Welcome!

The program will begin soon.

You will not hear audio until we begin.

Webinars

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Drilling Data Quality and Uncertainty: Pathways to Value

Eric Cayeux,
John Macpherson,
Carlos Damski
May 22, 2023

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Agenda

- Motivation and objective
- Data generation process: an important aspect of data quality
  - Capturing data generation using semantic graphs and networks
- Multiple interpretations of data: a source of gross error
  - Resolving data interpretation using the semantic description of signals
- Description of data relationships: the basis of uncertainty propagation
- Integration of Data Quality Management in Software

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Motivation and Objective

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Motivation

- Poor data quality and uncertainty can:
  - **Cause additional costs**:
    - Ex. Without a proper QAQC of directional surveying practices, 10 out of 24 wells were drilled with large uncertainties on the depth of oil/water contact and more generally formation tops, leading to suboptimal well placement and trajectory planning of the coming wells.

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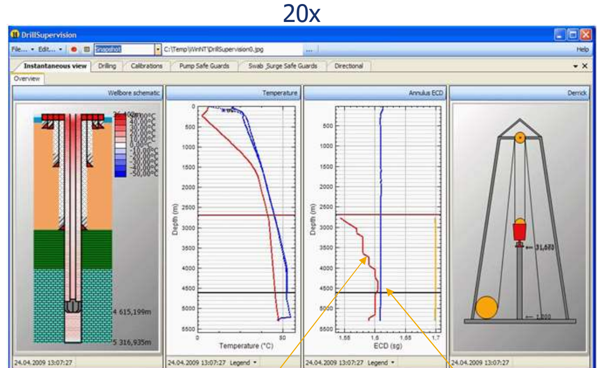
Motivation

- Poor data quality and uncertainty can:
  - **Cause additional costs**:
  - **Create additional risks**:

20x



Collapse pressure gradient

Annulus pressure gradient

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Motivation

- Poor data quality and uncertainty can:
  - **Cause additional costs**:
  - **Create additional risks**:
  - **Impede the proper use of data analytics**:

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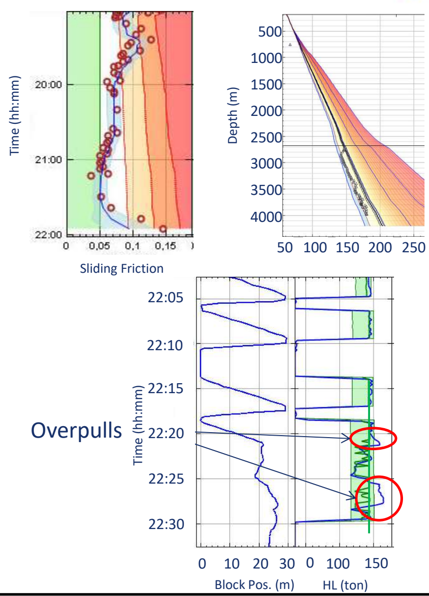
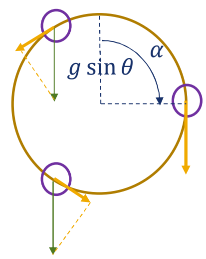
Motivation

- Poor data quality and uncertainty can:
  - **Cause additional costs**:
  - **Create additional risks**:
  - **Impede the proper use of data analytics**:
  - **Jeopardize taking timely decisions**:



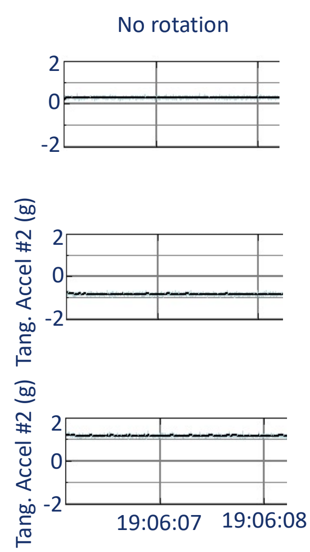
Research Questions

- Multi-disciplinary perspectives:
  - **How to ensure a seamless and lossless passage of information across disciplines?**
- Inherent uncertainties:
  - **How to ensure that uncertainty is captured and conveyed across disciplines?**
- Uncertainty propagation:
  - **How to capture the data generation workflows to propagate uncertainty?**
- Handling data quality:
  - **How to detect, mitigate and deal with low data quality?**



$\gamma_a = 0.15g$
γ_{t_1}=0.29g
γ_{t_2}=-0.83g
γ_{t_3}=1.16g ??

γ_{t_1} and γ_{t_2} →
$\theta = 57.4°$ and $\alpha = 20.1°$
γ_a and γ_{t_1} →
$\theta = 81.4°$ and $\alpha = 17.1°$
γ_a and γ_{t_2} →
$\theta = 81.4°$ and $\alpha = 62.9°$



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SPE Organizational Effort

- **Drilling Data Quality and Uncertainty Description (DDQUD),** with members from:
  - DSATS (Drilling Systems Automation),
  - WPTS (Wellbore Positioning) ,
  - DUPTS (Drilling Uncertainty Prediction)
- **Scope of work –** The primary mission of DDQUD is

  *to **increase** the **awareness** and **understanding** in the drilling community on how to describe **drilling data quality and uncertainty***

- **Method:**
  - List user stories
  - Rank criticality
  - Identify "low hanging fruit"
  - Describe data quality and uncertainty

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Data Generation Process:
Use Case Workflows, Abstraction, Semantic Graphs

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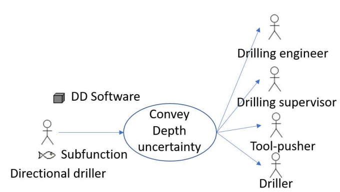
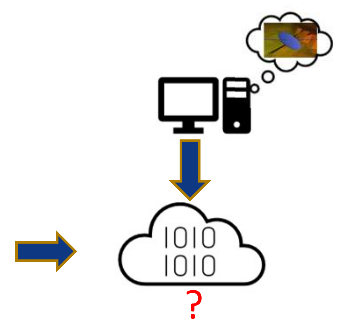
Motivational Use Case

How to convey well depth uncertainty across disciplines?

Use cases (actions achieving a discrete goal in a user story)

How can a use-case be described in a computer readable format?





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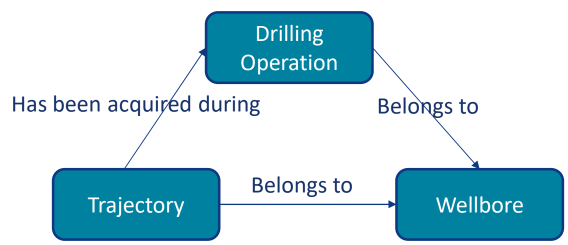
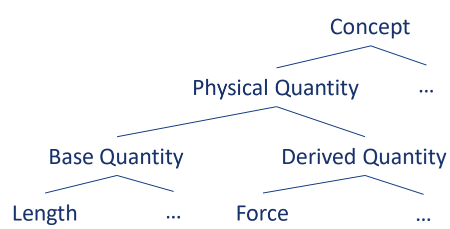
Semantic Graph as data abstraction

A collection of facts:

- A fact is an assertion that is true
- It can be represented as a relation between two concepts
  - subject verb object
  - head relationship tail
- A set of facts and relationships **creates a semantic graph**
- Concepts and verbs can be related hierarchically
  - Upwards = generalization
  - Downwards = specialization





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Semantic Graphs and Metadata

