Science-ing Up
Deep Earth Drill Bit Design

With MATLAB Production Server

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SOFTWARE ENGINEERING LEAD
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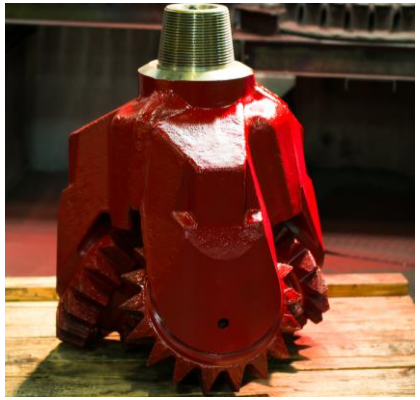
ReedHycalog | NOV

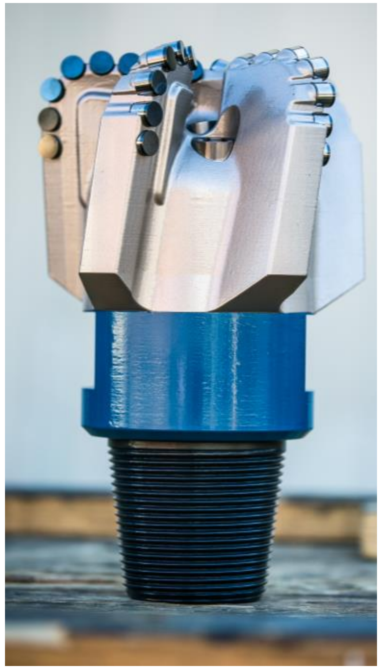
Deep Earth Drill Bits

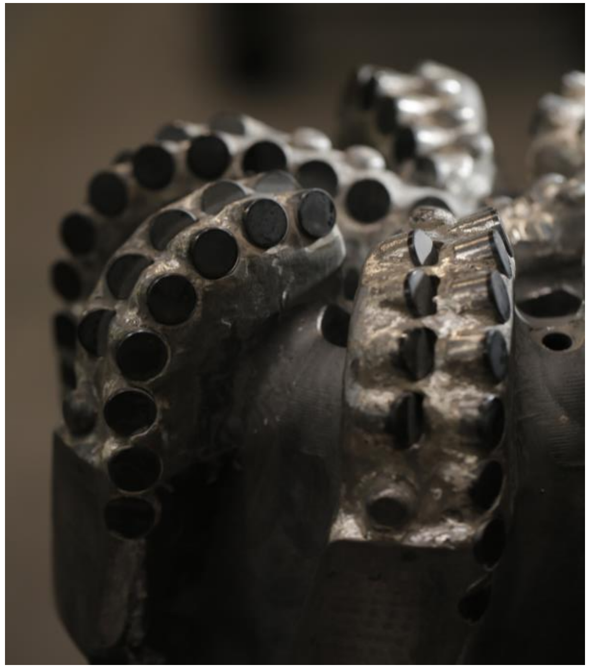
Roller Cone vs PDC



ROLLER CONE

- 1909 (Hughes)
- Rotating cutting structures
- 19% market share in 2019[1]



