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(54) **AUTOMATED DIRECTIONAL DRILLING CONTROL SYSTEM**

(71) Applicant: **Nabors Drilling Technologies USA, Inc.**, Houston, TX (US)

(72) Inventors: **Adam LaCroix**, Cypress, TX (US); **Trey Welch**, Conroe, TX (US); **Sachitananda Maddikunta**, Houston, TX (US)

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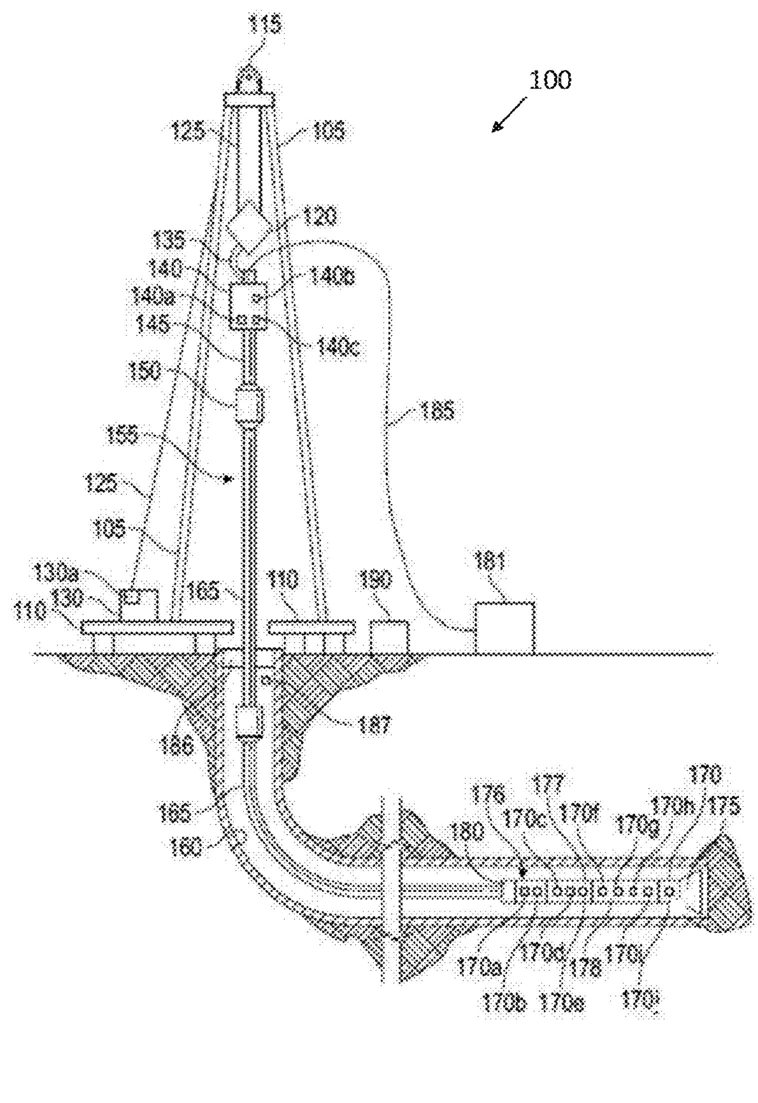
CPC ***E21B 44/04*** (2013.01); ***E21B 7/046*** (2013.01); ***E21B 45/00*** (2013.01)

(57) **ABSTRACT**

Systems and methods for an automated directional drilling control system including a programmable logic computer ("PLC") configured with one or more constraint and configured to calculate one or more metrics to automatically adjust drilling parameter setpoints to optimize performance. During performance of a first portion of a slide drill segment, the automated directional drilling control system is configured to maximize a rate of penetration ("ROP") while maintaining a desired slide score. After one or more conditions are met during the first portion of the slide drill segment, a second portion of the slide drill segment is performed during which the automated directional drilling control system controls either a ROP setpoint parameter or a weight on bit ("WOB") setpoint parameter while floating the setpoint of the non-controlling parameter at a value above its current average value. The selection of the controlling parameter can be toggled back and forth manually or automatically.



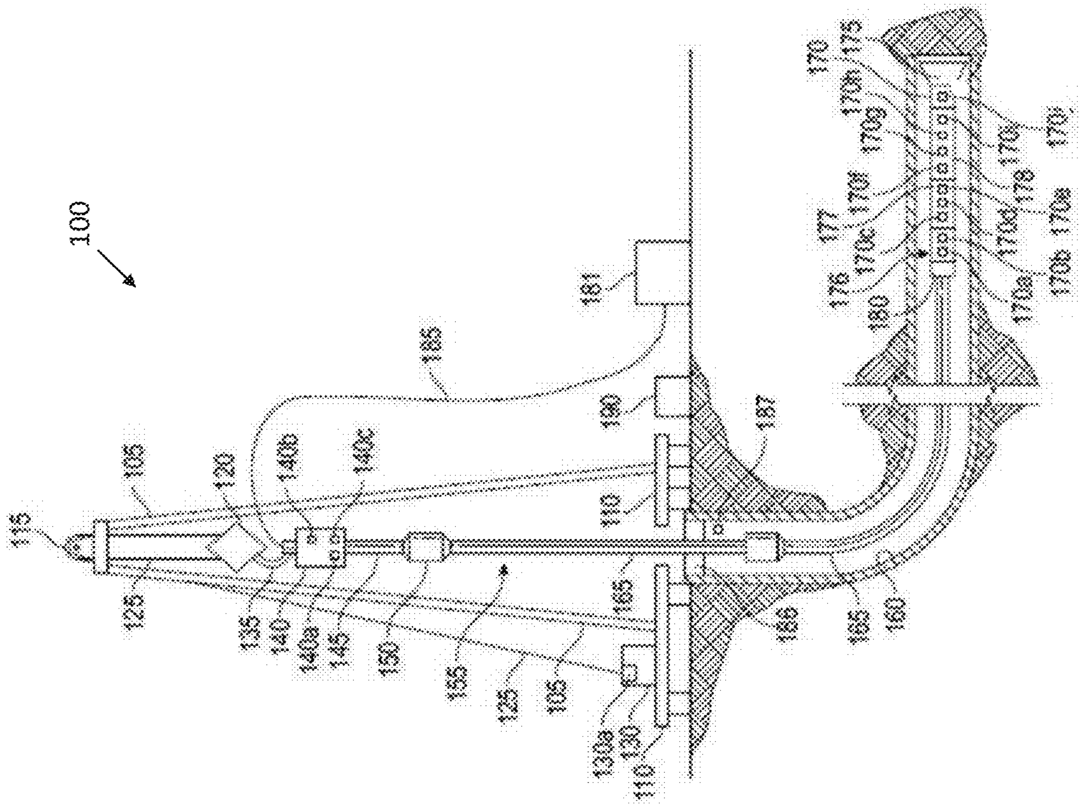

100
115
105
120
140b
140c
125
135
140
140a
145
150
155
165
110
190
181
185
187
186
160
130a
130
170
175
170h
170g
170f
177
170c
176
180
170i
178
170e
170d
170a
170b

FIG. 1

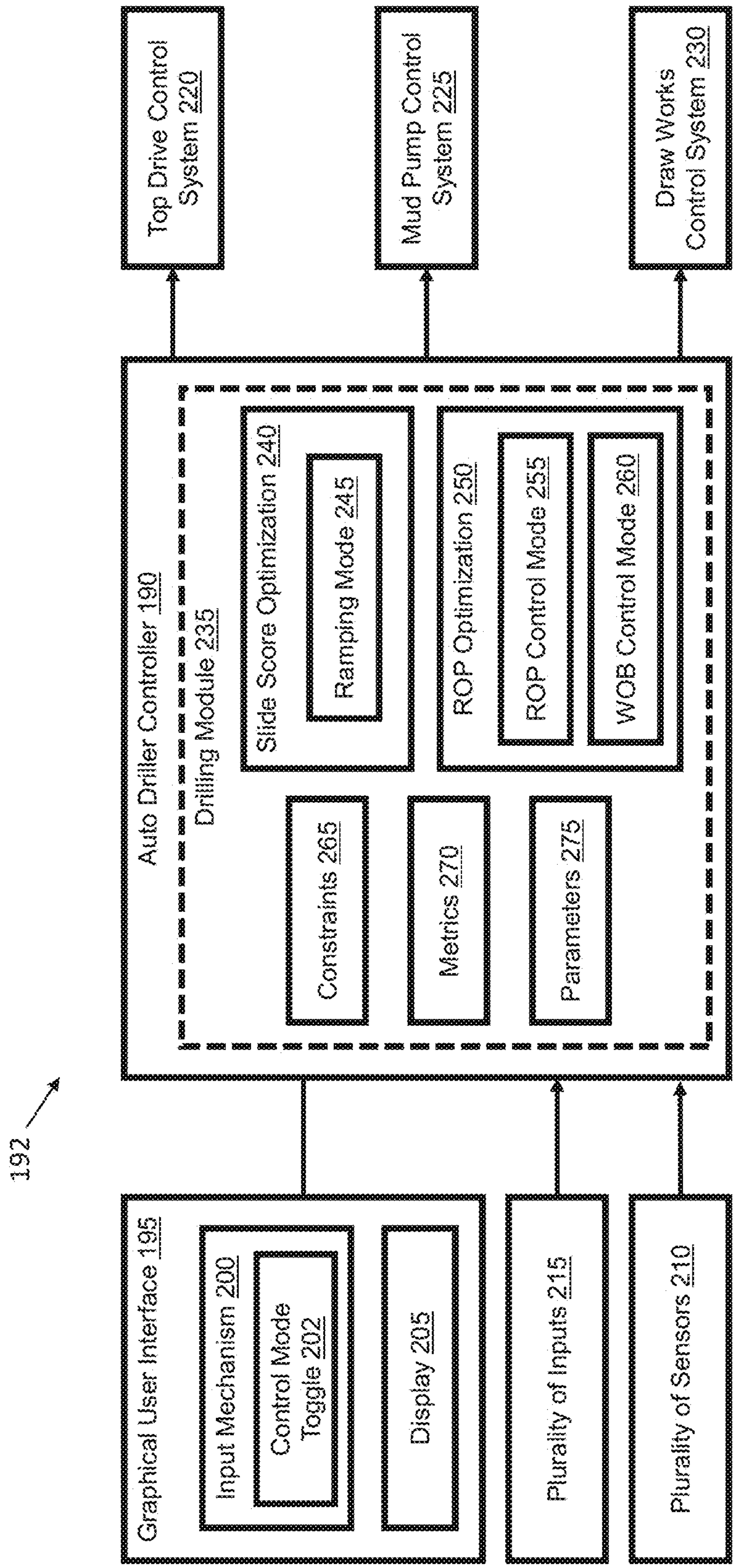

192
Top Drive Control System 220
Mud Pump Control System 225
Draw Works Control System 230
Auto Driller Controller 190
Drilling Module 235
Slide Score Optimization 240
Ramping Mode 245
ROP Optimization 250
ROP Control Mode 255
WOB Control Mode 260
Constraints 265
Metrics 270
Parameters 275
Graphical User Interface 195
Input Mechanism 200
Control Mode Toggle 202
Display 205
Plurality of Inputs 215
Plurality of Sensors 210

FIG. 2

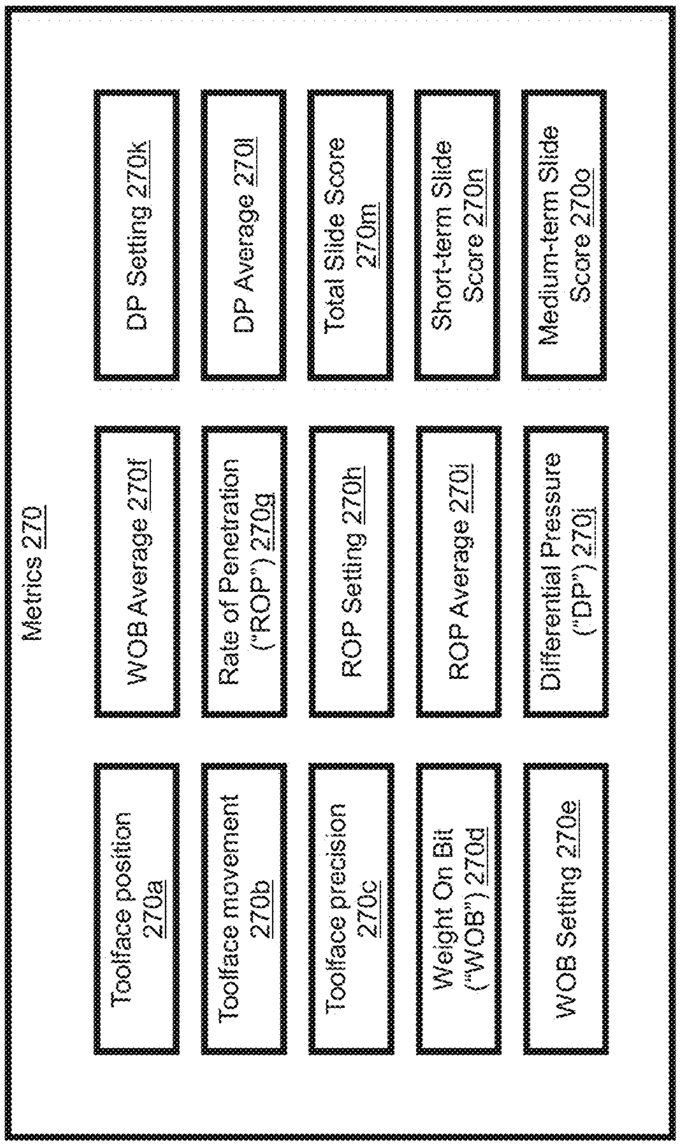

Metrics 270
Toolface position 270a
Toolface movement 270b
Toolface precision 270c
Weight On Bit ("WOB") 270d
WOB Setting 270e
WOB Average 270f
Rate of Penetration ("ROP") 270g
ROP Setting 270h
ROP Average 270i
Differential Pressure ("DP") 270j
DP Setting 270k
DP Average 270l
Total Slide Score 270m
Short-term Slide Score 270n
Medium-term Slide Score 270o

FIG. 3

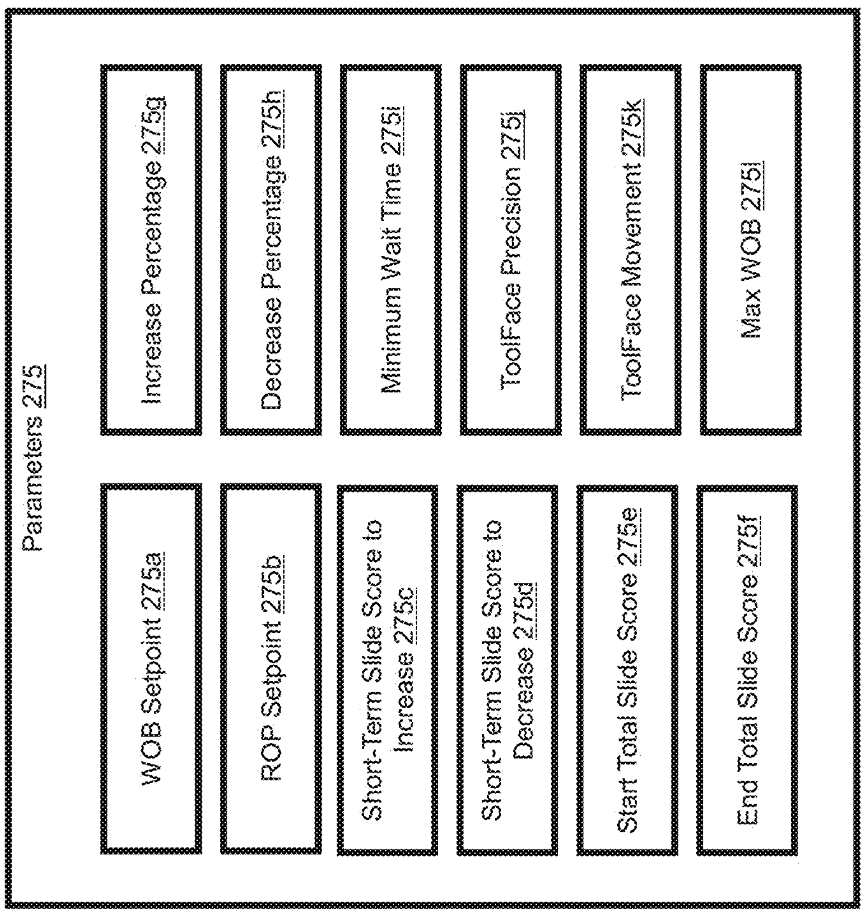

Parameters 275
WOB Setpoint 275a
ROP Setpoint 275b
Short-Term Slide Score to Increase 275c
Short-Term Slide Score to Decrease 275d
Start Total Slide Score 275e
End Total Slide Score 275f
Increase Percentage 275g
Decrease Percentage 275h
Minimum Wait Time 275i
ToolFace Precision 275j
ToolFace Movement 275k
Max WOB 275l