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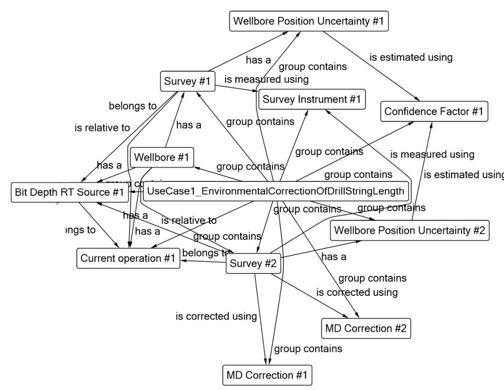
- Object Oriented Data schema = static model

  There is no computer readable information to understand why and how the data has been created

- **Semantic graph implies flexibility**

  A semantic graph can describe the meaning of the data and why it has been generated



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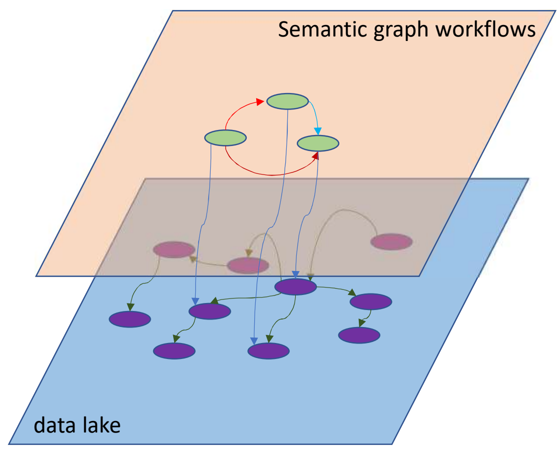
Semantic Graphs: Relationship to Data Repositories

- Semantic graphs
  - Point to where the data resides, do not themselves contain the data
  - Do capture data generation process that could not be stored in the data lake
  - Can be retrofitted since they are complimentary to data infrastructures



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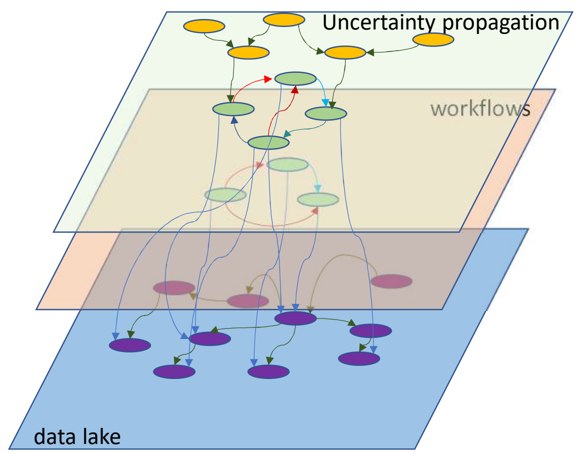
A multi-layered (network) perspective

- Different layers provide different views
  - The data lake view
  - The data generation analysis
  - The uncertainty propagation analysis
  - …
- Links and dependencies between layers



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Benefits

- Workflows are captured in semantic graphs:
  - Preserve how data is generated.
  - It is possible to analyze if work processes can be improved.
  - Repeating workflows can be (partially) automated.
  - Can be computed.
- The method complements existing data lake repositories:
  - No need to make drastic changes or costly conversion processes.
- Synergies between disciplines can be easier.

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Practicing with semantic graphs

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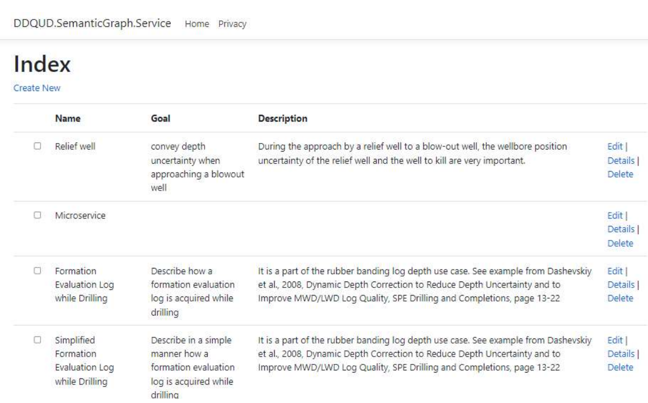
- A web application is available to experiment with semantic graphs: https://app.digiwells.no/DDQUDSemanticGraph/NamedGraphs
- It is possible to:
  - Display the details of existing graphs
  - Create new graph
  - Edit individual graph
  - Validate graph
  - Merge several graphs


DDQUD.SemanticGraph.Service Home Privacy

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Create New

	Name	Goal	Description	
☐	Relief well	convey depth uncertainty when approaching a blowout well	During the approach by a relief well to a blow-out well, the wellbore position uncertainty of the relief well and the well to kill are very important.	Edit | Details | Delete
☐	Microservice			Edit | Details | Delete
☐	Formation Evaluation Log while Drilling	Describe how a formation evaluation log is acquired while drilling	It is a part of the rubber banding log depth use case. See example from Dashevskiy et al., 2008, Dynamic Depth Correction to Reduce Depth Uncertainty and to Improve MWD/LWD Log Quality, SPE Drilling and Completions, page 13-22	Edit | Details | Delete
☐	Simplified Formation Evaluation Log while Drilling	Describe in a simple manner how a formation evaluation log is acquired while drilling	It is a part of the rubber banding log depth use case. See example from Dashevskiy et al., 2008, Dynamic Depth Correction to Reduce Depth Uncertainty and to Improve MWD/LWD Log Quality, SPE Drilling and Completions, page 13-22	Edit | Details | Delete

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Multiple Interpretations of Data

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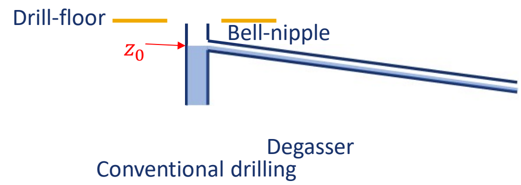
Motivational Example

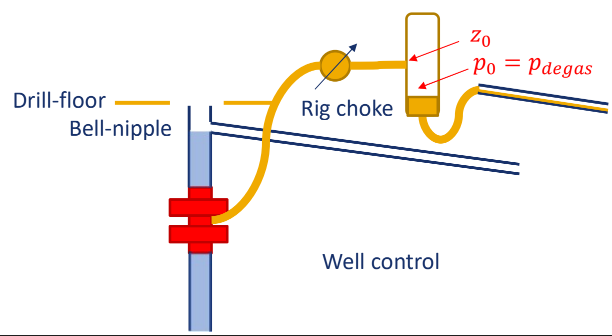
➢ Conversion of pressure in equivalent mud weight:

- $\rho_{emw} = \frac{p}{gz}$
- $\rho_{emw} = \frac{(p_z - p_0)}{g(z - z_0)}$



➢ There is no unique choice for p_0 and z_0

- Depends on the drilling method
- Top-side architecture
- The domain point of view
- May change with time



The Use of Independent References

- Application #1 converts Along string pressure measurements transmitted by wired pipe to ECD:
  - It is used by the high-speed telemetry provider
  - p_0 and z_0 are always atmospheric pressure and drill-floor
- Application #2 converts downhole annulus pressure from PWD to ECD:
  - It is used by the MWD engineer of the service company
  - p_0 and z_0 are chosen to be at the top of the liquid column in annulus, before any chokes or pumps
- Application #3 utilizes measured downhole ECD and kick, collapse and loss circulation events to update geo-pressure margins
  - It is used by the geo-mechanician expert of the operating company
  - p_0 and z_0 are at the origin of formation pressure build-up
- **What happens during a kick when the well is shut-in?**