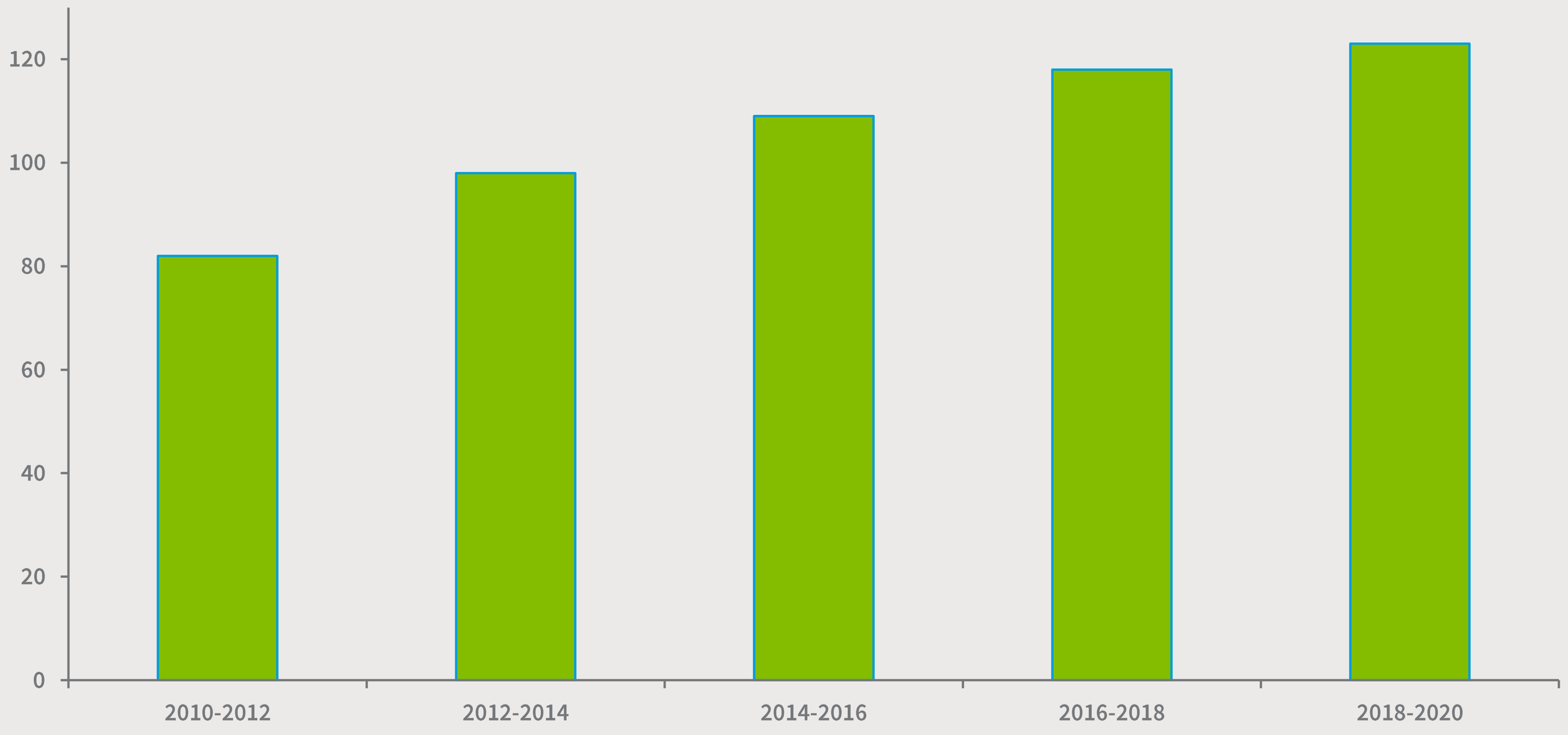


POLYCRYSTALLINE DIAMOND COMPACT (PDC)

- 1971 (GE)
- Fixed blades
- Cutters brazed on blade
  - Diamond cutting surface
  - Fine control over placement
- 81% market share in 2019[1]

Average Rate of Penetration (ft/h)

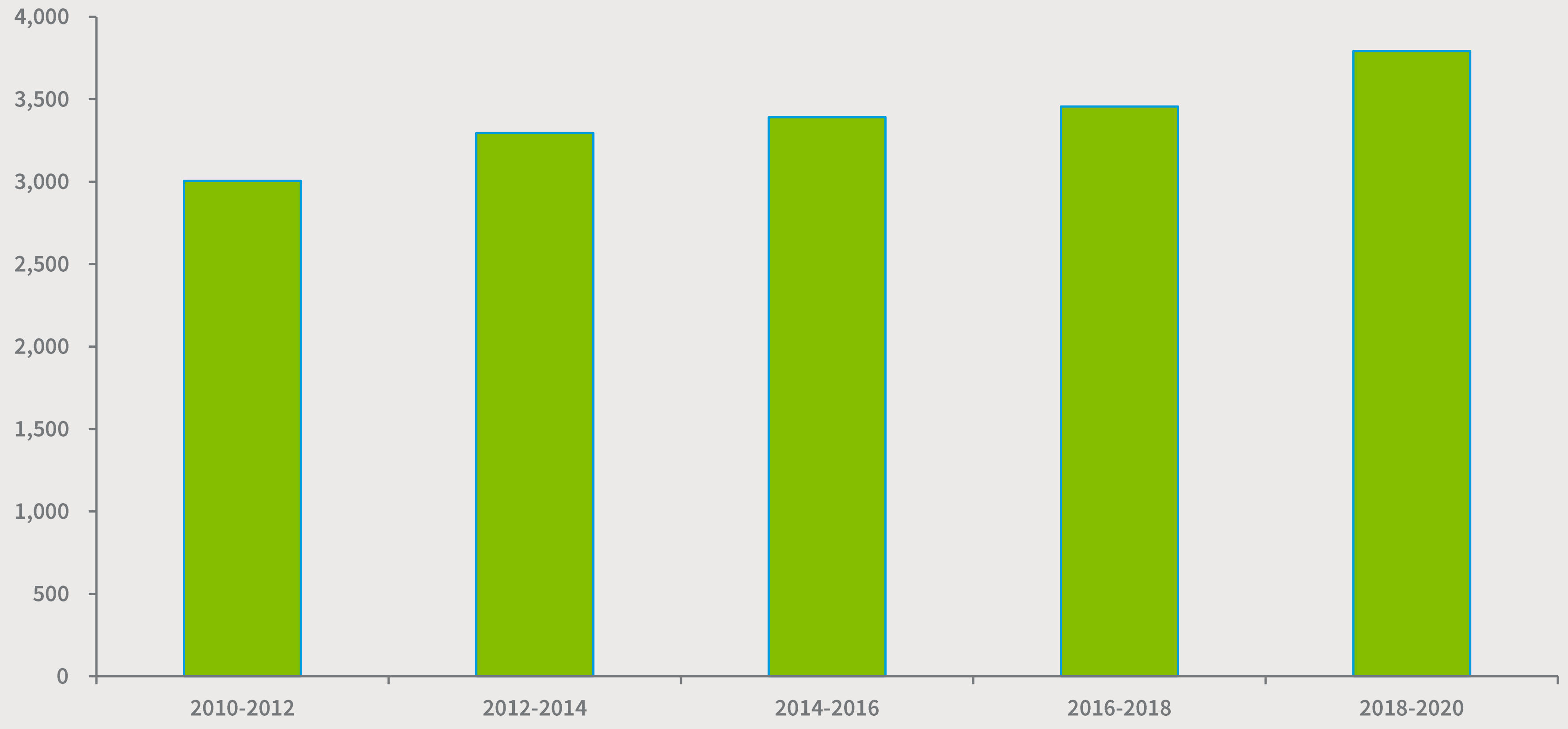
USA 2010-2020



spectra
drilling analysis software

Average Depth Drilled per Bit (ft)

