On autonomous drilling

Topplederkonferansen 2020 - Ptil, October 21’st

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Drilling and well modelling, NORCE Energy

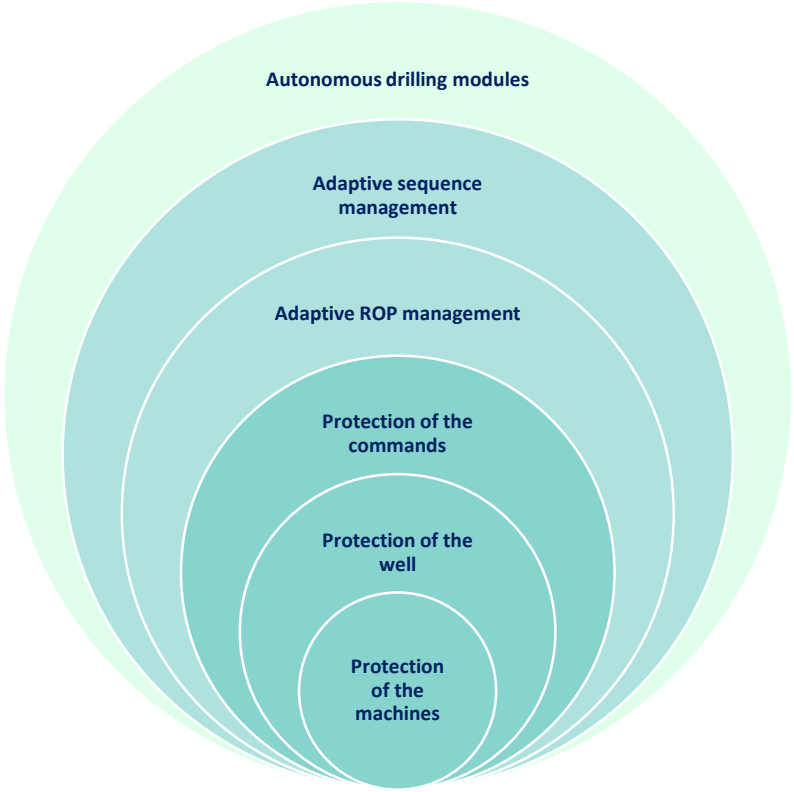
Agenda

- Introduction
- Autonomous versus automated drilling
- Autonomous drilling as an optimization problem
- Autonomous drilling as a safe process
- Conclusion

Introduction

DADPC: Demonstration of Automated Process Control (Demo 2000 Research project)

- Aim: To demonstrate autonomous drilling
- Built on top of existing technologies (commercially available)



Autonomous versus automated drilling

What is the difference between a robotized car manufacturing assembly line and a Boston Dynamic robot?

https://youtu.be/82w_r2D1Ooo

https://youtu.be/rVlhMGQgDkY

The robotized car manufacturing plant is **automated** with robots while Atlas is an **autonomous** robot

Autonomy is about to be flexible to changing environments and changing goals, to learn from experience and to make appropriate choices given perceptual limitations and finite computation.

Autonomous drilling

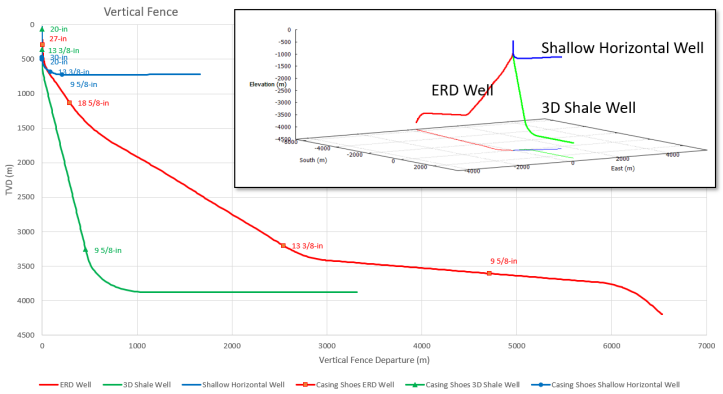
System compatible with:

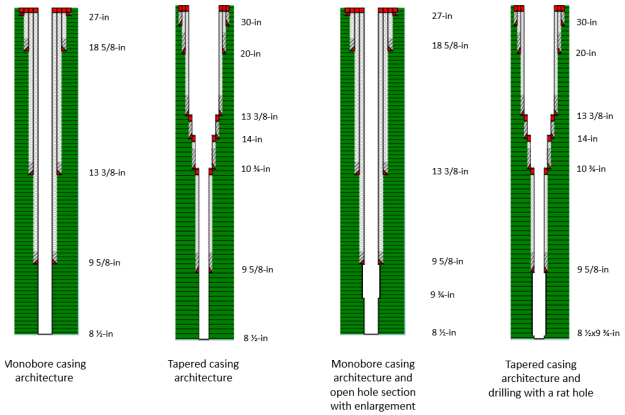
- Land rigs, fixed offshore platforms and floaters.
- Wide range of well dimensions: from shallow horizontal wells, to ERD wells and

3D shale well.

