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# SPE 191408

## Automating Directional Drilling: Technology Adoption Staircase Mapping Levels of Human Interaction

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SPE International
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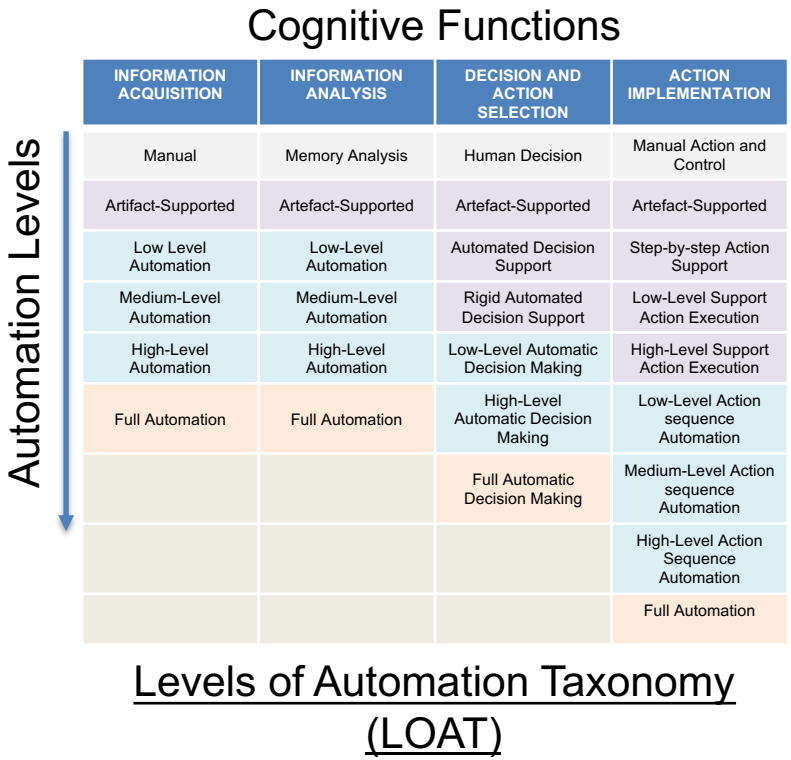
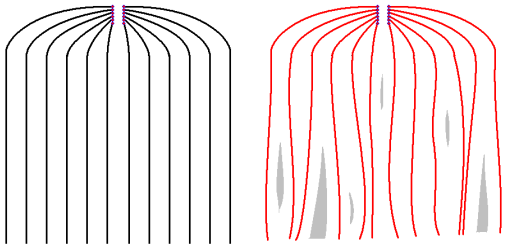
# AGENDA

- Goal of Automation
- Levels of Automation Taxonomy
- Directional Drilling Automation
  - Pre-well
  - Drilling Operations
- Conclusions



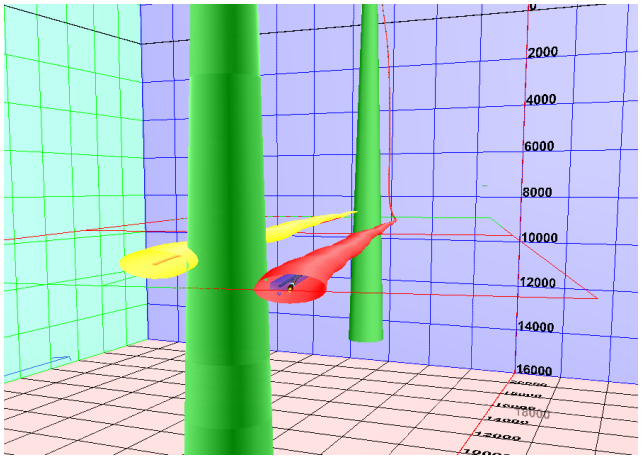
# Good Directional Drilling and Wellbore Surveying Practices

- Increased reservoir exposure
- Improved well bore quality
  - lower drilling costs
  - easier completion
  - lower production costs and $/BBL
- Increased Asset Value



## Challenges

- Increase in horizontal wells and lateral lengths
  - need for more experienced Directional Drillers
- Higher ROP
  - less available time for good decision making

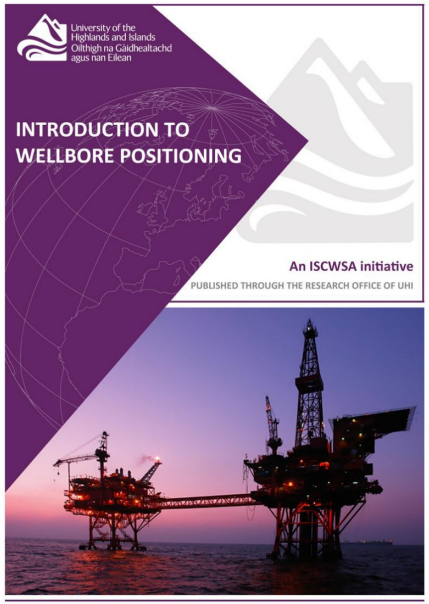


# Drive To Automation

## Operators asking for

- more **transparency** in Directional Drilling processes
- implementation of **best practices**
- more **consistency** (Continuous Improvement Process)
- reduced risk
- improved **HSE**
  - reduced personnel at wellsite
  - reduced impact on environment

**"Automation"**




Free eBook: http://www.uhi.ac.uk/en/research-enterprise/energy/wellbore-positioning-download

# LOAT - Levels of Automation

Automation Levels

| INFORMATION ACQUISITION | INFORMATION ANALYSIS | DECISION AND ACTION SELECTION | ACTION IMPLEMENTATION |
|---|---|---|---|
| Manual | Memory Analysis | Human Decision | Manual Action and Control |
| Artifact-Supported | Artefact-Supported | Artefact-Supported | Artefact-Supported |
| Low Level Automation | Low-Level Automation | Automated Decision Support | Step-by-step Action Support |
| Medium-Level Automation | Medium-Level Automation | Rigid Automated Decision Support | Low-Level Support Action Execution |
| High-Level Automation | High-Level Automation | Low-Level Automatic Decision Making | High-Level Support Action Execution |
| Full Automation | Full Automation | High-Level Automatic Decision Making | Low-Level Action sequence Automation |
| | | Full Automatic Decision Making | Medium-Level Action sequence Automation |
| | | | High-Level Action Sequence Automation |
| | | | Full Automation |

