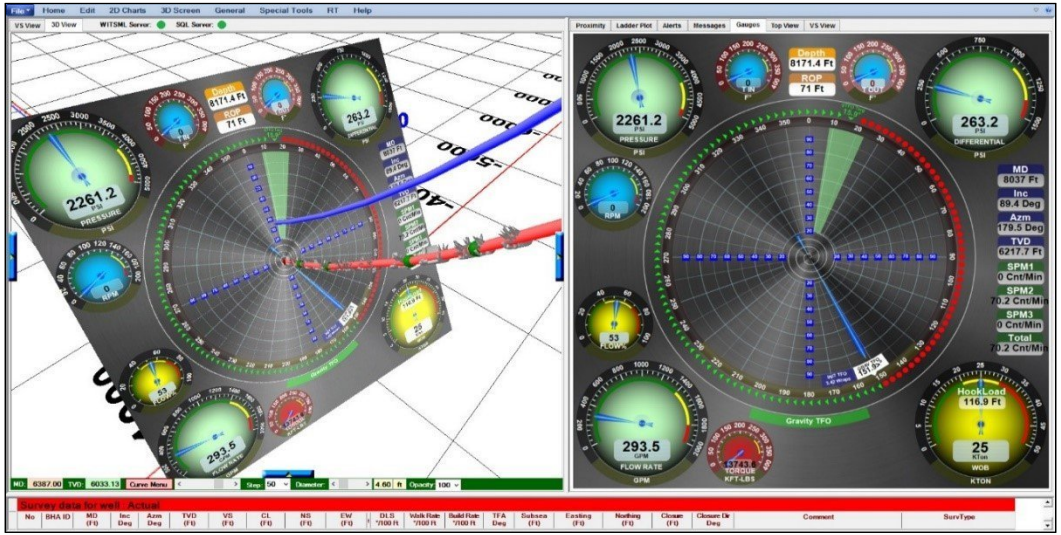
Well Planning Suites - Key advancements; field development planning, new ISCWSA tool codes & advanced realtime data capabilities

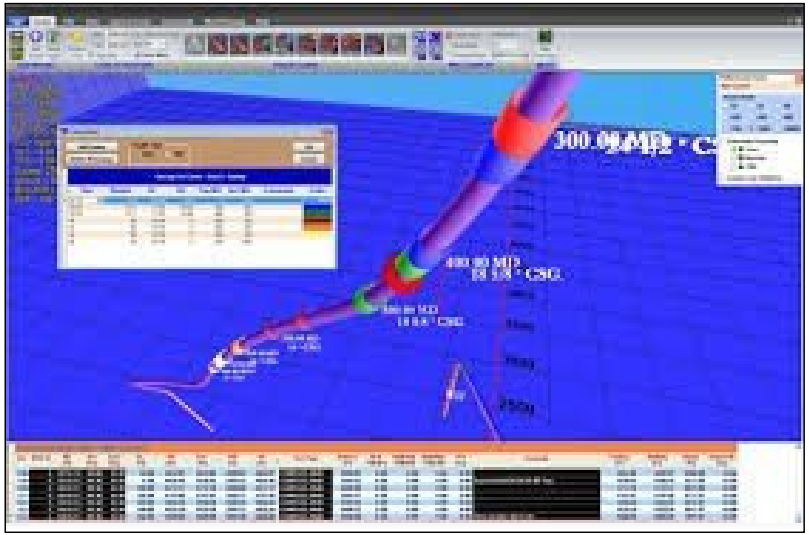


Wellbore Positioning
Past, Present and Future

Error modeling/well planning timeline.