- Tapered wellbore architectures, tapered drill-strings.
- Use of hole-opening or under-reaming.
- Water-based, oil-based and micronized drilling fluids.
- Use of downhole high-speed telemetry and inline rheological measurements if available

(autonomous drilling system is designed to work also if these are not available)



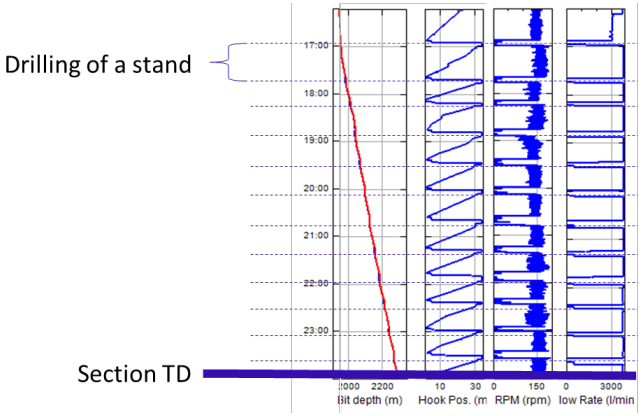


Boundaries of the project:

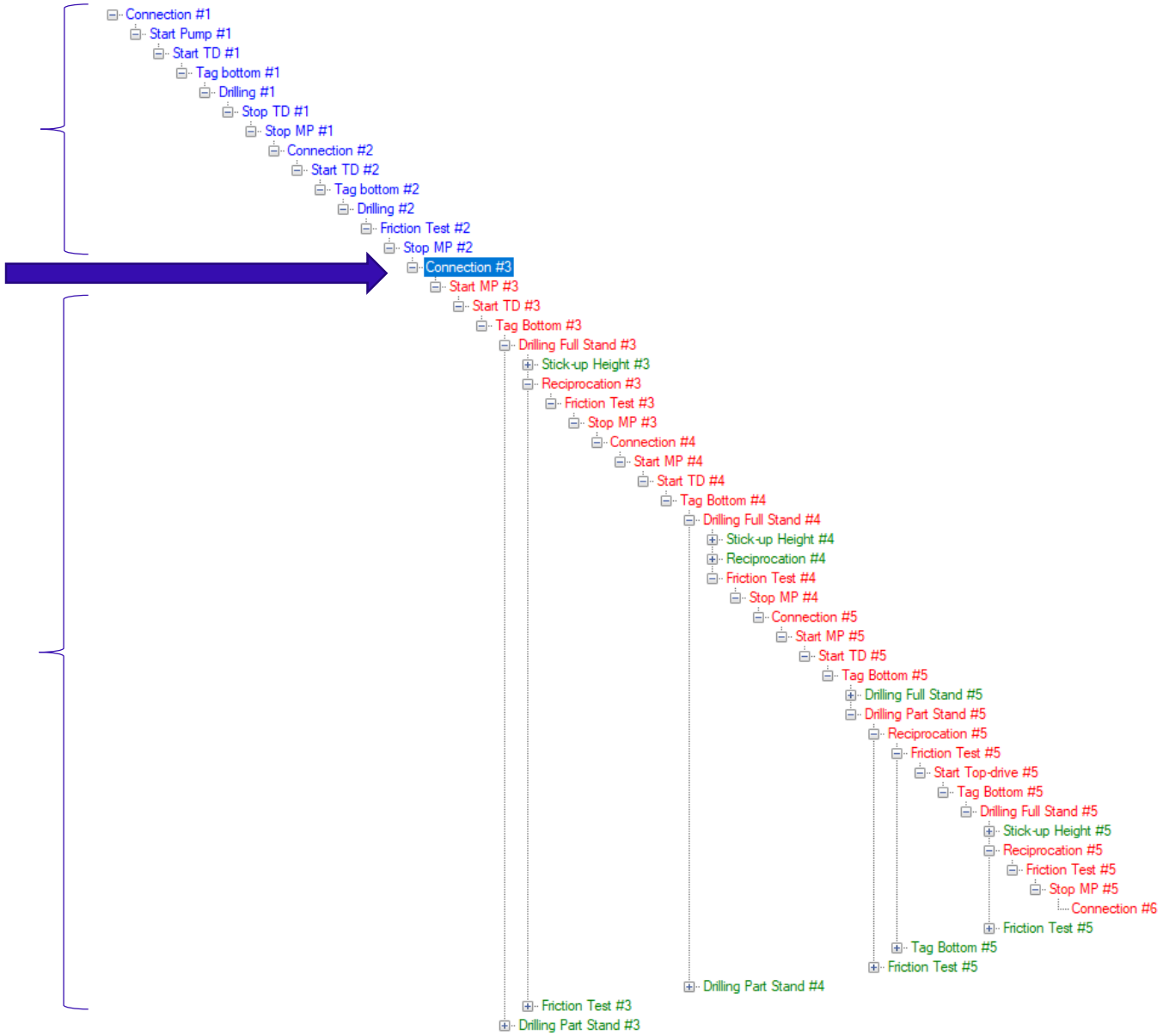
- Only focused on drilling to target depth (TD), i.e. do not include tripping, back-reaming, wiper trips.
- Only conventional drilling.
- Excluding directional drilling aspects.