USA 2010-2020



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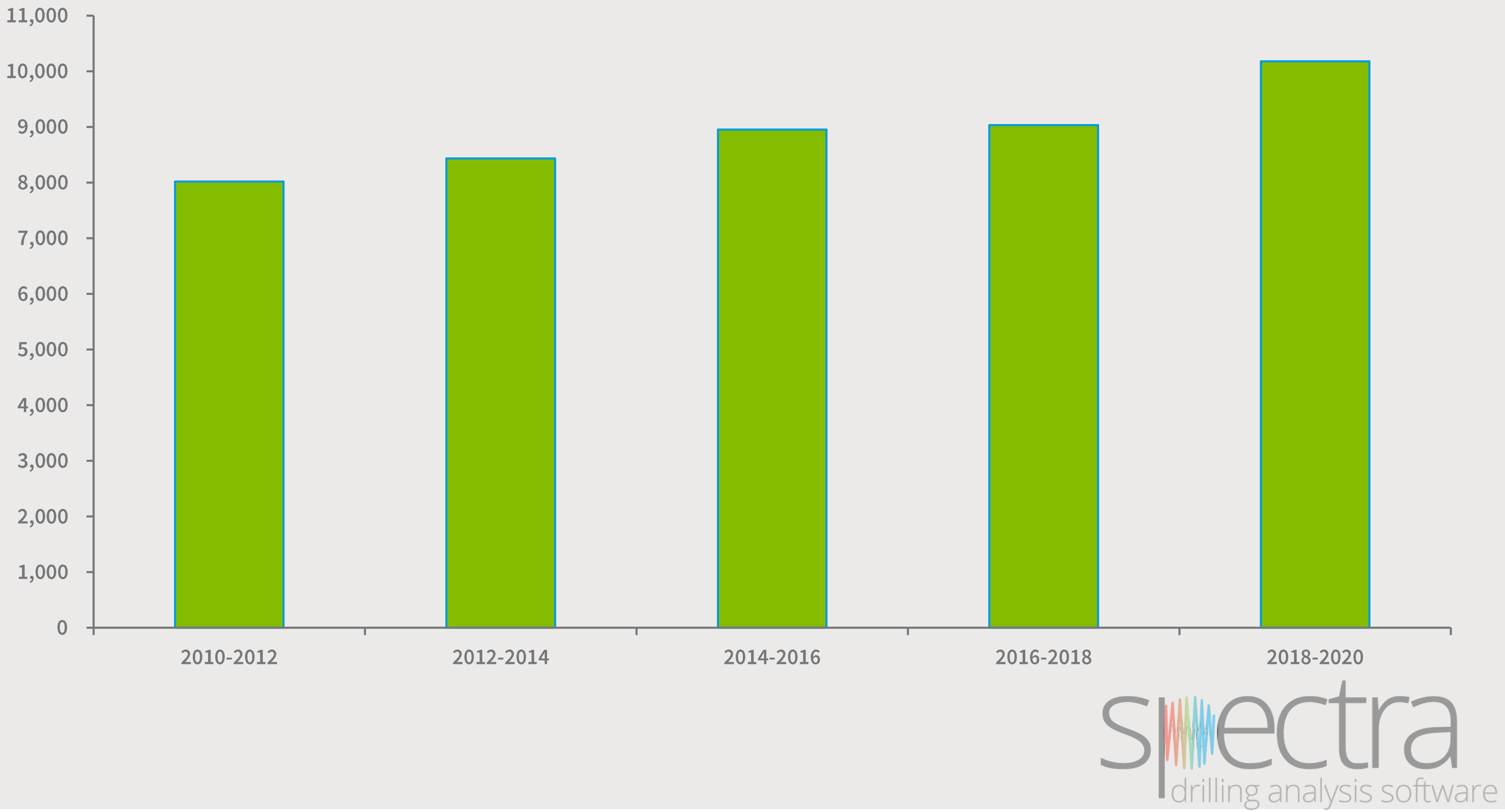
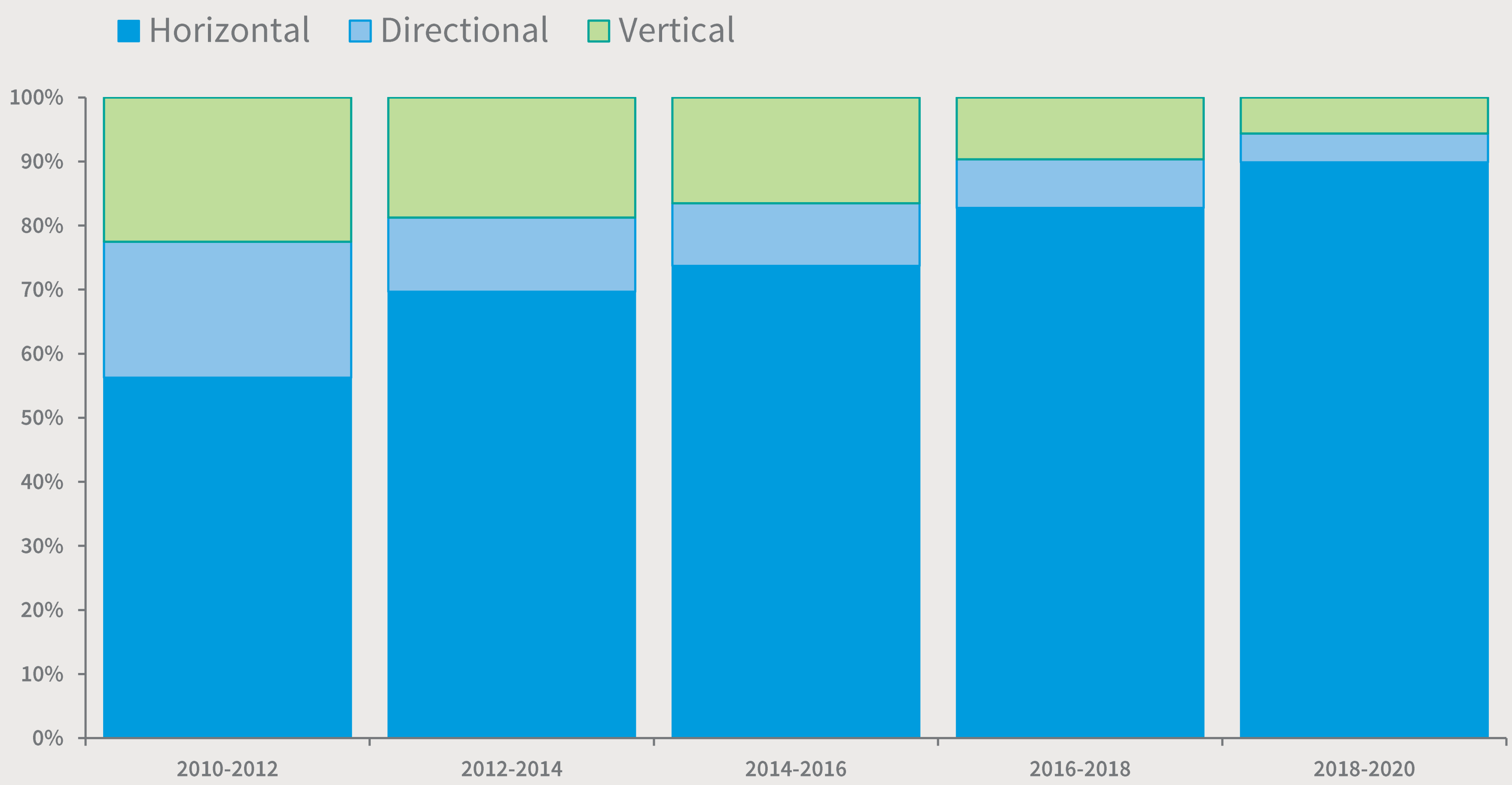
Average Depth Out (ft)