Level of Human Interaction

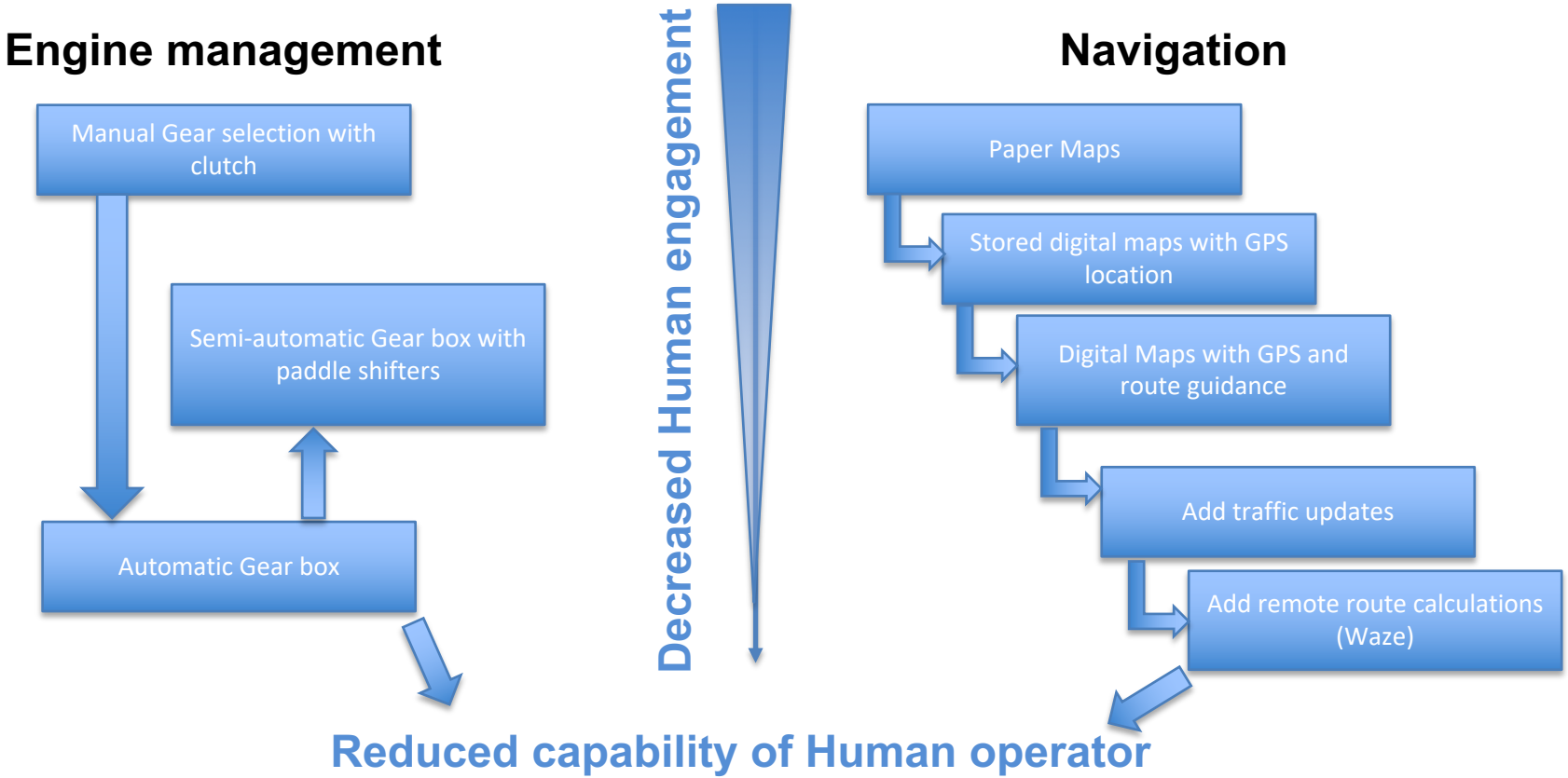
Manual

Human - increasing Artefact Support

System Automation - decreasing Human supervision

Full Automation

# LOAT - Levels of Automation – automotive examples



# LOAT - Four Cognitive Functions

- Data Acquisition
- Information Analysis
- Decision Making and Action Selection
- Action Implementation

Cognitive Functions

Automation Levels

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| | | | Full Automation |

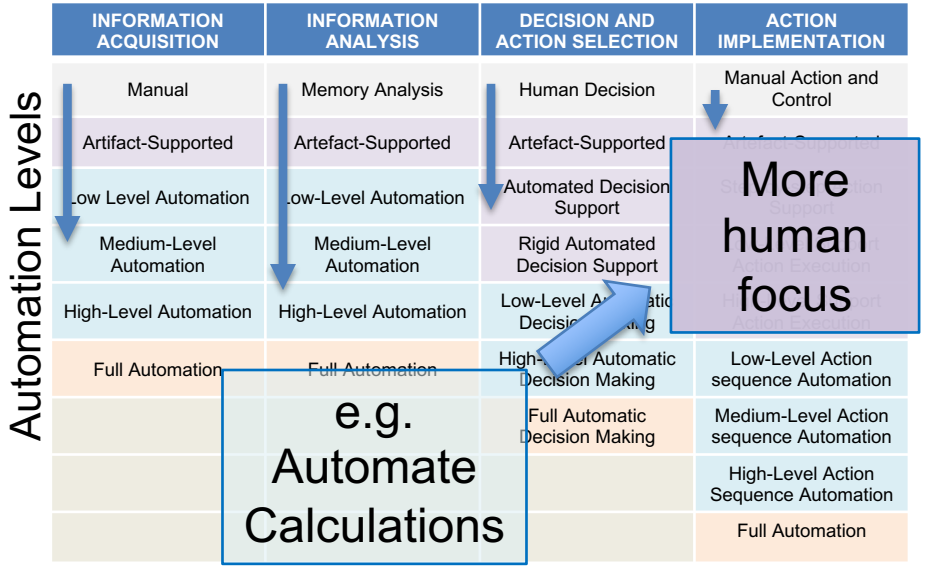
Levels of Automation Taxonomy (LOAT)