Autonomous drilling as an optimization problem

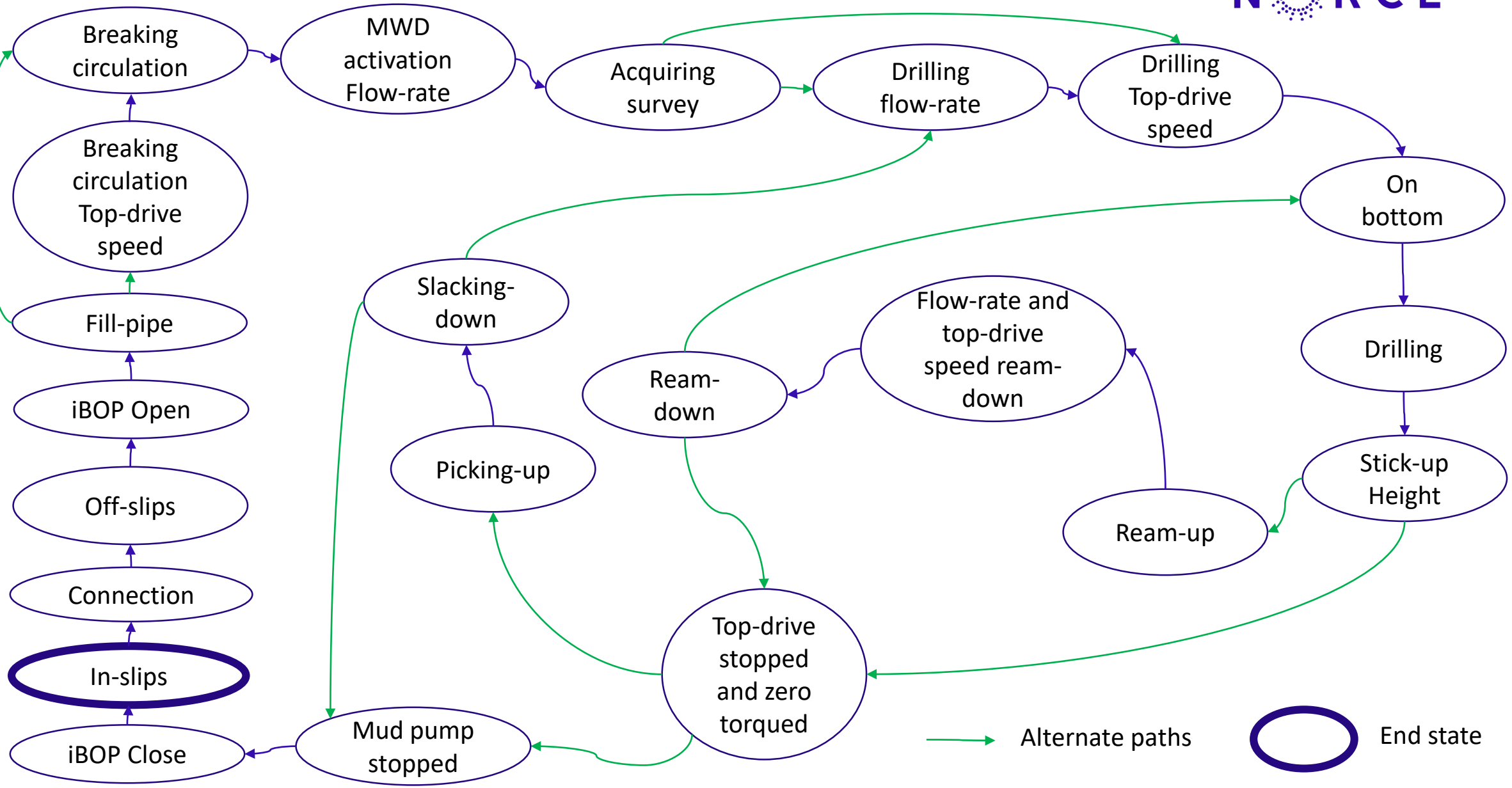
Sequence of operation that has been performed



The tree of possibilities to drill the next 3 stands
With the branch that corresponds to the optimal path in red and expanded



Autonomous drilling as an optimization problem



Autonomous drilling as an optimization problem

Risks:

- Bit vibrations that reduce performance
- Pack-off
- Bit/BHA/drill-string component failure
- Failure of drilling machines (or reaching their limits)
- Hole collapse
- Formation fracturing
- Formation fluid influx
- Formation washout
- Stuck pipe
- …

Performance:

- Drill fast
- Shorten Weight to Weight procedure
- Quick pipe handling during connection

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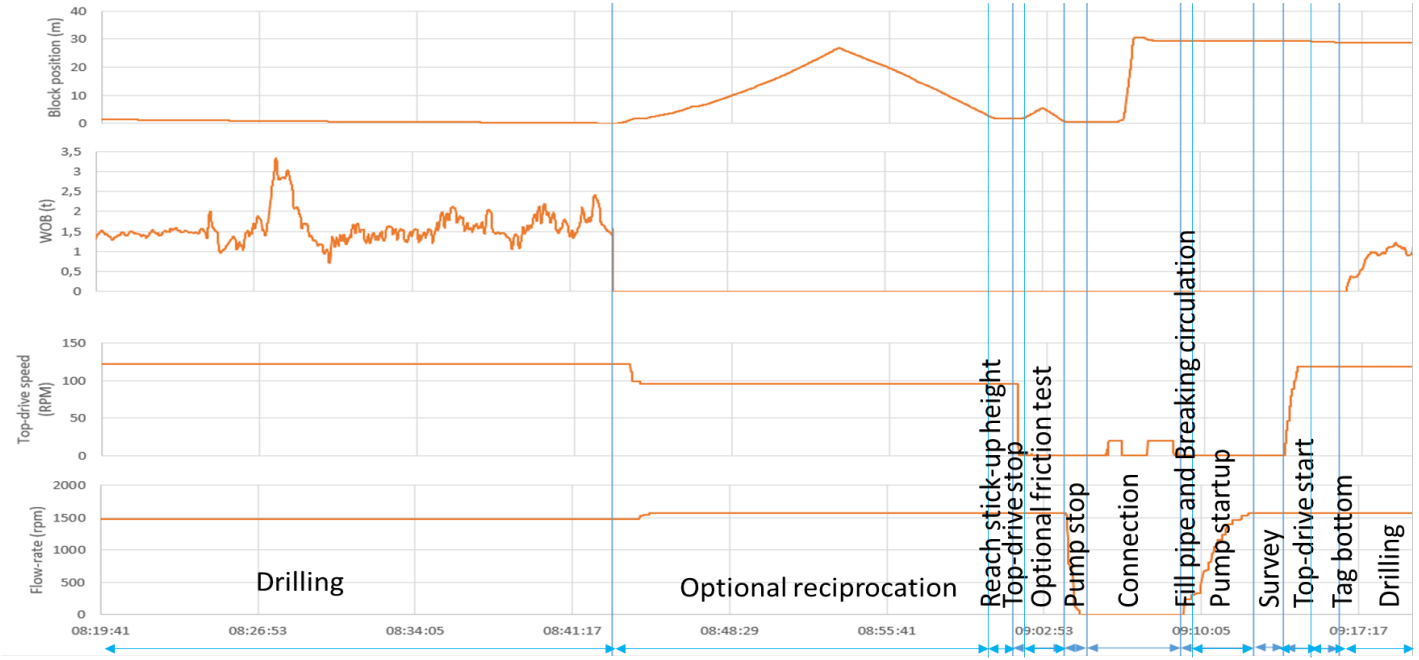

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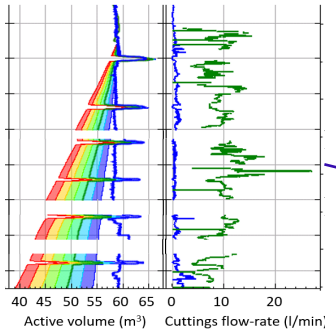
$$\underbrace{\Delta\tilde{t}_{TD}}_{\text{Time to TD}} = \underbrace{\sum_{i=1}^{n} \Delta\tilde{t}_{stand-drill,i}}_{\text{Necessary duration of the procedures to reach TD}} + \underbrace{\sum_{j=1}^{p} P(E_j)\Delta\tilde{t}_{remedial-E_j}}_{\text{Sum of the possible delays caused by drilling events}}$$