USA 2010-2020



Well Types

USA 2010-2020



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Design Objectives for PDC Bits

Rate of Penetration

- Less rig time = savings
- Efficient transfer of forces from surface to bit

Durability

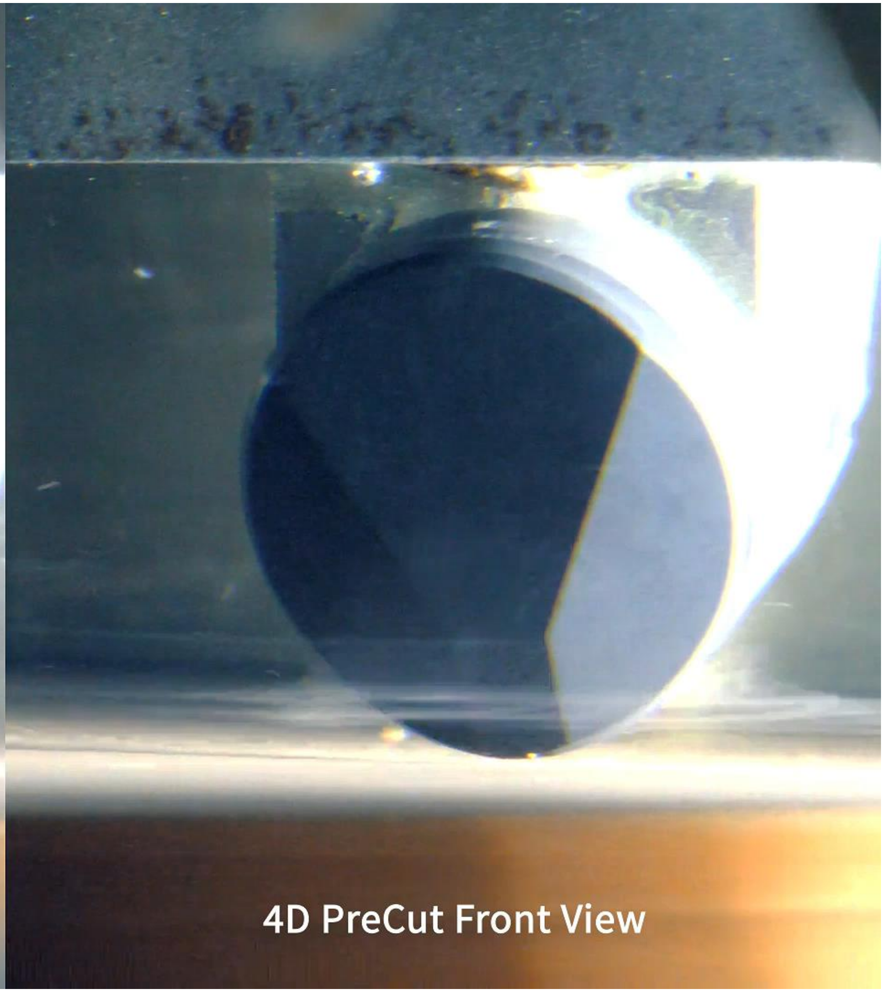
- Fewer bits to drill a section = savings
- Cutter wear

Steering

- Predictable tool face (torque)
- Minimize walk

PreCut (Pressurized Cutter Testing)