Well Planning Suites - Key advancements; field development planning, new ISCWSA tool codes & advanced realtime data capabilities





Wellbore Positioning
Past, Present and Future

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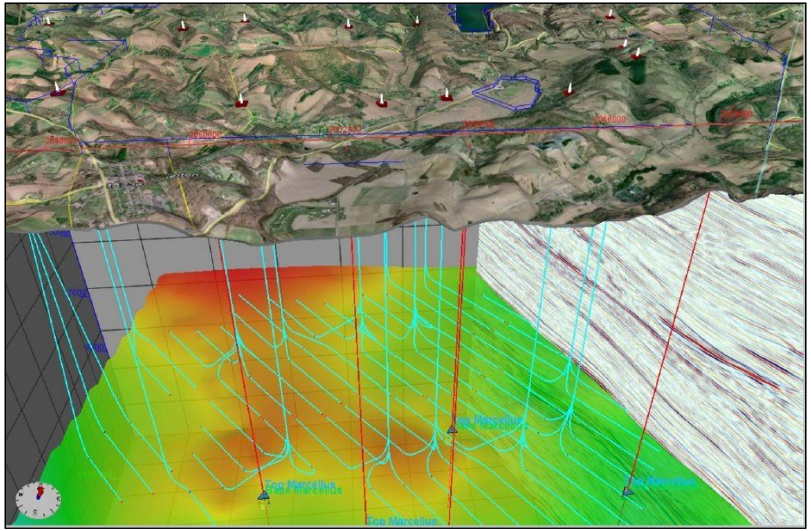
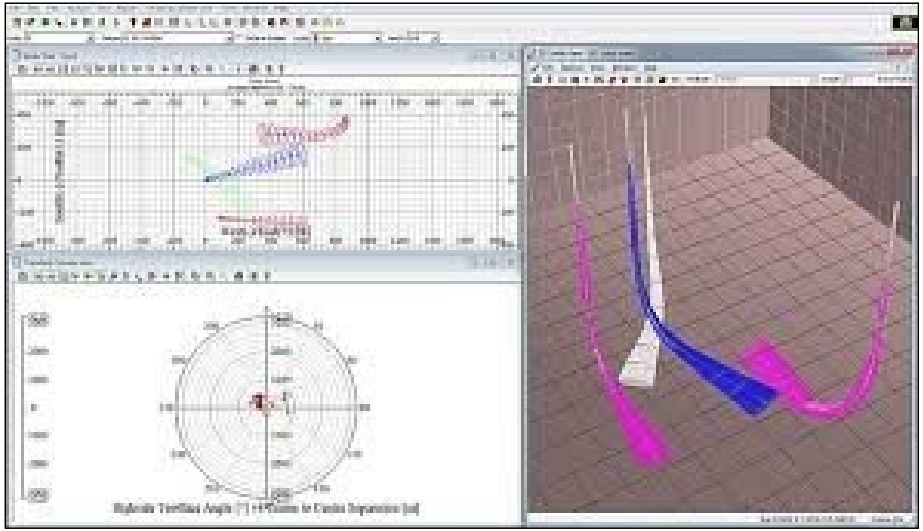
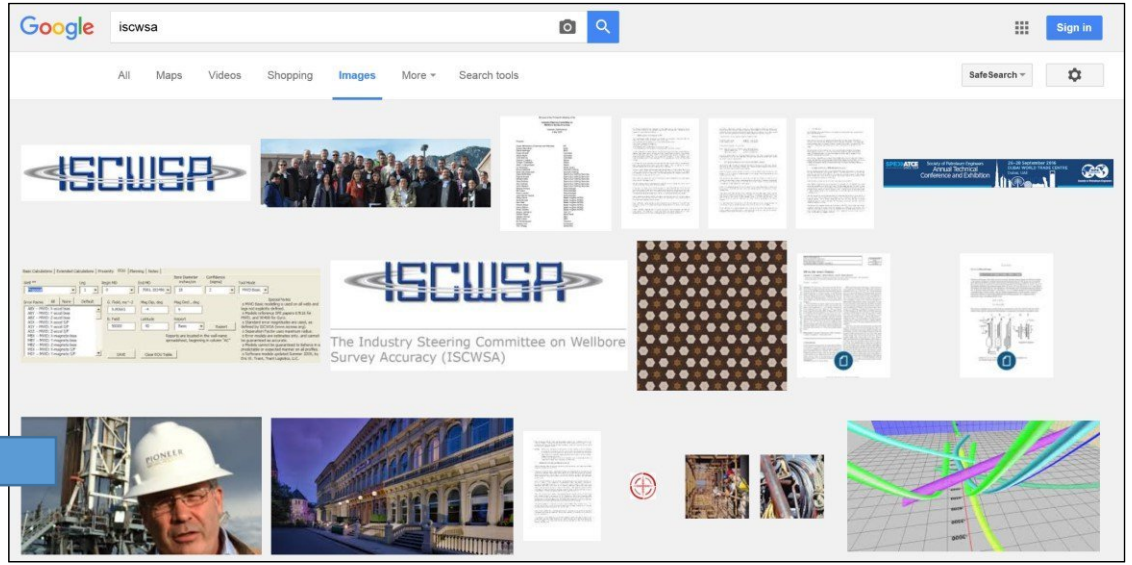