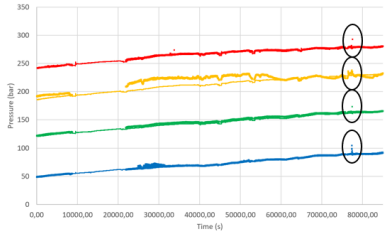
Autonomous drilling

Estimation of current downhole conditions

Observed vs expected pit volume decrease due to cuttings separation

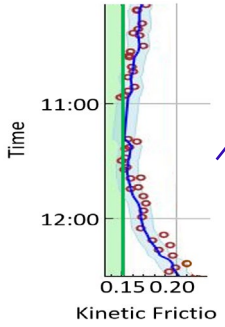


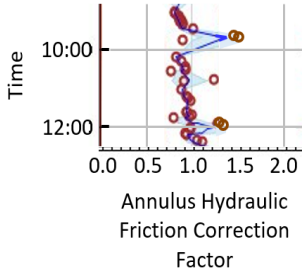
Hole cleaning



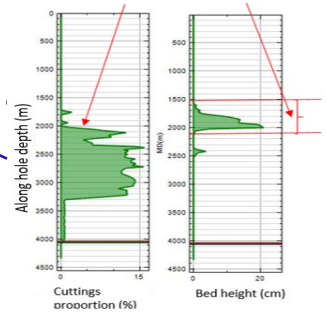
Observation of micro pack-offs

Evolution of mechanical friction





Evolution of annulus hydraulic friction



Modelled-based estimation of cuttings transport

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Autonomous drilling

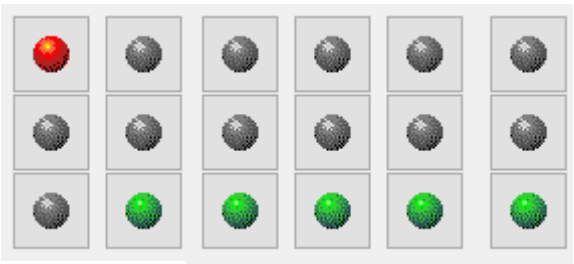
Risk mitigation and estimation

Stochastic simulation of drilling scenarios with variations of input parameters according to uncertainty

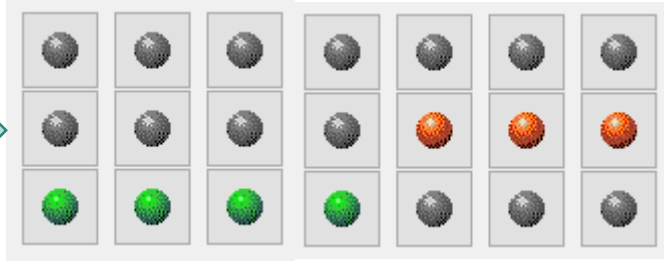
Estimation of the probability of drilling Incidents for each drilling scenario

Hole cleaning
Stick-slip
Lateral vibrations
Low ROP & high flow-rate
Buckling
High torque

Drilling Conditions



Risk levels



Downhole equipment failure
Surface equipment failure
Wellbore instability
Formation washout
Losses
Pack-off
Stuck-Pipe

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Autonomous drilling as an optimization problem

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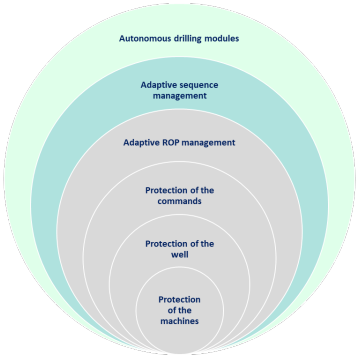

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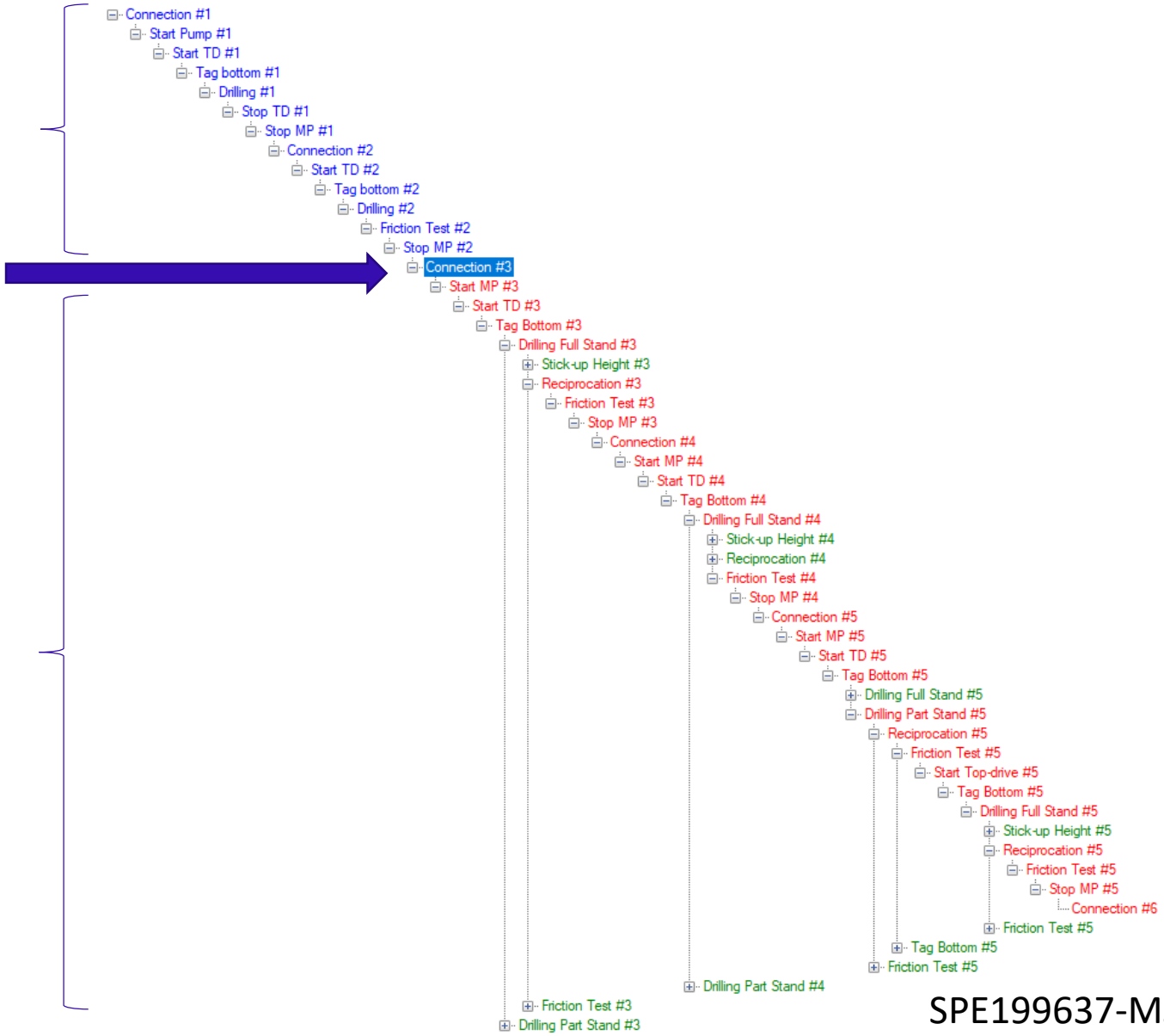

