New rotary steerable systems improve drilling efficiency

Latest tools offer greater precision, reliability

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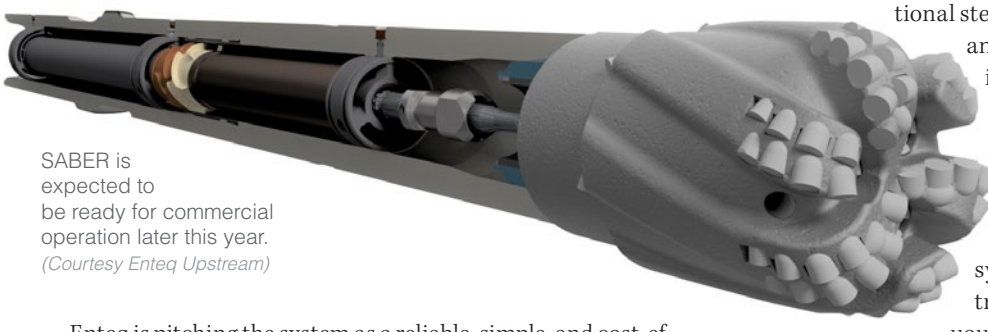
AS THE OFFSHORE DRILLING MARKET RECOVERS, downhole service providers are introducing and advancing rotary steerable systems (RSS) that enhance efficiency and deliver accurate wellbore placement and quality.

Enteq Upstream, the newest company to *Offshore*'s annual RSS directory, has introduced the SABER (Steer-At-Bit Enteq Rotary) tool for directional drilling. Shell has proven and tested an evolution of the concept, and the system is now ready for next-stage field trials.

SABER uses an internally directed pressure differential system to steer from the drill bit face, which is said to provide true 'at-bit' geosteering. The mechanically simple design, the company said, avoids the need for traditional pistons and pads susceptible to rapid wear and reliability issues, resulting in a smoother, more precise wellbore with easy to manage directional control.



SABER is expected to be ready for commercial operation later this year. *(Courtesy Enteq Upstream)*

Enteq is pitching the system as a reliable, simple, and cost-effective directional drilling alternative to current RSS options. The company licensed the designs and intellectual property from Shell in September 2019 following successful initial trials. Its technical team has since re-engineered the concept.

Baker Hughes has added the Lucida rotary steerable service to its directional drilling offerings.

According to the company, drilling performance is optimized through an integrated bottomhole assembly that features a customized drill bit, real-time dynamics sensors, and multi-chip module electronics. The near-bit dynamic sensors measure downhole weight-on-bit, torque, bending moment and direction, while the accelerometers in the primary electronics measure axial and lateral vibration as well as high-frequency torsional oscillations. The real-time bending moment and direction measurements are said to enhance directional control and can also be used for stringer detection. The multi-chip module electronics are said to increase reliability and operating range.

The new RSS enables drillers to hit their geological targets the first time, with no side tracks, the company claimed. Located near the bit, 16-sector gamma-ray sensors provide real-time formation data that enable quick decisions to geosteer or geo-stop.

Lucida is said to enhance wellbore quality through a combination of automated well path trajectory control and continuous proportional steering that automatically corrects wellbore course for any formation trends. The integration and automation in these systems, the company said, reduces wellbore tortuosity, providing a corresponding reduction in torque and drag, to drill better curve sections and longer and faster lateral sections. The automated well path trajectory control system is said to deliver precise control, even at very high penetration rates, with near-bit directional sensors that check azimuth and inclination every millisecond. The continuous proportional steering system addresses formation and drilling challenges by optimizing the drill bit and hydraulics program with precision-controlled pads that operate independently of bit pressure, flow rates, and drilling fluid properties.

According to the company, this system uses three precision-controlled pads to maintain a continuous proportional steering vector that drills a smooth, in-gauge hole. Steering control is not affected by drilling dynamics because the independent ribs are powered by internal hydraulic power on the decoupled slow rotating sleeve.

The new RSS is fully enabled for the company's remote operations services.

Schlumberger's PowerDrive Orbit G2 RSS is said to deliver higher abrasion resistance and dogleg severity (DLS) for tougher, longer runs. Its pad design increases abrasion resistance with metal-to-metal sealing to handle aggressive drilling fluids and severe downhole conditions for longer runs.