# LOAT - Levels of Automation

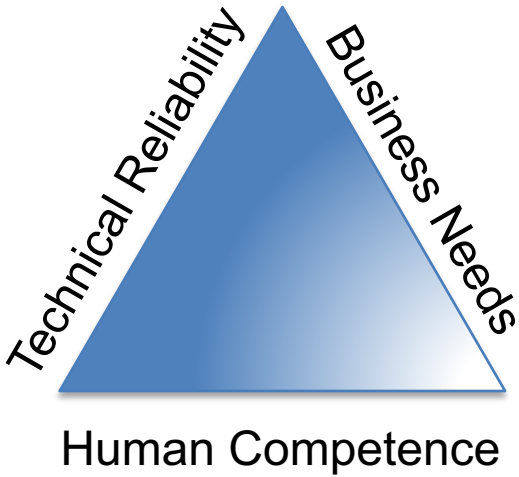
Each Function can be automated to a different level

- To allow focus where the human brings most value

- To maximize the benefits from validated automated processes.



# LOAT - Levels of Automation




Automation Levels

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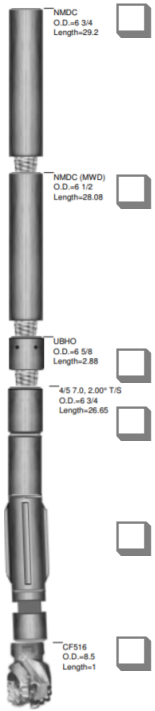
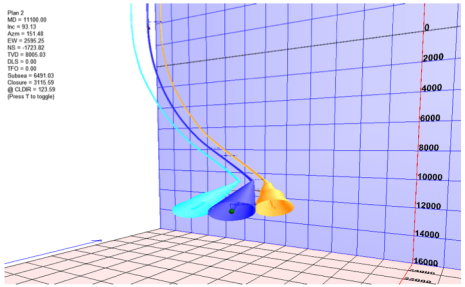
Achieve the right balance