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Autonomous drilling: safety features

- **Protection functions**:
  - **Safe operating envelopes (SOE)**:
    Acceptable limits (WOB, flow-rate, RPM) to:
    - Stay within acceptable pump pressure limits
    - Avoid buckling the string
    - Transport cuttings
    - Avoid stick-slip

  - **Fault detection Isolation and Recovery (FDIR)**:
    Quick drilling events are quite common, e.g. overpulls, set-down weights, over-pressures, etc.
    - Fast detection and reaction is often essential to avoid an escalating problem
    - Method: model-based using the observer-based approach
      - Overpull and set-down weight FDIR
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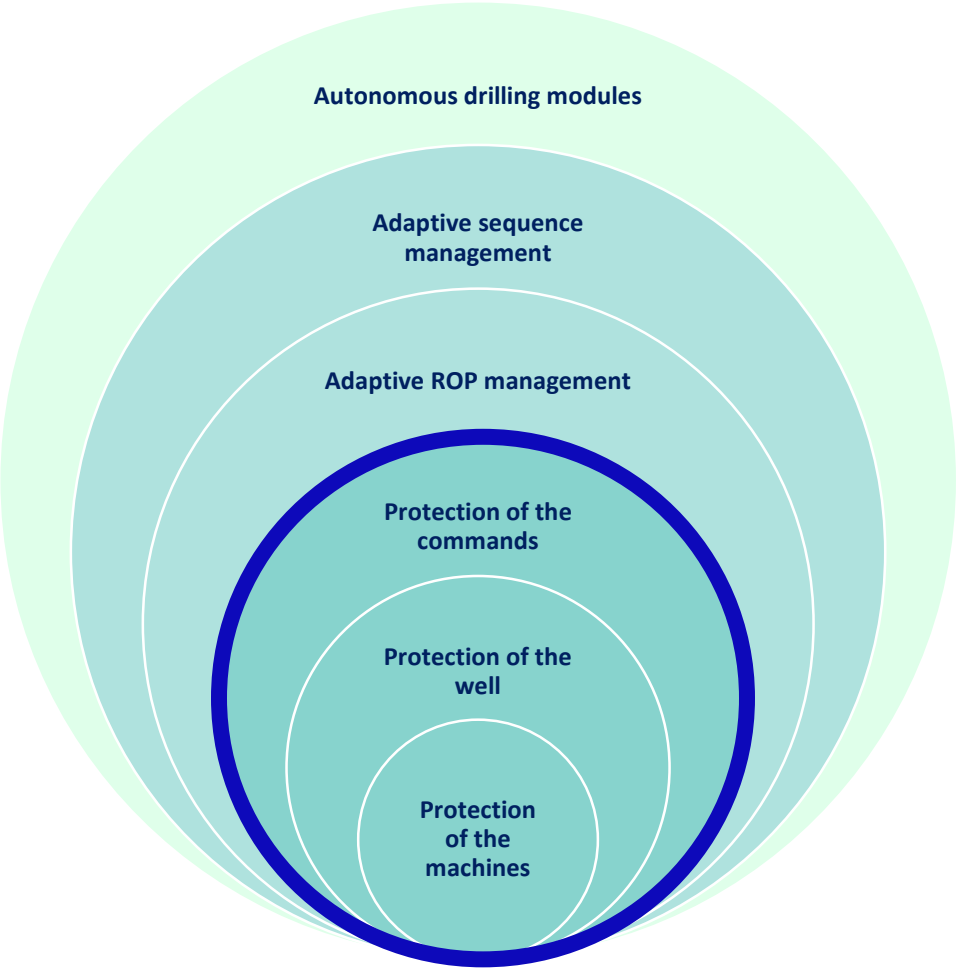