Wellbore Positioning
Past, Present and Future

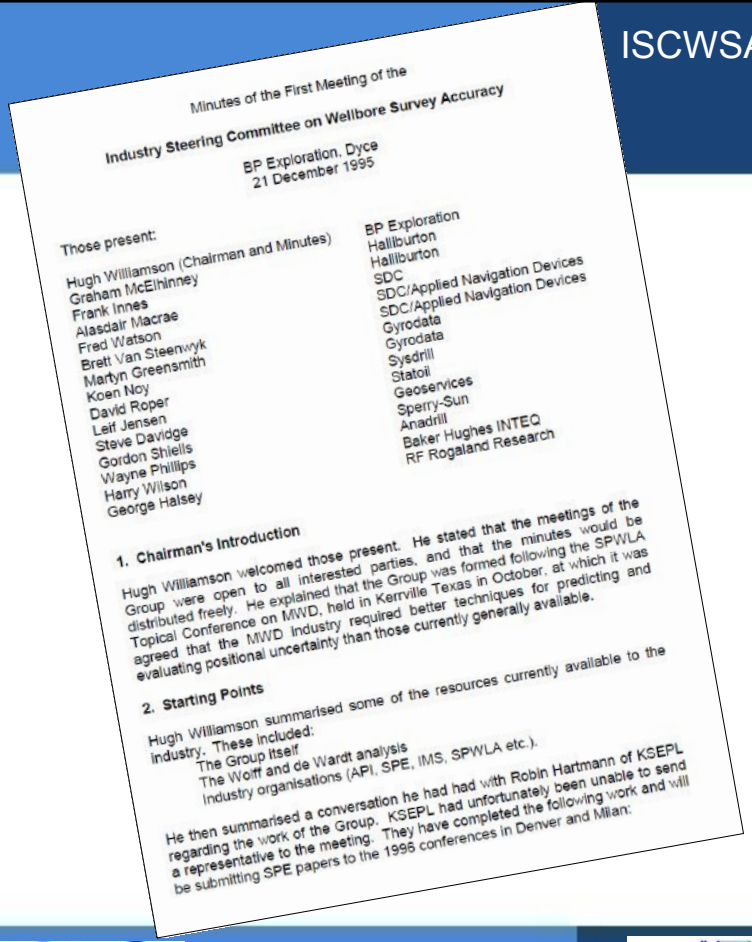
ISCWSA – Google Search…



Wellbore Positioning
Past, Present and Future

1995 – 1st Meeting

- ISCWSA formed and first official meeting was held in Aberdeen, Scotland
- BP Exploration, Dyce
- 21 December 1995



Minutes of the First Meeting of the

Industry Steering Committee on Wellbore Survey Accuracy

BP Exploration, Dyce
21 December 1995

Those present:

Hugh Williamson (Chairman and Minutes)	BP Exploration
Graham McElhinney	Halliburton
Frank Innes	Halliburton
Alasdair Macrae	SDC
Fred Watson	SDC/Applied Navigation Devices
Brett Van Steenwyk	SDC/Applied Navigation Devices
Martyn Greensmith	Gyrodata
Koen Noy	Gyrodata
David Roper	Sysdrill
Leif Jensen	Statoil
Steve Davidge	Geoservices
Gordon Shiells	Sperry-Sun
Wayne Phillips	Anadrill
Harry Wilson	Baker Hughes INTEQ
George Halsey	RF Rogaland Research

1. Chairman's Introduction

Hugh Williamson welcomed those present. He stated that the meetings of the Group were open to all interested parties, and that the minutes would be distributed freely. He explained that the Group was formed following the SPWLA Topical Conference on MWD, held in Kerrville Texas in October, at which it was agreed that the MWD industry required better techniques for predicting and evaluating positional uncertainty than those currently generally available.