The system includes six-axis continuous hold inclination and azimuth measurements to enable precise well positioning. This feature, along with closed-loop automation, the company said, provides smoother tangents with minimized tortuosity. Near-bit extended-range gamma ray measurements transmit additional well positioning data for improved real-time decision making.

The PowerDrive Orbit G2 RSS recently drilled the horizontal section of a complex well offshore Indonesia in one run.

Interbedded and fractured carbonates posed a challenge for drilling the horizontal section of wells in the East Java basin. To drill the horizontal, the operator needed to overcome the constant microdoglegs observed in offset wells that resulted in unstable DLS, severe shock and vibration, and stick/slip conditions, compromising directional control and ROP. Conventional RSS tools had difficulties precisely and consistently landing offset wells inside the reservoir with sufficient DLS, the company said.

In concert with the MicroScope HD resistivity and high-definition imaging-while drilling service to better navigate the well trajectory, the RSS was used to deliver higher DLS and wear resistance in harsh downhole conditions for longer runs with greater trajectory control.

According to the company, the system increased the maximum DLS by 50% and the average DLS by 80% while maintaining

2021 Rotary Steerable Systems Directory

Product trade name	Point-the-bit or Push-the-bit	Length (ft)	O. D.& I. D. (in.)	Hole size (in.)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations
APS Technology											
SureSteer-RSM (Rotary Steerable Motor) RSM675	Push	Steering Section (14.5'), Power Section (17.2')	OD: 7.78 ID: 1.5	8.375" to 8.75" nominal	5.5	Yes, Inclination and MTF to within 0.1°	Configurable	Yes and variable	150/302	20,000	None
SureSteer-RSS RSS475	Push	Steering Head - 10.6'	Nominal OD - 4.75" Steering Pad Upset OD - 5.75" ID 2.7 - 3.1"	6.0" to 6.75"	12.0	Yes, Inclination and MTF to within 0.1°	Configurable	Yes and variable	150/302 175/347 (option)	20,000	None
Baker Hughes • www.bakerhughes.com											
6.75" AutoTrak Curve (conventional motor can be added)	Continuous Proportional Steering	38 (fully inclusive of steering system & MWD) Steering head length = 9.3	OD: 6.75 ID: N/A	8.375 - 9.875	15	Yes Precise to within 0.2°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302	20,000	None
9.5" AutoTrak G3	Continuous Proportional Steering	58 (fully inclusive of steering system & MWD/LWD) Steering head length = 8.2	OD: 9.5 ID: N/A	12.00 - 28.00	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None
6.75" AutoTrak G3	Continuous Proportional Steering	50 (fully inclusive of steering system & MWD/LWD) Steering head length = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None
9.5" AutoTrak X-treme (Adds Integrated pre-contoured drilling motor)	Continuous Proportional Steering	88 (fully inclusive of steering system, motor power section & MWD/ LWD) Steering head length = 8.2	OD: 9.5 ID: N/A	12.00 - 28	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None
6.75" AutoTrak X-treme (Adds Integrated pre-contoured drilling motor)	Continuous Proportional Steering	76 fully inclusive of steering system, motor power section & MWD/ LWD) Steering head length = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	6.5	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302 (175/347 on request)	20,000 (25,000 & 30,000 on request)	None

a constant steering ratio and reducing wellbore tortuosity and microdoglegs.

Earlier this year, Weatherford deployed its Magnus RSS in the North Sea for the first time. A major operator in the UK decided to replace technology from the incumbent to drill re-entries in an existing field and boost production. According to the company, the Magnus system not only surpassed the technical limit set by the customer, but also drilled the first three re-entry wells an average of 33% faster than planned. This success led to contracts with two more customers in the region.

Key features of the push-the-bit tool include fully independent pad control, a fully rotating bias unit with minimal bottomhole assembly (BHA) stabilization, real-time BHA diagnostics, and autopilot functionality. The system comprises several modular components to facilitate quick and easy maintenance, even in remote locations.

The 2021 Rotary Steerable Systems Directory provides a detailed listing of the technology available on the market.