4D shaped cutter vs planar



Data Driven Bit Design

ReedHycalog Digital Experience Team

Orbit

- Physics Models
- Design Verification

creo®

- CAD Software
- Drill Bit Design

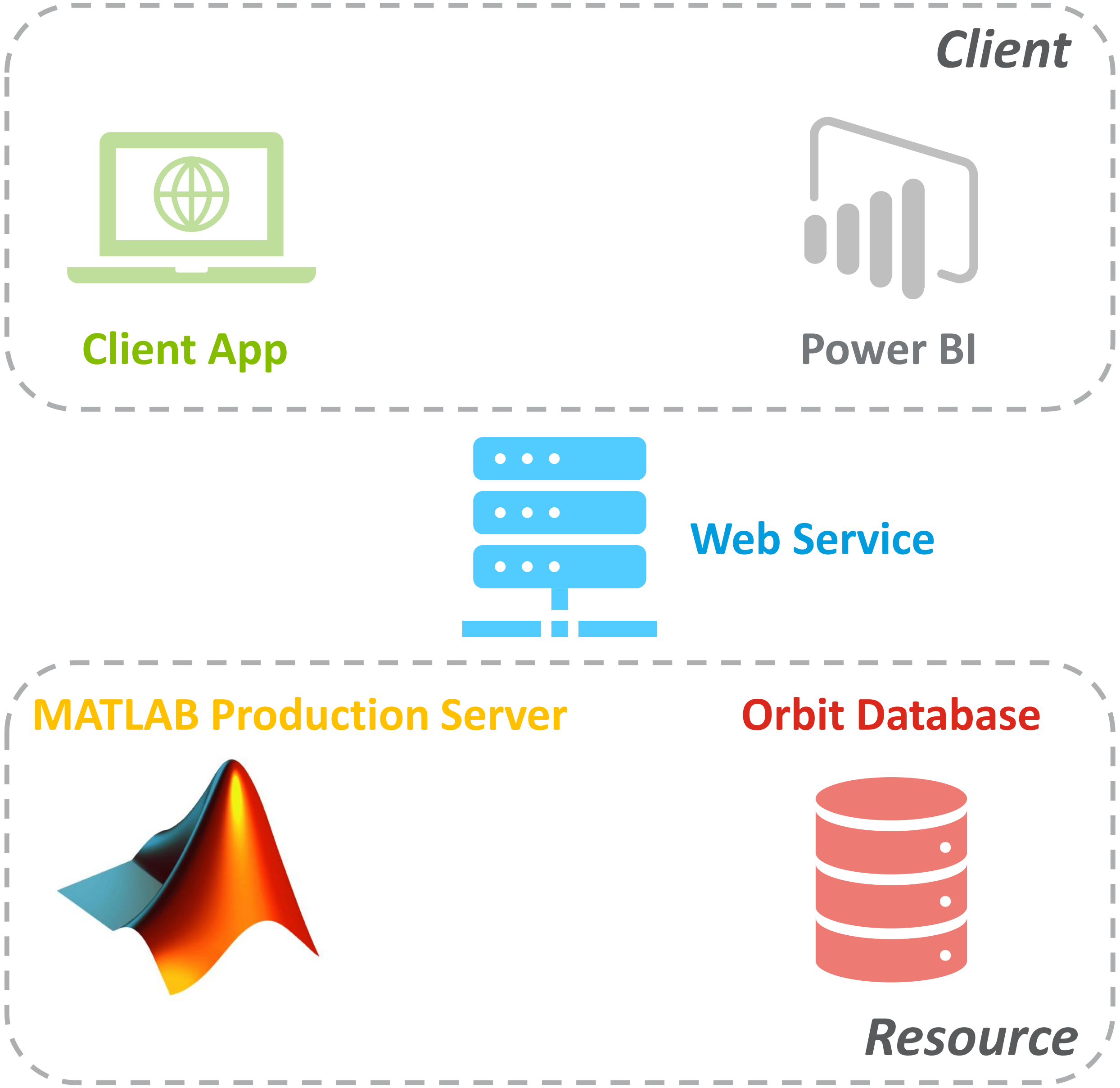
spectra
drilling analysis software

- Field data
- Drill string analysis

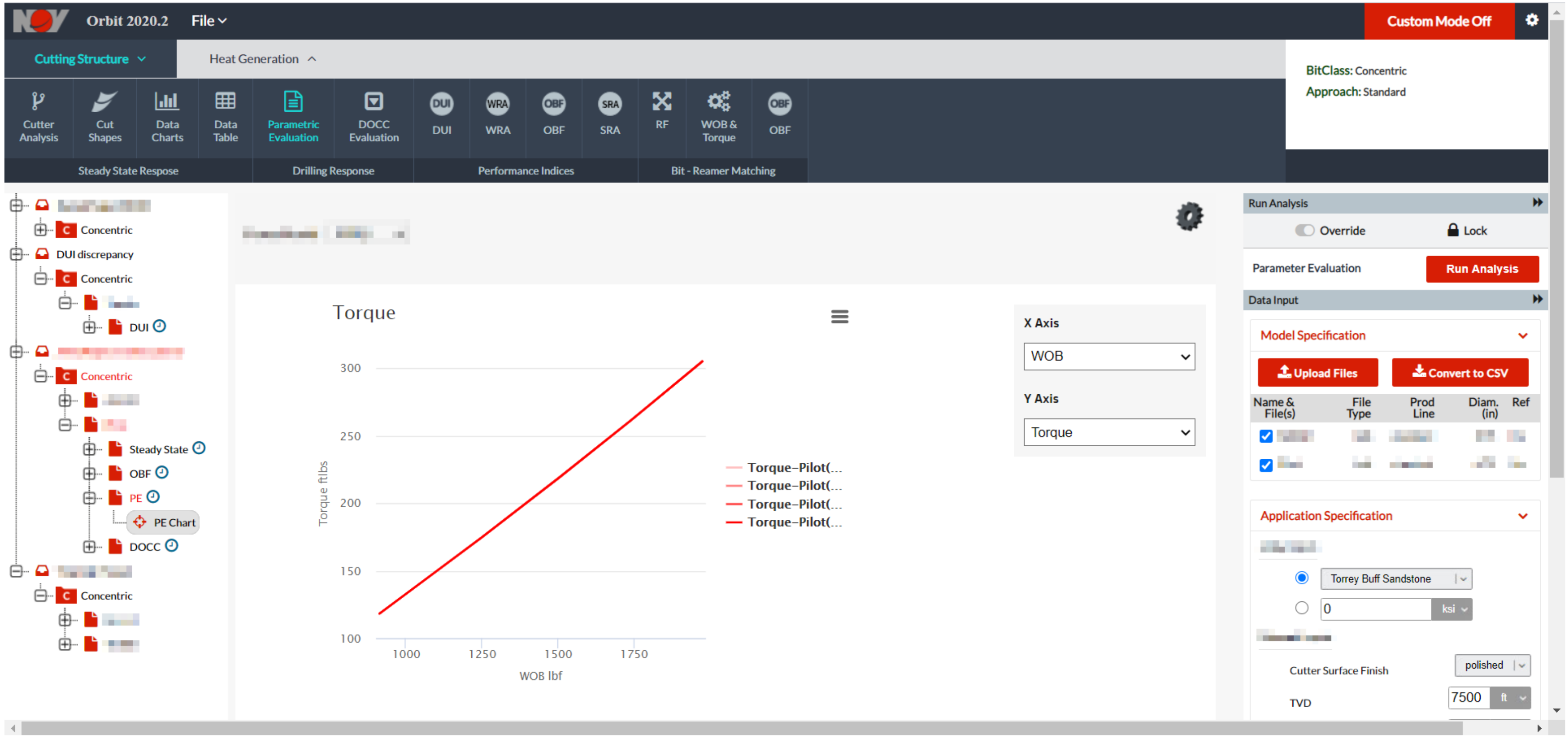
ReedHycalog Digital Experience Team

Orbit

Orbit Architecture



Orbit Client



Upload Design
- Schematic File
- Link to CAD

Run Analysis
- KPIs
- Simulations

Iterate
- Design Objectives

Export
- Design Review
- Sales

Why MATLAB Production Server?

Separation of concerns

- Intellectual property
- Engineers “own” code
- Performance

Rapid deployment

- Easy to use API