FIG. 4

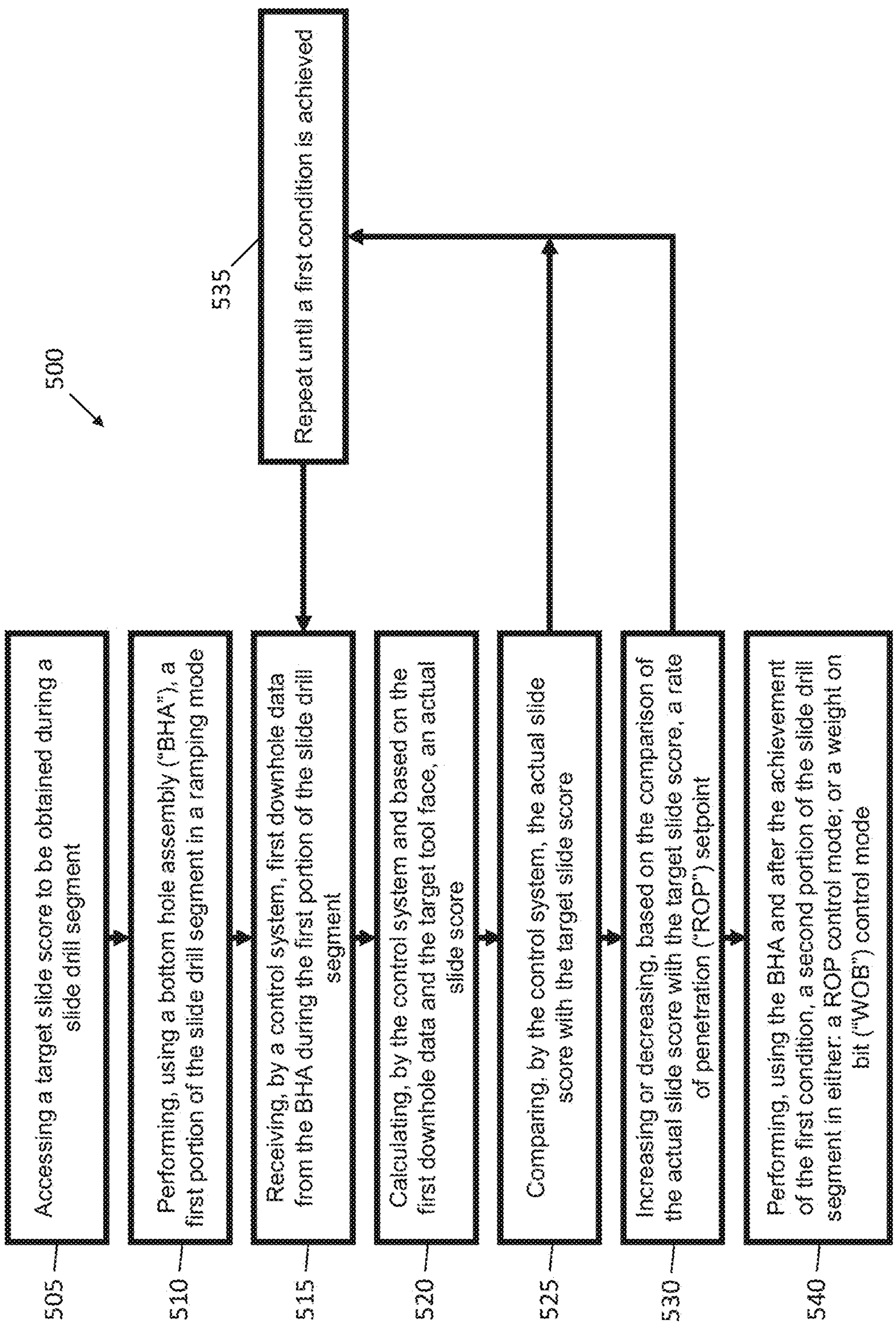

500
505
Accessing a target slide score to be obtained during a slide drill segment
510
Performing, using a bottom hole assembly ("BHA"), a first portion of the slide drill segment in a ramping mode
515
Receiving, by a control system, first downhole data from the BHA during the first portion of the slide drill segment
520
Calculating, by the control system and based on the first downhole data and the target tool face, an actual slide score
525
Comparing, by the control system, the actual slide score with the target slide score
530
Increasing or decreasing, based on the comparison of the actual slide score with the target slide score, a rate of penetration ("ROP") setpoint
535
Repeat until a first condition is achieved
540
Performing, using the BHA and after the achievement of the first condition, a second portion of the slide drill segment in either: a ROP control mode; or a weight on bit ("WOB") control mode

FIG. 5A

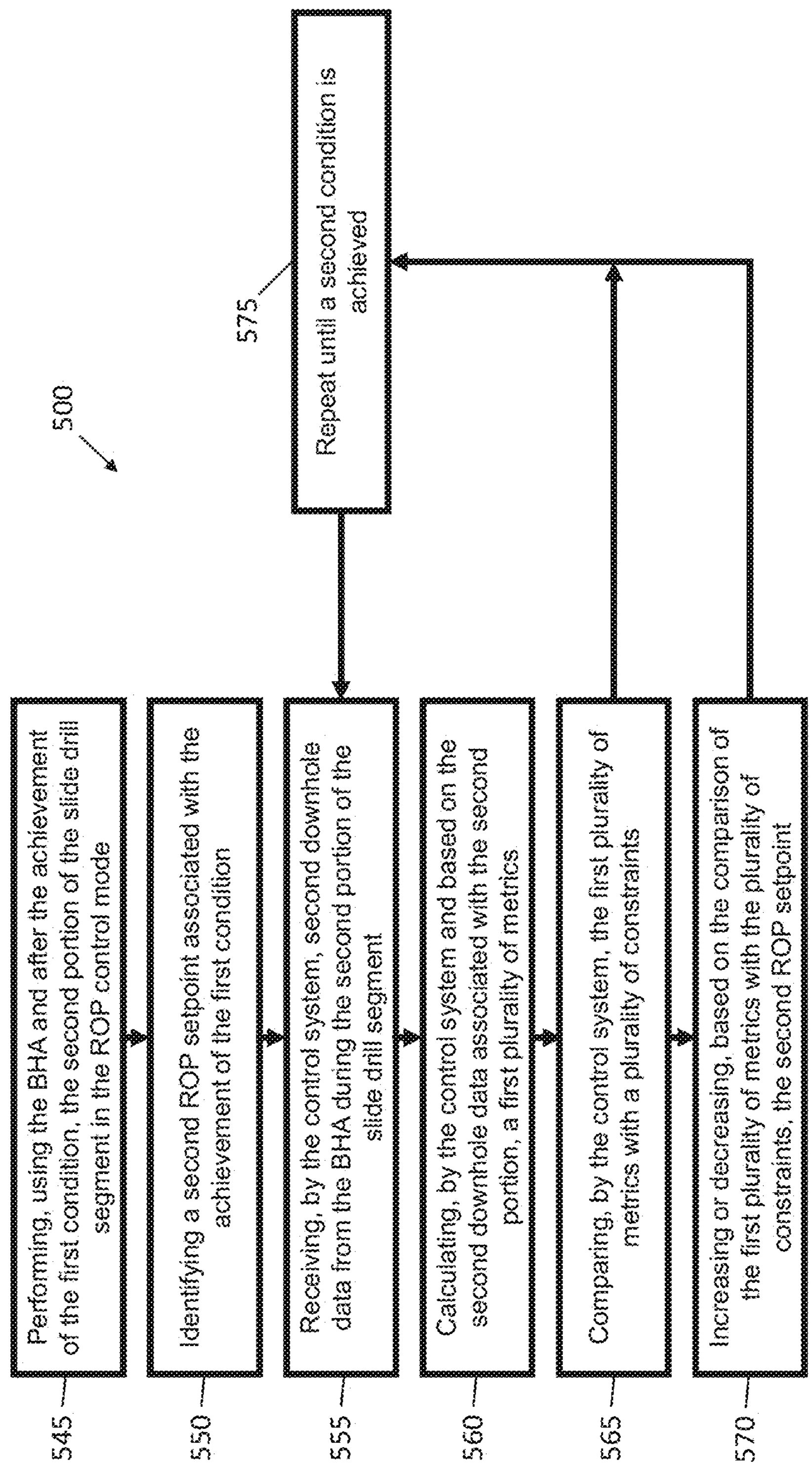

500
545
Performing, using the BHA and after the achievement of the first condition, the second portion of the slide drill segment in the ROP control mode
550
Identifying a second ROP setpoint associated with the achievement of the first condition
555
Receiving, by the control system, second downhole data from the BHA during the second portion of the slide drill segment
560
Calculating, by the control system and based on the second downhole data associated with the second portion, a first plurality of metrics
565
Comparing, by the control system, the first plurality of metrics with a plurality of constraints
570
Increasing or decreasing, based on the comparison of the first plurality of metrics with the plurality of constraints, the second ROP setpoint
575
Repeat until a second condition is achieved

FIG. 5B

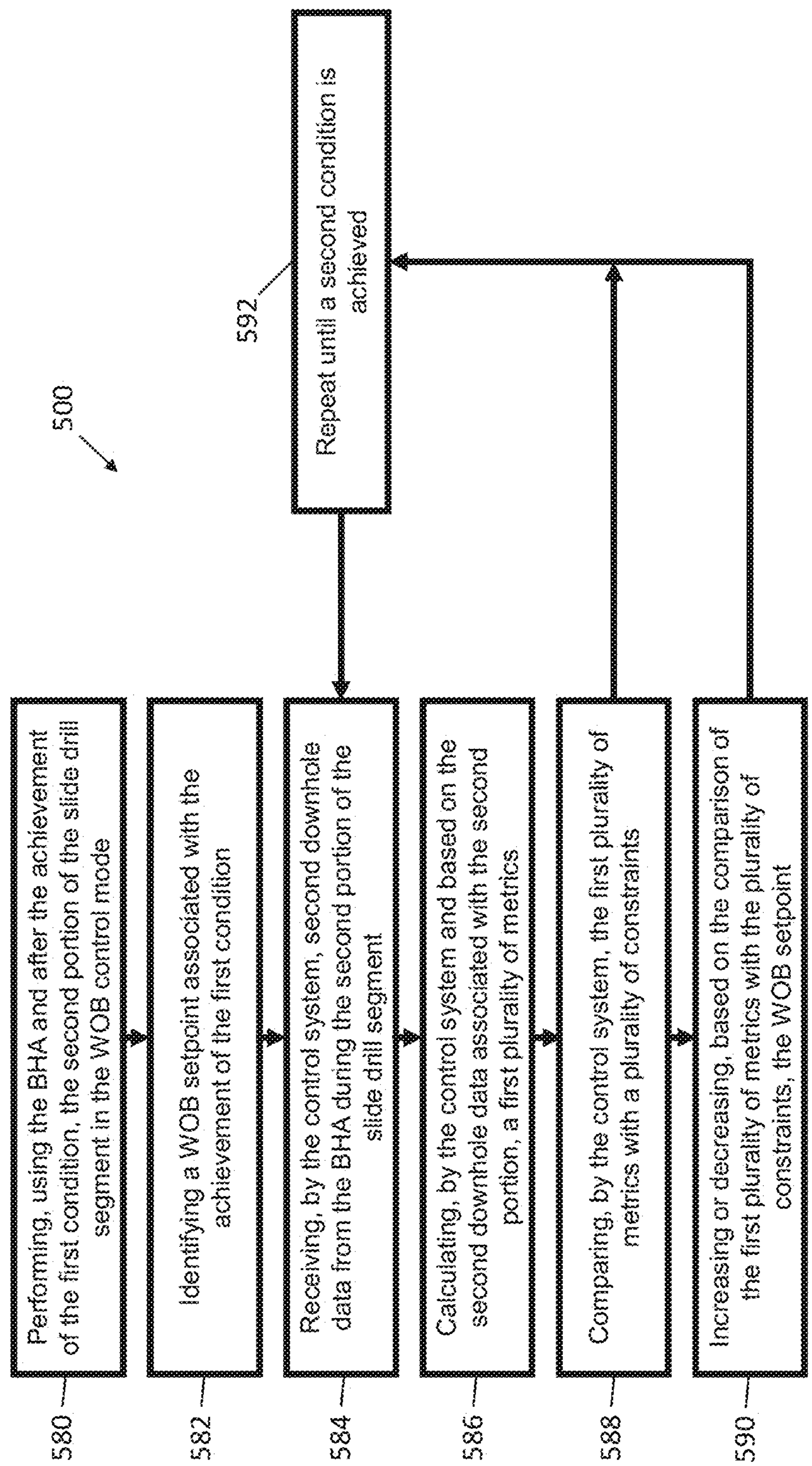

500
580
Performing, using the BHA and after the achievement of the first condition, the second portion of the slide drill segment in the WOB control mode
582
Identifying a WOB setpoint associated with the achievement of the first condition
584
Receiving, by the control system, second downhole data from the BHA during the second portion of the slide drill segment
586
Calculating, by the control system and based on the second downhole data associated with the second portion, a first plurality of metrics
588
Comparing, by the control system, the first plurality of metrics with a plurality of constraints
590
Increasing or decreasing, based on the comparison of the first plurality of metrics with the plurality of constraints, the WOB setpoint
592
Repeat until a second condition is achieved