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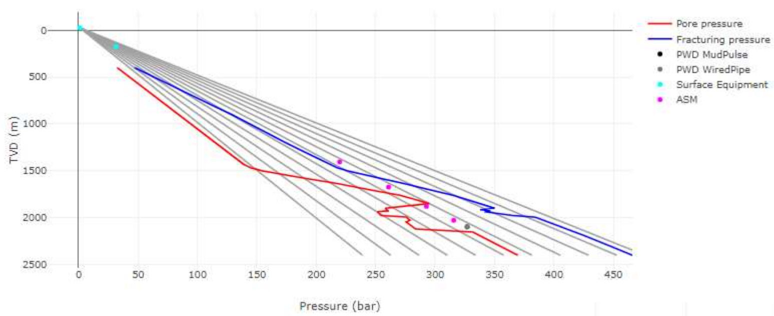
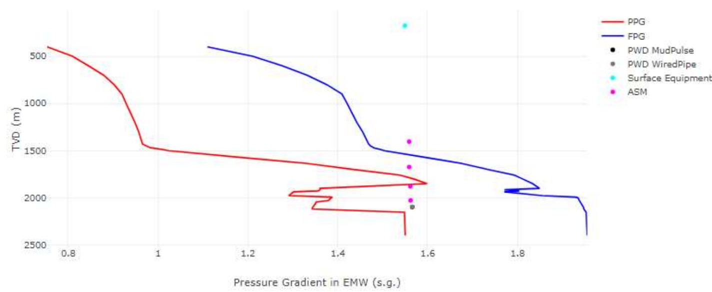
Reference Drill-floor



Conventional drilling
p_0 Atmospheric
z_0 Drill-floor



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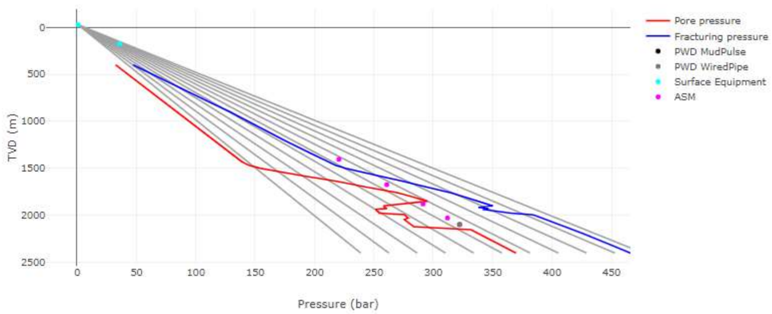
Reference Drill-floor



Closed BOP under Kick
p_0 atmospheric
z_0 Drill-floor

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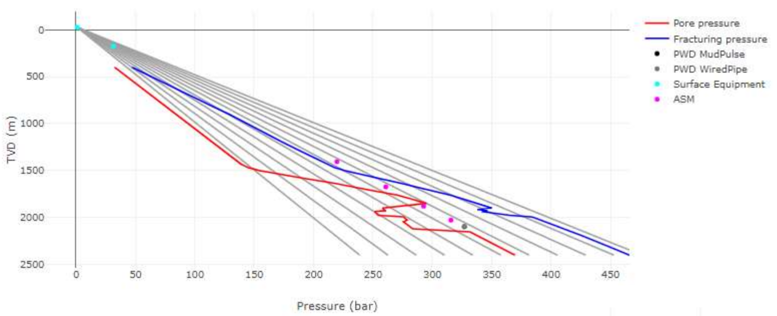
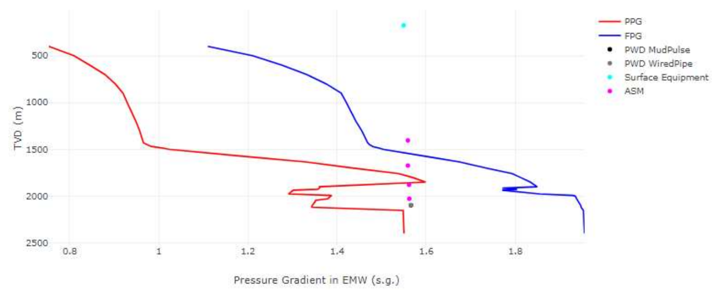
Reference Top of Fluid Column



Conventional drilling
p_0 Atmospheric
z_0 Drill-floor



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Reference Top of Fluid Column

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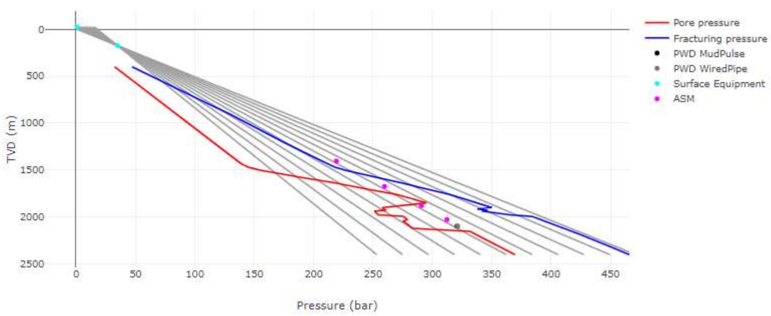
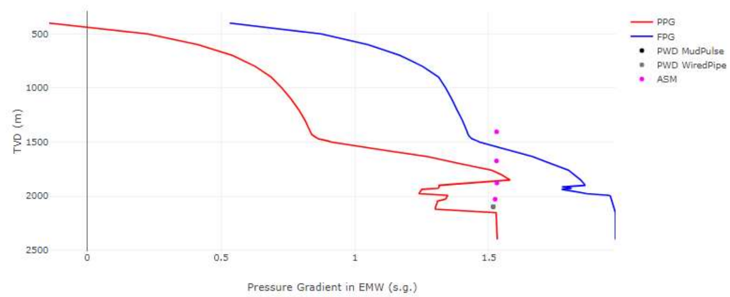


Closed BOP under kick

p_0 below BOP

z_0 BOP depth



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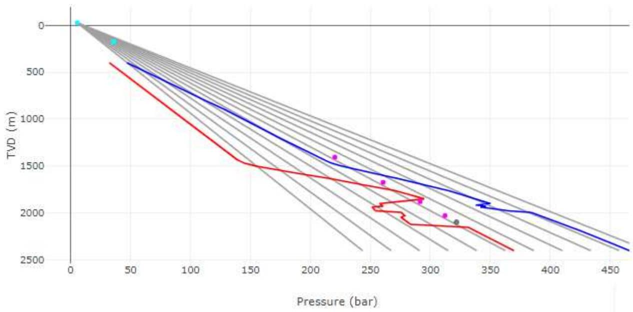
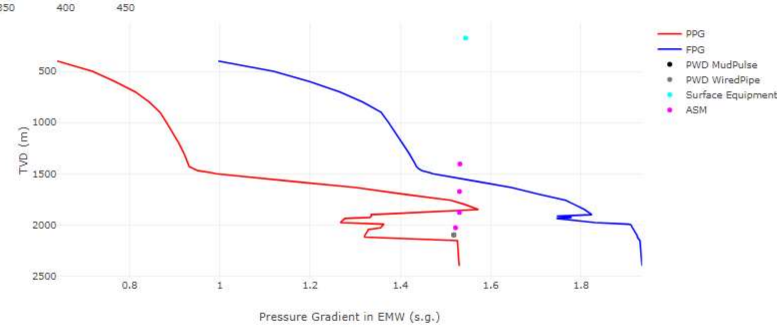
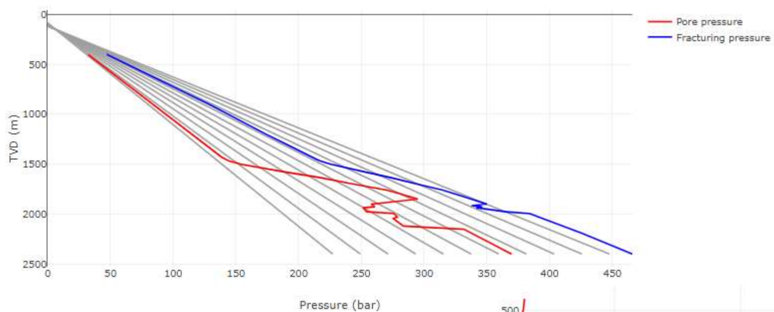
Reference Top of Fluid Column