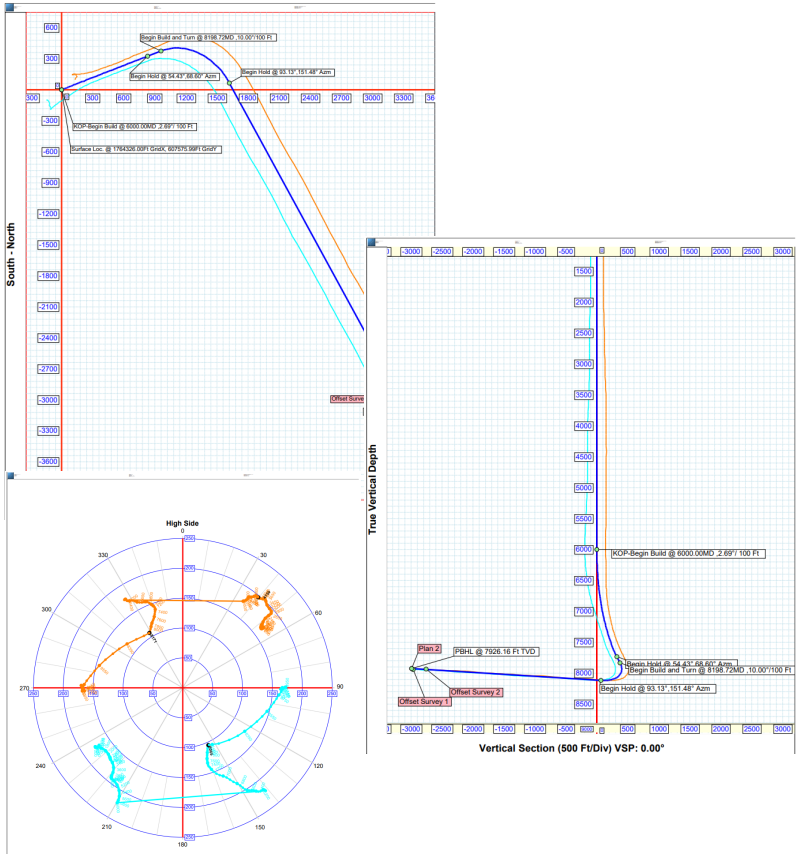
# Pre-well operations



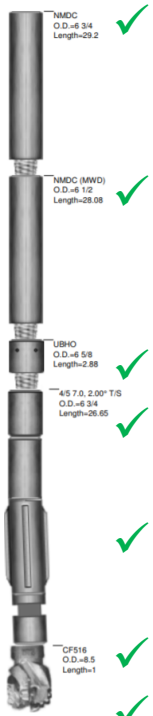

- ❑ Target Selection
- ❑ Well Planning
- ❑ BHA Selection

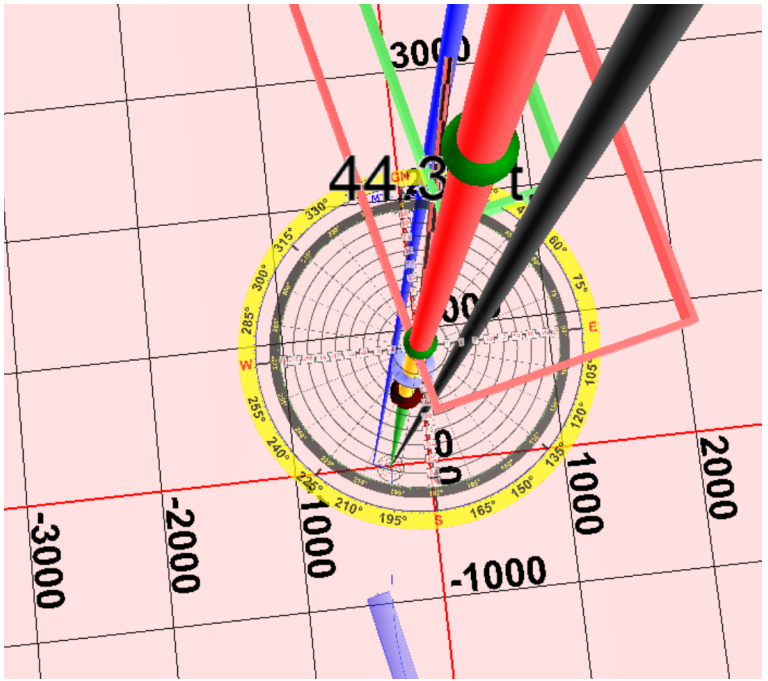
Low level Artefact Support



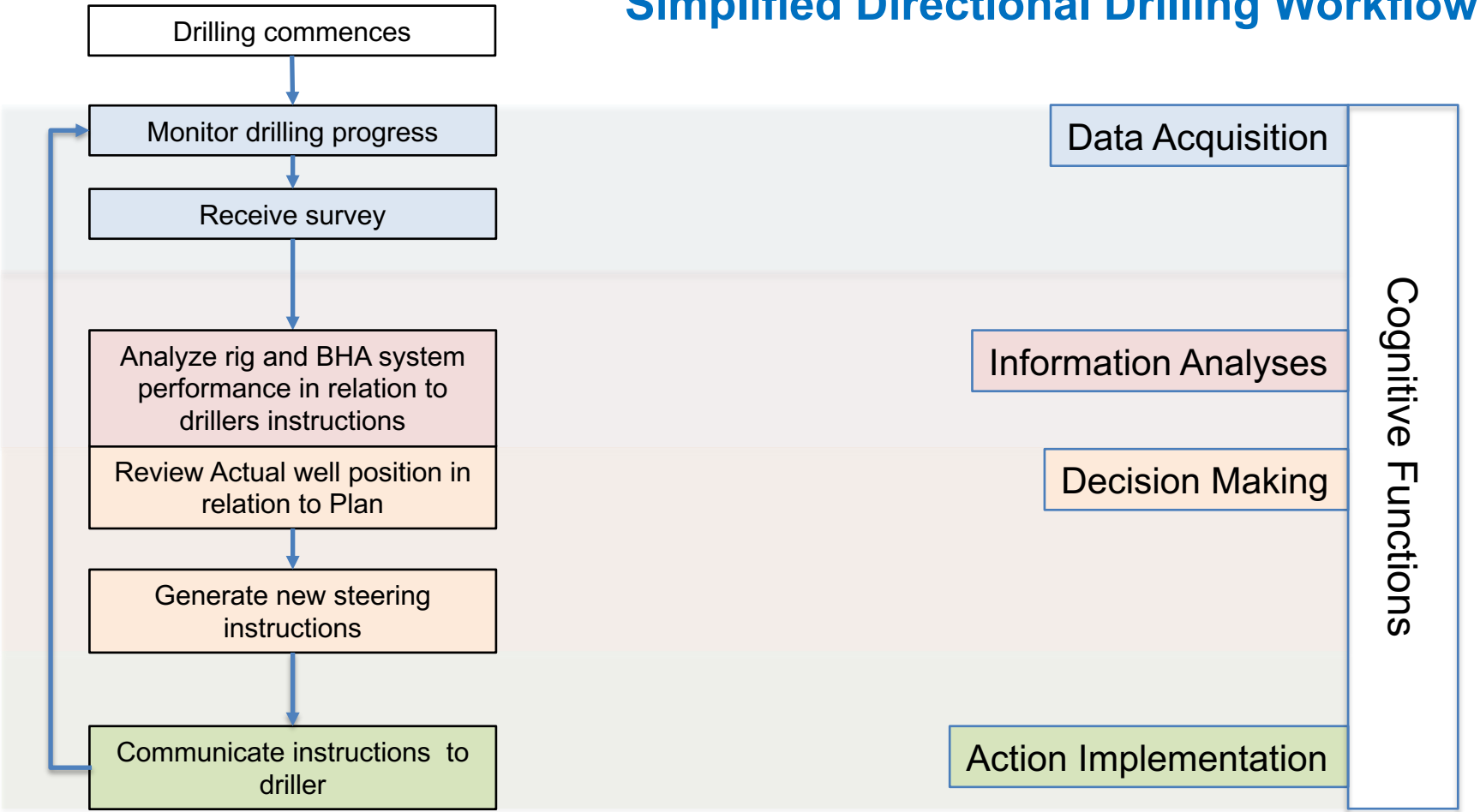


# Drilling Operations

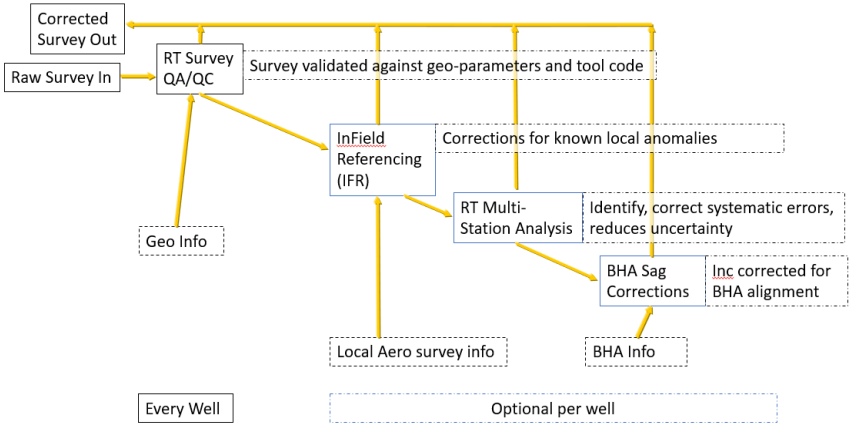


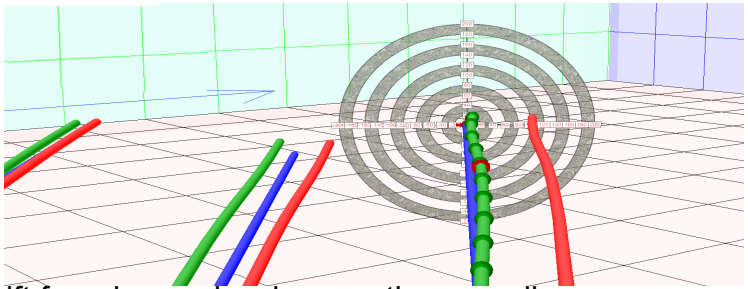
# Simplified Directional Drilling Workflow



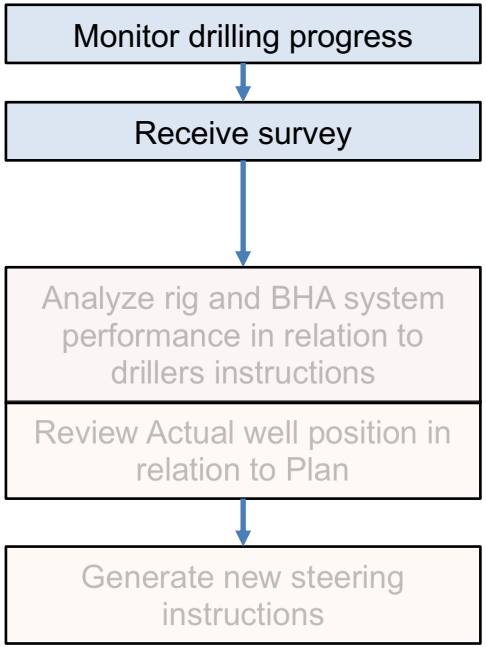
# Drilling Operations - Data Acquisition




PLAN – Blue
REAL TIME MWD SURVEY - Red
CORRECTED SURVEY – Green



Note the lateral shift from known local magnetic anomalies



# Drilling Operations - Data Acquisition

| INFORMATION ACQUISITION | Well Plan | BHA | Rig Equipment | Rig RT Drilling Data | Survey Data |
|---|---|---|---|---|---|
| Manual | Manual | Manual | **Manual** | | |