2. Starting Points

Hugh Williamson summarised some of the resources currently available to the industry. These included:

The Group itself
The Wolff and de Wardt analysis
Industry organisations (API, SPE, IMS, SPWLA etc.).

He then summarised a conversation he had had with Robin Hartmann of KSEPL regarding the work of the Group. KSEPL had unfortunately been unable to send a representative to the meeting. They have completed the following work and will be submitting SPE papers to the 1996 conferences in Denver and Milan:

Wellbore Positioning
Past, Present and Future

1st ISCWSA Meeting
1995

• Hugh Williamson	BP Exploration (Chair)
• Graham McElhinney	Halliburton
• Frank Innes	Halliburton
• Alasdair Macrae	Scientific Drilling Controls (SDC)
• Fred Watson	SDC / Applied Navigation Devices
• Brett Van Steenvvyk	SDC / Applied Navigation Devices
• Martyn Greensmith	Gyrodata
• Koen Noy	Gyrodata
• David Roper	Sysdrill
• Leif Jensen	Statoil
• Steve Davidge	Geoservices
• Gordon Shiells	Sperry-Sun
• Wayne Phillips	Anadrill
• Harry Wilson	Baker Hughes INTEQ
• George Halsey	RF Rogaland Research
• John Thorogood	BP Exploration
• Kamal Jardaneh	BP Exploration
• Alewyn van Asperen	KSEPL
• Steve Page	Geolink
• Ken Weeks	KRW Associates
• Mike Pollard	Saga
• John Turvill	Halliburton
• Steve Mullin	INTEQ