	Does tool require configuration based on anticipated flow rate?	Sensor distance (ft) Inc/Azm/GR/ Res	Control from surface (Downlink) (Y / N)	If yes, tool control method	Rig time req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
	No	4' Inc/Mag ToolFacE	Y	Mud Pumps and Rotary	3.5 to 8 min	0	80 RPM, 50 klb	300	600	None	Alternator driven off motor	Per APS Bit Recommen-dations	No - Can be operated below any LWD/MWD
	Yes	Inc (RSS) - 14.1' Gamma - 17.2' MWD Dir - 21.6'	Y	Mud Pumps and Rotary	3.5 to 8 min	0	200 RPM, 30 klb	150	350	None	Turbine Alternator driven by Mud flow	Per APS Bit Recommen-dations	MWD & LWD can be intergrated with steer-ing head
	Steering system: No MWD system: No	5.9 / 21.6 / 11.5 / NA	Y	Negative pulse from surface skid unit	While drilling ahead	0	400RPM 56 klbf	300	750	50 lb/bbl medium nutplug, Cedar Fiber	Turbine generator	Application specific	No
	Steering system: No MWD system: Yes	Inc: 3.9 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	300 RPM 100 klbf	300	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
	Steering system: No MWD system: Yes	Inc: 3.1 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 57 klbf	200	900	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
	Steering system: No MWD system: Yes	Inc: 3.9 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	300 RPM 60 klbf	530	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
	Steering system: No MWD system: Yes	Inc: 3.1 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 36 klbf	265	660	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes

2021 ROTARY STEERABLE DRILLING SYSTEMS DIRECTORY

Product trade name	Point-the-bit or Push-the-bit	Length (ft)	O. D.& I. D. (in.)	Hole size (in.)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations
9.5" AutoTrak eXpress (Base level RSS service)	Continuous Proportional Steering	64.6 (fully inclusive of steering system & MWD) Steering head length = 8.2	OD: 9.5 ID: N/A	12.00 - 28.00	6.5	Yes Precise to within 0.1°	Programmable from surface via downlink from 0-6.5° /100 ft	Yes	150/302	20,000	None
6.75" AutoTrak eXpress (Base level RSS service)	Continuous Proportional Steering	58.2 (fully inclusive of steering system & MWD) Steering head length = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	8	Yes Precise to within 0.1°	Programmable from surface via downlink from 0-8° /100 ft	Yes	150/302	20,000	None
9.5" AutoTrak V (RSS for vertical drilling)	Continuous Proportional Steering	24 fully inclusive. Steering head = 8.2	OD: 9.5 ID: N/A	12.00 - 28.00	Vertical Drilling	Yes Precise to within 0.1°	Vertical Drilling	Yes	150/302	20,000 (25,000 & 30,000 on request)	None
6.75" AutoTrak V (RSS for vertical drilling)	Continuous Proportional Steering	21 fully inclusive. Steering head = 7.2	OD: 6.75 ID: N/A	8.375 - 10.625	Vertical Drilling	Yes Precise to within 0.1°	Vertical Drilling	Yes	150/302	20,000 (25,000 & 30,000 on request)	None
6.75" AutoTrak eXact	Continuous Proportional Steering	38 (fully inclusive of steering system & MWD) Steering head length = 9.3	OD: 6.75 ID: N/A	8.375 - 9.875	15	Yes Precise to within 0.2°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302	20,000	None
4.75" AutoTrak eXact (can be integrated with pre-contoured drilling motor)	Continuous Proportional Steering	39 (fully inclusive of steering system & MWD) Steering head length = 9.62	OD: 4.75 ID: N/A	5.75 - 6.75	15	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	165/329	30,000	None
6.75" AutoTrak Curve Pro (conventional motor can be added)	Continuous Proportional Steering	38 (fully inclusive of steering system & MWD) Steering head length = 9.3	OD: 6.75 ID: N/A	8.375 - 9.875	15	Yes Precise to within 0.2°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	150/302	20,000	None
4.75" AutoTrak eXact Pro (can be integrated with pre-contoured drilling motor)	Continuous Proportional Steering	39 (fully inclusive of steering system & MWD) Steering head length = 9.62	OD: 4.75 ID: N/A	5.75 - 6.75	15	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	165/329	30,000	None
Lucida Rotatry Steerable Service	Continuous Proportional Steering	13.2 ft, RSS	OD: 4.75 ID: N/A	5.75 - 6.75	15	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	175/350	30,000	None
Lucida Heavy Duty Rotatry Steerable Service	Continuous Proportional Steering	13.2 ft, RSS	OD:5.23" ID: N/A	*6.75 *variation in size being introduced	15	Yes Precise to within 0.1°	Build Force programmable from surface via downlink. Target inclination in 0.125° increments	Yes	175/350	30,000	None

