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Large-Scale Deployment of a Closed-Loop Drilling Optimization System: Implementation and Field Results

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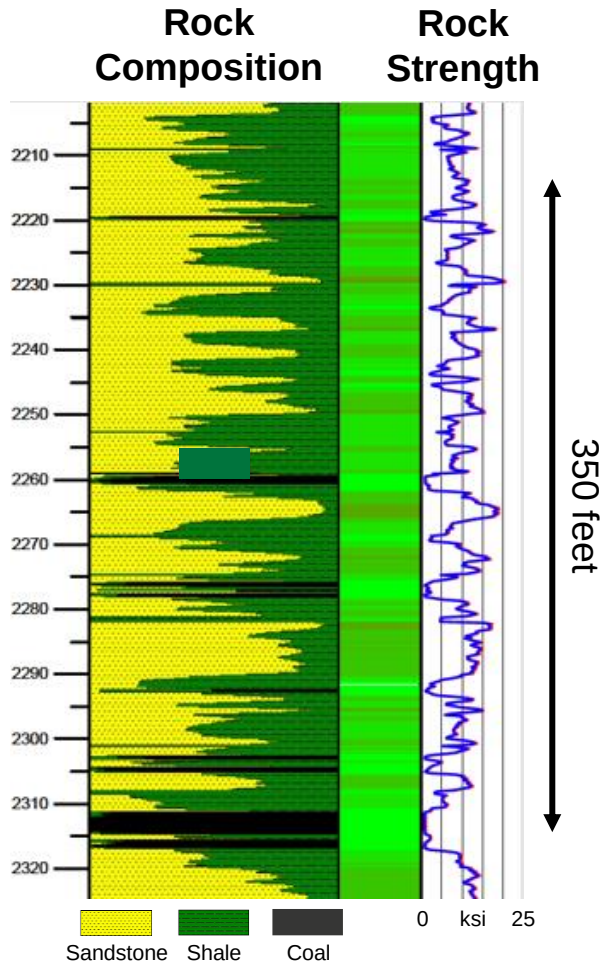
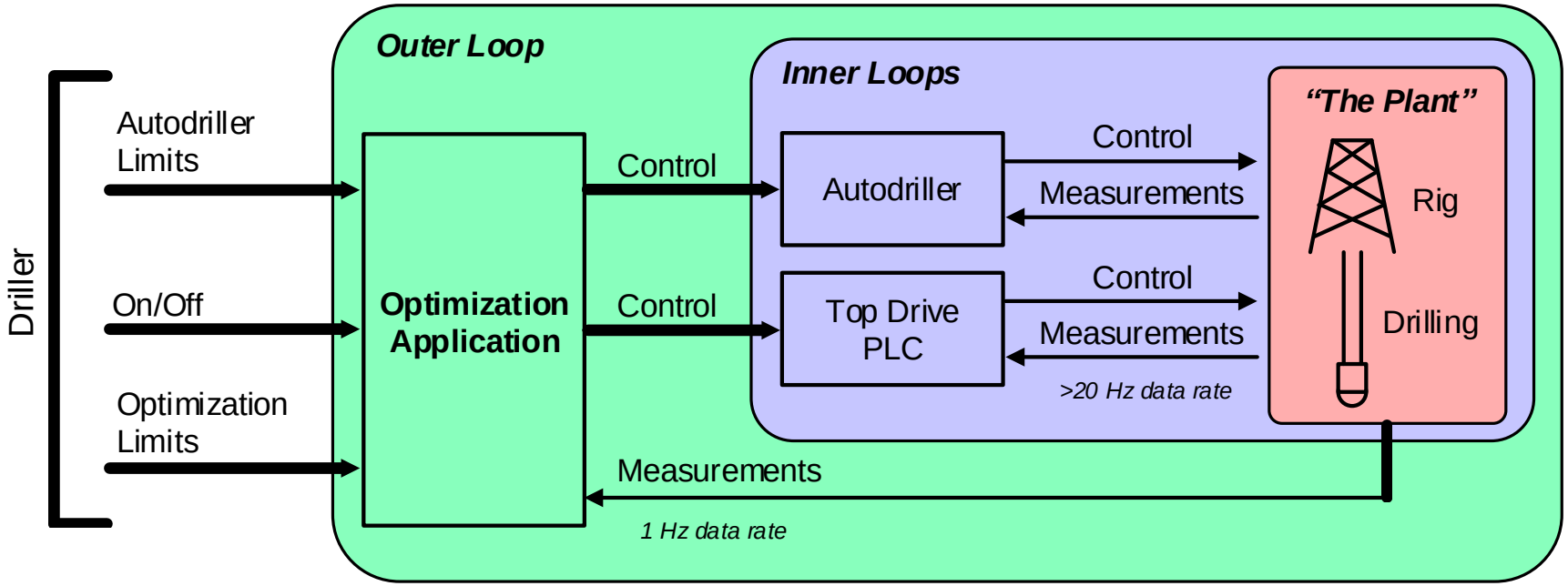
Introduction