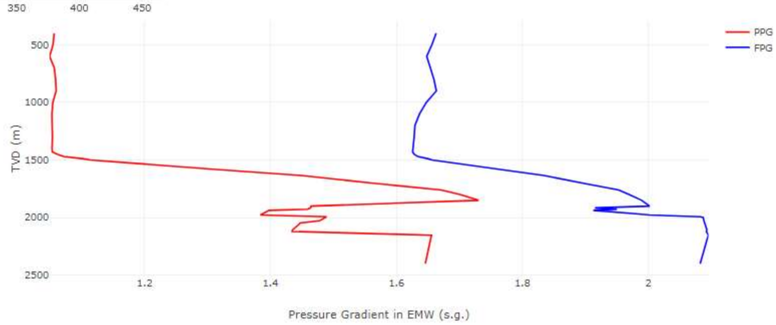


Closed Choke under kick
p_0 Upstream of choke
z_0 Choke elevation



Reference Top of Geopressure





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Reference Top of Geopressure

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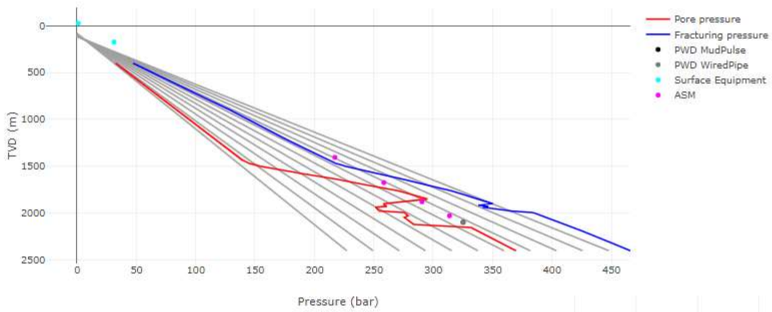
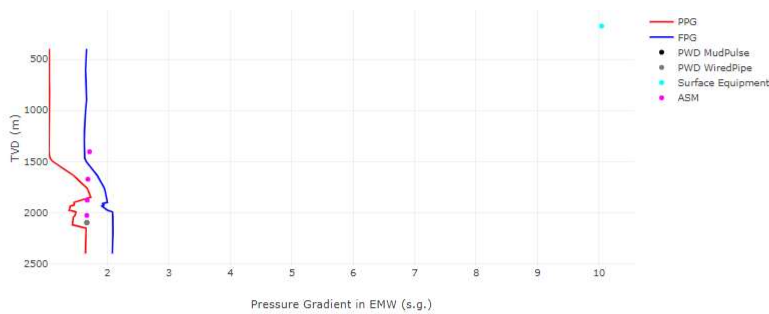


Conventional drilling
p_0 pressure at start formation pressure increase
z_0 TVD of start formation pressure increase



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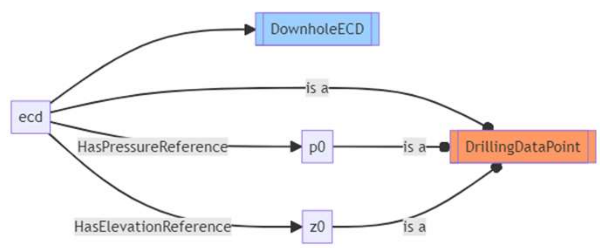
The Semantic Description of Signals

- Semantic description of signals:
  - Can express complex information about signals
    - Uncertainties
    - Logical positions
    - Dependency relations
    - Processing
    - Transmission
    - Control functions



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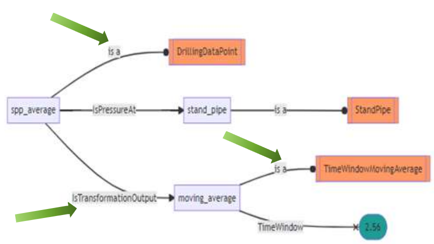
The Semantic Description of Signals

- Semantic description of signals:
  - Can express complex information about signals
    - Uncertainties
    - Logical positions
    - Dependency relations
    - Processing
    - Transmission
    - Control functions
  - Information retrieval:
    - Objective: «where is the wired pipe downhole pressure?»
    - Semantic graph = graph database
    - Query language: SPARQL

```
SELECT ?dataPoint
  WHERE {
      ?dataPoint a <http://ddhub.no/DrillingDataPoint> .
      ?dataPoint <http://ddhub.no/IsTransformationOutput> ?dataTrans .
      ?dataTrans a <http://ddhub.no/TimeWindowMovingAverage>.
    }
```



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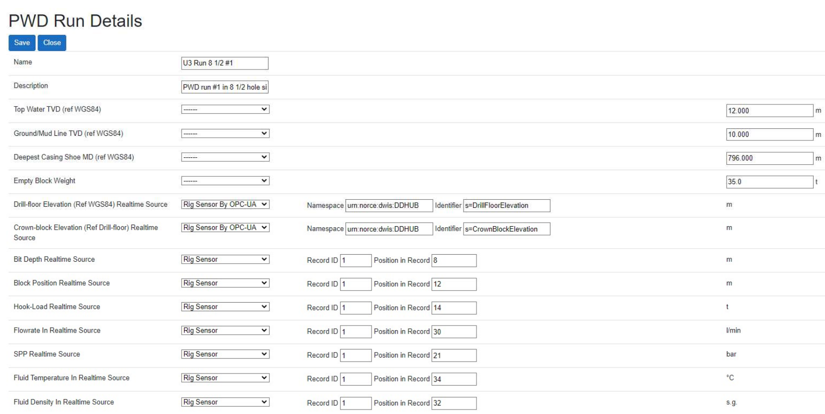
Multiple data sources

Multiple possibilities:
- WITS0
- WITSML
- OPC-UA
- UDP Datagram

Need to define the available data sources

And then link every signal the application uses to the right data source and with the correct configuration



How can we automate that process and make it seamless?

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Semantic Queries in a Client Application

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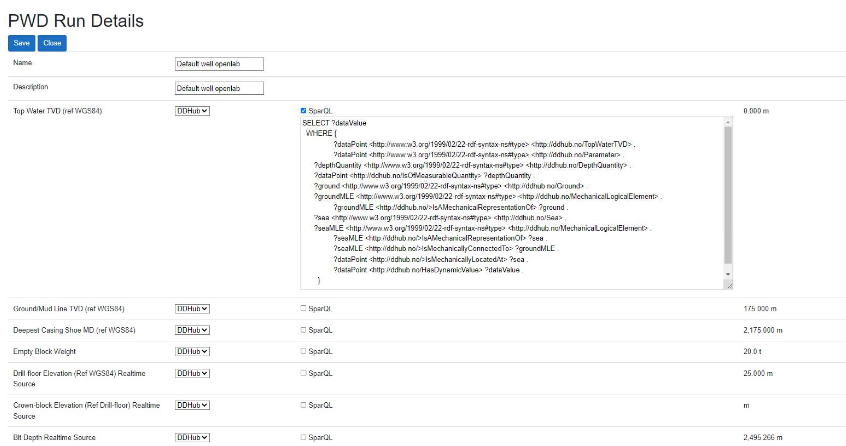
- The semantic queries are implicit for each signal and works for any configuration.
- The semantic queries are usually invisible to the end-user.
- But they can be inspected if one wishes so.