FIG. 5C

FIG. 6

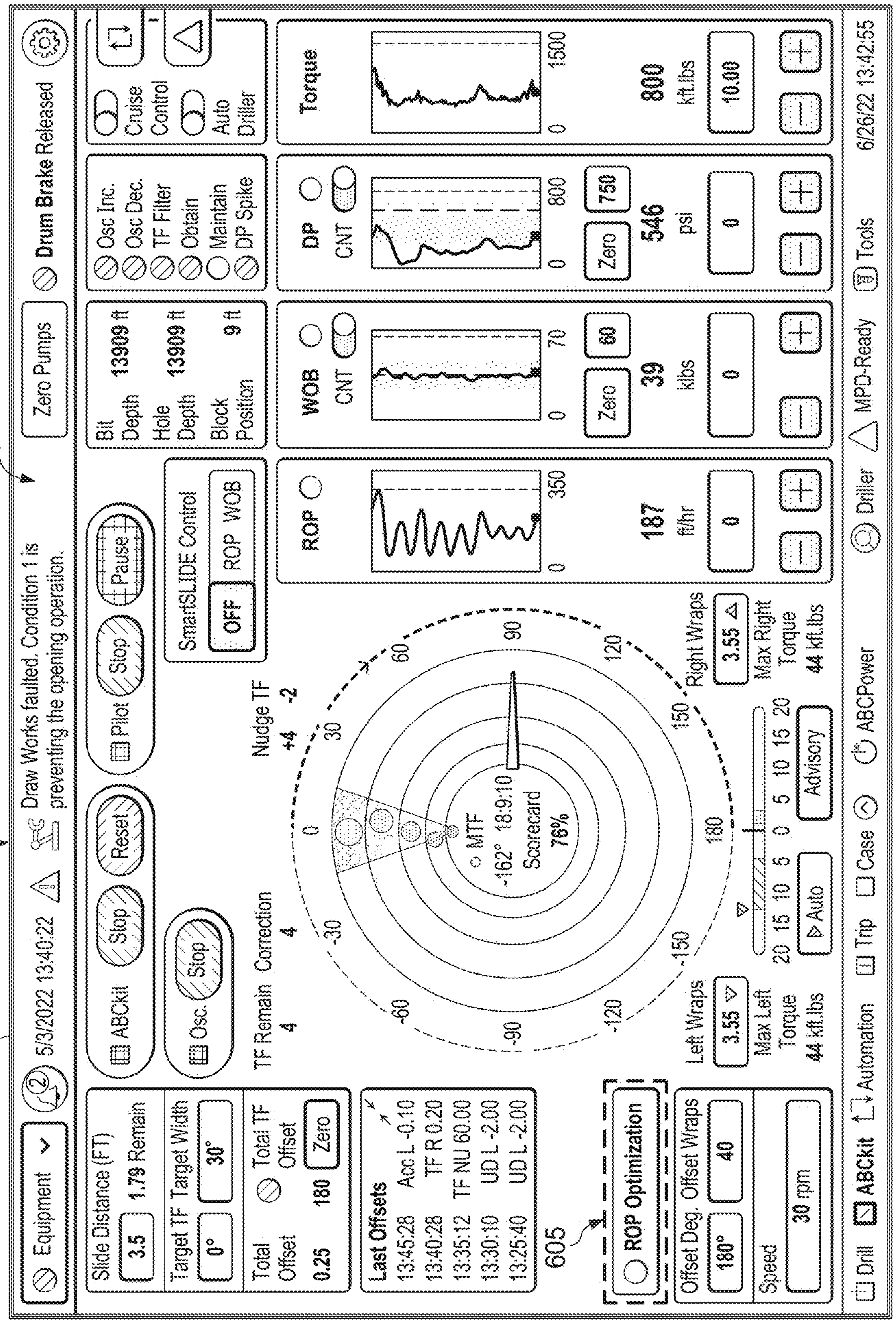
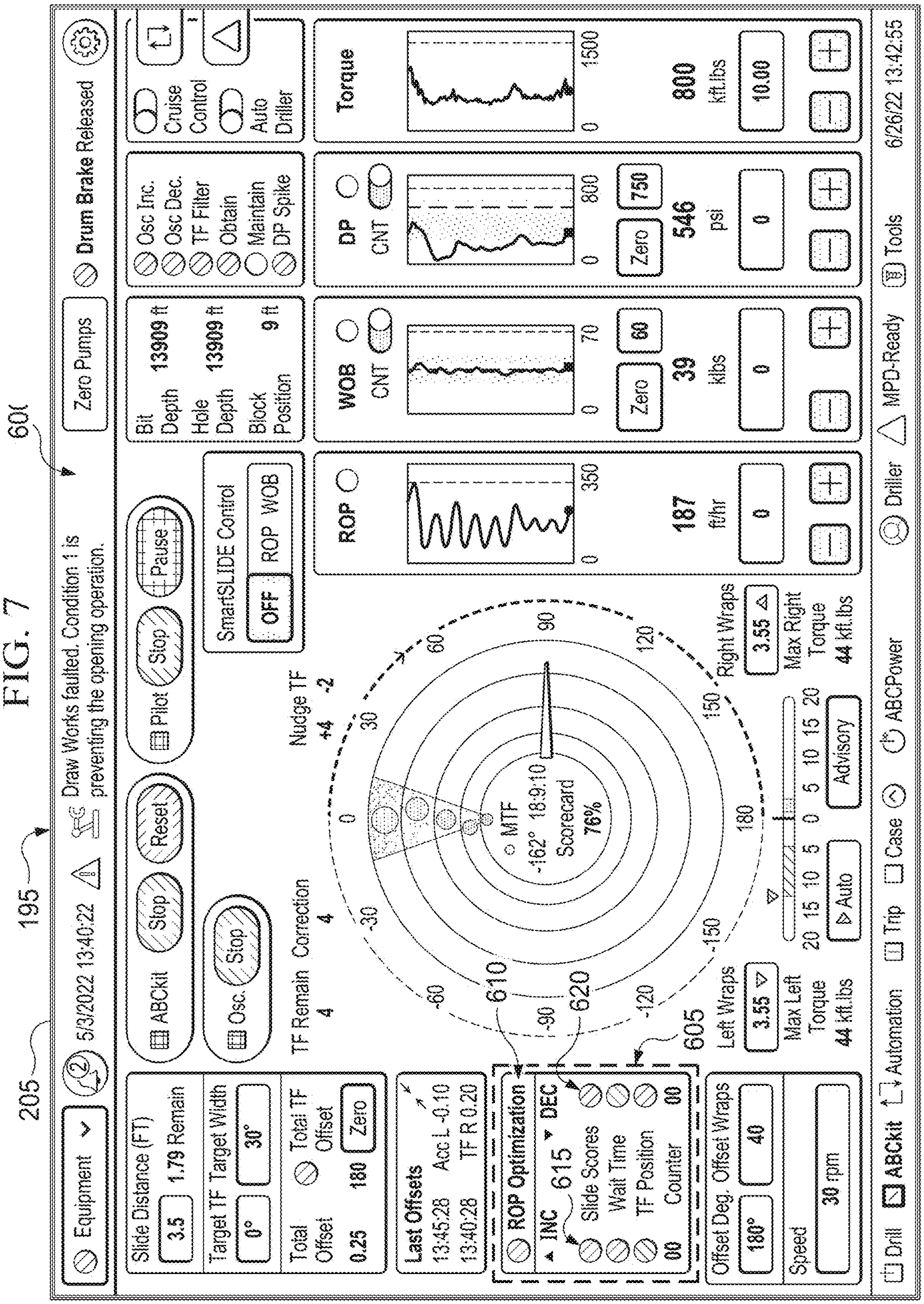
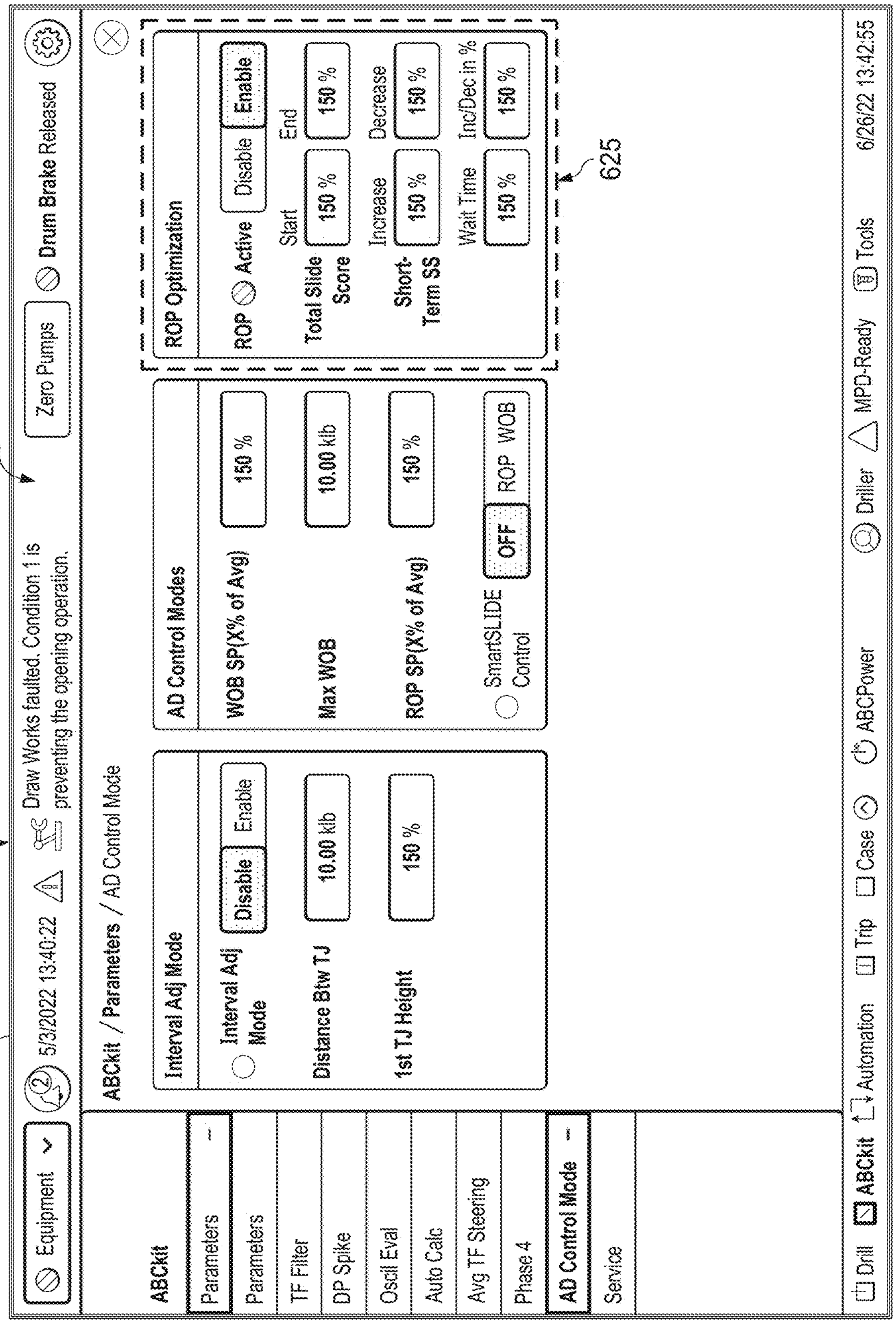

205
195
600
605
Equipment
5/3/2022 13:40:22
Draw Works faulted. Condition 1 is preventing the opening operation.
Zero Pumps
Drum Brake Released
Slide Distance (FT)
3.5
1.79 Remain
Target TF
Target Width
0°
30°
Total Offset
0.25
Total TF Offset
180
Zero
Last Offsets
13:45:28 Acc L -0.10
13:40:28 TF R 0.20
13:35:12 TF NU 60.00
13:30:10 UD L -2.00
13:25:40 UD L -2.00
ROP Optimization
Offset Deg.
Offset Wraps
180°
40
Speed
30 rpm
ABCkit
Stop
Reset
Pilot
Stop
Pause
Osc.
Stop
SmartSLIDE Control
OFF
ROP
WOB
TF Remain
4
Correction
4
Nudge TF
+4
-2
MTF
-162° 18:9:10
Scorecard
76%
Left Wraps
3.55
Max Left Torque
44 kft.lbs
Right Wraps
3.55
Max Right Torque
44 kft.lbs
Auto
Advisory
Bit Depth 13909 ft
Hole Depth 13909 ft
Block Position 9 ft
Osc Inc.
Osc Dec.
TF Filter
Obtain
Maintain
DP Spike
Cruise Control
Auto Driller
ROP
187
ft/hr
WOB
CNT
Zero
60
39
klbs
DP
CNT
Zero
750
546
psi
Torque
800
kft.lbs
10.00
Drill
ABCkit
Automation
Trip
Case
ABCPower
Driller
MPD-Ready
Tools
6/26/22 13:42:55

FIG. 7



195
205
600
605
610
615
620
Equipment
5/3/2022 13:40:22
Draw Works faulted. Condition 1 is preventing the opening operation.
Zero Pumps
Drum Brake Released
Slide Distance (FT)
3.5
1.79 Remain
Target TF
Target Width
0°
30°
Total Offset
0.25
Total TF Offset
180
Zero
Last Offsets
13:45:28 Acc L -0.10
13:40:28 TF R 0.20
ROP Optimization
INC
DEC
Slide Scores
Wait Time
TF Position
Counter
00
Offset Deg.
Offset Wraps
180°
40
Speed
30 rpm
ABCkit
Stop
Reset
Pilot
Pause
Osc.
SmartSLIDE Control
OFF
ROP
WOB
TF Remain
Correction
Nudge TF
MTF
-162° 18:9:10
Scorecard
76%
Left Wraps
3.55
Right Wraps
Max Left Torque
44 kft.lbs
Max Right Torque
Auto
Advisory
Bit Depth 13909 ft
Hole Depth 13909 ft
Block Position 9 ft
Osc Inc.
Osc Dec.
TF Filter
Obtain
Maintain
DP Spike
Cruise Control
Auto Driller
ROP
187
ft/hr
WOB
CNT
39
klbs
DP
546
psi
750
Torque
800
kft.lbs
10.00
Drill
Automation
Trip
Case
ABCPower
Driller
MPD-Ready
Tools
6/26/22 13:42:55

FIG. 8


205
195
800
Equipment
5/3/2022 13:40:22
Draw Works faulted. Condition 1 is preventing the opening operation.
Zero Pumps
Drum Brake Released
ABCkit
Parameters
Parameters
TF Filter
DP Spike
Oscil Eval
Auto Calc
Avg TF Steering
Phase 4
AD Control Mode
Service
ABCkit / Parameters / AD Control Mode
Interval Adj Mode
Interval Adj Mode
Disable
Enable
Distance Btw TJ
10.00 klb
1st TJ Height
150 %
AD Control Modes
WOB SP(X% of Avg)
150 %
Max WOB
10.00 klb
ROP SP(X% of Avg)
150 %
SmartSLIDE Control
OFF
ROP
WOB
ROP Optimization
ROP
Active
Disable
Enable
Total Slide Score
Start
150 %
End
150 %
Short-Term SS
Increase
150 %
Decrease
150 %
Wait Time
150 %
Inc/Dec in %
150 %
625
Drill
ABCkit
Automation
Trip
Case
ABCPower
Driller
MPD-Ready
Tools
6/26/22 13:42:55

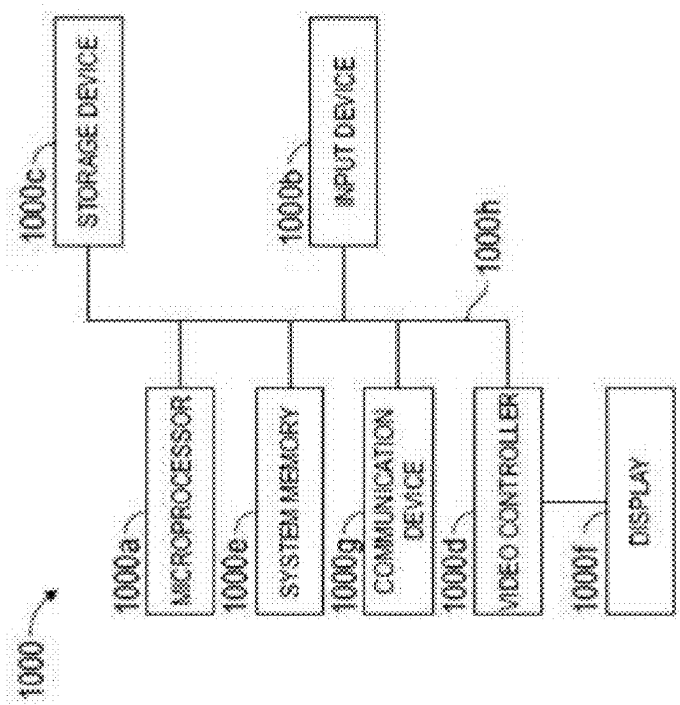

1000
1000a
MICROPROCESSOR
1000e
SYSTEM MEMORY
1000g
COMMUNICATION DEVICE
1000d
VIDEO CONTROLLER
1000f
DISPLAY
1000c
STORAGE DEVICE
1000b
INPUT DEVICE
1000h

FIG. 9

AUTOMATED DIRECTIONAL DRILLING CONTROL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of the filing date of U.S. Provisional Application No. 63/554,083, filed Feb. 15, 2024, the entire disclosure of which is hereby incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0002] The present disclosure relates, in general, to an automated directional drilling control system, and more particularly, to an automated directional drilling control system configured to automatically adjust drilling parameter setpoints to optimize performance.

BACKGROUND

[0003] Current directional drilling control systems rely on human intervention to operate and manually adjust drilling parameter setpoints. The method in which drilling parameters are adjusted during drilling operations, such as slide drilling operations, can significantly impact rate of penetration ("ROP") and tool face control, both of which ultimately affect the quality and efficiency of the drilling operation. When such drilling parameters are adjusted manually by one or more operators, variations in operator skill and competency can contribute to inconsistencies in the quality and efficiency of the drilling operation and human error can result in damage to a bottom hole assembly, all of which can contribute to increased costs and delays associated with the drilling operation.

[0004] The present disclosure introduces improved methods and systems for automatically adjusting directional drilling parameter setpoints to optimize performance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] FIG. **1** illustrates a drilling apparatus, according to one or more embodiments of the present disclosure;

[0006] FIG. **2** illustrates an automated directional drilling control system including one or more components of the drilling apparatus of FIG. **1**, according to one or more embodiments of the present disclosure;

[0007] FIG. **3** illustrates a plurality of metrics associated with the automated directional drilling control system of FIG. **2**, according to one or more embodiments of the present disclosure;

[0008] FIG. **4** illustrates a plurality of parameters associated with the automated directional drilling control system of FIG. **2**, according to one or more embodiments of the present disclosure;

[0009] FIG. **5**A illustrates a first portion of a method for operating the automated directional drilling control system of FIG. **2**, the first portion of the method including a ramping mode, according to one or more embodiments of the present disclosure;

[0010] FIG. **5**B illustrates a second portion of the method for operating the automated directional drilling control system of FIG. **2**, the second portion of the method including a ROP control mode, according to one or more embodiments;

[0011] FIG. **5**C illustrates a third portion of the method for operating the automated directional drilling control system of FIG. **2**, the third portion of the method including a WOB control mode;

[0012] FIG. **6** illustrates a schematic diagram of an example display apparatus showing a two-dimensional visualization, according to one or more embodiments of the present disclosure;

[0013] FIG. **7** illustrates the schematic diagram of the example display apparatus of FIG. **6** showing the two-dimensional visualization and a constraint table, according to one or more embodiments of the present disclosure;

[0014] FIG. **8** illustrates the schematic diagram of the example display apparatus of FIG. **6** showing a parameter table associated with the constraint table, according to one or more embodiments of the present disclosure; and

[0015] FIG. **9** illustrates a node for implementing one or more example embodiments of the present disclosure, according to one or more embodiments of the present disclosure.