	Does tool require configuration based on anticipated flow rate?	Sensor distance (ft) Inc/Azm/GR/ Res	Control from surface (Downlink) (Y / N)	If yes, tool control method	Rig time req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
	Steering system: No MWD system: Yes	Inc: 3.9 Others BHA dependent	Y	Flow rate change	While drilling ahead	0	300 RPM 100 klbf	300	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	No
	Steering system: No MWD system: Yes	Inc: 3.1 Others BHA dependent	Y	Flow rate change	While drilling ahead	0	400 RPM 55 klbf	200	900	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	No
	No	3.9 / NA / NA / NA	Y	Flow rate change	While drilling ahead	0	300 RPM 70 klbf	300	1,600	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	No
	No	3.1 / NA / NA / NA	Y	Flow rate change	While drilling ahead	0	400RPM 55 klbf	200	900	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	No
	Steering system: No MWD system: No	Inc: 5.9 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 56 klbf	300	750	Steering system: None MWD system: 40 lb/bbl fine nutplug (higher conc. on request)	Turbine generator	Application specific	Yes
	Steering system: No MWD system: No	Inc: 4.8 Others BHA dependent	Y	Negative pulse from surface skid unit	While drilling ahead	0	400 RPM 35 klbs	475	1,325	Steering system: None 40 ppb (114 kg/m³) medium nut plug, cedar fiber	Turbine generator	Application specific	Yes
	Steering system: No MWD system: No	5.9 / 5.8 / 11.5 / NA	Y	Negative pulse from surface skid unit & Automated Wellpath Trajecotory Control System	While drilling ahead & Automated Wellpath Trajecotory Control System	0	400RPM 56 klbf	300	750	50 lb/bbl medium nutplug, Cedar Fiber	Turbine generator	Application specific	No
	Steering system: No MWD system: No	Inc: 4.8 Azm : 4.8' Others BHA dependent	Y	Negative pulse from surface skid unit & Automated Wellpath Trajecotory Control System	While drilling ahead - Zero for Automated Wellpath Trajecotory Control System	0	400 RPM 35 klbs	475	1,325	Steering system: None 40 ppb (114 kg/m³) medium nut plug, cedar fiber	Turbine generator	Application specific	Yes
	Steering system: No MWD system: No	Inc: 5.9 Azm : 5.9' / GR4.1	Y	Negative pulse from surface skid unit & Automated Wellpath Trajecotory Control System	While drilling ahead Zero for Automated Wellpath Trajecotory Control System	0	400 RPM 35 klbs	120	350	50ppb fibrous LCM material, 80 ppb nut plug LCM material	Turbine generator	Integrated & Application specific	Not yet.
	Steering system: No MWD system: No	Inc: 5.9 Azm : 5.9' / GR4.1	Y	Negative pulse from surface skid unit & Automated Wellpath Trajecotory Control System	While drilling ahead & Zero for Automated Wellpath Trajecotory Control System	0	400 RPM 35 klbs	120	350	50ppb fibrous LCM material, 80 ppb nut plug LCM material	Turbine generator	Integrated & Application specific	Not yet