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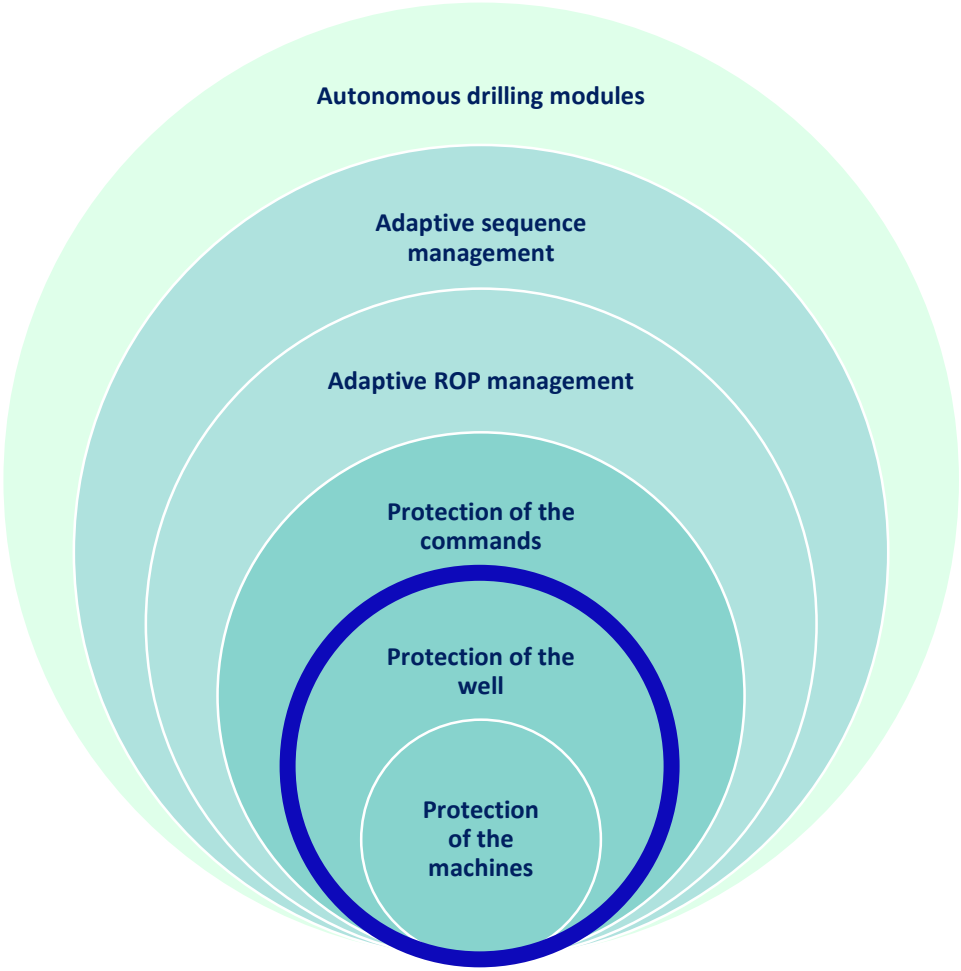