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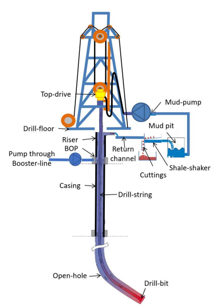
The Semantic Network Method

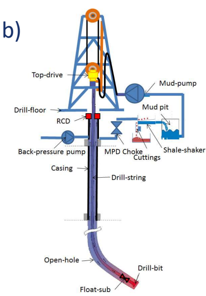
The semantic network method can be applied to describe concepts other than signals.
For example, it can be used to describe the configuration of a rig

a)



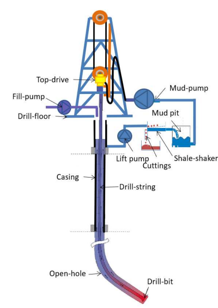
Floater with crown-block heave compensation in conventional drilling

b)



Fixed-platform with back-pressure MPD

c)



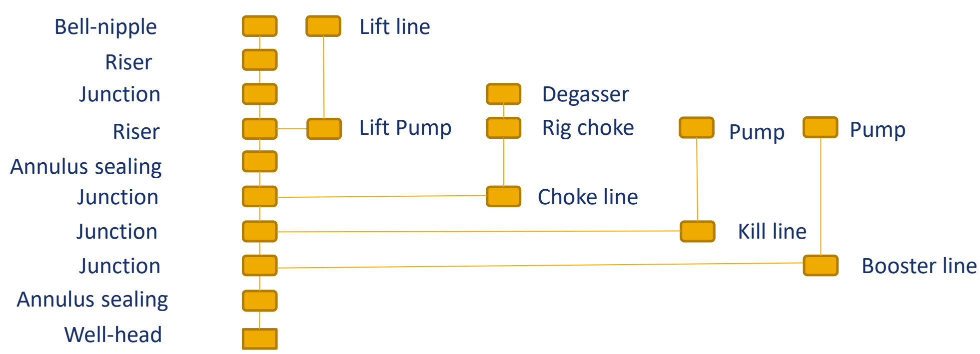
Low-level annulus drilling method

Describing the Hydraulic Network

To estimate EMW references, the system needs a description of the top-side architecture and its associated signals

There is a very large number of possibilities, probably difficult to cover all architectures:
- **Hydraulic network** above the well-head of pipes, pumps, chokes/sealing element, degasser, junctions (3-ways), …
- Each of which **can have sensors**, e.g., pressure, density, flowrate, opening ratio,…
- And the **signals may come from multiple sources**, e.g., rig sensors, MPD provider,…

MJD12



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Slide 35

MJD12 From Carlos: "suggestion to remove the text in this slide" (I deleted his bubble on the slide and rearranged the text)

Macpherson, John D, 5/4/2023

Semantic Description of Hydraulic Network

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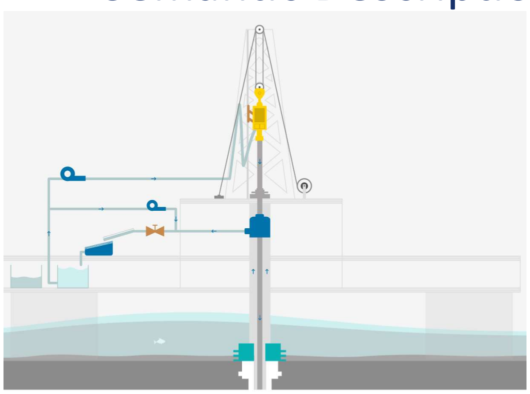

Architecture above Well-head

Element Name	Element Type	Element Downstream	Element Type Downstream
Riser	StandardAnnulus	Flow-diverter	FlowDiverter
BOP	AnnulusSealing	Riser	StandardAnnulus
Well-head	WellHead	BOP	AnnulusSealing
Flow-diverter	FlowDiverter	High-pressure Flow-line	StandardPipe
High-pressure Flow-line	StandardPipe	3-Way Connector	PipeBranching
3-Way Connector	PipeBranching	Choke	Choke
Choke	Choke	Low-pressure Flow-line	StandardPipe
Back-pressure Pump	Pump	Choke	Choke
Pump-line	StandardPipe	Back-pressure Pump	Pump
Pit	Pit	Pump-line	StandardPipe

- Rig publishes the semantic description,
- Application utilizes it to decide the most relevant reference for depth and pressure
- Change in rig activity, e.g., from conventional drilling to well control, is manageable without manual configuration

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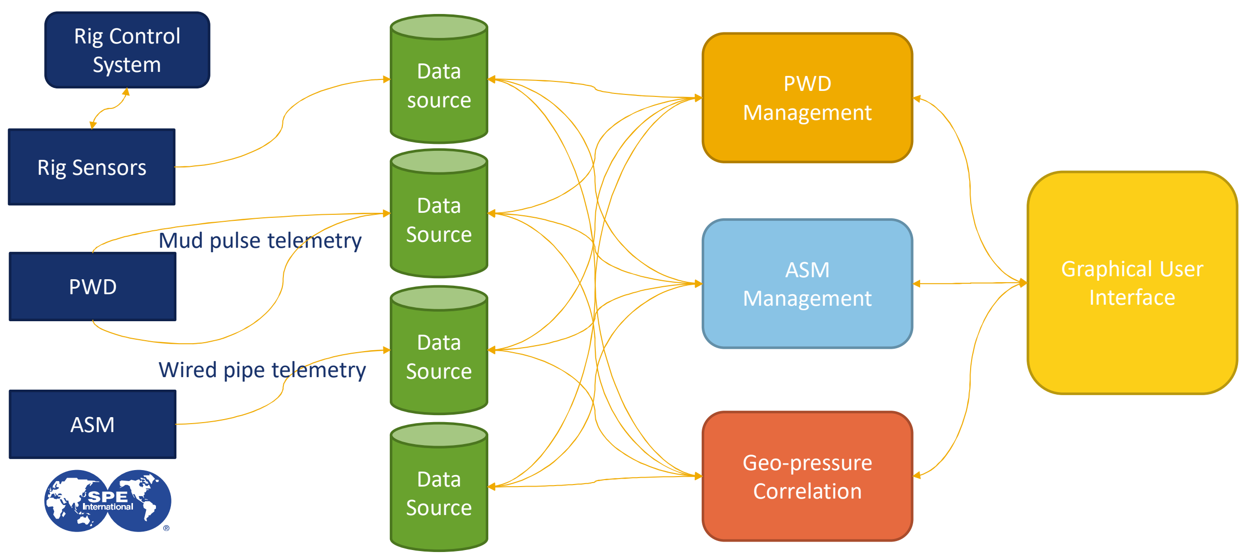
Running the Scenario