- Reduce well cost:
  - Minimize spud-to-TD time.
  - Maximize ROP / minimize flat-time.
- Rotary drilling optimized by continuous adjustment of process parameters (WOB, RPM).
- **Challenge: Formations can change rapidly.**
- Automation solution:
  - Closed-loop system based on proven advisory application.
  - Field results from 270 rigs and 1700 wells.



Control Scheme

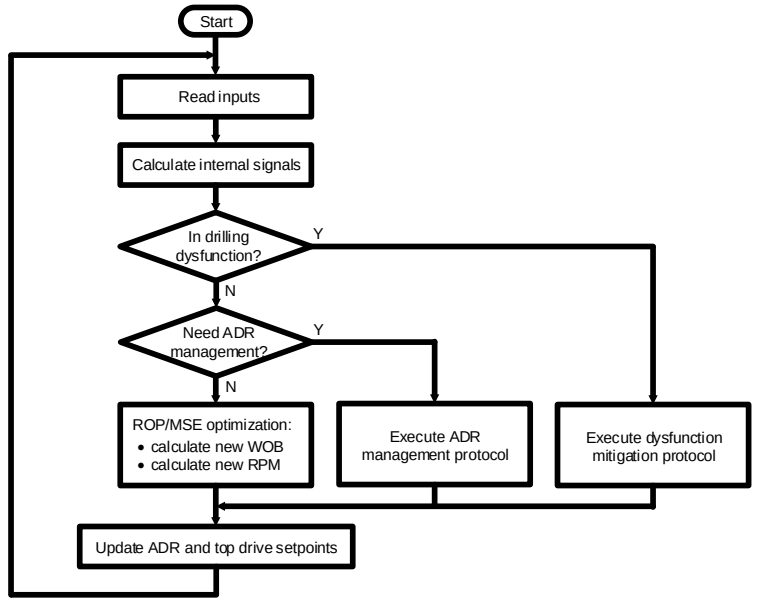


Driller supervises process and manages parameter limits.

Main Optimization Loop

Main loop runs once per second:

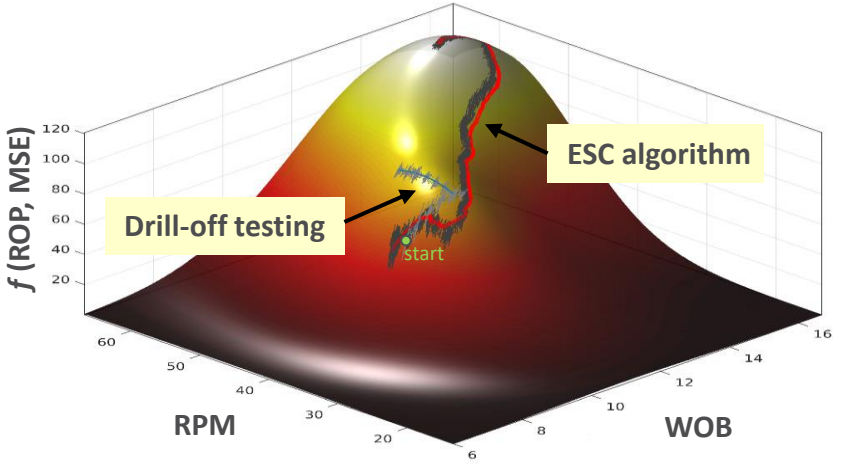
- If drilling dysfunction is detected,
  - mitigation protocol is executed.
- If autodriller (ADR) is not in good state,
  - ADR management protocol is executed.
- Otherwise,
  - perform ROP/MSE optimization.