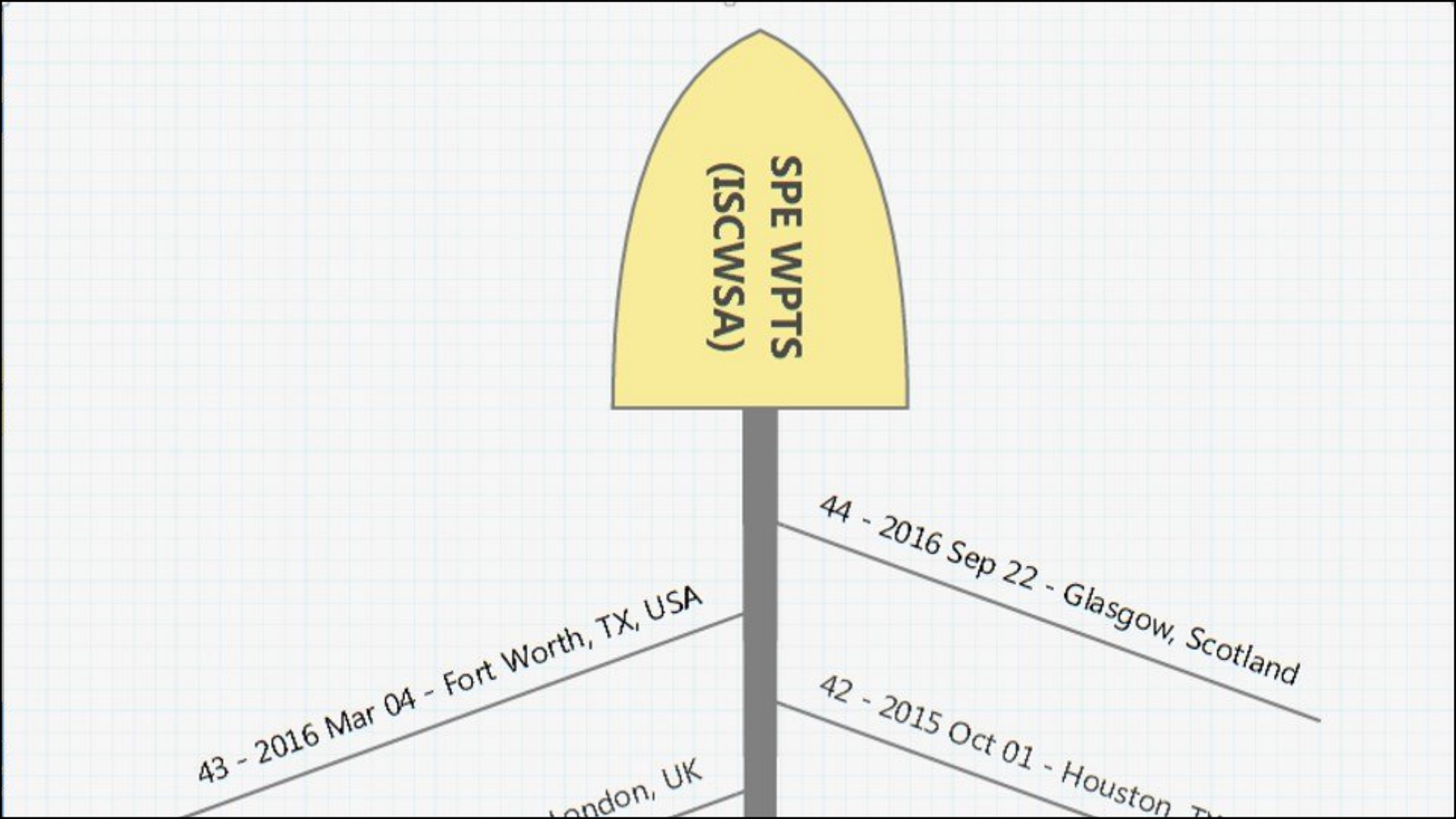
Wellbore Positioning
Past, Present and Future

ISCWSA History.

44th General Meeting
September 22nd, 2016
Glasgow, Scotland, UK

Wellbore Positioning Technical Section

The Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA)


SPE WPTS
(ISCWSA)
44 - 2016 Sep 22 - Glasgow, Scotland
43 - 2016 Mar 04 - Fort Worth, TX, USA
42 - 2015 Oct 01 - Houston, TX
London, UK

Wellbore Positioning
Past, Present and Future

Recent ISCWSA community achievements:

- **eBook, University Surveying Curricula**
  - University of the Highlands Masters Degree
- **More accurate geomagnetic field specification**
  - Global high-resolution models, near-rig disturbance field monitoring, new geomagnetic satellite missions
- **Widespread use of real-time survey management**
- **Dynamic FAC to verify that surveys fulfill tool codes**
  - Equations known for some time, but (except for Baker Hughes) only now finding widespread implementation
- **More accurate vertical depth**
  - Slide/rotate corrections, continuous inclination, inclination and azimuth near bit)