| Artifact-Supported | **Artifact-Supported** | **Artifact-Supported** | Artifact-Supported | | |
| Low Level Automation | Low Level Automation | | | **Low Level Automation** | **Low Level Automation** |
| Medium-Level Automation | Medium-Level Automation | | | Medium-Level Automation | Medium-Level Automation |
| High-Level Automation | | | | High-Level Automation | High-Level Automation |
| Full Automation | | | | | |

# Information Analyses Function

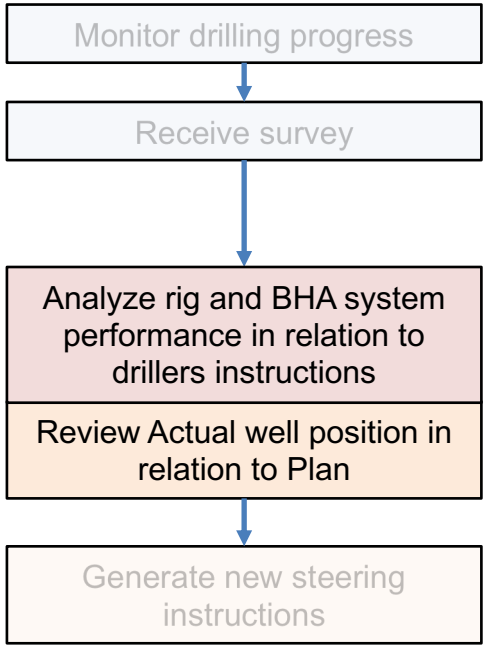
**Output used for** :

- Historical reports
- Real Time decision making

**Decision Making Function requires :**

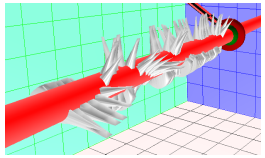
- Wellbore position vs desired position, including
  - Approved Surveys
  - last survey to bit

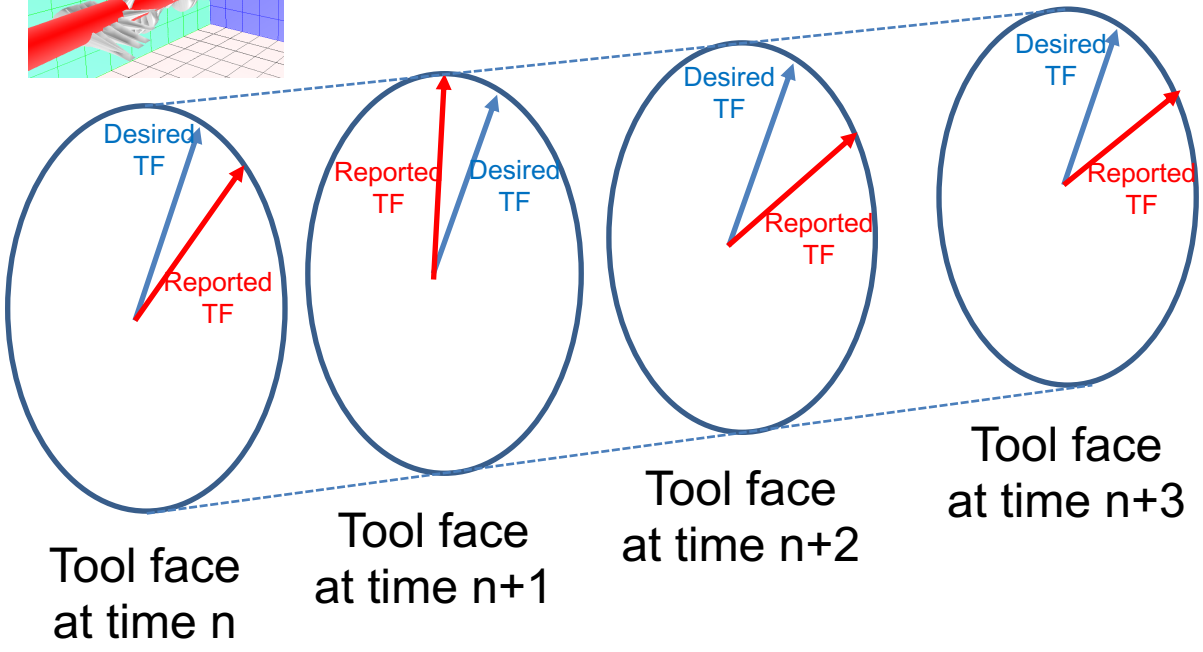
- Drilling system performance
  - BHA performance vs formation : Motor Yield, Build Rate, Turn Rate
  - ability to hold Tool Face