ROP/MSE Optimization

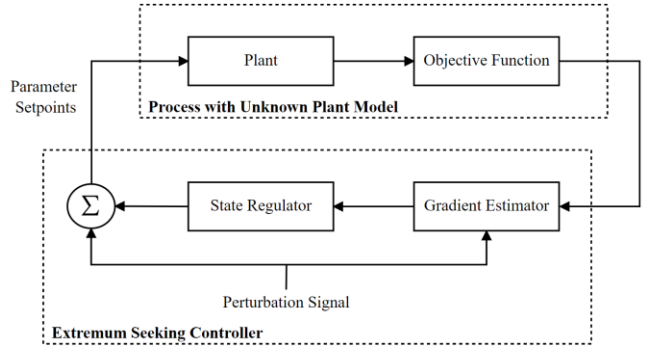
Challenges:

- Formation variation is random and non-stationary.
- Drilling process is difficult to model accurately.
- Scalability – must work at all rigs/formations/basins.

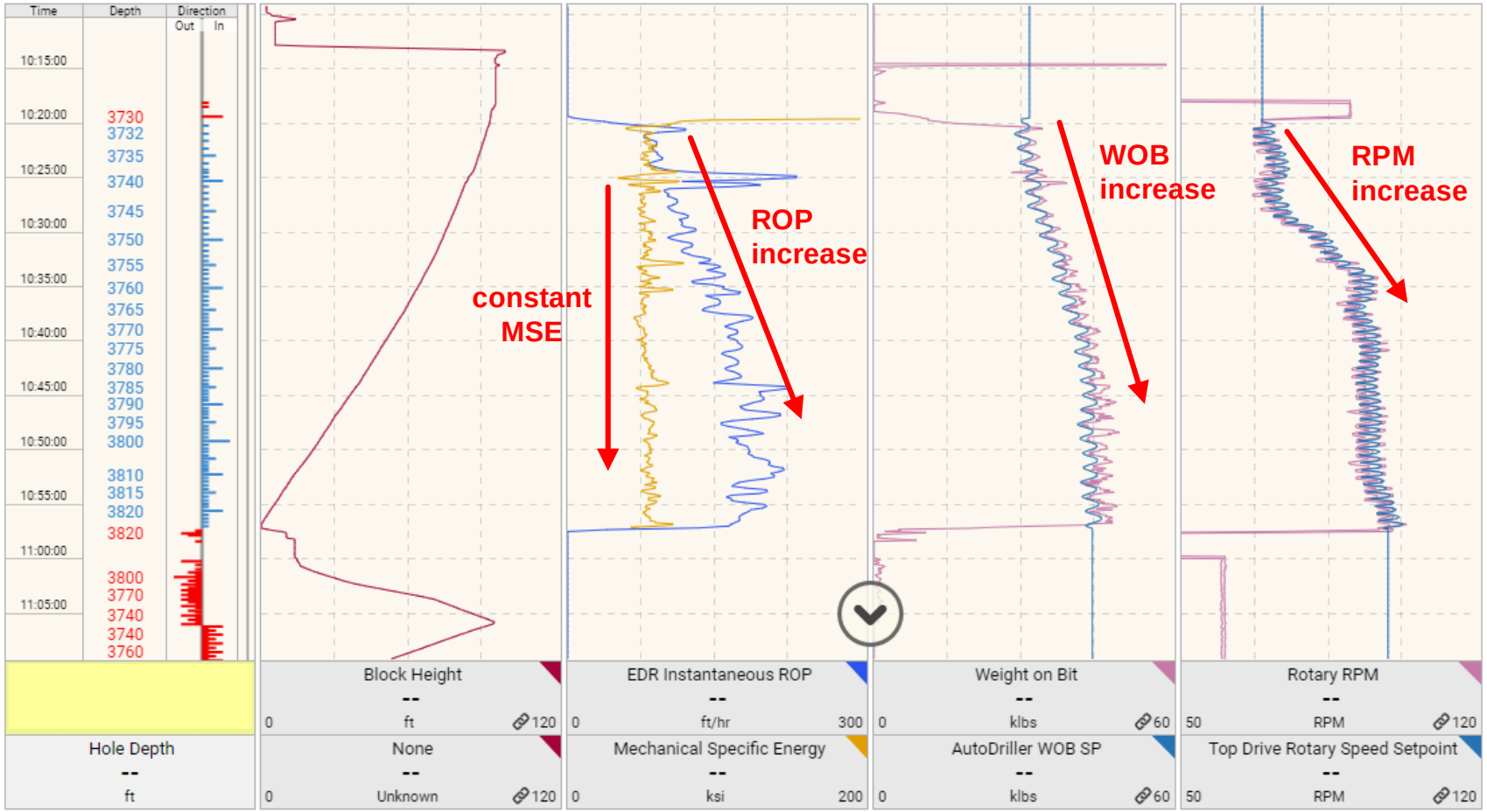


Solution:

- Extremum Seeking Control (input signal dithering):