- Few modifications to R&D code
- Automated management of runtime
- Update in place

Orbit Pipeline

MATLAB Code

- R&D
- Source Control

MPS Template

- Build Script
- Standard API
- .NET / Yeoman

CI/CD

- Automate
  - Build
  - Test
  - Deploy

UAT/Production

- Integration
- Validation
- Release

Case Studies

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Science-ing up Deep Earth Drill Bits

Predicting wear

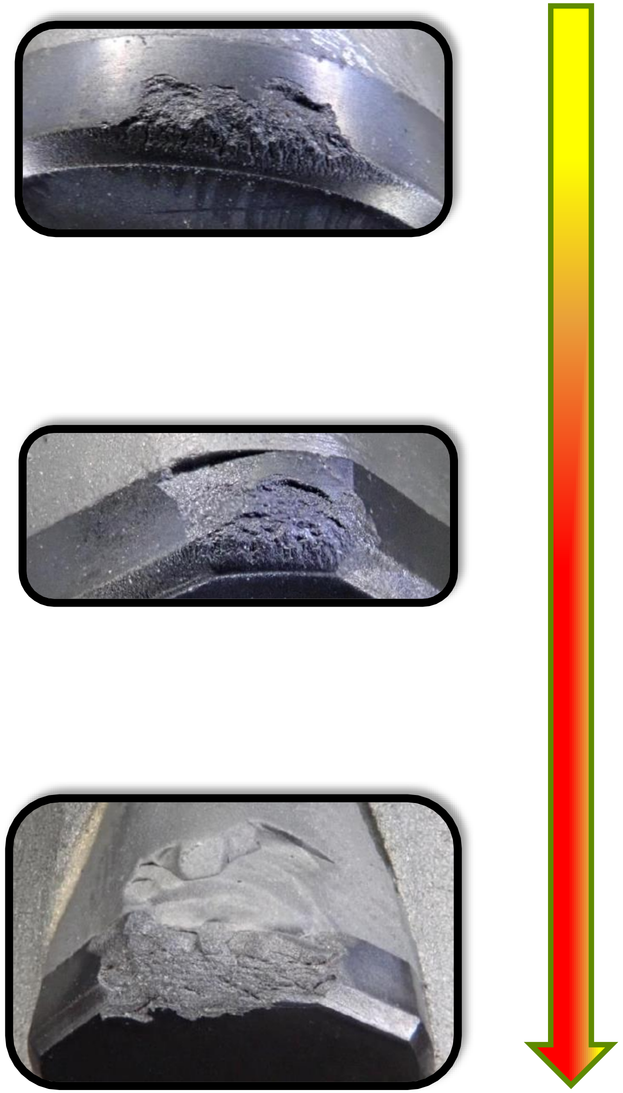
Cutter wear is costly

- Decreased efficiency
- Bits replaced mid section
- Health and Safety

What drives cutter wear?

- Mechanical wear? Abrasion?
- Thermal conditions downhole
  - Substrate-to-diamond table bond degrades
  - Diamond degrades