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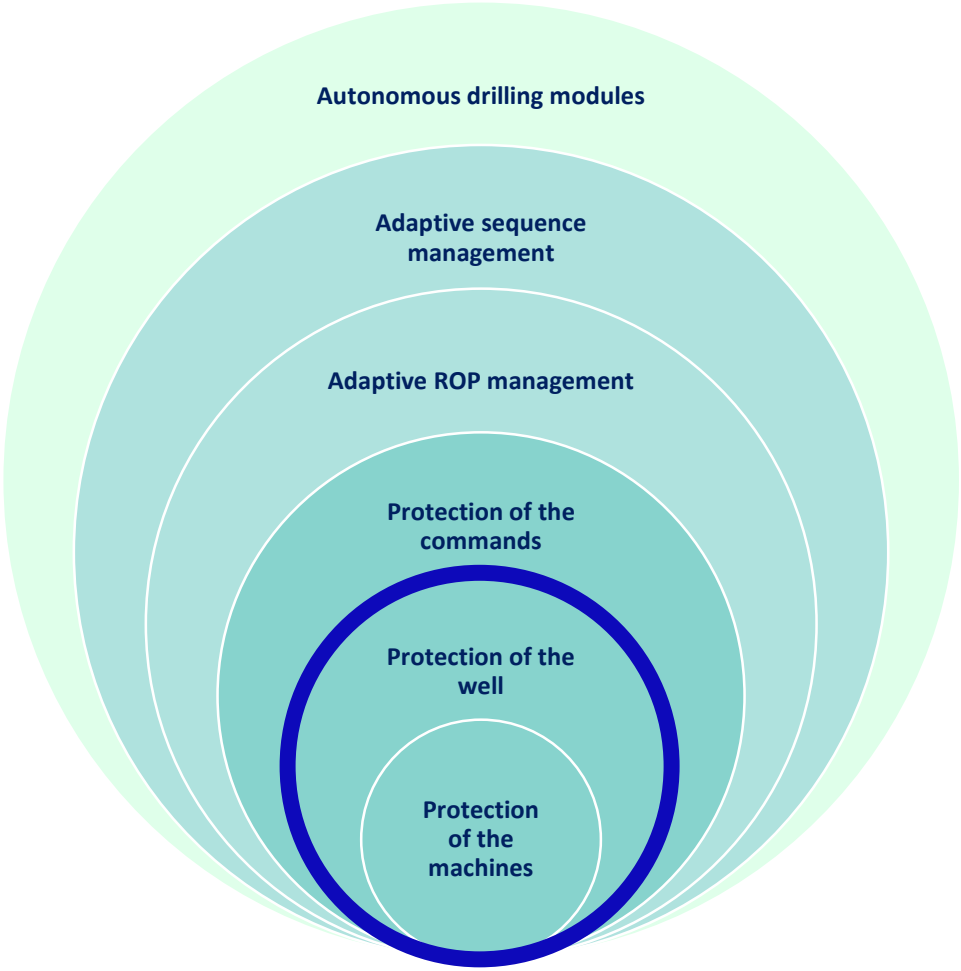
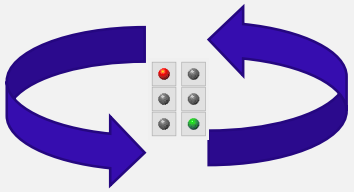
- **Safe mode management: transition from autonomous to manual drilling (to be published at SPE/IADC Drilling Conference 2021)**



Infrastructure for new drilling technologies



OPENLAB DRILLING

Drilling controll room

The drilling control room is a facility for research, innovation and demonstration of new drilling software, control systems and drilling concepts. Downhole simulations can be run with a large variety of scenarios with 3D visualization of the drill floor.

READ MORE

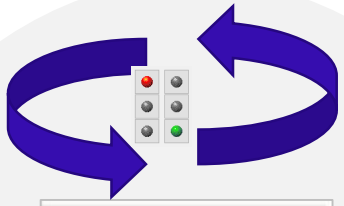
Web enabled drilling simulator

The OpenLab Web Client is an online drilling simulator that runs realistic models for well hydraulics and drillstring mechanics. The web client also serves as an education, development and testing platform for students, lecturers and researchers within the drilling community.

TRY IT NOW !

Testing in unique virtual rig environment

Verification against simulated or real drilling data

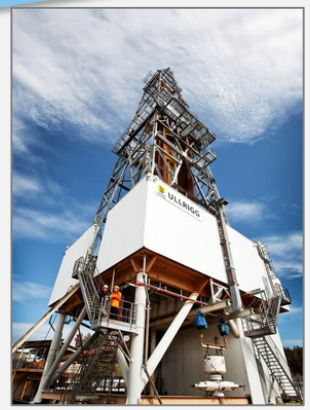


Interface to full scale rig at IRIS

Perform drilling and well operations from a physical rig with measurements from virtual wells to demonstrate new technology or study work procedures and human factors.

READ MORE

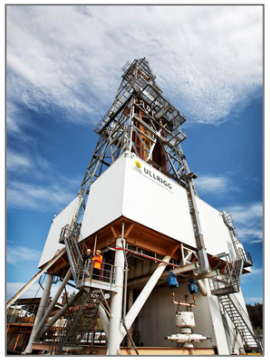
Full-scale testing at Ullrigg



Offshore deployment

Way forward

- Autonomous drilling demonstration OpenLab (October 28’th)
- Autonomous drilling demonstration on Ullrigg.
- DADPC next phase.
- SFI DigiWells



Conclusion

NORCE

Autonomous drilling

- An **adaptative solution** that:
  - balances performance and level of risks
  - balances the necessity for additional operations with availability of measurements

- A **self-learning system** that:
  - Estimates formation rock drillability
  - Estimates unexpected downhole drilling condition deviations

- A system that has its own **protection mechanisms**:
  - Safe operating envelopes to keep the commands within acceptable values
  - Fault detection, isolation and recovery procedures to automatically react to quick drilling events

- A system that implements a **safe mode management** for a smooth transition from autonomous to manual drilling in case of failures.

Acknowledgement

The authors acknowledge the Research Council of Norway, AkerBP, Equinor, Repsol Norge AS, TOTAL, Vår Energi and Petrobras for financing the work through the Demo2000 funding program. The presented work is a research cooperation between Canrig Drilling Technology, Odfjell Drilling, NORCE, NOV and Sekal.

Thank you!