Wellbore Positioning Past, Present and Future

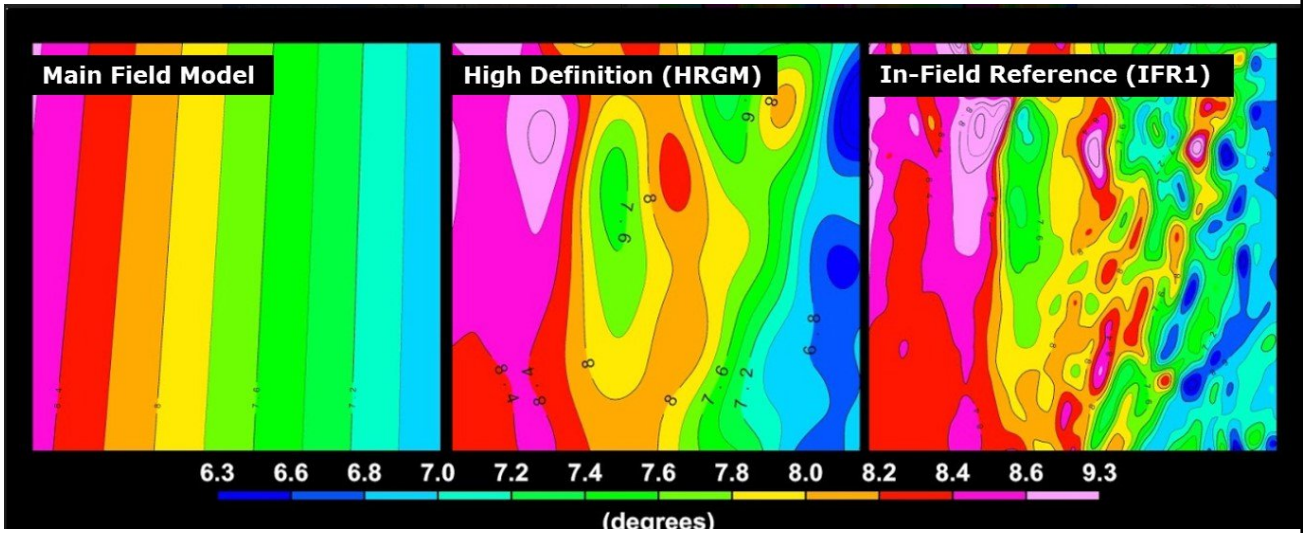
2016 -

- Survey Systems greatly improved.
- Improved Sensors and MWD transmission rates.
- Running procedures better defined.
- Realistic Tool Codes in place for all Gyro and MWD systems
- Far better understanding of Earths Field and corrections…....

Wellbore Positioning Past, Present and Future

2016 -

- Modern day operations are giving rise to a significant number of multi well pads with extended laterals.
- The slightest errors in magnetic correction can cause unacceptable lateral position shift.
- Using a high definition magnetic model identifies anomalies and ensures correct declination values are used.