Extreme temperatures accelerate cutter wear



Mitigating Thermal Wear

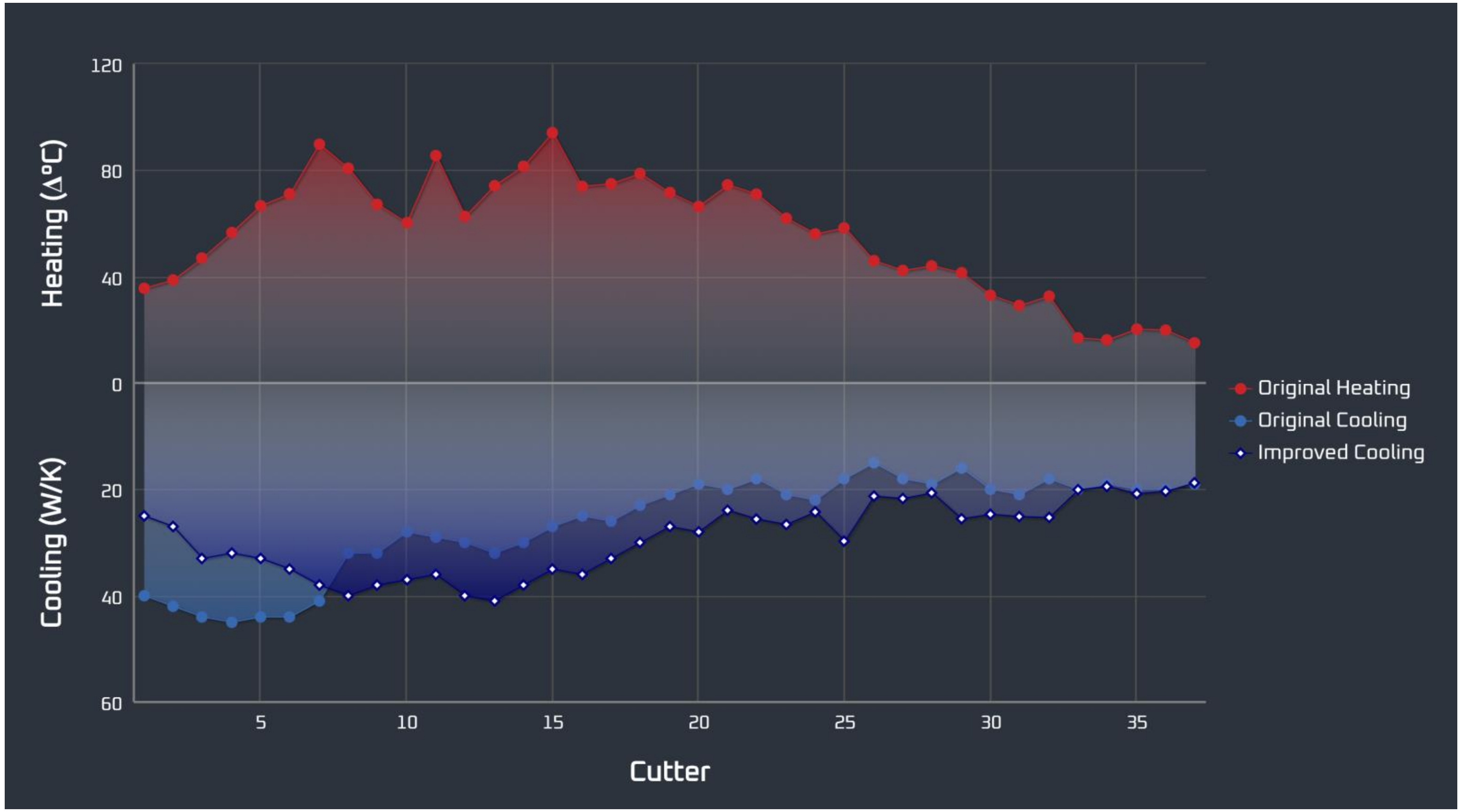
- Cutter Technology
  - Materials
  - Manufacturing Process
- Heat generation
  - Friction
  - Propagation
  - Cutter placement
- Heat transfer
  - Drilling fluid
  - Nozzle placement

A Solution

- Thermal load model
  - R&D Team (Babaie Aghdam)
  - Friction & heat propagation
  - Finite element analysis
  - Validated in the field (dulls)
  - Algorithm implemented in MATLAB
- Orbit
  - Pipeline
  - New visualization
  - Integration with computational fluid dynamics (nozzle placement)

Thermal Analysis Chart

Thermal load vs cooling efficiency



- Cutters ordered by radius
- Top axis: increase in cutter temperature
  - MATLAB model
- Bottom axis: heat transfer (drilling fluid)
  - Computational Fluid Dynamics (CFD)

Workflow:

- Run thermal load analysis (Orbit)
- Export to CFD
- Upload CFD output to Orbit

A better physics model

Extrapolate cutter forces to whole bit.

- Originally based on experiments run at surface.

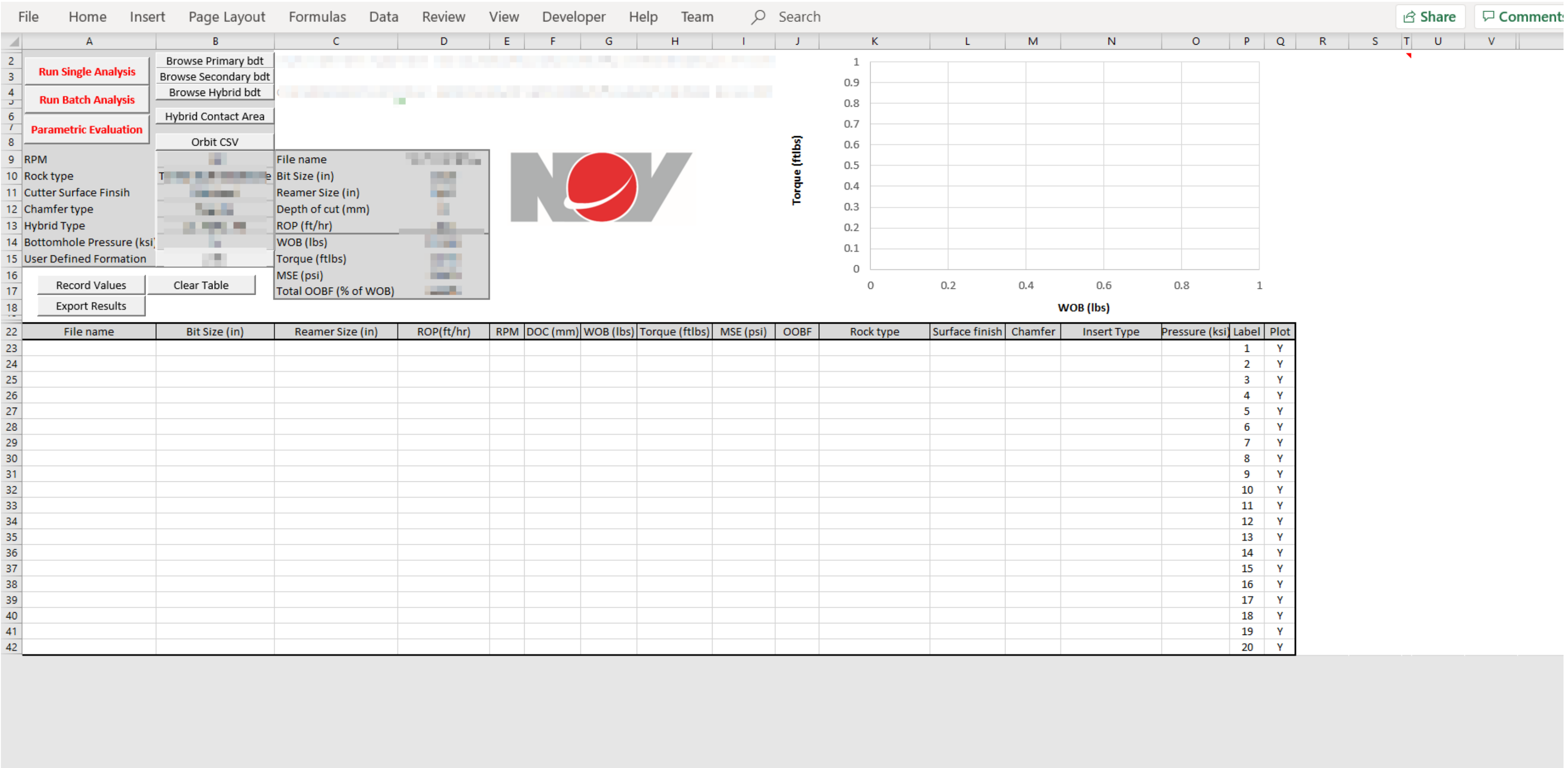
Material properties of rock change under pressure