DETAILED DESCRIPTION

[0016] The systems and methods disclosed herein provide improvements to the methods and system used for directional drilling in oil and gas drilling operations. It is to be understood that the present disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting.

[0017] FIG. **1** illustrates a schematic view of an apparatus **100** demonstrating one or more aspects of the present disclosure. The apparatus **100** is or includes a land-based drilling rig. However, one or more aspects of the present disclosure are applicable or readily adaptable to any type of drilling rig, such as jack-up rigs, semisubmersibles, drill ships, coil tubing rigs, well service rigs adapted for drilling and/or re-entry operations, and casing drilling rigs, among others within the scope of the present disclosure.

[0018] Generally, the apparatus **100** monitors, in real-time, drilling operations relating to a wellbore and creates and/or modifies drilling instructions based on the monitored drilling operations. As used herein, the term "real-time" is thus meant to encompass close to real-time, such as within about 10 seconds, preferably within about 5 seconds, and more preferably within about 2 seconds. "Real-time" can also encompass an amount of time that provides data based on a wellbore drilled to a given depth to provide actionable data according to the present invention before a further wellbore being drilled achieves that depth.

[0019] Apparatus **100** includes a mast **105** supporting lifting gear above a rig floor **110**. The lifting gear includes a crown block **115** and a traveling block **120**. The crown block **115** is coupled at or near the top of the mast **105**, and the traveling block **120** hangs from the crown block **115** by a drilling line **125**. One end of the drilling line **125** extends from the lifting gear to draw works **130**, which is configured to reel out and reel in the drilling line **125** to cause the traveling block **120** to be lowered and raised relative to the rig floor **110**. The draw works **130** may include a rate of penetration ("ROP") sensor **130***a*, which is configured for detecting an ROP value or range, and a controller to feed-out and/or feed-in of a drilling line **125**. The other end of the drilling line **125**, known as a dead line anchor, is anchored to a fixed position, possibly near the draw works **130** or elsewhere on the rig.

[0020] A hook **135** is attached to the bottom of the traveling block **120**. A top drive **140** is suspended from the hook **135**. A quill **145**, extending from the top drive **140**, is attached to a saver sub **150**, which is attached to a drill string **155** suspended within a wellbore **160**. Alternatively, the quill **145** may be attached to the drill string **155** directly.

[0021] The term "quill" as used herein is not limited to a component which directly extends from the top drive **140**, or which is otherwise conventionally referred to as a quill. For example, within the scope of the present disclosure, the "quill" may additionally or alternatively include a main shaft, a drive shaft, an output shaft, and/or another component which transfers torque, position, and/or rotation from the top drive or other rotary driving element to the drill string, at least indirectly. Nonetheless, albeit merely for the sake of clarity and conciseness, these components may be collectively referred to herein as the "quill."

[0022] The drill string **155** includes interconnected sections of drill pipe or tubulars **165** and a BHA **170**, which includes a drill bit **175**. The BHA **170** may include one or more measurement-while-drilling ("MWD") or wireline conveyed instruments **176**, flexible connections **177**, motors **178**, bent housing and bent subs for point-the-bit drilling, a controller **180**, stabilizers, and/or drill collars, among other components. One or more pumps **181** may deliver drilling fluid to the drill string **155** through a hose or other conduit **185**, which may be connected to the top drive **140**.

[0023] The downhole MWD or wireline conveyed instruments **176** may be configured for the evaluation of physical properties such as pressure, temperature, torque, weight-on-bit ("WOB"), vibration, inclination, azimuth, toolface orientation in three-dimensional space, and/or other downhole parameters. These measurements may be made downhole, stored in solid-state memory for some time, sent to the controller **180**, and downloaded from the instrument(s) at the surface and/or transmitted real-time to the surface. Data transmission methods may include, for example, digitally encoding data and transmitting the encoded data to the surface, possibly as pressure pulses in the drilling fluid or mud system, acoustic transmission through the drill string **155**, electronic transmission through a wireline or wired pipe, and/or transmission as electromagnetic pulses. The MWD tools and/or other portions of the BHA **170** may have the ability to store measurements for later retrieval via wireline and/or when the BHA **170** is tripped out of the wellbore **160**.

[0024] In an example embodiment, the apparatus **100** may also include a rotating blow-out preventer ("BOP") **186**, such as if the wellbore **160** is being drilled utilizing underbalanced or managed-pressure drilling methods. In such embodiment, the annulus mud and cuttings may be pressurized at the surface, with the actual desired flow and pressure possibly being controlled by a choke system, and the fluid and pressure being retained at the well head and directed down the flow line to the choke by the rotating BOP **186**. The apparatus **100** may also include a surface casing annular pressure sensor **187** configured to detect the pressure in the annulus defined between, for example, the wellbore **160** (or casing therein) and the drill string **155**. It is noted that the meaning of the word "detecting," in the context of the present disclosure, may include detecting, sensing, measuring, calculating, and/or otherwise obtaining data. Similarly, the meaning of the word "detect" in the context of the present disclosure may include detect, sense, measure, calculate, and/or otherwise obtain data.

[0025] In the example embodiment depicted in FIG. **1**, the top drive **140** is utilized to impart rotary motion to the drill string **155**. However, aspects of the present disclosure are also applicable or readily adaptable to implementations utilizing other drive systems, such as a power swivel, a rotary table, a coiled tubing unit, a downhole motor, and/or a conventional rotary rig, among others.

[0026] The apparatus **100** may include a downhole annular pressure sensor **170*a*** coupled to or otherwise associated with the BHA **170**. The downhole annular pressure sensor **170*a*** may be configured to detect a pressure value or range in the annulus-shaped region defined between the external surface of the BHA **170** and the internal diameter of the wellbore **160**, which may also be referred to as the casing pressure, downhole casing pressure, MWD casing pressure, or downhole annular pressure. These measurements may include both static annular pressure (pumps off) and active annular pressure (pumps on). However, in other embodiments the downhole annular pressure may be calculated using measurements from a plurality of other sensors located downhole or at the surface of the well.

[0027] The apparatus **100** may additionally or alternatively include a shock/vibration sensor **170*b*** that is configured for detecting shock and/or vibration in the BHA **170**. The apparatus **100** may additionally or alternatively include a mud motor delta pressure (AP) sensor **170*c*** that is configured to detect a pressure differential value or range across the one or more motors **178** of the BHA **170**. In some embodiments, the mud motor AP may be alternatively or additionally calculated, detected, or otherwise determined at the surface, such as by calculating the difference between the surface standpipe pressure just off-bottom and pressure once the bit touches bottom and starts drilling and experiencing torque. The one or more motors **178** may each be or include a positive displacement drilling motor that uses hydraulic power of the drilling fluid to drive the bit **175**, also known as a mud motor. One or more torque sensors, such as a bit torque sensor, may also be included in the BHA **170** for sending data to a controller **190** that is indicative of the torque applied to the bit **175**.

[0028] The apparatus **100** may additionally or alternatively include a toolface sensor **170*e*** configured to estimate or detect the current toolface orientation or toolface angle. The toolface sensor **170*c*** may be or include a conventional or future-developed gravity toolface sensor which detects toolface orientation relative to the Earth's gravitational field. Alternatively, or additionally, the toolface sensor **170*c*** may be or include a conventional or future-developed magnetic toolface sensor which detects toolface orientation relative to magnetic north or true north. However, other toolface sensors may also be utilized within the scope of the present disclosure, including non-magnetic toolface sensors and non-gravitational inclination sensors. The toolface sensor **170*c*** may also, or alternatively, be or include a conventional or future-developed gyro sensor. The apparatus **100** may additionally or alternatively include a WOB sensor **170*f*** integral to the BHA **170** and configured to detect WOB at or near the BHA **170**. The apparatus **100** may additionally or alternatively include an inclination sensor **170*g*** integral to the BHA **170** and configured to detect inclination at or near the BHA **170**. The apparatus **100** may additionally or alternatively include an azimuth sensor **170***h* integral to the BHA **170** and configured to detect azimuth at or near the BHA **170**. The apparatus **100** may additionally or alternatively include a torque sensor **140***a* coupled to or otherwise associated with the top drive **140**. The torque sensor **140***a* may alternatively be located in or associated with the BHA **170**. The torque sensor **140***a* may be configured to detect a value or range of the torsion of the quill **145** and/or the drill string **155** (e.g., in response to operational forces acting on the drill string). The top drive **140** may additionally or alternatively include or otherwise be associated with a speed sensor **140***b* configured to detect a value or range of the rotational speed of the quill **145**. In some embodiments, the BHA **170** also includes another directional sensor **170***i* (e.g., azimuth, inclination, toolface, combination thereof, etc.) that is spaced along the BHA **170** from a first directional sensor (e.g., the inclination sensor **170***g*, the azimuth sensor **170***h*). For example, and in some embodiments, the sensor **170***i* is positioned in the MWD **176** and the first directional sensor is positioned along another portion of the BHA **170**, with a known distance between them, for example 20 feet, configured to estimate or detect the current toolface orientation or toolface angle. The sensors **170***a*-**170***j* are not limited to the arrangement illustrated in FIG. **1** and may be spaced along the BHA **170** in a variety of configurations.

[0029] The top drive **140**, the draw works **130**, the crown block **115**, the traveling block **120**, drilling line or dead line anchor may additionally or alternatively include or otherwise be associated with a WOB or hook load sensor **140***c* (WOB calculated from the hook load sensor that can be based on active and static hook load) (e.g., one or more sensors installed somewhere in the load path mechanisms to detect and calculate WOB, which can vary from rig-to-rig) different from the WOB sensor **170***f*. The WOB sensor **140***f* may be configured to detect a WOB value or range, where such detection may be performed at the top drive **140**, the draw works **130**, or other component of the apparatus **100**. Generally, the hook load sensor **140***c* detects the load on the hook **135** as it suspends the top drive **140** and the drill string **155**.

[0030] The detection performed by the sensors described herein may be performed once, continuously, periodically, and/or at random intervals. The detection may be manually triggered by an operator or other person accessing a human-machine interface ("HMI") or GUI, or automatically triggered by, for example, a triggering characteristic or parameter satisfying a predetermined condition (e.g., expiration of a time period, drilling progress reaching a predetermined depth, drill bit usage reaching a predetermined amount, etc.). Such sensors and/or other detection means may include one or more interfaces which may be local at the well/rig site or located at another, remote location with a network link to the system.

[0031] In some embodiments, the controller **180** is configured to control or assist in the control of one or more components of the apparatus **100**. For example, the controller **180** may be configured to transmit operational control signals to the controller **190**, the draw works **130**, the top drive **140**, other components of the BHA **170**, and/or the pump **181**. The controller **180** may be a stand-alone component that forms a portion of the BHA **170** or be integrated in another sensor that forms a portion of the BHA **170**. The controller **180** may be configured to transmit the operational control signals or instructions to the draw works **130**, the top drive **140**, other components of the BHA **170**, and/or the pump **181** via wired or wireless transmission means which, for the sake of clarity, are not depicted in FIG. **1**.

[0032] The apparatus **100** also includes the controller **190**, which is or forms a portion of a computing system, configured to control or assist in the control of one or more components of the apparatus **100**. For example, the controller **190** may be configured to transmit operational control signals to the draw works **130**, the top drive **140**, the BHA **170** and/or the pump **181**. The controller **190** may be a stand-alone component installed near the mast **105** and/or other components of the apparatus **100**. In an example embodiment, the controller **190** includes one or more systems located in a control room proximate the mast **105**, such as the general-purpose shelter often referred to as the "doghouse" serving as a combination tool shed, office, communications center, and general meeting place. The controller **190** may be configured to transmit the operational control signals to the draw works **130**, the top drive **140**, the BHA **170**, and/or the pump **181** via wired or wireless transmission means which, for the sake of clarity, are not depicted in FIG. **1**.

[0033] In some embodiments, the controller **190** is not operably coupled to the top drive **140**, but instead may include other drive systems, such as a power swivel, a rotary table, a coiled tubing unit, a downhole motor, and/or a conventional rotary rig, among others.

[0034] In some embodiments, the controller **190** controls the flow rate and/or pressure of the output of the mud pump **181**.

[0035] In some embodiments, the controller **190** controls the feed-out and/or feed-in of the drilling line **125**, rotational control of the draw works (in v. out) to control the height or position of the hook **135** and may also control the rate the hook **135** ascends or descends. However, example embodiments within the scope of the present disclosure include those in which the draw-works-drill-string-feed-off system may alternatively be a hydraulic ram or rack and pinion type hoisting system rig, where the movement of the drill string **155** up and down is via something other than the draw works **130**. The drill string **155** may also take the form of coiled tubing, in which case the movement of the drill string **155** in and out of the hole is controlled by an injector head which grips and pushes/pulls the tubing in/out of the hole. Nonetheless, such embodiments may still include a version of the draw works controller, which may still be configured to control feed-out and/or feed-in of the drill string **155**.

[0036] Generally, the apparatus **100** also includes a hook position sensor that is configured to detect the vertical position of the hook **135**, the top drive **140**, and/or the travelling block **120**. The hook position sensor may be coupled to, or be included in, the top drive **140**, the draw works **130**, the crown block **115**, and/or the traveling block **120** (e.g., one or more sensors installed somewhere in the load path mechanisms to detect and calculate the vertical position of the top drive **140**, the travelling block **120**, and the hook **135**, which can vary from rig-to-rig). The hook position sensor is configured to detect the vertical distance the drill string **155** is raised and lowered, relative to the crown block **115**. In some embodiments, the hook position sensor is a draw works encoder, which may be the ROP sensor **130***a*. In some embodiments, the apparatus **100** also includes a rotary RPM sensor that is configured to detect the rotary RPM of the drill string **155**. This may be measured at the top drive **140** or elsewhere, such as at surface portion of the drill string **155**. In some embodiments, the apparatus **100** also includes a quill position sensor that is configured to detect a value or range of the rotational position of the quill **145**, such as relative to true north or another stationary reference. In some embodiments, the apparatus **100** also includes a pump pressure sensor that is configured to detect the pressure of mud or fluid that powers the BHA **170** at the surface or near the surface. In some embodiments, the apparatus also includes a MSE sensor that is configured to detect the MSE representing the amount of energy required per unit volume of drilled rock. In some embodiments, the MSE is not directly sensed, but is calculated based on sensed data at the controller **190** or other controller. In some embodiments, the apparatus **100** also includes a bit depth sensor that detects the depth of the bit **175**.

[0037] In one or more embodiments, the apparatus **100** may be utilized for directional drilling using a bent sub. Directional drilling includes both rotating drilling and slide drilling. During rotating drilling, the entire drill string **155**, including the bent sub, is rotated using the top drive **140**. Rotating drilling is typically used for vertical drilling (or "building"). During slide drilling, rotation of the drill string **155** is stopped, weight is applied to the drill bit **175**, and the motors **178** associated with the BHA **170** rotate the drill bit **175** while pointed, using the bent sub, in a direction to steer the bit **175** and well bore.

[0038] FIG. **2** is a diagrammatic illustration of a data flow for an automated directional control system **192** involving at least a portion of the apparatus **100**, according to one embodiments. Generally, the controller **190** is operably coupled to or includes a GUI **195**. The GUI **195** includes an input mechanism **200** for user-inputs or drilling parameters. The input mechanism **200** may include a touch-screen, keypad, voice-recognition apparatus, dial, button, switch, slide selector, toggle, such as a control mode toggle **202**, joystick, mouse, data base and/or other conventional or future-developed data input device. Such input mechanism **200** may support data input from local and/or remote locations. Alternatively, or additionally, the input mechanism **200** may include means for user-selection of input parameters, such as predetermined toolface set point values or ranges, such as via one or more drop-down menus, input windows, etc. Drilling parameters may also or alternatively be selected by the controller **190** via the execution of one or more database look-up procedures. In general, the input mechanism **200** and/or other components within the scope of the present disclosure support operation and/or monitoring from stations on the rig site as well as one or more remote locations with a communications link to the system, network, local area network ("LAN"), wide area network ("WAN"), Internet, satellite-link, and/or radio, among other means. The GUI **195** may also include a display **205** for visually presenting information to the user in textual, graphic, or video form. The display **205** may also be utilized by the user to input the input parameters in conjunction with the input mechanism **200**. For example, the input mechanism **200** may be integral to or otherwise communicably coupled with the display **205**. In some embodiments, the display **205** is arranged to present visualizations of a down hole environment, such as a two-dimensional visualization and/or a three-dimensional visualization. Depending on the implementation, the display **205** may include, for example, an LED or LCD display computer monitor, touchscreen display, television display, a projector, or other display device. The GUI **195** and the controller **190** may be discrete components that are interconnected via wired or wireless means. Alternatively, the GUI **195** and the controller **190** may be integral components of a single system or controller. The controller **190** is configured to receive electronic signals via wired or wireless transmission means (not shown) from a plurality of sensors **210** included in the apparatus **100**, where each sensor is configured to detect an operational characteristic or parameter. The controller **190** also includes a drilling module **235** to control a drilling operation. In the embodiment shown, the drilling module is or includes a smartslide program configured to control at least a portion of a slide drill segment of the drilling operation.