Product trade name	Point-the-bit or Push-the-bit	Length (ft)	O. D.& I. D. (in.)	Hole size (in.)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations
Enteq Upstream											
SABER	Push-the-bit	6'	5 1/8" / 3 1/2"	6"-6 3/4"	8 °/100'	Yes. Inc +/- 0.25 degs. Azi - +/- 0.5 degs.	5% steps	No, duty cycle based	175 °C / 347 °F	20k	None
Nabors Drilling Services											
OrientXpress Rotary Steerable Tool 700 Series	Hybrid	12.5	7.1 OD 1.6 ID	7 7/8" to 8 3/4"	15	Yes Inclination (+/-0.1) Azimuth (+/- 1 deg)	Continuous	Yes	150°C	20,000	None
National Oilwell Varco											
VectorZIEL 800	Push the bit	30	OD: 8" ID: N/A	12 1/4" - 13 7/8"	5	Yes (0.1)	5%	Yes	150°C - 302°F	20,000	None
VectorZIEL 600	Push the bit	28	OD: 6.75" ID: N/A	8 1/2" - 9 7/8"	8	Yes (0.1)	5%	Yes	150°C - 302°F	20,000	None
VectorZIEL 400	Push the bit	26	OD: 4.75" ID: N/A	6" - 6 3/4"	8	Yes (0.1)	5%	Yes	150°C - 302°F	20,000	None
VectorEXAKT 900	Push the bit	26	OD: 9" ID: N/A	14 3/4" - 17 1/2"	Vertical Drilling	Yes (0.1)	Vertical Drilling	Yes	150°C - 302°F	20,000	None
VectorEXAKT 800	Push the bit	25	OD: 8" ID: N/A	12 1/4" - 13 7/8"	Vertical Drilling	Yes (0.1)	Vertical Drilling	Yes	150°C - 302°F	20,000	None
Sanvean Technologies • Scout Downhole											
9.625" Rotary Steerable Scout	Push	18.22	OD: 9.63 ID: 2.75	12.25 - 16.00	3	Yes +/- 0.1°	25%	Yes	150/302	20,000	None
7.125" Rotary Steerable Scout	Push	14.11	OD: 7.13 ID: 1.63	8.5 - 8.75	6	Yes +/- 0.1°	25%	Yes	150/302	20,000	None
Schlumberger • +1-281-285-8500											
PowerDrive Archer 675	Hybrid-Point-the-bit	16.15	OD: 6.75 ID: N/A	8.375 - 9.675	15	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000	Optimized for Drilling conditions
PowerDrive Archer 475	Hybrid-Point-the-bit	14.98	OD: 4.75 ID: N/A	5.875 - 6.75	18	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000	Optimized for Drilling conditions
PowerDrive Orbit G2 1100	Hybrid Push-the-bit	15.06	OD: 11 ID: N/A	20 - 28	2	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000 (35,000 Optional)	Optimized for Drilling conditions
PowerDrive Orbit G2 900	Hybrid Push-the-bit	13.94	OD: 9 ID: N/A	12 - 18.5	5	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000 (35,000 Optional)	Optimized for Drilling conditions

	Does tool require configuration based on anticipated flow rate?	Sensor distance (ft) Inc/Azm/GR/ Res	Control from surface (Downlink) (Y / N)	If yes, tool control method	Rig time req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
	Y	4'/4'/7'/7'	Y	Manual Pump Stroke Manipulation	3-5 mins	0 deg	400 RPM / 35 klbs	150	400	50lbs/bbl medium nutplug	Downhole Generator	Specific internal pin requirements.	Available Options - AZ GR, AZ Res, PWD.
	Yes (generator)	Inc/Azi 6.8ft Azi GR 22ft	Yes	Flow	3 mins (while drilling)	0	400 / 60K	400	700	None	Turbine alternator driven by mud flow	Nabors specifications preferred	Integrated with Nabors AccuMP or AccuSteer
	No	6/6/6/30	Y	Mud flow via surface skid	Avg 6 min	0	400 / 56,000	500	1100	Steering system none, MWD, 50ppb med nut plug	Turbine Gemerator	Application Specific	Yes
	No	4/4/4/29	Y	Mud flow via surface skid	Avg 6 min	0	400 / 45,000	290	650	Steering system none, MWD, 50ppb med nut plug	Turbine Gemerator	Application Specific	Yes
	No	4/4/4/27	Y	Mud flow via surface skid	Avg 6 min	0	400 / 16,000	210	300	Steering system none, MWD, 50ppb med nut plug	Turbine Gemerator	Application Specific	Yes
	No	6/NA/6/NA	Y	Mud flow via surface skid	Avg 6 min	Vertical Drilling	300 / 90,000	630	1500	Steering system none, MWD, 50ppb med nut plug	Turbine Gemerator	Application Specific	No
	No	6/NA/6/NA	Y	Mud flow via surface skid	Avg 6 min	Vertical Drilling	300 / 56,000	520	1100	Steering system none, MWD, 50ppb med nut plug	Turbine Gemerator	Application Specific	No
	No	8.42, 9.67, NA, NA	Y	Rotary	3 Minutes	0	400 RPM/85 klbf	500 psi pressure drop at bit	1800	60 lb/bbl med nut plug	Lithium Batteries	Application Specific	No
	No	5.17, 6.42, NA, NA	Y	Rotary	3 Minutes	0	400 RPM/55 klbf	500 psi pressure drop at bit	800	60 lb/bbl med nut plug	Lithium Batteries	Application Specific	No
	Optimized for Drilling conditions	Inc / Azm 9.9 / 12.01 GR 9.01	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM As per Smith PDC bit guidelines	220	650	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 8.41 / 10.51 GR 7.51	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM As per Smith PDC bit guidelines	130	355	35 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 8.86 / 11.06 GR 8.07	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 225 klbf	280	2000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 7.71 / 9.91 GR 6.92	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 370 klbf	280	2,000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular