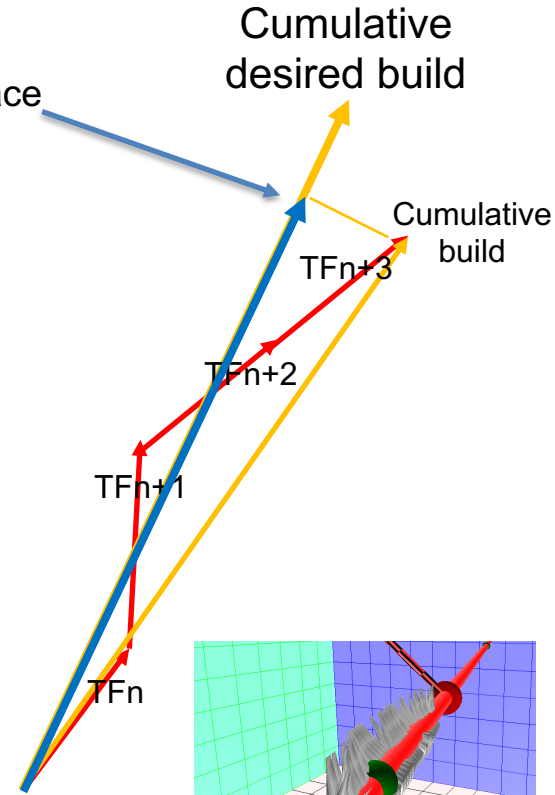


# Tool Face Efficiency

Weighted average of a slide pointing in the direction of the **desired** Tool Face





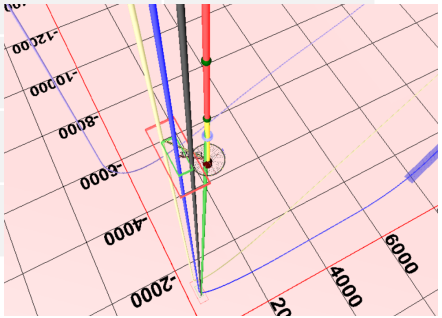



# Information Analyses Function

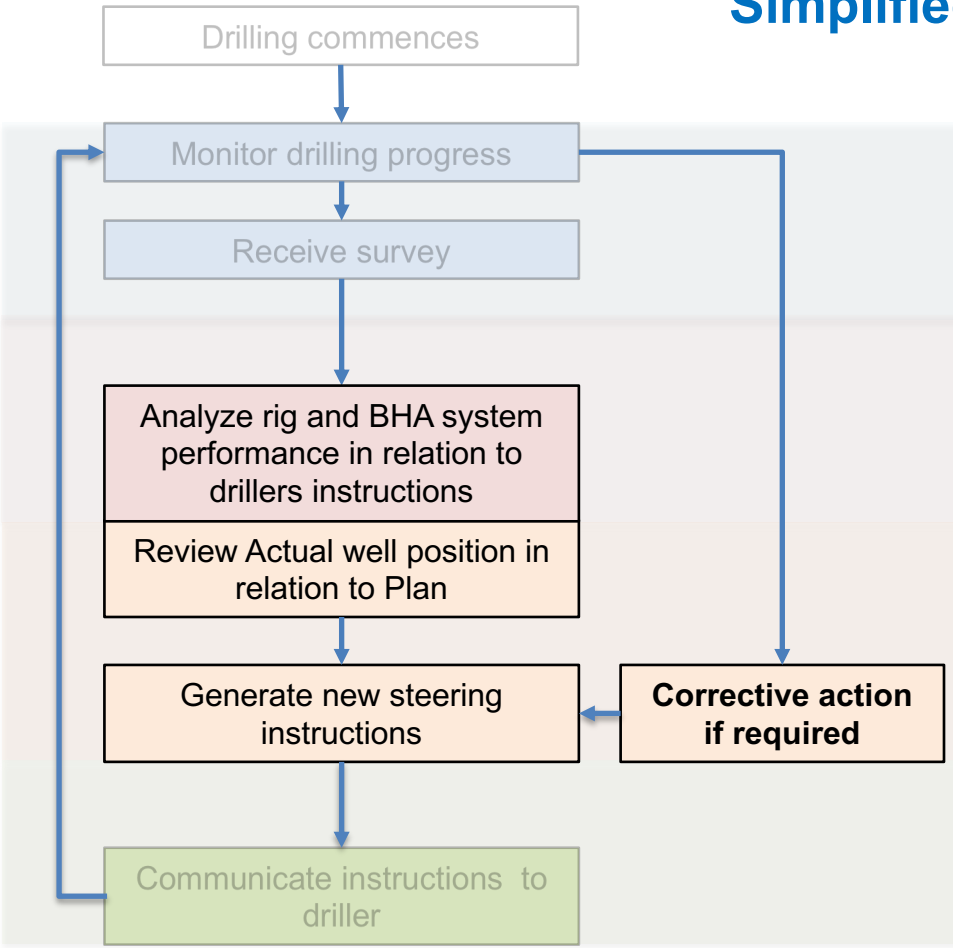
Supported by calculators for years


| INFORMATION ACQUISITION | INFORMATION ANALYSIS | DE SE |
|---|---|---|
| | Memory Analysis | |
| | Artefact-Supported | |
| | Low-Level Automation | |
| | Medium-Level Automation | |
| | **High-Level Automation** | |
| | Full Automation | |