[0039] The drilling module **235** may include a variety of sub modules, with each of the sub modules being associated with a predetermined workflow or recipe that executes a task from beginning to end. In the embodiment shown, the drilling module **235** includes a slide score optimization submodule **240**, including a ramping mode **245**, and a ROP optimization submodule **250**, including a ROP control mode **255** and a WOB control mode **260**. Often, the predetermined workflow includes a set of computer-implemented instructions for executing the task from beginning to end, with the task being one that includes a repeatable sequence of steps that take place to implement the task. The drilling module **235** generally implements the task of completing a steering operation, which steers the BHA **170** along the planned drilling path; recommends and executes the addition of another stand to the drill string **155**; recommends and executes the process of tripping out the BHA **170**; among other operations. Generally, the instructions for executing a task are based on a plurality of rules or constraints **265**. Using the data provided from a plurality of inputs **215** or the plurality of sensors **210**, the drilling module **235** is configured to calculate a plurality of metrics **270**. Using the plurality of metrics **270**, and referencing the plurality of constraints **265**, the drilling module **235** is configured to generate instructions that address trends in the data and keeps the drilling operation within tolerances and/or windows, and is further configured to adjust one or more drilling parameters **275** controlled by the drilling module **235**.

[0040] The drilling module **235** may be further configured to generate a control signal, such as via intelligent adaptive control, and provide the control signal to the top drive control system **220**, the mud pump control system **225**, and/or the draw works control system **230** to adjust and/or maintain the toolface orientation. For example, the drilling module **235** may provide one or more signals to the top drive control system **220** and/or the draw works control system **230** to increase or decrease WOB and/or quill position, such as may be required to accurately "steer" the drilling operation or increase ROP. In some embodiments, the controller **190** is also operably coupled to a top drive control system **220**, a mud pump control system **225**, and a draw works control system **230**, and is configured to send signals to each of the control systems **220**, **225**, and **230** to control the operation of the top drive **140**, the mud pump **181**, and the draw works **130**. However, in other embodiments, the controller **190** includes each of the control systems **220**, **225**, and **230** and thus sends signals to each of the top drive **140**, the mud pump **181**, and the draw works **130**.

[0041] In some embodiments, the top drive control system **220** includes the top drive **140**, the speed sensor **140***b*, the torque sensor **140***a*, and the hook load sensor **140***c*. The top drive control system **220** is not required to include the top drive **140**, but instead may include other drive systems, such as a power swivel, a rotary table, a coiled tubing unit, a downhole motor, and/or a conventional rotary rig, among others.

[0042] In some embodiments, the mud pump control system **225** includes a mud pump controller and/or other means for controlling the flow rate and/or pressure of the output of the mud pump **181**.

[0043] In some embodiments, the draw works control system **230** includes the draw works controller and/or other means for controlling the feed-out and/or feed-in of the drilling line **125**. Such control may include rotational control of the draw works (in v. out) to control the height or position of the hook **135** and may also include control of the rate the hook **135** ascends or descends.

[0044] The plurality of sensors **210** may include the ROP sensor **130***a;* the torque sensor **140***a;* the quill speed sensor **140***b;* the hook load sensor **140***c;* the surface casing annular pressure sensor **187**; the downhole annular pressure sensor **170***a;* the shock/vibration sensor **170***b;* the toolface sensor **170***c;* the MWD WOB sensor **170***d;* the mud motor delta pressure sensor; the bit torque sensor **172***b;* the hook position sensor; a rotary RPM sensor; a quill position sensor; a pump pressure sensor; a MSE sensor; a bit depth sensor; and any variation thereof. The data detected by any of the sensors in the plurality of sensors **210** may be sent via electronic signal to the controller **190** via wired or wireless transmission. The functions of the sensors **130***a*, **140***a*, **140***b*, **140***c*, **187**, **170***a*, **170***b*, **170***c*, **170***d*, **172***a*, and **172***b* are discussed above and will not be repeated here.

[0045] In some embodiments the top drive control system **220** includes the torque sensor **140***a*, the quill position sensor, the hook load sensor **140***c*, the pump pressure sensor, the MSE sensor, and the rotary RPM sensor, and a controller and/or other means for controlling the rotational position, speed and direction of the quill or other drill string component coupled to the drive system (such as the quill **145** shown in FIG. **1**). The top drive control system **220** is configured to receive a top drive control signal from the drilling module **235**, if not also from other components of the apparatus **100**. The top drive control signal directs the position (e.g., azimuth), spin direction, spin rate, and/or oscillation of the quill **145**.

[0046] In some embodiments, the draw works control system **230** comprises the hook position sensor, the ROP sensor **130***a*, and the draw works controller and/or other means for controlling the length of drilling line **125** to be fed-out and/or fed-in and the speed at which the drilling line **125** is to be fed-out and/or fed-in.

[0047] In some embodiments, the mud pump control system **225** comprises the pump pressure sensor and the motor delta pressure sensor **172***a*.

[0048] FIG. **3** illustrates the plurality of metrics **270**, according to one or more embodiments. In one or more embodiments, as discussed above, the plurality of metrics **270** may be generated or referenced by the drilling module **235**. In one or more embodiments, the plurality of metrics **270** include: (a) a toolface position **270***a*, which indicates which direction the high side of the motor is facing with respect to magnetics or gravity MWD readings; (b) a toolface movement **270***b*, which is the distance in degrees between consecutive toolface values, where positive values indicate clockwise movement and negative values indicate counter-clockwise movement; (c) a toolface precision **270***c*, which is the running average of the absolute values of each of the last five toolface distances from the average toolface, measured in degrees; (d) a WOB **270***d*, which is the raw value or actual value of the WOB; (e) a WOB setting **270***e*, which is a setpoint for the WOB in the drilling module **235** that limits the amount of WOB used for drilling; (f) a WOB average **270***f*, which is the running average WOB calculated over a period of time, such as, for example, the previous one minute period of drilling; (g) a ROP **270***g*, which is the raw value or actual value of the ROP; (h) a ROP setting **270***h*, which is a setpoint for the ROP in the drilling module **235** that limits the amount of ROP used for drilling; (i) a ROP average, which is the running average ROP calculated using the change in position of the traveling block **120** over a period of time, such as, for example, the previous one minute period of drilling; (j) a differential pressure **270***j*, which is the raw value or actual value of the differential pressure, and which, in one or more embodiments, refers to the difference in pressure between the pressure exerted by the drilling fluid in the wellbore and the pressure of the formation at a given depth; (k) a differential pressure setting **270***k*, which is the setpoint for the differential pressure in the drilling module **235** that limits the amount of differential pressure used for drilling; (l) a differential pressure average **270***l*, which is the running average differential pressure calculated over a period of time, such as, for example, the previous one minute period of drilling; (m) a total slide score **270***m*, which is a current slide score calculation that covers the entirety of the slide, grading the accuracy of the toolfaces relative to a target toolface, as a percentage from −100% to 100%; (n) a short-term slide score **270***n*, which is a running slide score for a period of time, such as, for example, a previous two minute period of the slide; and (o) a medium-term slide score **2700**, which is a running slide score for a period of time that is longer than the period of time associated with the short-term slide score **270***n*, such as, for example, a previous five minute period of drilling.

[0049] In one or more embodiments, the metrics **270** may also include, for example, a toolface distribution to target (e.g., percentage of toolface values within X degrees of the advisory toolface angle), resultant slide vector (e.g., the aggregate toolface direction of all toolface measurements throughout a single slide), current slide distance, remaining slide distance, bit proximity to steering line or steering window, qualitative information that describes the adherence of the as-drilled trajectory to the planned trajectory or input steering line, real-time information about the actual current inclination and azimuth of the BHA, as measured at the each stationary survey, and real-time information about the projected current inclination and azimuth of the bit, as well as other types of sensor data and feedback from various drilling systems.

[0050] FIG. **4** illustrates the plurality of drilling parameters **275** that may be adjusted by the drilling module **235** before or during a drilling operation. In one or more embodiments, each of the plurality of parameters is initially set via the plurality of inputs **215** received from a user via the GUI **195** or received automatically from a databased, recipe, well plan, etc. In one or more embodiments, the plurality of drilling parameters **275** includes: (a) a WOB setpoint **275***a;*

and (b) a ROP setpoint **275***b*. In one or more embodiments, the WOB setpoint **275***a* and the ROP setpoint **275***b* may be the only drilling parameters used by the drilling module **235** to control the drilling operation. In one or more embodiments, either the WOB setpoint **275***a* or the ROP setpoint **275***b* is controlling and the other is floating. As used herein, "floating" refers to setting the non-controlling parameter setpoint to a value that is a predetermined percentage above the current running average value metric of that parameter. For example, when the drilling module **235** is operating in the ROP control mode **255** of the ROP optimization submodule **250**, the ROP setpoint **275***b* is the controlling parameter that is continuously adjusted while the WOB setpoint **275***a* is the floating parameter that is maintained at a predetermined percentage above the WOB average **270***f*. For further example, when the drilling module **235** is operating in the WOB control mode **260** of the ROP optimization submodule **250**, the WOB setpoint **275***a* is the controlling parameter that is continuously adjusted while the ROP setpoint **275***b* is the floating parameter that is maintained at a predetermined percentage above the ROP average **270***i*.

[0051] In one or more embodiments, the plurality of drilling parameters **275** further includes: (c) a short-term slide score to increase **275***c*, which is a minimum short-term slide score and the average of the short-term slide score **270***n* and the medium-term slide score **2700** to trigger an increase in the controlling parameter; (d) a short-term slide score to decrease **275***d*, which is the maximum short-term slide score and the average of the short-term slide score **270***n* and the medium-term slide score **2700** to trigger a decrease in the controlling parameter; (e) a start total slide score **275***e*, which is the minimum total slide score **270***m* at a start of a slide to trigger an increase of the controlling parameter and the maximum value to trigger a decrease of the controlling parameter; (f) an end total slide score **275***f*, which is the minimum total slide score **270***m* at an end of a slide to trigger an increase of the controlling parameter and the maximum value to trigger a decrease of the controlling parameter, where a total slide score constraint is a moving value that changes linearly over the course of a slide if the start and end total slide scores are different; (g) an increase percentage **275***g*, which is a user- or recipe-defined percentage increase of ROP or WOB, depending on which control mode is being used, to be used anytime adjustment of the controlling parameter is triggered by the logic of the controller **190**; (h) a decrease percentage **275***h*, which is a user- or recipe-defined percentage decrease of ROP or WOB, depending on which control mode is being used, to be used anytime a decrease of the controlling parameter is triggered by the logic of the controller **190**; (i) a minimum wait time **275***i*, which is an amount of time that the drilling module **235** must wait before reevaluating whether the controlling parameter can be increased or decreased, such that a timer associated with the minimum wait time **275***i* resets after each adjustment of the controlling parameter, and, in one or more embodiments, the minimum wait time **275***i* has a default of 30 seconds plus at least one toolface position **270***a* must be received during this time, otherwise the drilling module **235** will wait up to an additional 30 seconds to receive a new toolface position **270***a*; (j) a toolface precision **275***j*, which is constantly calculated and must be less than 100 to increase parameters; (k) a toolface movement **275***k*, which is constantly calculated and must be less than 100 to increase parameters; and (l) a max WOB **275***l*, which is the maximum WOB setpoint that the drilling module **235** will write to the controller **190**.

[0052] In one or more embodiments, the initial setpoints for the plurality of parameters **275** may be received via user input or may be accessed from a recipe or database. In one or more embodiments, the initial setpoint of the percentage associated with the WOB setpoint **275***a* may be in the range from 0-percent to 150-percent, such that the WOB setpoint **275***a* 0-percent to 150-percent greater than an average WOB. In one or more embodiments, the initial setpoint of the percentage associated with the ROP setpoint **275***b* may be in the range from 0-percent to 150-percent, such that the ROP setpoint **275***b* 0-percent to 150-percent greater than an average ROP. In one or more embodiments, the initial setpoint of the short-term slide score to increase **275***c* may be in the range of −100 to 100. In one or more embodiments, the initial setpoint of the short-term slide score to decrease **275***d* may be in the range of 0 to 100. In one or more embodiments, the initial setpoint of the start total slide score **275***e* may be in the range of −50 to 100. In one or more embodiments, the initial setpoint of the end total slide score **275***f* may be in the range of 0 to 100. In one or more embodiments, the initial setpoint for the increase percentage **275***g* may be in the range of 1-percent to 20-percent. In one or more embodiments, the initial setpoint for the decrease percentage **275***h* may be in the range of 1-percent to 20-percent. In one or more embodiments, the initial setpoint for the minimum wait time **275***i* may be 30-seconds, 50-seconds, 70-seconds, 90-seconds, 120-seconds, or between 30- and 120-seconds. In one or more embodiments, the initial setpoint of the max WOB **275***l* may be in the range of 5 klb to 95 klb. In one or more embodiments, the initial setpoint, or proactive offset, for the toolface precision **275***i* and/or the toolface movement **275***k* may be from 0-degrees to 90-degrees.

[0053] In one or more other embodiments, the plurality of parameters, which may be received via the input mechanism **200** and/or from a database, may include a well plan input, a maximum WOB input, a top drive input, a draw works input, a mud pump input, best practices input, operating parameters, and equipment identification input, etc. In some embodiments, the plurality of operating parameters may include a maximum slide distance; a maximum dogleg severity; and a minimum radius of curvature. The plurality of operating parameters also includes orientation-tolerance window ("OTW") parameters, such as an inclination tolerance range and an azimuth tolerance range. The plurality of operating parameters also includes parameters that define an unwanted downhole trend, such as an equipment output trend parameters, geology trend parameters, and other downhole trend parameters. The plurality of operating parameters also includes location-tolerance window ("LTW") parameters, such as an offset direction, an offset distance, geometry, size, and dip angle. In some embodiments, the maximum slide distance may be zero. That is, no slides are recommended while the BHA **170** extends within a first formation type or during a specific period of time relative to the drilling process. The maximum slide distance is not limited to zero feet, but may be any number of feet or distance, such as for example 10 ft., 20 ft., 30 ft., 40, ft. 50 ft., 90 ft., etc. Generally, the maximum dogleg severity is the change in inclination over a distance and measures a build rate on a micro-level (e.g., 3°/100 ft.) while the minimum radius of curvature is associated with a build rate on a macro-level (e.g., 1°/1,000 ft.).

[0054] The orientation-tolerance window parameters include an inclination tolerance range and an azimuth tolerance range. In some embodiments, the inclination tolerance range and the azimuth tolerance range are associated with a location along the well plan and change depending upon the location along the well plan. That is, at some points along the well plan the inclination tolerance range and the azimuth tolerance range may be greater than the inclination tolerance range and the azimuth tolerance range along other points along the well plan.

[0055] FIG. **5**A-**5**C, with continued reference to FIGS. **1**-**4**, illustrates a method **500** of operating the automated directional drilling control system **192**, according to one or more embodiments.

[0056] In general, the automated directional drilling control system **192** of the present disclosure automatically adjusts drilling parameter setpoints (e.g., the setpoints of each of the plurality of parameters **275**) to optimize performance. Based on slide drilling performance goals, a set of constraints (e.g., the plurality of constraints **265**) is configured in a programmable logic computer ("PLC") associated with the controller **190** to optimize ROP and/or tool face control (or "slide scores") during slide drilling operations by automatically manipulating the drilling parameter setpoint when running an automated directional drilling control system. In one or more embodiments, the automated directional drilling control system **192** continually increases ROP and/or other drilling parameters if the constraints **265** are met. Automating the control of the drilling parameters standardizes the adjustment and control of the drill, which improves the consistency and efficiency of the drilling operation and reduces the incidence of human error. In one or more embodiments, the automated directional drilling control system monitors a plurality of conditions of the drilling operation. In one or more embodiments, a plurality of sensors (e.g., plurality of sensors **210**) associated with the apparatus **100** transmit data associated with these conditions to the automated directional drilling control system **192** and to the controller **190**. Using the logic with which the PLC of the controller **190** is programmed, and based on the data received from the plurality of sensors **210**, the automated directional drilling control system **192** continuously calculates a plurality of metrics (e.g., the plurality of metrics **270**) to be evaluated against the constraints **265**. In one or more embodiments, the metrics **270** may be calculated and evaluated in real-time, or near real-time. In or more embodiments, calculating the metrics **270** may include calculating running averages using real-time and historical data. Based on the evaluation of the metrics **270** against the constraints **265**, the controller **190** may increase, decrease, or maintain one or more of the drilling parameters **275**.