Product trade name	Point-the-bit or Push-the-bit	Length (ft)	O. D.& I. D. (in.)	Hole size (in.)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations
PowerDrive Orbit G2 825	Hybrid Push-the-bit	13.72	OD: 8.25 ID: N/A	10.625 - 11.625	6	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000 (35,000 Optional)	Optimized for Drilling conditions
PowerDrive Orbit G2 675	Hybrid Push-the-bit	13.43	OD: 6.75 ID: N/A	8.375 - 9.675	8	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302 (175/350 optional)	20,000 (35,000 Optional)	Optimized for Drilling conditions
PowerDrive Orbit G2 475	Hybrid Push-the-bit	13.38	OD: 4.75 ID: N/A	5.875 - 6.75	10	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302 (175/350 optional)	20,000	Optimized for Drilling conditions
PowerV 1100	Hybrid Push-the-bit	15.22	OD: 11 ID: N/A	20 - 28	Vertical Drilling	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000 (35,000 Optional)	Optimized for Drilling conditions
PowerV 900	Hybrid Push-the-bit	14.05	OD: 9 ID: N/A	12 - 18.5	Vertical Drilling	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000 (35,000 Optional)	Optimized for Drilling conditions
PowerV 825	Hybrid Push-the-bit	13.84	OD: 8.25 ID: N/A	10.625 - 11.625	Vertical Drilling	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000 (35,000 Optional)	Optimized for Drilling conditions
PowerV 675	Hybrid Push-the-bit	13.53	OD: 6.75 ID: N/A	8.375 - 9.675	Vertical Drilling	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302 (175/350 optional)	20,000 (35,000 Optional)	Optimized for Drilling conditions
PowerV 475	Hybrid Push-the-bit	13.5	OD: 4.75 ID: N/A	5.875 - 6.75	Vertical Drilling	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302 (175/350 optional)	20,000	Optimized for Drilling conditions
PowerDrive Xcel 675	Point-the-bit	24.93	OD: 6.75 ID: N/A	8.375-10.625	8	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000	None
PowerDrive Xcel 900	Point-the-bit	27.89	OD: 9.00 ID: N/A	12-17.5	6.5	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	150/302	20,000	None
PowerDrive ICE	Hybrid Push-the-bit	34.26	OD: 6.75 ID: N/A	8.5	8	Yes, Azimuth and Inclination +/- 0.1°	1% and 1° TF resolution	Adjustable on Fully Rotating Tool	200/392	30,000	Optimized for Drilling conditions
Scientific Drilling International											
HALO 650	Push-the-bit / proportional control.	35.5 ft	OD: 6.50" ID: N/A	7.875" - 9.875"	15	Yes, azimuth to 0.5 deg, inclination to 0.125 deg	Controllable in 12.5% Force or 0.125 deg increments	Yes, in Autopilot modes deviation force will auto adjust.	150 deg c / 302 deg F	20k psi	None
HALO 500	Push-the-bit / proportional control.	35.5 ft	OD: 5.00" ID: N/A	5.875"- 6.75"	13	Yes, azimuth to 0.5 deg, inclination to 0.125 deg	Controllable in 12.5% Force or 0.125 deg increments	Yes, in Autopilot modes deviation force will auto adjust.	150 deg c / 302 deg F	20k psi	None