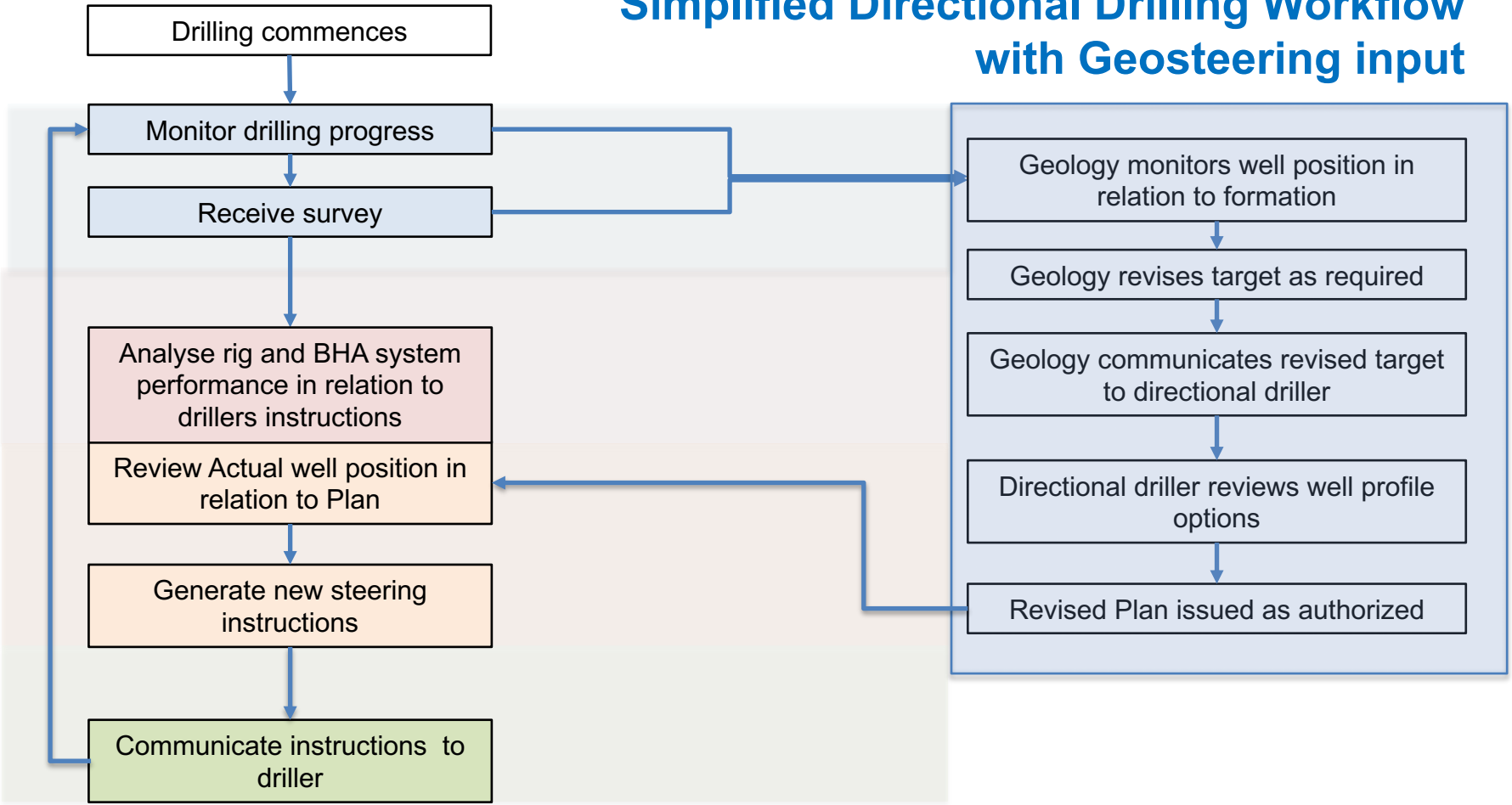
<u>Modern Automation Systems</u>
Capable of analyzing and presenting results every time a new data point is available



# Simplified Directional Drilling Workflow Decision Points



# Simplified Directional Drilling Workflow with Geosteering input



# Drilling Operations - Decision Making and Action Selection

Decisions

- current Path adequate
- current BHA adequate to drill ahead
- slide or rotate
- slide length and Tool Face

- consider
    - relative ROP between steering and rotating
    - wellbore quality
    - anti-collision risks
    - future pad slots

- Balance Wellbore Quality with ROP and risk

# Drilling Operations - Decision Making and Action Selection

Automated Decision Making :