[0057] Now, with specific reference to FIG. **5**A, a first portion of method **500** for operating the automated directional drilling control system **192** is shown and described according to one or more embodiments of the present disclosure. In one or more embodiments, method **500** is executed using the drilling module **235** stored on the controller **190**.

[0058] At step **505**, a target slide score (or "slide score goal") to be obtained during a slide drill segment of a drilling operation is accessed. In one or more embodiments, the target slide score may be received by the controller **190** via a user input manually entered via the input mechanism **200** of the GUI **295**. In one or more embodiments, the target slide score may be accessed from a recipe stored in a database that may be positioned locally or remotely relative to the controller **190**. In one or more embodiments, the target slide score may include a range of acceptable slide scores. In one or more embodiments, the target slide score is associated with a target toolface of the BHA while performing the slide drill segment. In one or more embodiments, the target toolface is received via a user input using the input mechanism **200** of the GUI **295**. In one or more embodiments, the target toolface is accessed from a recipe stored in a database. In one or more embodiments, a target slide score is accessed at the beginning of each slide segment of a drilling operation. In one or more embodiments, the target slide score is accessed at the beginning of a first slide drill segment and may remain the same throughout two or more slide drill segments.

[0059] At step **510**, a first portion of the slide drill segment is performed, using the BHA **170**, in the ramping mode **245** of the slide score optimization submodule **240** of the drilling module **235**. In the ramping mode **245**, the drilling module **235** will continue to increase ROP as long as the target slide score is being achieved. This enables the system to maximize ROP without sacrificing accuracy of the direction of the slide.

[0060] At step **515**, during performance of the first portion of the slide drill segment in ramping mode **245**, downhole data is received from the plurality of sensors **210** associated with the apparatus **100**, including the BHA **170**. In one or more embodiments, the downhole data may include data associated with one or more of the plurality of parameters **275**. In one or more embodiments, the downhole data may include data associated with toolface precision **275*j*** and toolface movement **275*k***. In one or more embodiments, the downhole data is received by the controller **190**.

[0061] At step **520**, the downhole data and the target slide score are used by the controller **190** and/or the drilling module **235** to calculate an actual slide score associated with the first portion of the slide drill segment. In one or more embodiments, the actual slide score is calculated by receiving a set number of consecutive toolface readings from the plurality of sensors **210** during a period and comparing the received toolface readings with the target toolface.

[0062] At step **525**, the actual slide score calculated in step **520** is compared with the target slide score to determine whether the first portion of the slide drill segment is being performed as desired and is following the desired trajectory, path, or direction. In one or more embodiments, where the target slide score includes a range of acceptable slide scores, the comparison performed at step **525** includes a determination of whether the actual slide score is inside or outside the range of acceptable slide scores. In one or more embodiments, if the comparison at step **525** does not indicate or trigger an adjustment of the automated directional drilling control system **192**, then the method **500** proceeds to step **535**, which includes repeating steps **515** through **530** until a first condition is achieved. In one or more embodiments, if the comparison at step **525** does indicate or triggers an adjustment of the automated directional drilling control system **192**, then the method **500** proceeds to step **530**.

[0063] At step **530**, a ROP or ROP setpoint associated with the first portion of the slide drill segment is increased or decreased based on the comparison of the actual slide score with the target slide score. As generally stated above, as long as the target slide score is being achieved, the controller **190** will maximize ROP. In one or more embodiments, if the actual slide score is within a predetermined threshold associated with the target slide score, the ROP setpoint will be increased, and if the actual slide score is outside the predetermined threshold, the ROP setpoint will be decreased, or in some embodiments, remain unchanged. In one or more embodiments, where the target slide score includes a range of acceptable slide scores, if the actual slide score is within the range of acceptable slide score, the ROP setpoint will be increased, and if the actual slide score is outside the range of acceptable slide scores, the ROP setpoint will be decreased, or in some embodiments, remain unchanged. In one or more embodiments, the controller **190** implements the increase or decrease of the ROP setpoint. In one or more embodiments, adjusting the ROP setpoint is associated with, or triggers, adjustment of one or more of the plurality of parameters **275**. In one or more embodiments, adjusting the ROP setpoint includes or is associated with control signals being sent from the controller **190** to one or more of the top drive control system **220**, the mud pump control system **225**, and the draw works control system **230**. In one or more embodiments, after increasing or decreasing the ROP setpoint at step **530**, the method **500** continues to step **535**, which includes repeating steps **515** through **530** until a first condition is achieved.

[0064] At step **540**, a second portion of the slide drill segment is performed, using the BHA and after the first condition has been achieved, in either the ROP control mode **255** or the WOB control mode **260** of the ROP optimization submodule **250** of the drilling module **235**.

[0065] In one or more embodiments, the first condition includes the actual toolface or the actual slide score being equal to the target toolface or the target slide score, respectively. In one or more embodiments, the first condition includes receiving a selection associated with activating the ROP optimization submodule **250**. In one or more embodiments, the first condition includes receiving a selection associated with activating either the ROP control mode **255** or the WOB control mode **260**. In one or more embodiments, the first condition includes one or more conditions associated with the automated directional drilling control system **192** being achieved, which allows the ROP optimization submodule **250** to become active. In one or more embodiments, the one or more conditions that allow the ROP optimization submodule **250** to become active include: (a) a ROP optimization feature associated with the ROP optimization submodule **250** is ENABLED; (b) the apparatus **100**, the controller **190**, and the drilling module **235** are running and operational; (c) a pilot is ON and in a maintain mode, which is an automatic running mode and which is associated with a current slide sequence; (d) the bit is on bottom relative to the hole, where "on bottom" means, for example, the hole depth minus 0.5 ft, such that, for example, the bit depth is greater than or equal to the hole depth minus 0.5 ft; (e) a minimum number of toolfaces have been received, which may be a predetermined number of toolfaces; and (f) at least 1-minute of downhole data associated with the plurality of metrics **270**, including ROP **270***g*, WOB **270***d*, and differential pressure **270***j* data, have been received such that running averages, including WOB average **270***f*, ROP average **270***i*, and differential pressure average **270***l* can be calculated and utilized in the ROP optimization submodule **250**. Ensuring one or more of these conditions associated with the ROP optimization submodule **250** becoming active is achieved facilitates appropriate selections of initial setpoints of the plurality of parameters **275** and ensures that the differential pressure has stabilized after reaching (or "tagging") the bottom of the hole. In one or more embodiments, the ROP optimization submodule **250** may become active before or during each slide segment, or each portion of each slide segment.

[0066] Generally, before the ROP optimization submodule **250** becomes active, a recipe or user-defined parameter setpoints will be used. When the ROP optimization submodule **250** becomes active, the controller **190** sets the initial setpoint of the controlling parameter (e.g., ROP setpoint **275***b* or WOB setpoint **275***a*) to its current average (e.g., ROP average **270***i* or WOB average **270***f*) and begins "floating" the other parameter setpoint above its current average by a user-defined percentage. In one or more embodiments, a control mode toggle (e.g., control mode toggle **202**) is used when the ROP optimization submodule **250** is active to facilitate toggling or switching between the ROP control mode **255** and the WOB control mode **260** to effectively select which parameter is controlling and which parameter is floating throughout each slide segment, or each portion of each slide segment. If, in one or more embodiments, neither the ROP setpoint **275***b* or the WOB setpoint **275***a* is selected as the controlling parameter using, for example, the control mode toggle **202**, when the ROP optimization submodule **250** becomes active and enabled, then the parameter with a current actual value closest to its setpoint is automatically selected as the controlling parameter until a new controlling parameter is selected using the control mode toggle **202**.

[0067] In one or more embodiments, the setpoints of the floating parameters are blocked or prevented from being changed manually by a user or operator. In one or more embodiments, there are two sets of constraints **265** used to determine whether the controlling parameter should be increased to drill faster or decreased to drill slower during performance of the slide. In one or more embodiments, the sets of constraints incorporate one or more of the plurality of parameters **275** to constrain the controlling parameter and the operation of the automated directional drilling control system **192**. In one or more embodiments, if either set of constraints **265** is met, the controller **190** will adjust the controlling parameter setpoint by a user-defined percentage. After each adjustment, a timer associated with the wait time for recalculating and reevaluating the metrics **270** against the constraints **265** is reset and another adjustment cannot be made until at least the minimum wait time **275***i* has been reached again or expired. The rest of the constraints **265** for either set of constraints must also continue to be met when the minimum wait time **275***i* expires to make another adjustment to the controlling parameter.

[0068] FIG. **5**B illustrates a second portion of method **500**, according to one or more embodiments. In the second portion of method **500**, the second portion of the slide drill segment is performed, using the BHA **170** and after the achievement of the first condition, in the ROP control mode **255** of the ROP optimization submodule **250**.

[0069] At step **545**, the second portion of the slide drill segment is performed, using the BHA **170** and after the achievement of the first condition, in the ROP control mode **255**. In one or more embodiments, when operating in ROP control mode **255**, the ROP setpoint **275***b* is the controlling parameter of the plurality of parameters **275** during the performance of the second portion of the slide drill segment.

[0070] At step **550**, a second ROP setpoint **275***b* associated with the achievement of the first condition is identified. In one or more embodiments, the second ROP setpoint **275***b*, as the controlling parameter, is initially set to the current ROP average **270***i*, from which value the second ROP setpoint **275***b* is then adjusted during performance of the second portion of the slide drill segment. The other parameters, including the WOB setpoint **275***a*, of the plurality of parameters **275** are floating parameters that are set to values above their respective current average values so that those non-controlling parameters do not interfere with the controlling parameter's ability to control the performance of the second portion of the slide drill segment. In one or more embodiments, when in ROP control mode **255**, the WOB setpoint **275***a* is floated at a value that is a predetermined percentage greater than the WOB average **270***f*. In one or more embodiments, the predetermined percentage is a user defined value that is input via the GUI **195**, or it is accessed from a recipe stored in a database. In one or more embodiments, the WOB setpoint **275***a* is continuously and automatically updated and rewritten every 10-seconds to account for changes in the value of the WOB average **270***f*. That way, the WOB setpoint **275***a* will continuously float above the current WOB average **270***f*. In one or more embodiments, however, the WOB setpoint **275***a* will not be adjusted to exceed the max WOB **275***l*.

[0071] At step **555**, during performance of the second portion of the slide drill segment in ROP control mode **255**, second downhole data is received from the plurality of sensors **210** associated with the apparatus **100**, including the BHA **170**. In one or more embodiments, the second downhole data may include data associated with one or more of the plurality of parameters **275**. In one or more embodiments, the second downhole data is received by the controller **190**.

[0072] At step **560**, a first plurality of metrics, such as, for example, the plurality of metrics **270**, are calculated based on or using the second downhole data associated with the second portion of the slide drill segment. In one or more embodiments, the first plurality of metrics **270** are calculated using the controller **190**. In one or more embodiments, the first plurality of metrics **270** are calculated using the drilling module **235**.

[0073] At step **565**, the first plurality of metrics **270** are compared with a plurality of constraints, such as, for example, the plurality of constraints **265**. In one or more embodiments, the plurality of constraints **265** include two sets of constraints: (a) a set of constraints for increasing the setpoint of the controlling parameter; and (b) a set of constraints for decreasing the setpoint of the controlling parameter. In one or more embodiments, if none of the plurality of constraints are met by the first plurality of metrics **270**, no adjustments are made to the controlling parameter and the method proceeds to step **575**, which includes repeating steps **555** through **570**. In one or more embodiments, if the plurality of constraints are met by the first plurality of metrics **270**, the method proceeds to step **570**.

[0074] At step **570**, the second ROP setpoint **275***b* is increased or decreased based on the comparison of the first plurality of metrics **270** with the plurality of constraints **265**. In one or more embodiments, the second ROP setpoint **275***b* is increased if the first plurality of metrics **270** meet or satisfy a set of constraints for increasing the setpoint of the controlling parameter, and the second ROP setpoint **275***b* is decreased if the first plurality of metrics **270** meet or satisfy a set of constraints for increasing the setpoint of the controlling parameter, which sets of constraints will be described in more detail below.

[0075] At step **575**, steps **555** through **570** are repeated until a second condition is achieved. In one or more embodiments, the second condition includes the control mode toggle **202** being switched from ROP control mode **255** to WOB control mode **260**. In one or more embodiments, the second condition includes receiving a selection associated with deactivating the ROP optimization submodule **250**. In one or more embodiments, the second condition includes an actual slide score associated with the second portion of the slide drill segment deviating from a target slide score to a value outside acceptable thresholds or outside a range of acceptable slide scores, which, in one or more embodiments, may return the drilling module **235** to the slide score optimization submodule **240**.

[0076] FIG. **5**C illustrates a third portion of method **500**, according to one or more embodiments. In the third portion of method **500**, the second portion of the slide drill segment is performed, using the BHA **170** and after the achievement of the first condition, in the WOB control mode **260** of the ROP optimization submodule **250**. In one or more embodiments, as is described herein, the third portion of the method **500** may occur after the first portion of the method **500** rather than the second portion of the method **500**.

[0077] At step **580**, the second portion of the slide drill segment is performed, using the BHA **170** and after the achievement of the first condition, in the WOB control mode **260**. In one or more embodiments, when operating in WOB control mode **260**, the WOB setpoint **275***a* is the controlling parameter of the plurality of parameters **275** during the performance of the second portion of the slide drill segment.

[0078] At step **582**, a WOB setpoint **275***a* associated with the achievement of the first condition is identified. In one or more embodiments, the WOB setpoint **275***a*, as the controlling parameter, is initially set to the current WOB average **270***f*, plus 1 klbs in some embodiments, from which value the WOB setpoint **275***a* is then adjusted during performance of the second portion of the slide drill segment. The other parameters, including the ROP setpoint **275***b*, of the plurality of parameters **275** are floating parameters that are set to values above their respective current average values so that such non-controlling parameters do not interfere with the controlling parameter's ability to control the performance of the second portion of the slide drill segment. In one or more embodiments, when in WOB control mode **260**, the ROP setpoint **275***b* is floated at a value that is a predetermined percentage greater than the ROP average **270***i*. In one or more embodiments, the predetermined percentage is a user defined value that is input via the GUI **195**, or it is accessed from a recipe stored in a database. In one or more embodiments, the ROP setpoint **275***b* is continuously and automatically updated and rewritten every 10-seconds to account for changes in the value of the ROP average **270***i*. That way, the ROP setpoint **275***b* will continuously float above the current ROP average **270***i*. In one or more embodiments, however, the ROP setpoint **275***b* will not be adjusted below 15 ft/hr. In one or more embodiments, each time the floating value of the ROP setpoint **275***b* is adjusted, the ROP ramps to the new ROP setpoint **275***b* linearly over an 8-second period of time.

[0079] At step **584**, during performance of the second portion of the slide drill segment in WOB control mode **260**, second downhole data is received from the plurality of sensors **210** associated with the apparatus **100**, including the BHA **170**. In one or more embodiments, the second downhole data may include data associated with one or more of the plurality of parameters **275**. In one or more embodiments, the second downhole data is received by the controller **190**.

[0080] At step **586**, a first plurality of metrics, such as, for example, the plurality of metrics **270**, are calculated based on or using the second downhole data associated with the second portion of the slide drill segment performed in WOB control mode **260**. In one or more embodiments, the first plurality of metrics **270** are calculated using the controller **190**. In one or more embodiments, the first plurality of metrics **270** are calculated using the drilling module **235**.

[0081] At step **588**, the first plurality of metrics **270** are compared with a plurality of constraints, such as, for example, the plurality of constraints **265**. In one or more embodiments, the plurality of constraints **265** include two sets of constraints: (a) a set of constraints for increasing the setpoint of the controlling parameter; and (b) a set of constraints for decreasing the setpoint of the controlling parameter. In one or more embodiments, if none of the plurality of constraints are met by the first plurality of metrics **270**, no adjustments are made to the controlling parameter and the method proceeds to step **592**, which includes repeating steps **584** through **590**. In one or more embodiments, if the plurality of constraints is met by the first plurality of metrics **270**, the method proceeds to step **590**.

[0082] At step **590**, the WOB setpoint **275***a* is increased or decreased based on the comparison of the first plurality of metrics **270** with the plurality of constraints **265**. In one or more embodiments, the WOB setpoint **275***a* is increased if the first plurality of metrics **270** meet or satisfy a set of constraints for increasing the setpoint of the controlling parameter, and the WOB setpoint **275***a* is decreased if the first plurality of metrics **270** meet or satisfy a set of constraints for increasing the setpoint of the controlling parameter, which sets of constraints will be described in more detail below.