Wellbore Positioning Past, Present and Future

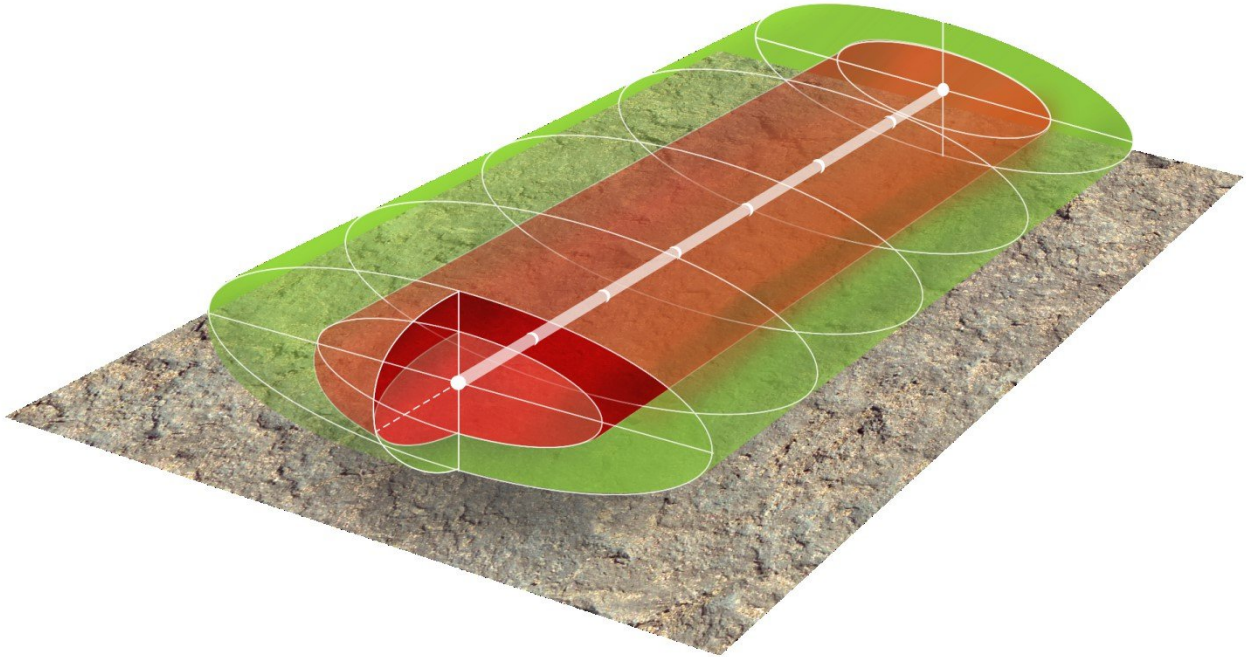
2016 –

MWD surveys do not give an exact position of the wellbore

All we can say is:

"With 95% confidence, the wellbore is within the green cylinder"

Further advanced corrections (IFR & MSA)reduce this cylinder by over 50%, as shown in red



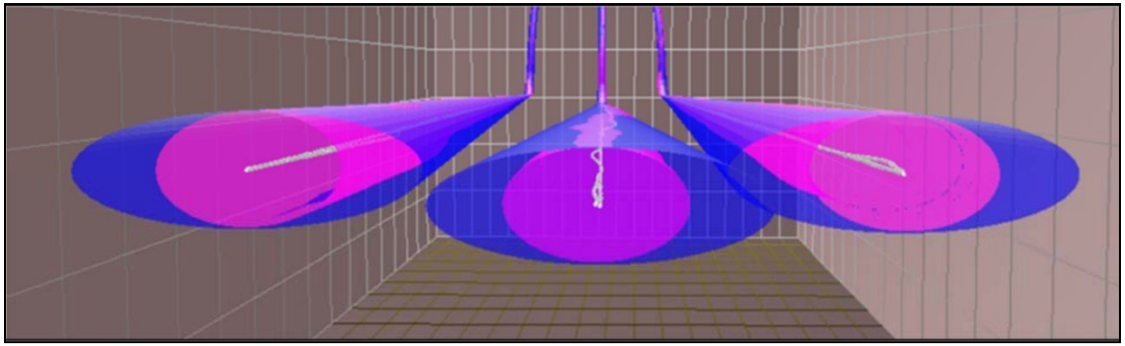
Wellbore Positioning Past, Present and Future

2016 –

Standard MWD surveying has large uncertainties

Real-time corrections significantly reduce positional errors

- Prevents gross human or instrument errors
- Results in more accurate wellbore placement and spacing
- Reduces ellipses of positional uncertainty
- Reduces collision risk
- Helps achieve economic field development



Wellbore Positioning Past, Present and Future

2016 -

- More Operator acceptance of using QC on all Survey Systems reducing EOU's and further increasing quality of wellbore positioning
- Higher Data Transmission Rates for all MWD systems
- Incorporation of more sensors into Drilling Systems
- Industry standards
- ???

Wellbore Positioning Past, Present and Future

- **Proactively deal with increasing regulation**
- **Complete API RP78 Wellbore Positioning**
- **Complete the Unified Collision Avoidance Rule & Management Processes**
  - Documented by two SPE Technical Papers
- **Strengthen eBook, Education & Outreach**
- **Further improve error models**

Wellbore Positioning Past, Present and Future

- **Directional Software Advancements**
  - Combined Surveys
  - Continuous drilling & memory trip data
- **ISCWSA error models available in G&G (Geology & Geophysics) software apps.**
  - Evaluate directional survey uncertainties with geological and seismic uncertainties
- **Hold gyro surveys to same QC standards as MWD systems**
  - Question - Why are operators not QC'ing raw gyro data? in particular for continuous mode

Wellbore Positioning
Past, Present and Future

Congratulations to all members of the ISCWSA, past and present for their contributions since 1995 to ensure our Industry is now using better than ever data for greater confidence in where their wells really are located!

Future Crew Change? Need New Recruits

Thank you.