  - Simple – minimal tuning parameters.
  - Adaptable – continuously seeks the peak.
  - Robust – no model-based assumptions.



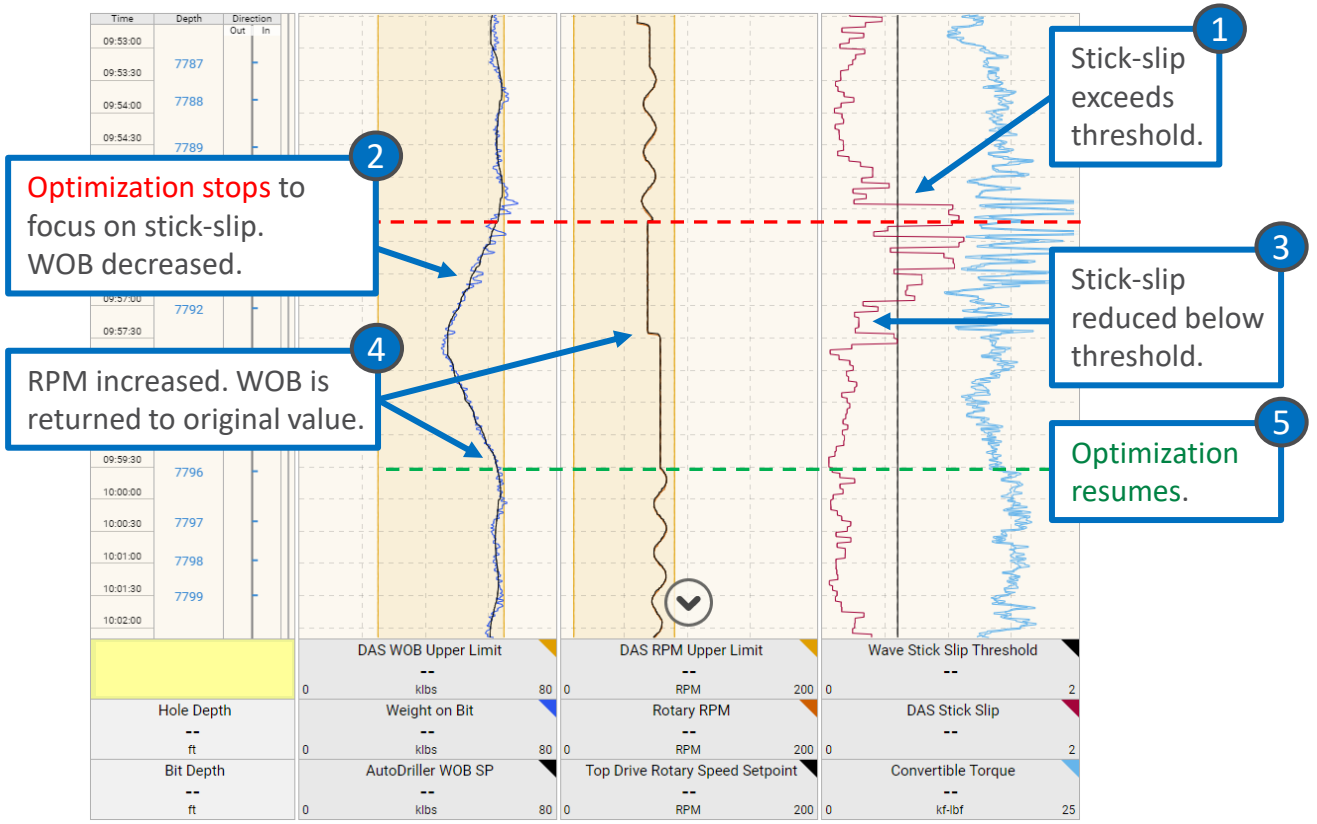
ROP/MSE Optimization



Dysfunction Mitigation

When drilling dysfunction is detected, an automated protocol is used to remove the condition.