[0083] At step **592**, steps **584** through **590** are repeated until a second condition is achieved. In one or more embodiments, the second condition includes the control mode toggle **202** being switched from WOB control mode **260** to ROP control mode **255**. In one or more embodiments, the second condition includes receiving a selection associated with deactivating the ROP optimization submodule **250**. In one or more embodiments, the second condition includes an actual slide score associated with the second portion of the slide drill segment deviating from a target slide score to a value outside acceptable thresholds or outside a range of acceptable slide scores, which, in one or more embodiments, may return the drilling module **235** to the slide score optimization submodule **240**.

[0084] In one or more embodiments, method **500** may include performing a first portion of a slide drill segment in ramping mode **245** under slide score optimization submodule **240** and performing a second portion of the slide drill segment in ROP control mode **255** under ROP optimization submodule **250**. In one or more embodiments, method **500** may include performing a first portion of a slide drill segment in ramping mode **245** under slide score optimization submodule **240** and performing a second portion of the slide drill segment in WOB control mode **260** under ROP optimization submodule **250**. In one or more embodiments, method **500** may include performing a first portion of a slide drill segment in ramping mode **245** under slide score optimization submodule **240**, performing a second portion of the slide drill segment in ROP control mode **255** under ROP optimization submodule **250**, and performing a third portion of the slide drill segment in WOB control mode **260** under ROP optimization submodule **250**. In one or more embodiments, method **500** may include performing a first portion of a slide drill segment in ramping mode **245** under slide score optimization submodule **240**, performing a second portion of the slide drill segment in WOB control mode **260** under ROP optimization submodule **250**, and performing a third portion of the slide drill segment in ROP control mode **255** under ROP optimization submodule **250**.

[0085] In one or more embodiments, as discussed above, the plurality of constraints **265** may include a first set of constraints for increasing the controlling parameter and a second set of constraints for decreasing the controlling parameter.

[0086] In one or more embodiments, the set of constraints for increasing the controlling parameter include: (a) the minimum wait time **275***i* since the previous increase or decrease, or since the last evaluation of the constraints, has expired, or if a new toolface has not been received, waiting an additional 30-seconds after the expiration of the minimum wait time **275***i;* (b) the short-term slide score **270***n* is greater than the short-term slide score to increase **275***c;* (c) the average of the short- and medium-term slide scores **270***n,* **2700** is greater than the short-term slide score to increase **275***c;* (d) the total slide score **270***m* is greater than the total slide score, which changes from the start total slide score **275***e* to the end total slide score **275***f* over the course of any given slide distance; (e) the average toolface movement **270***b* is less than 100-degrees; (f) the toolface precision is less than 100-degrees; and (g) with respect to the toolface position **270***a*, either: the last toolface movement **270***b* was clockwise and was between left advisory and 90-degrees right of target; the last toolface movement **270***b* was counterclockwise and was within 90-degrees right to the target; the last toolface movement **270***b* was counterclockwise and left of target and the toolface movement **270***b* was less than 20-degrees and was within left advisory boundary to target; or after minimum time to wait **275***i* plus 30-seconds and the last toolface movement **270***b* was between left advisory boundary to 90-degrees right of target. In one or more embodiments, if each of these constraints is satisfied, the controlling parameter, whether it is the ROP setpoint **275***a* or the WOB setpoint **275***b,* is increased.

[0087] In one or more embodiments, the set of constraints for decreasing the controlling parameter include: (a) the minimum wait time **275***i* since the previous increase or decrease, or since the last evaluation of the constraints, has expired, or if a new toolface has not been received, waiting an additional 30-seconds after the expiration of the minimum wait time **275***i;* (b) the short-term slide score **270***n* is less than the short-term slide score to decrease **275***d;* (c) the average of the short- and medium-term slide scores **270***n,* **2700** is less than the short-term slide score to decrease **275***d;* (d) the total slide score **270***m* is less than the total slide score, which changes from the start total slide score **275***e* to the end total slide score **275***f* over the course of any given slide distance; and (e) with respect to the toolface position **270***a*, either: the last toolface movement **270***b* was counterclockwise and was between right advisory and 90-degrees left of target; the last toolface movement **270***b* was clockwise and was within 90-degrees left to the target; the last toolface movement **270***b* was clockwise and the toolface movement **270***b* was less than 20-degrees and was within right advisory boundary to target; or after minimum time to wait **275***i* plus 30-seconds and the last toolface movement **270***b* was between right advisory boundary to 90-degrees left of target. In one or more embodiments, if each of these constraints is satisfied, the controlling parameter, whether it is the ROP setpoint **275***a* or the WOB setpoint **275***b*, is decreased.

[0088] In one or more embodiments, if an increase is triggered when operating in ROP control mode **255**, the ROP setpoint **275***a* is increased by a predetermined percentage. In one or more embodiments, if a decrease is triggered when operating in ROP control mode **255**, the ROP setpoint **275***a* is decreased by a predetermined percentage. In one or more embodiments, if an increase is triggered when operating in WOB control mode **260**, either: if a valid ROP/WOB ratio has been calculated, the WOB setpoint **275***b* is increased by 1 klbs to 4 klbs based on the ratio; or if a valid ROP/WOB ratio has not been calculated, the WOB setpoint **275***b* is increased by 1 klbs to 4 klbs based on a predetermined percentage. In one or more embodiments, if a decrease is triggered when operating in WOB control mode **260**, the WOB setpoint **275***b* is decreased by a predetermined percentage, but in some embodiments, may not be decreased by more than 3 klbs. In one or more embodiments, any of the triggered increases or decreases may be made based on a determined ratio or relationship between any of the plurality of parameters **275**.

[0089] In one or more embodiments, the ROP/WOB ratio may only be calculated when an adjustment in the controlling parameter is triggered. In one or more embodiments, the ratio may be calculated as the change in the ROP average **270***i* divided by the change in the WOB average **270***f*. In one or more embodiments, the initial values of the ROP average **270***i* and the WOB average **270***f* are obtained when an increase in the controlling parameter is triggered, i.e., all constraints for increase have been met. Then, in one or more embodiments, the values of the subsequent ROP average **270***i* and WOB average **270***f* are obtained when the next adjustment is triggered or after a predetermined amount of time (e.g., default of 2-minutes), whichever is less. Using this ratio facilitates the ability to adjust the WOB setpoint **275***b* to yield a specific percentage change in ROP **270***g*. In one or more embodiments, if the ratio is less than 1, then the ratio should not be used when adjusting the WOB setpoint **275***b*, rather, in such situations, the WOB setpoint **275***b* should be increased by the predetermined percentage. In one or more embodiments, if the ratio is greater than 1 and yields a WOB **270***d* increase of less than 1 klb, the WOB setpoint **275***b* should be increased by 1 klb. In one or more embodiments, if the ratio yields a WOB **270***d* increase of more than 4 klbs, then the WOB setpoint **275***b* should be increased by 4 klbs.

[0090] In one or more embodiments, the controller **190** may also apply a corrective quill position adjustment depending on the tool face position **270***a* at the time an increase or decrease of the controlling parameter is triggered to counter the expected relative torque and toolface movement **270***b*. In one or more embodiments, this corrective quill position adjustment is referred to as a proactive offset.

[0091] In one or more embodiments, when all of the constraints for triggering an increase in the controlling parameter have been met, the controller **190** will automatically make a quill correction only in the clockwise direction using a proactive offset degrees parameter, which may be one of the plurality of parameters **275**. In one or more embodiments, this automatic quill correction is user-defined and may be anywhere from 0 to 90 degrees in magnitude. In one or more embodiments, if the last toolface position **270***a* was between the target toolface and 90 degrees counterclockwise of the target toolface, the entire user-defined proactive quill correction should be applied. However, in one or more embodiments, if the last toolface position **270***a* was between the target toolface and 90 degrees clockwise of the target toolface, only the proactive quill correction minus the error between the target toolface and the current toolface should be applied, and a “Toolface Remaining” tag should be reset to the default value found from a “Correction Frequency” tag on the display **205** of the GUI **195**. This prevents toolface corrections from being made at the same time as a proactive quill correction where they could potentially cancel each other out.

[0092] In one or more embodiments, when all of the constraints for triggering a decrease in the controlling parameter have been met, the controller **190** will automatically make a quill correction only in the counterclockwise direction using the proactive offset degrees parameter. In one or more embodiments, this automatic quill correction should be user-defined and can be anywhere from 0 to 90 degrees in magnitude. If the last toolface position **270***a* was between the target toolface and 90 degrees clockwise of the target toolface, the entire user-defined proactive quill correction should be applied. However, in one or more embodiments, if the last toolface position **270***a* was between the target toolface and 90 degrees counterclockwise of the target toolface, only the proactive quill correction minus the error between the target toolface and the current toolface should be applied, and the “Toolface Remaining” tag should be reset to the default value found from the “Correction Frequency” tag on the display **205** of the GUI **195**. This prevents toolface corrections from being made at the same time as a proactive quill correction where they could potentially cancel each other out.

[0093] FIG. **6** illustrates a schematic diagram of an example display apparatus, such as display **205** of GUI **195** showing a two-dimensional visualization **600**, according to one or more embodiments of the present disclosure. As shown in FIG. **6**, the two-dimensional visualization **600** includes an indicator **605** associated with the ROP optimization submodule **250**, which, as shown, is grayed-out when the ROP optimization submodule **250** is inactive.

[0094] FIG. **7** illustrates the two-dimensional visualization **600** including the indicator **605** associated with the ROP optimization submodule **250**. In the embodiment shown in FIG. **7**, the ROP optimization submodule **250** is active and the indicator **605** associated with the ROP optimization submodule **250** is expanded to show a constraints table **610** including one or more status indicators **615** associated with the set of constraints **265** for increasing the controlling parameter and one or more status indicators **620** associated with the set of constraints for decreasing the controlling parameter.

[0095] FIG. **8** illustrates another two-dimensional visualization **800** including a parameter table **625** associated with the plurality of parameters **275** and associated with the constraint table **610**, according to one or more embodiments of the present disclosure.

[0096] By adjusting the drilling parameter setpoints throughout the drilling operation automatically using the control system, significantly more efficient rates of penetration and tool face control, which are both indicators of the quality of the slide execution, are realized. The automated control of the drilling parameter setpoints to achieve the performance goals eliminates concerns and issues associated with human operators making individual decisions. The automated control system of the present disclosure will provide operators with a step change in slide drilling rate of penetration, minimize dependency and variability between drillers, reduce training time, promote scaling of the operation, and reduce overall costs.

[0097] FIG. **9** is a diagrammatic illustration of a node for implementing one or more example embodiments of the present disclosure, according to one or more aspects of the present disclosure.

[0098] In an example embodiment, as illustrated in FIG. **9** with continuing reference to FIGS. **1-4**, **5**A, **5**B, **50**, and **6-8**, an illustrative node **1000** for implementing one or more of the example embodiments described above and/or illustrated in FIGS. **1-4**, **5**A, **5**B, **5**C, and **6-8** is depicted. The node **1000** includes a microprocessor **1000***a*, an input device **1000***b*, a storage device **1000***c*, a video controller **1000***d*, a system memory **1000***e*, a display **1000***f*, and a communication device **1000***g* all interconnected by one or more buses **1000***h*. In several example embodiments, the storage device **1000***c* may include a floppy drive, hard drive, CD-ROM, optical drive, any other form of storage device and/or any combination thereof. In several example embodiments, the storage device **1000***c* may include, and/or be capable of receiving, a floppy disk, CD-ROM, DVD-ROM, or any other form of computer-readable medium that may contain executable instructions. In several example embodiments, the communication device **1000***g* may include a modem, network card, or any other device to enable the node to communicate with other nodes. In several example embodiments, any node represents a plurality of interconnected (whether by intranet or Internet) computer systems, including without limitation, personal computers, mainframes, PDAs, smartphones and cell phones.

[0099] In several example embodiments, one or more of the components of the systems described above and/or illustrated in FIGS. **1-4**, **5**A, **5**B, **50**, and **6-8** include at least the node **1000** and/or components thereof, and/or one or more nodes that are substantially similar to the node **1000** and/or components thereof. In several example embodiments, one or more of the above-described components of the node **1000**, the apparatus **10**, and/or the example embodiments described above and/or illustrated in FIGS. **1-4**, **5**A, **5**B, **5**C, and **6-8** include respective pluralities of same components.

[0100] In several example embodiments, one or more of the applications, systems, and application programs described above and/or illustrated in FIGS. **1-4**, **5**A, **5**B, **5**C, and **6-8** include a computer program that includes a plurality of instructions, data, and/or any combination thereof; an application written in, for example, Arena, HyperText Markup Language (HTML), Cascading Style Sheets (CSS), JavaScript, Extensible Markup Language (XML), asynchronous JavaScript and XML (Ajax), and/or any combination thereof; a web-based application written in, for example, Java or Adobe Flex, which in several example embodiments pulls real-time information from one or more servers, automatically refreshing with latest information at a predetermined time increment; or any combination thereof. The one or more server(s), in some embodiments may be remote (e.g., remote from apparatus **100** and/or the well stimulation apparatus) and accessible by a cloud or other network described herein. In other embodiments, the one or more server(s) are described as one or more edge server(s) and are located on a portion of apparatus **100** and/or the well stimulation apparatus.

[0101] In several example embodiments, a computer system typically includes at least hardware capable of executing machine readable instructions, as well as the software for executing acts (typically machine-readable instructions) that produce a desired result. In several example embodiments, a computer system may include hybrids of hardware and software, as well as computer sub-systems.

[0102] In several example embodiments, hardware generally includes at least processor-capable platforms, such as client-machines (also known as personal computers or servers), and hand-held processing devices (such as smart phones, tablet computers, personal digital assistants (PDAs), or personal computing devices (PCDs), for example). In several example embodiments, hardware may include any physical device that is capable of storing machine-readable instructions, such as memory or other data storage devices. In several example embodiments, other forms of hardware include hardware sub-systems, including transfer devices such as modems, modem cards, ports, and port cards, for example.

[0103] In several example embodiments, software includes any machine code stored in any memory medium, such as RAM or ROM, and machine code stored on other devices (such as floppy disks, flash memory, or a CD ROM, for example). In several example embodiments, software may include source or object code. In several example embodiments, software encompasses any set of instructions capable of being executed on a node such as, for example, on a client machine or server. In some embodiments, software includes one or more software modules including code, programming object, programming structure, or combinations thereof. In one or more embodiments, the one or more software modules comprise, by way of nonlimiting examples, a web application, a mobile application, and a standalone application. In various embodiments, software modules are in more than one computer program or application. In some embodiments, the software modules are hosted by more than one machine. In some embodiments, the software modules are hosted by more than one machine in more than one location.

[0104] In several example embodiments, combinations of software and hardware could also be used for providing enhanced functionality and performance for certain embodiments of the present disclosure. In an example embodiment, software functions may be directly manufactured into a silicon chip. Accordingly, it should be understood that combinations of hardware and software are also included within the definition of a computer system and are thus envisioned by the present disclosure as possible equivalent structures and equivalent methods.

[0105] In several example embodiments, computer readable mediums include, for example, passive data storage, such as a random-access memory (RAM) as well as semi-permanent data storage such as a compact disk read only memory (CD-ROM). One or more example embodiments of the present disclosure may be embodied in the RAM of a computer to transform a standard computer into a new specific computing machine. In several example embodiments, data structures are defined organizations of data that may enable an embodiment of the present disclosure. In an example embodiment, a data structure may provide an organization of data, or an organization of executable code.

[0106] In several example embodiments, any networks and/or one or more portions thereof may be designed to work on any specific architecture. In an example embodiment, one or more portions of any networks may be executed on a single computer, local area networks, client-server networks, wide area networks, internets, hand-held and other portable and wireless devices and networks.

[0107] In several example embodiments, a database may be any standard or proprietary database software. In several example embodiments, the database may have fields, records, data, and other database elements that may be associated through database specific software. In several example embodiments, data may be mapped. In several example embodiments, mapping is the process of associating one data entry with another data entry. In an example embodiment, the data contained in the location of a character file can be mapped to a field in a second table. In several example embodiments, the physical location of the database is not limiting, and the database may be distributed. In an example embodiment, the database may exist remotely from the server, and run on a separate platform. In an example embodiment, the database may be accessible across the Internet. In several example embodiments, more than one database may be implemented.

[0108] In several example embodiments, a plurality of instructions stored on a computer readable medium may be executed by one or more processors to cause the one or more processors to carry out or implement in whole or in part the above-described operation of each of the above-described example embodiments of the system, the method, and/or any combination thereof. In several example embodiments, such a processor may include one or more of the microprocessor **1000***a*, any processor(s) that are part of the components of the system, and/or any combination thereof, and such a computer readable medium may be distributed among one or more components of the system. In several example embodiments, such a processor may execute the plurality of instructions in connection with a virtual computer system. In several example embodiments, such a plurality of instructions may communicate directly with the one or more processors, and/or may interact with one or more operating systems, middleware, firmware, other applications, and/or any combination thereof, to cause the one or more processors to execute the instructions.