	Does tool require configuration based on anticipated flow rate?	Sensor distance (ft) Inc/Azm/GR/ Res	Control from surface (Downlink) (Y / N)	If yes, tool control method	Rig time req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
	Optimized for Drilling conditions	Inc / Azm 7.85 / 10.05 GR 7.06	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 270 klbf	280	2000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 7.10 / 9.30 GR 6.31	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 180 klbf	210	970	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 6.85/ 8.95 GR 5.96	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 31 klbf	120	355	35 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 8.99 / 11.19 GR 8.19	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 225 klbf	280	2000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 7.71 / 9.91 GR 6.92	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 370 klbf	280	2,000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 7.94 / 10.14 GR 7.14	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 270 klbf	280	2000	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 7.10 / 9.30 GR 6.31	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 180 klbf	210	970	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 6.85/ 8.95 GR 5.96	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 31 klbf	120	355	35 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	Optimized for Drilling conditions	Inc / Azm 14.5 / 12.9 GR 15.83	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 55 klbf	260	805	50 lb/bbl med. nut plug	Turbine generator	Application specific - bi-center compatible	Modular
	Optimized for Drilling conditions	Inc / Azm 16.2 / 14.6 GR 10.89	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 75 klbf	260	1,800	50 lb/bbl med. nut plug	Turbine generator	Application specific - bi-center compatible	Modular
	Optimized for Drilling conditions	Inc / Azm 13.30/13.30	Y	Flow rate and/or RPM change	While drilling ahead	0	350 RPM 105.6 klbf	275	800	50 lb/bbl med. nut plug	Turbine generator	Application specific	Modular
	No	PWD - 2.3' NBI/NBA - 5.9' AZ GR - 15.4' Survey - 21.0'	Y	Rig pumps - variable flow rate.	3-6 mins with confirmation. Downlinks can be performed while drilling ahead. Full MWD decoding possible during downlink.	Vertical	350 RPM / 60 klbs WOB	300 gpm	650 gpm	50 ppb medium fibrous	System powered by downhole generator. Lithium battery used for flow off surveys.	Application Specific	Single collar loadout, with steering unit and integrated MWD system.
	No	PWD - 2.1' NBI/NBA - 5.5' AZ GR - 14.4' Survey - 21.0'	Y	Rig pumps - variable flow rate.	3-6 mins with confirmation. Downlinks can be performed while drilling ahead. Full MWD decoding possible during downlink.	Vertical	350 RPM / 30 klbs WOB	210 gpm	425 gpm	50 ppb medium fibrous	System powered by downhole generator. Lithium battery used for flow off surveys.	Application Specific	Single collar loadout, with steering unit and integrated MWD system.

Product trade name	Point-the-bit or Push-the-bit	Length (ft)	O. D.& I. D. (in.)	Hole size (in.)	Max DLS capability (°/100')	Automated closed loop deviation control (yes/no) (+/-degrees)	Build rate increment	Is deviation force continuous?	Max temp (°C /°F)	Max internal pressure (psi)	Other special pressure limitations
TerraVici Drilling Solutions • Rameen Bakhtiary rameen.bakhtiary@terravici.com											
TerraPoint 475 RSS	Point-the-bit	20	4.75	6.00 - 6.75	15	Yes ±1°	0-100% "Slide" Time, 1° TF Resolution	Yes	150 / 302	20,000	None
TerraPoint 650 RSS	Point-the-bit	22	6.5	7.875 - 9.875	12	Yes ±1°	0-100% "Slide" Time, 1° TF Resolution	Yes	150 / 302	20,000	None
TerraPoint 800 RSS	Point-the-bit	23	8	9.875 - 12.25	4	Yes ±1°	0-100% "Slide" Time, 1° TF Resolution	Yes	150 / 302	20,000	None
Weatherford • John Rice, Global Service Line Manager - RSS John.Rice@weatherford.com Brad Zukiwsky, Product Champion - Ma											
Revolution 825 rotary steerable system (Core, Heat)	Point	17.8	OD: 8.25 ID: 2.75	10.625 -18.25	7.5	Yes	Variable	Yes	149/300 Core 175/347 Heat	25,000 Core 30,000 Heat	None
Revolution 675 rotary steerable system (Core, Heat)	Point	14.8	OD: 6.75 ID: 2.0	7.875 - 9.875	10	Yes	Variable	Yes	149/300 Core 175/347 Heat	25,000 Core 30,000 Heat	None
Revolution 475 rotary steerable system (Core, Heat)	Point	12.9	OD: 4.75 ID: 1.75	5.875 - 6.75	10	Yes	Variable	Yes	149/300 Core 175/347 Heat	25,000 Core 30,000 Heat	None
Magnus 1100 Rotary Steerable System	Push	22.7	OD: 11.00 ID: 2.75	14.75 - 18.50	5	Yes	Variable	Yes	150/302	25,000	None
Magnus 950 Rotary Steerable System	Push	22.7	OD: 9.50 ID: 2.75	12.00 - 14.50 -	6	Yes	Variable	Yes	150/302	25,000	None
Magnus 675 Rotary Steerable System	Push	21.5	OD: 6.75 ID: 2.0	8.375 - 9.875	10	Yes	Variable	Yes	150/302	30,000	None