Stick-Slip Protocol



- Stick-slip protocol
- Stringer protocol
- RCD protocol
- Motor stall protocol
- Etc.

Autodriller (ADR) Management

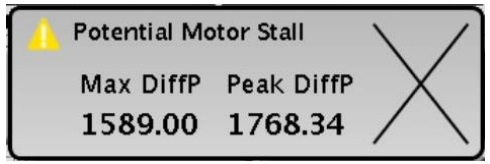
- Operating state of ADR is critical for closed-loop optimization.
- ADR control issues[1]:
  - Poor setpoint tracking.
  - Control loop oscillations.
- ADR should be in a favorable control state for optimization.

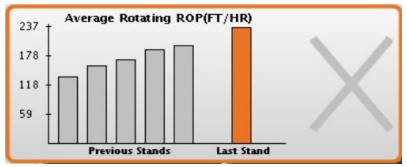
ADR Condition	System Response
Control loop oscillations	Adjust setpoints to put ADR back in WOB-control mode
Torque limiting	
DIFP limiting	

[1] Pastusek et al. "Drill Rig Control Systems: Debugging, Tuning, and Long Term Needs". SPE-181415.

Deployment Challenge #1: Human Factors

- **Organizational buy-in** is needed[2].
- **User trust** is needed:
  - Driller must have confidence that system operating as designed → notifications/alerts.