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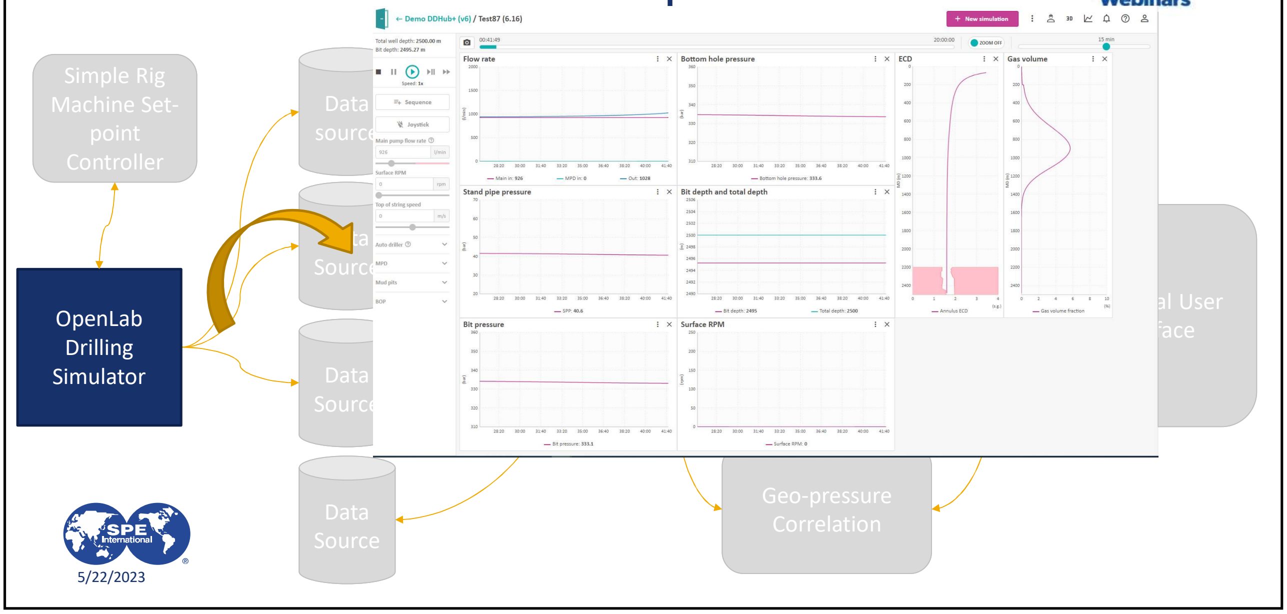
Demo Setup



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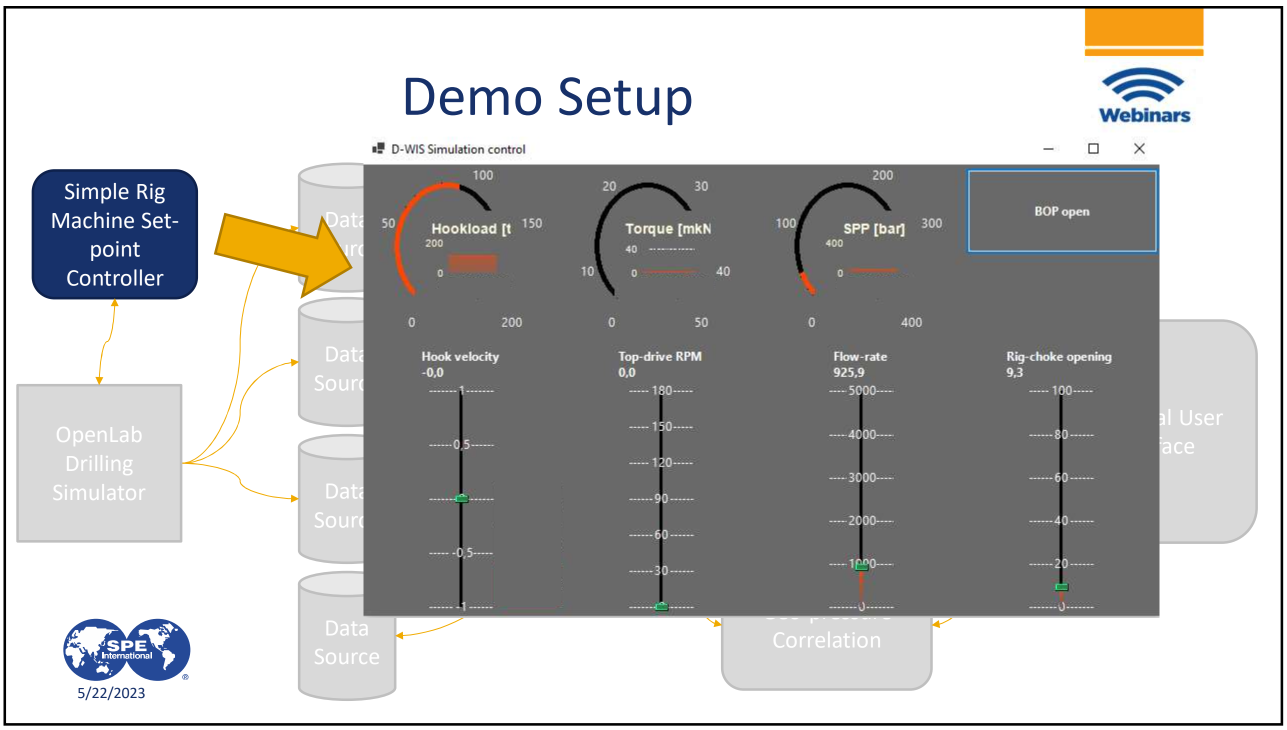
Demo Setup
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Simple Rig Machine Set-point Controller
OpenLab Drilling Simulator
Data Source
Correlation
D-WIS Simulation control
Hookload [t
Torque [mkN
SPP [bar]
BOP open
Hook velocity
-0,0
Top-drive RPM
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Flow-rate
925,9
Rig-choke opening
9,3
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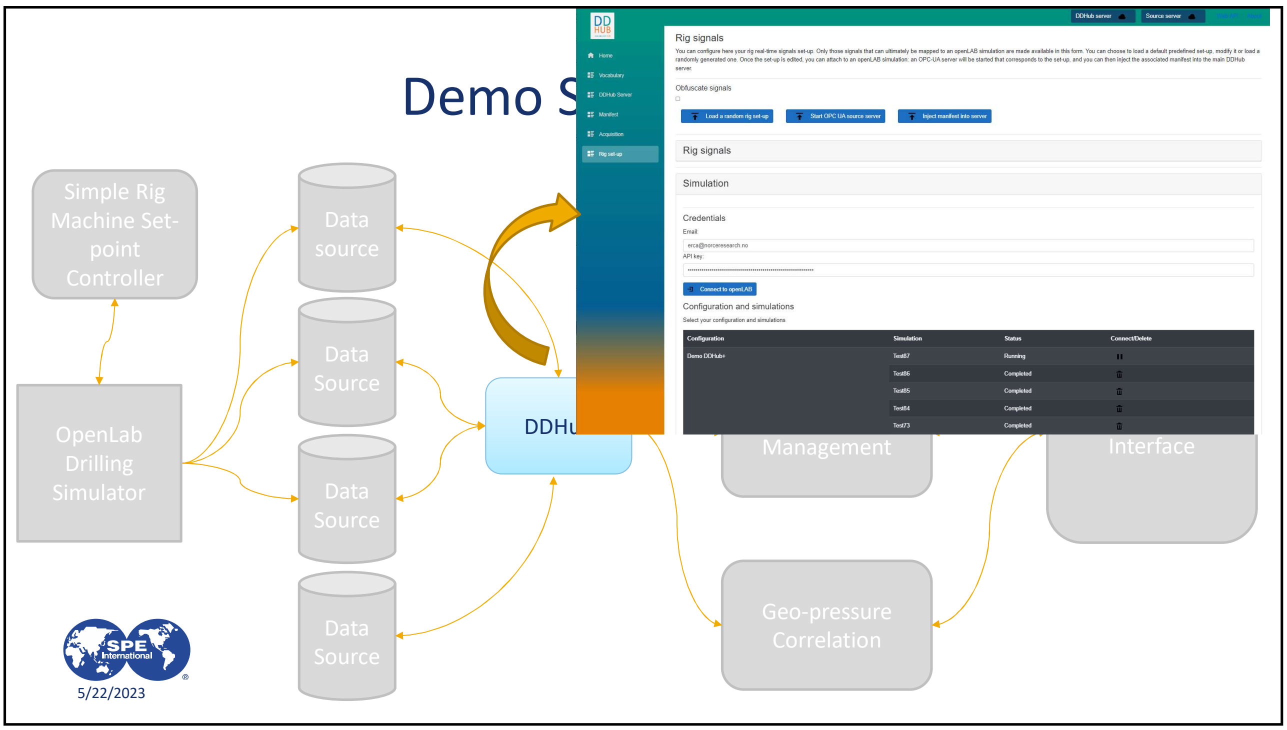
Demo S
Simple Rig Machine Set-point Controller
OpenLab Drilling Simulator
Data source
Data Source
Data Source
Data Source
DDHu
Management
Interface
Geo-pressure Correlation
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DD HUB
Home
Vocabulary
DDHub Server
Manifest
Acquisition
Rig set-up
DDHub server
Source server
Rig signals
You can configure here your rig real-time signals set-up. Only those signals that can ultimately be mapped to an openLAB simulation are made available in this form. You can choose to load a default predefined set-up, modify it or load a randomly generated one. Once the set-up is edited, you can attach to an openLAB simulation: an OPC-UA server will be started that corresponds to the set-up, and you can then inject the associated manifest into the main DDHub server.
Obfuscate signals
Load a random rig set-up
Start OPC UA source server
Inject manifest into server
Rig signals
Simulation
Credentials
Email:
erca@norceresearch.no
API key:
Connect to openLAB
Configuration and simulations
Select your configuration and simulations
Configuration
Simulation
Status
Connect/Delete
Demo DDHub+
Test87
Running
Test86
Completed
Test85
Completed
Test84
Completed
Test73
Completed