can improve consistency

between individual directional drillers,

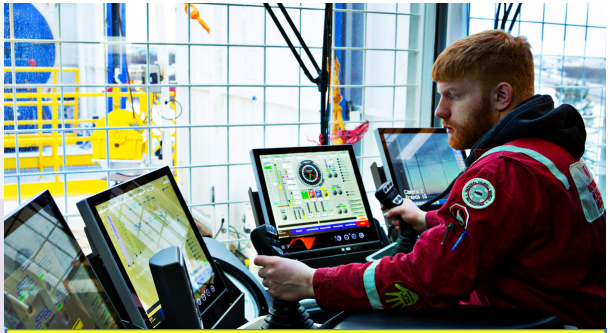
between wells

of delivery of company policies

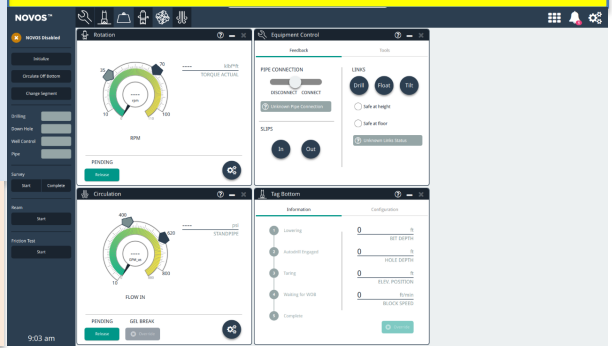
| DSA-R LOAT LEVELS | Directional Drilling Automation System Levels |
|---|---|
| C0. The human generates decision options, selects the appropriate ones, and decides on all actions to be performed. | |
| C1. The human generates decision options, makes a selection and decides on all actions to be performed utilizing paper or other non-digital artifacts | C1a. The human generates decision options, makes a selection and decides on all actions to be performed utilizing paper or other non-digital artifacts |
| | C1b. The human generates decision options, makes a selection, and decides all actions to be performed, with digital artefact support. |
| C2. Automated Decision Support, where the system proposes one or more decision alternatives, and the human can select one of those or use one of his/her own. | C2a. System offers rotate or slide alternatives with slide length and tool face Set Points, for human to pass to Driller |
| | C2b. System recommends Set Points and allows modifications before passing to Driller |
| C3. Rigid Automation Decision Support, where the human may only select one of the system generated options or request that new options be generated. | C3a. System recommends Set Points and asks for human selection before passing to Driller |
| | C3b. System recommends Set Points and passes them to Driller unless human aborts |
| C4. Low Level Automatic Decision Making, where the system generates options, decides autonomously which to perform, and informs the human. | C4. System recommends Set Points and passes them to the Driller or drilling control system, while informing the human |
| C5. High Level Automatic Decision Making, where the system generates options, decides autonomously which to perform, and informs the human only if requested. | C5. System recommends Set Points and passes them to the Driller or Drilling Control System, while informing the human only if requested |
| C6. Full Automation Decision Making, where the system generates options, decides autonomously which to perform, without informing the human. | C6. System recommends Set Points and passes them to Drilling Control System for Action. |

# Drilling Operations - Action Implementation

| | |
|---|---|
| Manual | **Verbal** communications from Directional Driller to Driller<br>*Driller enters parameters and implements* |
| Human - increasing Artefact Support | **Digital** Communications from Automation System to Driller<br>*Driller enters parameters and implements* |
| System Automation - decreasing Human supervision | **Digital** Communications from Automation System to Rig Control System<br>*Driller authorizes implementation* |
| Full Automation | **Digital** Communications from Automation System to Rig Control System<br>*Rig Control System implements automatically* |



**Driller responsible for rig operations**




Images courtesy of NOV

# Drilling Operations - Action Implementation

Higher levels of automation require:

the involvement of Rig Control System builders

increased acceptance and implementation of the automated decisions

| DSA-R LOAT LEVELS | Directional Drilling Automation System equipment examples | Directional Drilling Automation System Implementation Level |
|---|---|---|
| D0. Human executes and controls manually. | D0. Mechanical and SCR rigs | D0. Directional Driller gives Set Points to Driller verbally. |
| D1. Artefact-supported Action Implementation. The human executes and controls actions with the help of mechanical non-software based tools | D1. Joystick and electronic control system rigs. | D1. Display the received Set Points to the driller for manual input and implementation. |
| D2. Step-by-step Action Support. The system assists the operator in performing actions by executing part of the action and/or by providing guidance for its execution, However, each action is based on human initiative and the human keeps full control of its execution | D2. Autodriller maintaining WOB, ROP, or Diff P set points. | D2. The Set Points are received by the Rig Control System (RCS) and displayed to the driller for manual input and implementation. |
| D3. Low-level Support of Action Sequence Execution. The system performs automatically a sequence of actions after activation by the human. The human maintains full control of the sequence and can modify or interrupt the sequence during its execution | D3a. Top Drive Oscillator systems assisting with transfer of weight down hole to the bit and helping to maintain downhole Tool Face. | 3a. The Set Points are received by the Rig Control System (RCS), displayed to the driller, and implemented after approval or modification by the driller. |
| | D3b. | D3b. The Set Points are received by the Rig Control System (RCS), displayed to the driller, and implemented after approval by the driller. |
| D4. High level Support of Action Sequence Execution. The system performs automatically a sequence of action after activation by the human. The human can monitor all the sequence and can interrupt it during its execution. | D4. | D4. The Set Points are received by the Rig Control System (RCS), displayed to the driller, and implemented unless driller aborts. |
| D5. Low-level Automation of Action Sequence Execution. The system initiates and executes automatically a series of actions. The human can monitor all the sequence and can modify or interrupt it during its execution. | D5. | D5. The Set Points are received by the Rig Control System (RCS) and implemented while informing driller. |
| D6. Medium-level Automation of Action Sequence Execution. The system initiates and executes automatically a sequence of actions. The human can monitor all the sequence and can interrupt it during its execution | D6. | The Set Points are received by the Rig Control System (RCS) and implemented, informing driller only if requested. |
| D7. High-level Automation of Action Sequence Execution. The system initiates and executes a sequence of actions. The human can only monitor part of it and has limited opportunities to interrupt it. | D7. | The Set Points are received by the Rig Control System (RCS) and implemented, informing driller only if requested. |
| D8. Full Automation of Action Sequence Execution. The system initiates and executes a sequence of actions. The human cannot monitor nor interrupt it until the sequence is terminated. | D8. | The Set Points are received by the Rig Control System (RCS) and implemented through completion of the sequence without human interference. |

# Conclusions

- The LOAT can be applied beneficially to Directional Drilling Automation
- It can help manage expectations and provide a path forward

- Best practices in wellbore placement are being widely adopted
- Wellbore survey management programs are being progressively automated

- Value can be delivered with proper management of existing data flows
- Automated systems can improve operational efficiencies for directional wells
- Each cognitive function can be automated to a different level

**Automation is neither all or nothing**
**nor the end goal**
**but a means of providing value when used appropriately**



# Thank You