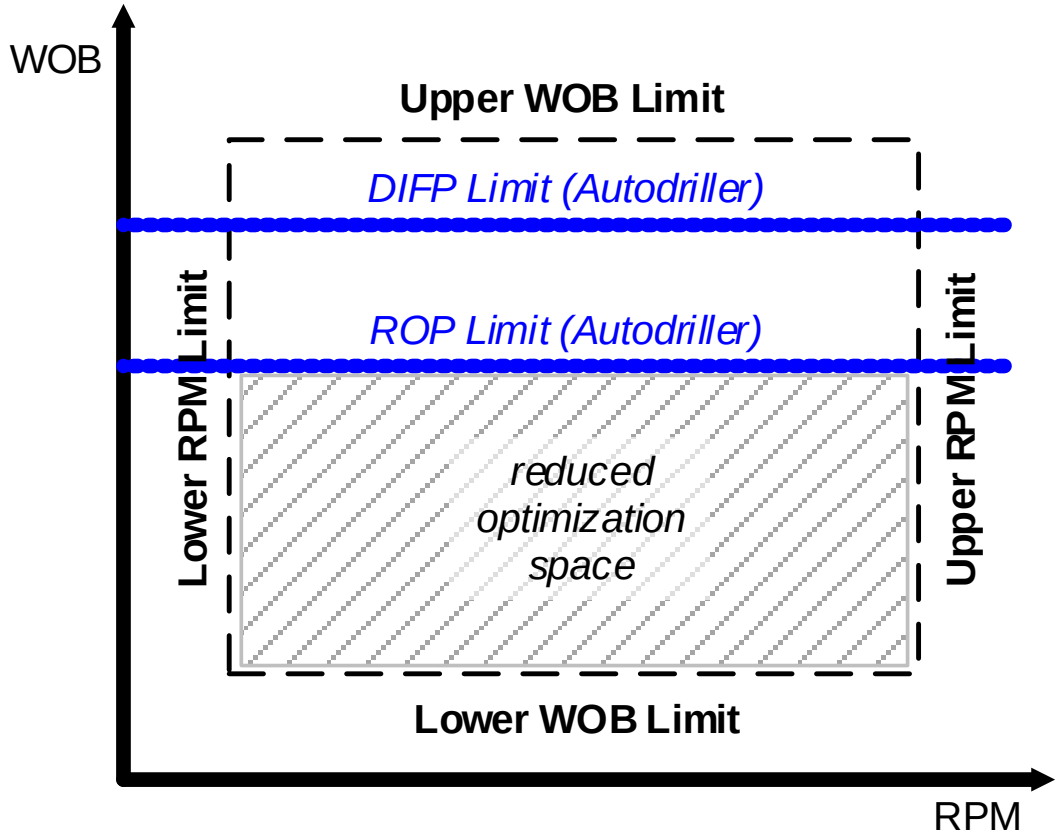




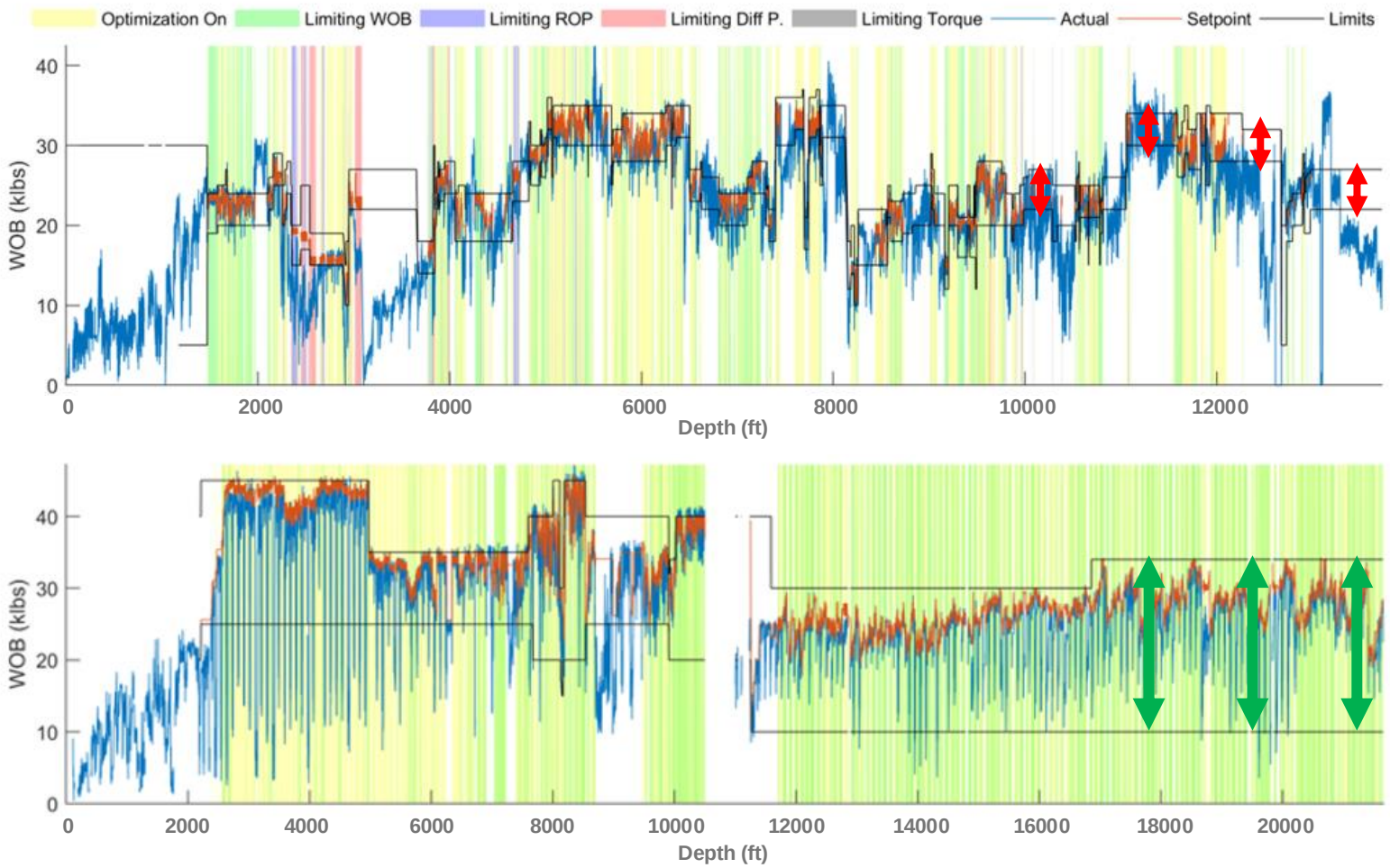
[2] Behounek et al. "Change Management Challenges Deploying a Rig-Based Drilling Advisory System". SPE-194184.