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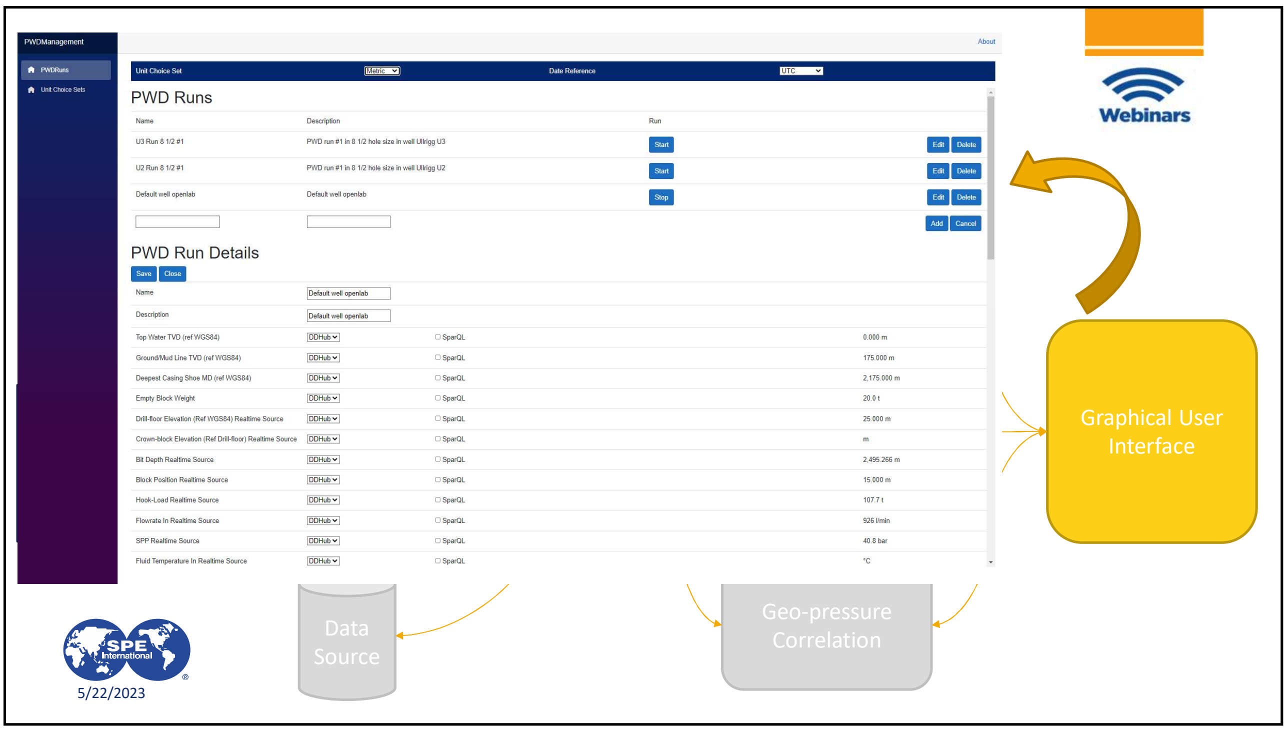
PWDManagement
PWDRuns
Unit Choice Sets
About
Unit Choice Set
Metric
Date Reference
UTC
PWD Runs
Name
Description
Run
U3 Run 8 1/2 #1
PWD run #1 in 8 1/2 hole size in well Ullrigg U3
Start
Edit
Delete
U2 Run 8 1/2 #1
PWD run #1 in 8 1/2 hole size in well Ullrigg U2
Default well openlab
Stop
Add
Cancel
PWD Run Details
Save
Close
Top Water TVD (ref WGS84)
Ground/Mud Line TVD (ref WGS84)
Deepest Casing Shoe MD (ref WGS84)
Empty Block Weight
Drill-floor Elevation (Ref WGS84) Realtime Source
Crown-block Elevation (Ref Drill-floor) Realtime Source
Bit Depth Realtime Source
Block Position Realtime Source
Hook-Load Realtime Source
Flowrate In Realtime Source
SPP Realtime Source
Fluid Temperature In Realtime Source
DDHub
SparQL
0.000 m
175.000 m
2,175.000 m
20.0 t
25.000 m
2,495.266 m
15.000 m
107.7 t
926 l/min
40.8 bar
°C
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Graphical User Interface
Data Source
Geo-pressure Correlation
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5/22/2023

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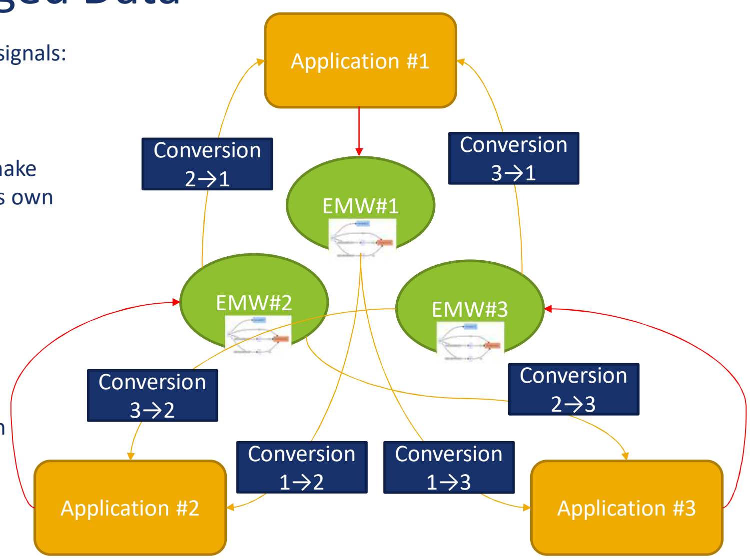
Semantics: Interpreting the Meaning of Exchanged Data