	Does tool require configuration based on anticipated flow rate?	Sensor distance (ft) Inc/Azm/GR/ Res	Control from surface (Downlink) (Y / N)	If yes, tool control method	Rig time req'd to communicate change in target (minutes)	Minimum kickoff inclination (degrees)	Max RPM / WOB	Min flow rate (gpm)	Max flow rate (gpm)	LCM limits	Power source	Bit requirements	Integrated LWD?
	Yes	Inc / Azm 10 / 10	Y	Flow Rate Change, MWD Direct-Connect/Hop, EM Downlink	Can Downlink While Drilling (Adjustable DL time from 3:20 to 20:00 based on conditions)	0	300 RPM / 25,000 lb (me-chanical)	200	350	40 lb/bbl med. nut plug	Turbine generator	Application Specific	No - Will function below any MWD/LWD
	Yes	Inc / Azm 10 / 10	Y	Flow Rate Change, MWD Direct-Connect/Hop, EM Downlink	Can Downlink While Drilling (Adjustable DL time from 3:20 to 20:00 based on conditions)	0	300 RPM / 50,000 lb (me-chanical)	410	750	40 lb/bbl med. nut plug	Turbine generator	Application Specific	No - Will function below any MWD/LWD
	Yes	Inc / Azm 10 / 10	Y	Flow Rate Change, MWD Direct-Connect/Hop, EM Downlink	Can Downlink While Drilling (Adjustable DL time from 3:20 to 20:00 based on conditions)	0	300 RPM / 55,000 lb (me-chanical)	410	750	40 lb/bbl med. nut plug	Turbine generator	Application Specific	No - Will function below any MWD/LWD
gnus RSS bradley.zukiwsky@weatherford.com www.weatherford.com													
	No	14/14/16/42	Y	Drillstring rotation or negative pulse from surface	Typically < 3	0	180 RPM 90 klb	No minimum requirement	1,500	Steering system: None MWD system: 80 lb/bbl fine/ med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	No	12/ 12/14/40	Y	Drillstring rotation or negative pulse from surface	Typically < 3	0	200 RPM 50 klb	No minimum requirement	750	Steering system: None MWD system: 80 lb/bbl fine/ med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	No	9/ 9/16/39	Y	Drillstring rotation or negative pulse from surface	Typically < 3	0	200 RPM 25 klb	No minimum requirement	350	Steering system: None MWD system: 80 lb/bbl fine/ med (higher conc. on request)	Lithium batteries	Long passive gauge PDC	Yes
	Yes	7/7/7/47	Y	Negative pulse from surface	Typically < 3	0	300 RPM / 90 klb	No minimum requirement	1,400	80 lb/bbl fine/ med (higher conc. on request)	Turbine Generator or Lithium batteries	None	Yes
	Yes	7/7/7/47	Y	Negative pulse from surface	Typically < 3	0	300 RPM / 90 klb	No minimum requirement	1,200	80 lb/bbl fine/ med (higher conc. on request)	Turbine Generator or Lithium batteries	None	Yes
	Yes	6/6/6/444	Y	Negative pulse from surface	Typically < 3	0	300 RPM / 50 klb	No minimum requirement	700	80 lb/bbl fine/ med (higher conc. on request)	Turbine Generator or Lithium batteries	None	Yes