Deployment Challenge #2: Conservative Parameter Limits

For optimal drilling, true equipment limits should be used.



Deployment Challenge #3: Following the Limit Roadmap



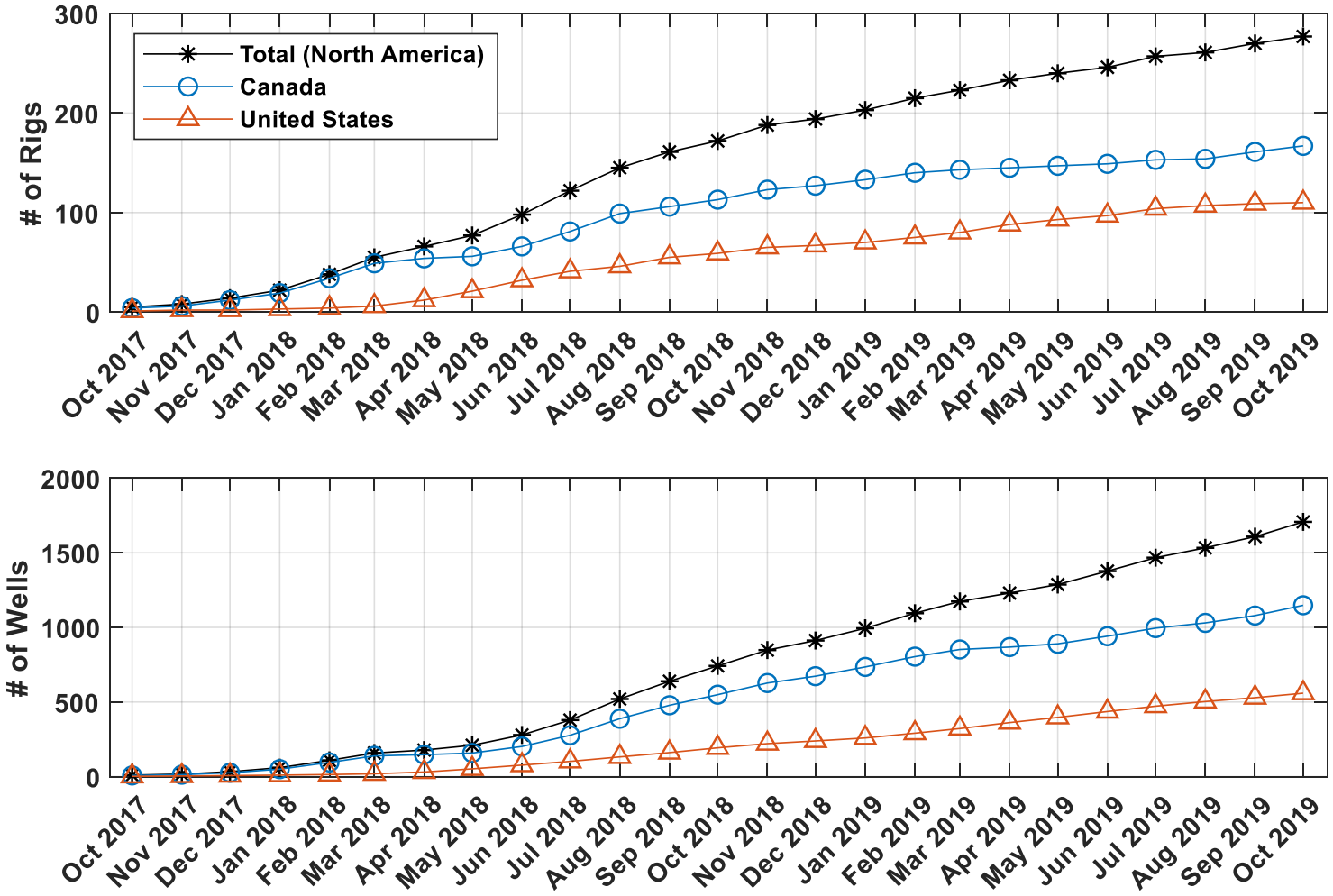
Bad Practice:

- Small optimization window
- Frequent, ad-hoc changes

Good Practice:

- Wide limit window
- Infrequent changes
- Allow system to optimize

Field Deployment



ROP Improvement

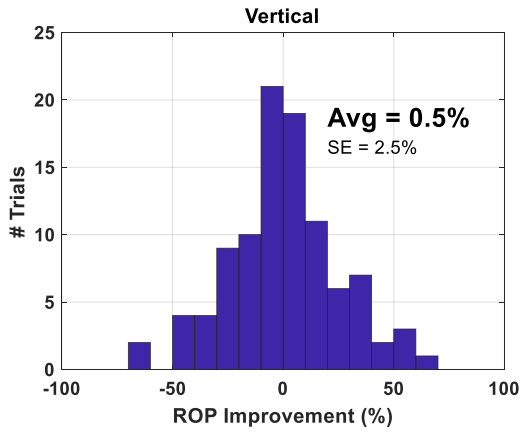
Each drilling trial has 3 consecutive wells.

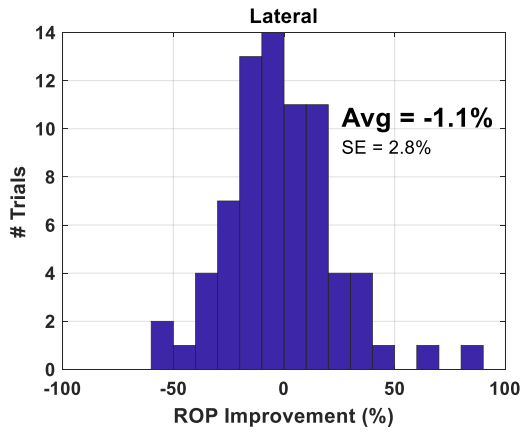
1st well — **No system**

2nd well — **No system**

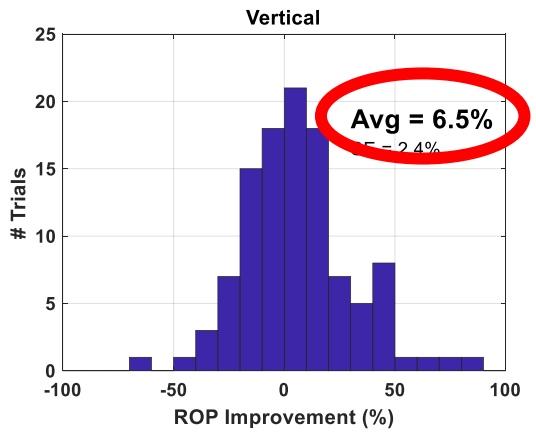
3rd well — **With system**

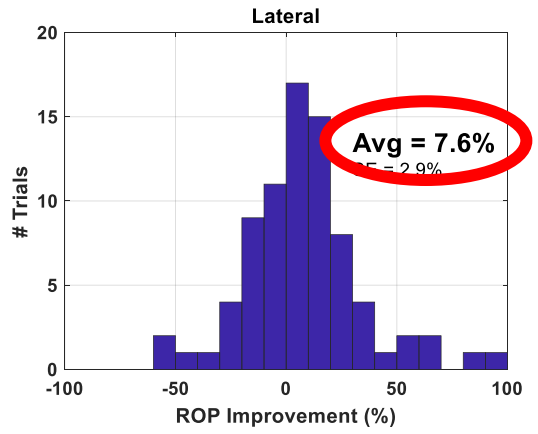
~90 trials





~90 trials





Top quartile ROP improvement = 18.1% and 17.4%.

Conclusions

- Formations change rapidly → need closed-loop optimization:
  - Simple (no model) algorithm is best for scalability.
  - Mitigate dysfunction with triggered protocols.
  - Create a good limit roadmap and follow it.
- Large-scale deployment: 270+ rigs, 1700+ wells, 8 countries.
- Average rotary ROP improvement of 7% (top quartile = 18%) in 90 drilling trials.

Acknowledgements / Thank You / Questions

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