- Each application can publish the semantic of its signals:
  - This can change with time
- Other applications that need these signals:
  - Can interpret the published meaning and make the necessary transformation to adapt to its own expectations without human intervention.
  - This is done on the fly
- Consequently:
  - Timely adaptation
  - Systematic behavior
  - Avoid erroneous configuration
  - Reduce dependence on human intervention



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Description of Data Relationships
The basis for the propagation of uncertainty

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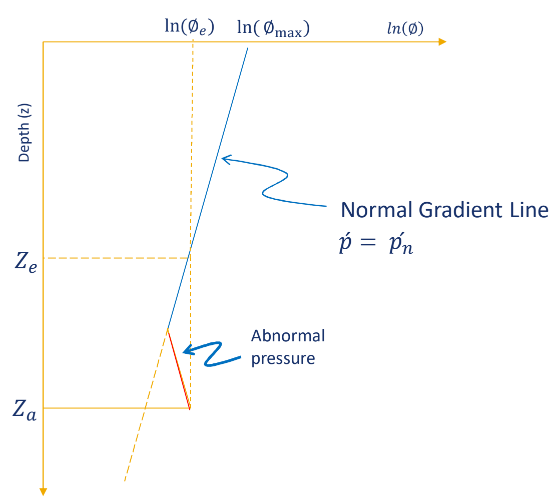
Example: High Level Sources of Uncertainty

What are the high-level sources of uncertainty in the estimation of geopressure margins?

- There is uncertainty in the geopressure prognosis
- There is uncertainty in wellbore position
- There is uncertainty in the stratigraphic model
- There is uncertainty in the downhole fluid pressure estimation
- There is uncertainty in the in-situ formation pressure estimates



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MJD15

Example: Next Level Sources of Uncertainty

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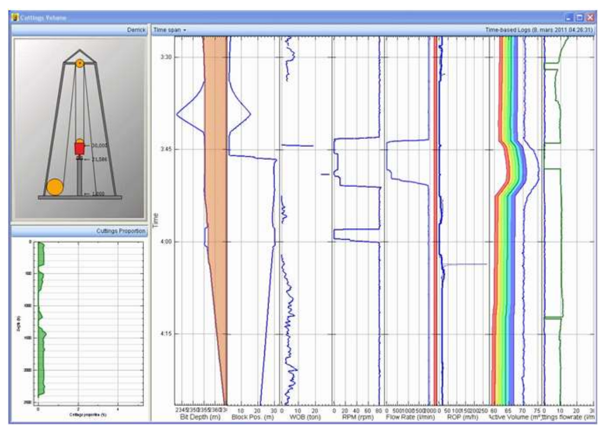
What are the sources of uncertainties in the estimation of downhole fluid pressures?

- There is uncertainty in the mud density
- There is uncertainty in the mud rheological behavior
- There is uncertainty in the downhole temperature
- There is uncertainty in the cuttings load



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Slide 45

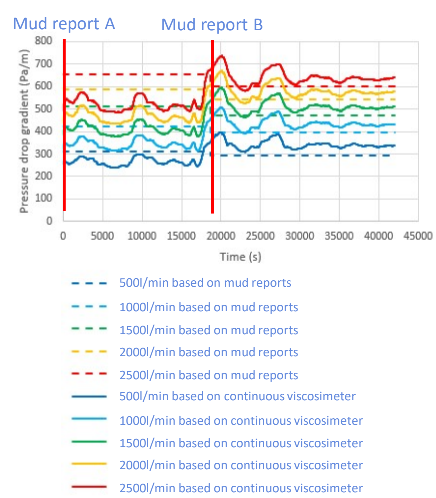
MJD15 Changed this to next level to go with the previous slide "high level", and removed the "bubble" about level 1 from Carlos.

Macpherson, John D, 5/4/2023

Example: Yet a Lower Level Sources of Uncertainty

What are the sources of uncertainties in estimating the mud rheological behavior?

- There is uncertainty/errors because the Couette rheometer assumes a Newtonian fluid
- There is uncertainty caused by additional constituents
- Taking too sparse measurements is detrimental to uncertainty



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Uncertainty Description and Propagation

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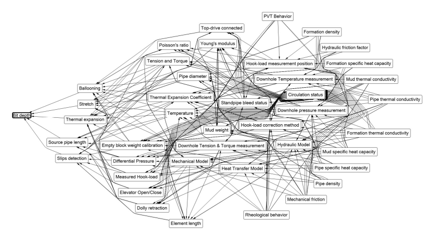
- Any scientific or engineering measurement (data) has uncertainty
  - Uncertainty propagates when data is combined
  - Where to store uncertainty information?
- Uncertainty propagation is recursive:
  - Sources of uncertainty have their own sources of uncertainty
- Relationships mean a source influences a target
  - Leads to a weighted graph:
  - How much a source influences the uncertainty of the target



An example influence diagram

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Integration of Data Quality Management in Software

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- Using semantics graphs and networks, it should be possible to describe uncertainty in applications
- It cannot be expected that end-users describe workflows in term of semantic graphs, but it can be expected that software uses semantic graphs to describe data relationships and meaning
- Applications can attach semantic information when they exchange data
  - The accumulation of the semantic attachments, each time data is exchanged allows to capture the workflow in a distributed fashion
  - But applications need to be changed to document the meaning of the exchanged data

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Closing Remarks

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Conclusion

- **Drilling Data Quality and Uncertainty**
  - Has consequences on costs, risks and timely decision making
  - Is exacerbated by multi-disciplinary workflows
- **To be addressed**
  - Need to account for data generation workflows
  - Exchanged information shall be “self-descriptive” to allow correct interpretation by other applications
  - Data dependence on other sources shall be tracked and evaluated to propagate uncertainty
- **Possible methods**
  - Semantic networks can be constructed to capture work processes
  - Data can be accompanied with a semantical description of their meaning and the principles of their generation
  - Influence diagrams can be built to facilitate the analysis of the propagation of uncertainty
- **Practical solutions**
  - Uncertainty is managed by software applications
  - Software solutions decorate exchanged data with semantical information

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Further information

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- Cayeux, E., Damski, C., Macpherson, J., Laing, M., Annaiyappa, P., Harbidge, P., Edwards, M., and J. Carney. "Connecting Multilayer Semantic Networks to Data Lakes: The Representation of Data Uncertainty and Quality." SPE Drill & Compl 38 (2023): 18–33. doi: https://doi.org/10.2118/208754-PA

- Coming paper: "Analysis of the Sources of Uncertainty in Geopressure Estimation While Drilling". Paper SPE-214962-MS to presented at the SPE Annual Technical Conference and Exhibition in San Antonio, TX, USA, Oct 16-18, 2023.

- Information and code can be found on github: https://github.com/spe-ddqud (Contact Eric to get access)

- Regular posts on SPE-DSATS.org: https://www.spe-dsats.org/group/drilling-data-quality-uncertainty-description/discussion

- List of User Stories for Drilling Data Quality and Uncertainty: https://dsabok.org/drilling-data-quality-uncertainty/

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Acknowledgement

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Thank you
Any questions?

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