[0109] In several example embodiments, the elements and teachings of the various illustrative example embodiments may be combined in whole or in part in some or all of the illustrative example embodiments. In addition, one or more of the elements and teachings of the various illustrative example embodiments may be omitted, at least in part, and/or combined, at least in part, with one or more of the other elements and teachings of the various illustrative embodiments.

[0110] Any spatial references such as, for example, "upper," "lower," "above," "below," "between," "bottom," "vertical," "horizontal," "angular," "upwards," "downwards," "side-to-side," "left-to-right," "right-to-left," "top-to-bottom," "bottom-to-top," "top," "bottom," "bottom-up," "top-down," etc., are for the purpose of illustration only and do not limit the specific orientation or location of the structure described above.

[0111] In several example embodiments, while different steps, processes, and procedures are described as appearing as distinct acts, one or more of the steps, one or more of the processes, and/or one or more of the procedures may also be performed in different orders, simultaneously, and/or sequentially. In several example embodiments, the steps, processes and/or procedures may be merged into one or more steps, processes, and/or procedures.

[0112] In several example embodiments, one or more of the operational steps in each embodiment may be omitted. Moreover, in some instances, some features of the present disclosure may be employed without a corresponding use of the other features. Moreover, one or more of the above-described embodiments and/or variations may be combined in whole or in part with any one or more of the other above-described embodiments and/or variations and this is within the contemplated scope of disclosure herein, unless stated otherwise.

[0113] The phrase "at least one of A and B" should be understood to mean "A, B, or both A and B." The phrases "one or more of the following: A, B, and C" and "one or more of A, B, and C" should each be understood to mean "A; B; C; A and B; B and C; A and C; or all three of A, B, and C."

[0114] The present disclosure provides a method, including: (a) accessing a target slide score to be obtained during a slide drill segment; wherein the target slide score is associated with a target tool face; (b) performing, using a bottom hole assembly ("BHA"), a first portion of the slide drill segment in a ramping mode; wherein performing, using the BHA, the first portion of control system steerable system, first downhole data from the BHA during the first portion of the slide drill segment; (d) calculating, by the control system and based on the first downhole data and the target tool face, an actual slide score; (e) comparing, by the control system, the actual slide score with the target slide score; (f) increasing or decreasing, based on the comparison of step (e), a rate of penetration ("ROP") setpoint; and (g) repeating steps (c)-(f) until a first condition is achieved; and (h) performing, using the BHA and after the achievement of the first condition, a second portion of the slide drill segment in either: a ROP control mode; or a weight on bit ("WOB") control mode. In one or more embodiments, the first condition includes the actual slide score being equal to the target slide score. In one or more embodiments, the second portion of the slide drill segment is performed in ROP control mode; and wherein performing the second portion of the slide drill segment in ROP control mode includes: (i) identifying a second ROP setpoint associated with the achievement of the first condition; (j) receiving, by the control system, second downhole data from the BHA during the second portion of the slide drill segment; (k) calculating, by the control system and based on the second downhole data associated with the second portion, a first plurality of metrics; (l) comparing, by the control system, the first plurality of metrics with a plurality of constraints; (m) increasing or decreasing, based on the comparison of step (l), the second ROP setpoint; and (n) repeating steps (j)-(m) until a second condition is achieved. In one or more embodiments, the second ROP setpoint is based on a historical ROP from the performance of the first portion of the slide drill segment. In one or more embodiments, the first condition includes receipt, by the control system, of a first selection including a selection of the ROP control mode; and the second condition includes receipt, by the control system, of a second selection including a selection of the WOB control mode. In one or more embodiments, the second portion of the slide drill segment is performed in WOB control mode; and wherein performing the second portion of the slide drill segment in WOB control mode includes: (i) identify a WOB setpoint associated with the achievement of the first condition; (j) receiving, by the control system, second downhole data from the BHA during the second portion of the slide drill segment; (k) calculating, by the control system and based on the second downhole data associated with the second portion, a first plurality of metrics; (l) comparing, by the control system, the first plurality of metrics with the plurality of constraints; (m) increasing or decreasing, based on the comparison of step (l), the WOB setpoint; and (n) repeating steps (j)-(m) until a second condition is achieved. In one or more embodiments, increasing the WOB setpoint includes increasing the WOB setpoint by a predetermined value. In one or more embodiments, the predetermined value is based on a ratio. In one or more embodiments, the ratio is the change in an average ROP over the change in an average WOB. In one or more embodiments, the method further includes (o) performing, using the BHA and after the achievement of the second condition, a third portion of the slide drill segment in ROP control mode; wherein performing the third portion of the slide drill segment in ROP control mode includes: (p) identifying a second ROP setpoint associated with the achievement of the second condition; (q) receiving, by the control system, third downhole data from the BHA during the third portion of the slide drill segment; (r) calculating, by the control system and based on the third downhole data associated with the third portion, a second plurality of metrics; (s) comparing, by the control system, the second plurality of metrics with the plurality of constraints; (t) increasing or decreasing, based on the comparison of step(s), the second ROP setpoint; and (u) repeating steps (q)-(t) until a third condition is achieved. In one or more embodiments, the target slide score includes a range of acceptable slide scores; step (e) further includes determining that the actual slide score is within the range of acceptable slide scores of the target slide score; and step (f) further includes increasing, based on the determination that the actual slide score is within the range of acceptable slide scores of the target slide score, the ROP setpoint. In one or more embodiments, step (h) includes: assigning, when in ROP control mode, a value to a WOB setpoint that is a predetermined percentage above an average WOB; and assigning, when in WOB control mode, a value to a second ROP setpoint that is a predetermined percentage above an average ROP.

[0115] The present disclosure also provides a system, including: a non-transitory computer readable medium having stored thereon a plurality of instructions, wherein the instructions are executed with one or more processors so that the following steps are executed: (a) accessing a target slide score to be obtained during a slide drill segment; wherein the target slide score is associated with a target tool face; (b) performing, using a bottom hole assembly ("BHA"), a first portion of the slide drill segment in a ramping mode; wherein performing, using the BHA, the first portion of the slide drill segment in ramping mode includes: (c) receiving first downhole data from the BHA during the first portion of the slide drill segment; (d) calculating, based on the first downhole data and the target tool face, an actual slide score; (e) comparing the actual slide score with the target slide score; (f) increasing or decreasing, based on the comparison of step (e), a rate of penetration ("ROP") setpoint; and (g) repeating steps (c)-(f) until a first condition is achieved; and (h) performing, using the BHA and after the achievement of the first condition, a second portion of the slide drill segment in either: a ROP control mode; or a weight on bit ("WOB") control mode. In one or more embodiments, the first condition is the target slide score. In one or more embodiments, the second portion of the slide drill segment is performed in ROP control mode; and performing the second portion of the slide drill segment in ROP control mode includes: (i) identifying a second ROP setpoint associated with the achievement of the first condition; (j) receiving second downhole data from the BHA during the second portion of the slide drill segment; (k) calculating, based on the second downhole data associated with the second portion, a first plurality of metrics; (l) comparing the first plurality of metrics with a plurality of constraints; (m) increasing or decreasing, based on the comparison of step (l), the second ROP setpoint; and (n) repeating steps (j)-(m) until a second condition is achieved. In one or more embodiments, the second ROP setpoint is an average ROP when step (i) is executed. In one or more embodiments, the first condition includes receipt of a first user selection including a selection of the ROP control mode; and the second condition includes receipt of a second user selection including a selection of the WOB control mode. In one or more embodiments, the second portion of the slide drill segment is performed in WOB control mode; and performing the second portion of the slide drill segment in WOB control mode includes: (i) identify a WOB setpoint associated with the achievement of the first condition; (j) receiving second downhole data from the BHA during the second portion of the slide drill segment; (k) calculating, based on the second downhole data associated with the second portion, a first plurality of metrics; (l) comparing the first plurality of metrics with the plurality of constraints; (m) increasing or decreasing, based on the comparison of step (l), the WOB setpoint; and (n) repeating steps (j)-(m) until a second condition is achieved. In one or more embodiments, the target slide score includes a range of acceptable slide scores; step (e) further includes determining that the actual slide score is within the range of acceptable slide scores of the target slide score; and step (f) further includes increasing, based on the determination that the actual slide score is within the range of acceptable slide scores of the target slide score, the ROP setpoint. In one or more embodiments, step (h) includes: assigning, when in ROP control mode, a value to a WOB setpoint that is a predetermined percentage above an average WOB; and assigning, when in WOB control mode, a value to a second ROP setpoint that is a predetermined percentage above an average ROP.

[0116] It is understood that variations may be made in the foregoing without departing from the scope of the present disclosure.

[0117] In several embodiments, one or more of the operational steps in each embodiment may be omitted. Moreover, in some instances, some features of the present disclosure may be employed without a corresponding use of the other features. Moreover, one or more of the embodiments disclosed above, or variations thereof, may be combined in whole or in part with any one or more of the other embodiments described above, or variations thereof.

[0118] Although several embodiments have been described in detail above, the embodiments described are illustrative only and are not limiting, and those skilled in the art will readily appreciate that many other modifications, changes and/or substitutions are possible in the embodiments without materially departing from the novel teachings and advantages of the present disclosure. Accordingly, all such modifications, changes, and/or substitutions are intended to be included within the scope of this disclosure as defined in the following claims. In the claims, any means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures. Moreover, it is the express intention of the applicant not to invoke 35 U.S.C. § 112(f) for any limitations of any of the claims herein, except for those in which the claim expressly uses the word "means" together with an associated function.

What is claimed is:

1. A method comprising:

(a) accessing a target slide score to be obtained during a slide drill segment;

wherein the target slide score is associated with a target tool face;

(b) performing, using a bottom hole assembly ("BHA"), a first portion of the slide drill segment in a ramping mode;

wherein performing, using the BHA, the first portion of the slide drill segment in ramping mode comprises:

(c) receiving, by a control system, first downhole data from the BHA during the first portion of the slide drill segment;

(d) calculating, by the control system and based on the first downhole data and the target tool face, an actual slide score;

(e) comparing, by the control system, the actual slide score with the target slide score;

(f) increasing or decreasing, based on the comparison of step (e), a rate of penetration ("ROP") setpoint; and

(g) repeating steps (c)-(f) until a first condition is achieved; and

(h) performing, using the BHA and after the achievement of the first condition, a second portion of the slide drill segment in either:

a ROP control mode; or

a weight on bit ("WOB") control mode.

2. The method of claim **1**,

wherein the first condition includes the actual slide score being equal to the target slide score.

3. The method of claim **1**,

wherein the second portion of the slide drill segment is performed in ROP control mode; and

wherein performing the second portion of the slide drill segment in ROP control mode comprises:

(i) identifying a second ROP setpoint associated with the achievement of the first condition;

(j) receiving, by the control system, second downhole data from the BHA during the second portion of the slide drill segment;

(k) calculating, by the control system and based on the second downhole data associated with the second portion, a first plurality of metrics;

(l) comparing, by the control system, the first plurality of metrics with a plurality of constraints;

(m) increasing or decreasing, based on the comparison of step (l), the second ROP setpoint; and

(n) repeating steps (j)-(m) until a second condition is achieved.

4. The method of claim **3**,

wherein the second ROP setpoint is based on a historical ROP from the performance of the first portion of the slide drill segment.

5. The method of claim **3**,

wherein the first condition includes receipt, by the control system, of a first selection including a selection of the ROP control mode; and

wherein the second condition includes receipt, by the control system, of a second selection including a selection of the WOB control mode.

6. The method of claim **1**,

wherein the second portion of the slide drill segment is performed in WOB control mode; and

wherein performing the second portion of the slide drill segment in WOB control mode comprises:

(i) identify a WOB setpoint associated with the achievement of the first condition;

(j) receiving, by the control system, second downhole data from the BHA during the second portion of the slide drill segment;

(k) calculating, by the control system and based on the second downhole data associated with the second portion, a first plurality of metrics;

(l) comparing, by the control system, the first plurality of metrics with a plurality of constraints;

(m) increasing or decreasing, based on the comparison of step (l), the WOB setpoint; and

(n) repeating steps (j)-(m) until a second condition is achieved.

7. The method of claim **6**,

wherein increasing the WOB setpoint comprises increasing the WOB setpoint by a predetermined value.

8. The method of claim **7**,

wherein the predetermined value is based on a ratio.

9. The method of claim **8**,

wherein the ratio is a change in an average ROP over the change in an average WOB.

10. The method of claim **6**, further comprising:

(o) performing, using the BHA and after the achievement of the second condition, a third portion of the slide drill segment in ROP control mode;

wherein performing the third portion of the slide drill segment in ROP control

(p) identifying a second ROP setpoint associated with the achievement of the second condition;

(q) receiving, by the control system, third downhole data from the BHA during the third portion of the slide drill segment;
(r) calculating, by the control system and based on the third downhole data associated with the third portion, a second plurality of metrics;
(s) comparing, by the control system, the second plurality of metrics with the plurality of constraints;
(t) increasing or decreasing, based on the comparison of step(s), the second ROP setpoint; and
(u) repeating steps (q)-(t) until a third condition is achieved.

11. The method of claim **1**,
wherein the target slide score includes a range of acceptable slide scores;
wherein step (e) further comprises determining that the actual slide score is within the range of acceptable slide scores of the target slide score; and
wherein step (f) further comprises increasing, based on the determination that the actual slide score is within the range of acceptable slide scores of the target slide score, the ROP setpoint.

12. The method of claim **1**,
wherein step (h) comprises:
assigning, when in ROP control mode, a value to a WOB setpoint that is a predetermined percentage above an average WOB; and
assigning, when in WOB control mode, a value to a second ROP setpoint that is a predetermined percentage above an average ROP.

13. A system, comprising:
a non-transitory computer readable medium having stored thereon a plurality of instructions, wherein the instructions are executed with one or more processors so that the following steps are executed:
(a) accessing a target slide score to be obtained during a slide drill segment;
wherein the target slide score is associated with a target tool face;
(b) performing, using a bottom hole assembly ("BHA"), a first portion of the slide drill segment in a ramping mode;
wherein performing, using the BHA, the first portion of the slide drill segment in ramping mode comprises:
(c) receiving first downhole data from the BHA during the first portion of the slide drill segment;
(d) calculating, based on the first downhole data and the target tool face, an actual slide score;
(e) comparing the actual slide score with the target slide score;
(f) increasing or decreasing, based on the comparison of step (e), a rate of penetration ("ROP") setpoint; and
(g) repeating steps (c)-(f) until a first condition is achieved; and
(h) performing, using the BHA and after the achievement of the first condition, a second portion of the slide drill segment in either:
a ROP control mode; or
a weight on bit ("WOB") control mode.

14. The system of claim **13**,
wherein the first condition is the target slide score.

15. The system of claim **13**,
wherein the second portion of the slide drill segment is performed in ROP control mode;
wherein performing the second portion of the slide drill segment in ROP control mode comprises:
(i) identifying a second ROP setpoint associated with the achievement of the first condition;
(j) receiving second downhole data from the BHA during the second portion of the slide drill segment;
(k) calculating, based on the second downhole data associated with the second portion, a first plurality of metrics;
(l) comparing the first plurality of metrics with a plurality of constraints;
(m) increasing or decreasing, based on the comparison of step (l), the second ROP setpoint; and
(n) repeating steps (j)-(m) until a second condition is achieved.

16. The system of claim **15**,
wherein the second ROP setpoint is an average ROP when step (i) is executed.

17. The system of claim **15**,
wherein the first condition includes receipt of a first user selection including a selection of the ROP control mode; and
wherein the second condition includes receipt of a second user selection including a selection of the WOB control mode.

18. The system of claim **13**,
wherein the second portion of the slide drill segment is performed in WOB control mode; and
wherein performing the second portion of the slide drill segment in WOB control
(i) identify a WOB setpoint associated with the achievement of the first condition;
(j) receiving second downhole data from the BHA during the second portion of the slide drill segment;
(k) calculating, based on the second downhole data associated with the second portion, a first plurality of metrics;
(l) comparing the first plurality of metrics with a plurality of constraints;
(m) increasing or decreasing, based on the comparison of step (l), the WOB setpoint; and
(n) repeating steps (j)-(m) until a second condition is achieved.

19. The system of claim **13**,
wherein the target slide score includes a range of acceptable slide scores;
wherein step (e) further comprises determining that the actual slide score is within the range of acceptable slide scores of the target slide score; and
wherein step (f) further comprises increasing, based on the determination that the actual slide score is within the range of acceptable slide scores of the target slide score, the ROP setpoint.

20. The system of claim **13**, wherein step (h) comprises:

assigning, when in ROP control mode, a value to a WOB setpoint that is a predetermined percentage above an average WOB; and

assigning, when in WOB control mode, a value to a second ROP setpoint that is a predetermined percentage above an average ROP.

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