- Brittle at surface, ductile at depth

A new standard

- Pressurized drilling lab
- Discrete element analysis
- AMBAR Model (Rahmani)

The Prototype



- Excel spreadsheet
- Extensive VBA routines
- Calculation performed on hidden sheets

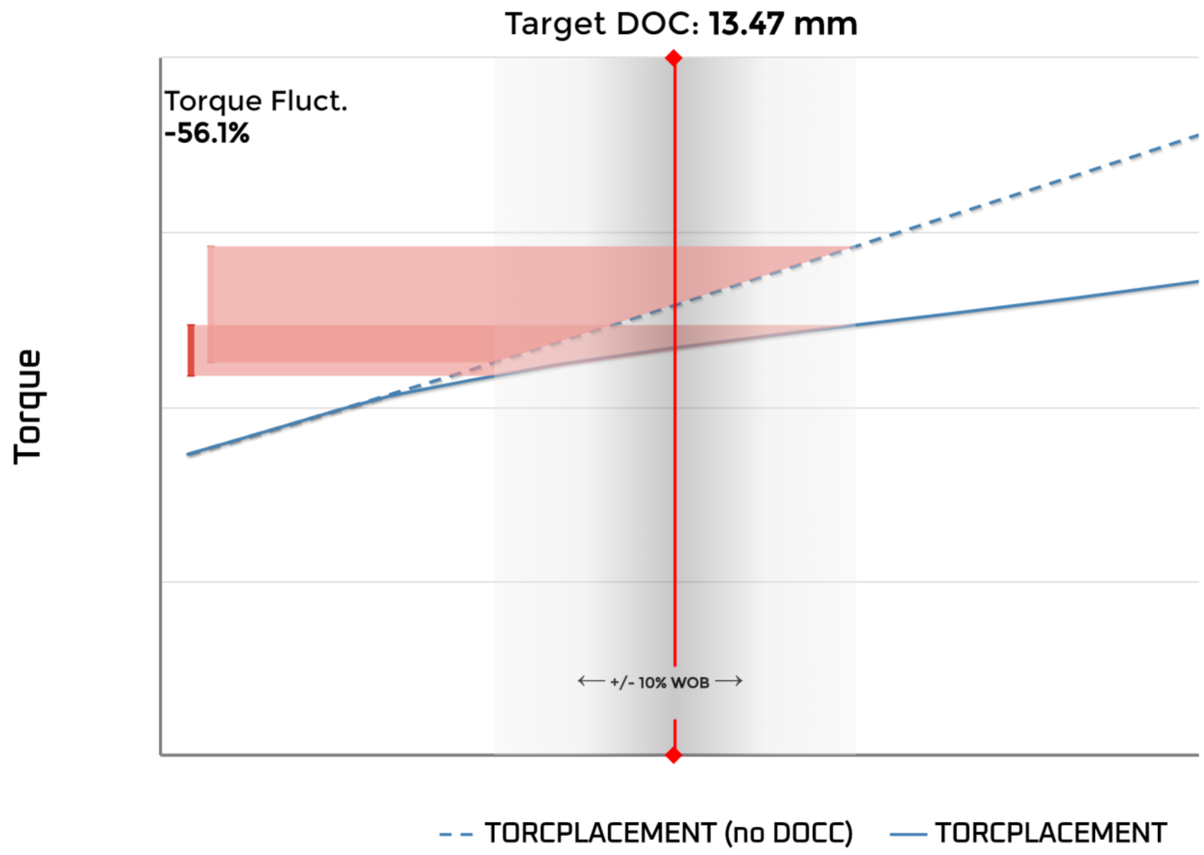
Limitations:

- Hard to maintain, distribute
- User manages artifacts

AMBAR in Orbit

- Integration
  - Rewritten in MATLAB
  - Pipeline
  - Automated
    - No need to manage artifacts
- Continuous improvement
  - Multiple iterations pushed since release
- Reception
  - Engineers have greater confidence in output
    - Better usage
    - Sales support
  - New Analyses

Torque Control



Torque variation makes steering harder

- Hooke's law
- Weight on bit fluctuation
- Torque control components (TCC)

AMBAR

- Better model for TCC
- Better model downhole
- Enables finer analysis like DOCC