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Vessel DP Operability, (1.2)

KBOS: Achieving 9-Second Emergency Disconnect! Dramatically Enhancing Operability and Reducing Process Safety Exposure with DP MODU's

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Abstract

Kinetic Pressure Control has developed the K-BOS technology, a pyrotechnically actuated shear/seal device which can secure the well in milliseconds. These capabilities achieve a step change in reducing the time to secure the well during an Emergency Disconnect Sequence on a dynamically positioned (DP) MODU.

For most DP rigs, the K-BOS achieves a 9 second EDS: KBOS shear/shear + LMRP connector release. The technology could be further developed and deliver a rapid release connector to provide a one-second EDS capability.

The paper summarizes the methodology and results of a parametric study performed to quantify the DP operability improvement by using the K-BOS, based on the following scenarios:

- US GOM – DP drillship; N Sea – DP semi
- Water depth range from 350’ to 6300’
- EDS times : 1 second, 9 seconds, 32 seconds, 73 seconds)

The results of the study indicate a substantial improvement in DP operability both in terms of increased environmental criteria and decreasing (Shallow) water depths. The technology can be leveraged to achieve several diverse objectives. Examples include:

- Potential to deploy DP rigs in shallow water, and in areas of congested infrastructure which may preclude moored rigs
- Optimized engine configuration to achieve Greenhouse gas emission reduction; reduced fuel consumption
- Alternative to BOP tethering systems

K-BOS can be combined with riser management systems and automated disconnect features to provide an integrated approach to deliver predictable incident free DP operations and reduce process safety risk exposure on DP MODU’s

Abbreviations / Definitions

BM: Bending Moment
BML: Below Mudline
BOP: Blowout Preventer
BHA: Bottom Hole Assembly
CO2: Carbon Dioxide
DP: Dynamic Positioning
EDS: Emergency Disconnect Sequence
FE: Finite Element
GOM: Gulf of Mexico
H2S: Hydrogen Sulphide
HS: Significant Wave Height
K-BOS: Kinetic Blowout Stopper
LFJ: Lower flex joint
LMRP: Lower Marine Riser Package
MODU: Mobile Offshore Drilling Unit
MYS: Minimum Yield Strength
OD: Outside Diameter
POD: Point of Disconnect
PSI: pounds per square inch
RWC: Red Watch Circle
TP: Wave Period
UFJ: Upper Flex Joint
WH: Wellhead

Introduction

The K-BOS is an electrically initiated, pyro-mechanical device which performs the critical functions of shearing and sealing during drilling, completions or intervention well control operations. It is a fast acting design that shears and seals in under 1 second. The patented design, utilizing the power of kinetic energy, greatly limits the potential existential threat posed by blowouts by being able to shear and seal under any conditions. This includes shearing and sealing under unmitigated blowout flow and pressure conditions as well as shearing through heavy well bore elements including tool joints, BHAs and large OD casing.

The K-BOS working components are housed within a pressure vessel referred to as a K-BOS Bonnet. An insert is placed within the main body block and hermetically seals the working components from the well bore fluids prior to activation.

The 18 ¾: K-BOS has the following shearing specifications:

- Min-Max Tubular OD – 0”-18”
- Min-Max Tubular weight – 0”-220 ppf
- Slick line: 1/8” OD; Braided cable wireline: 5/16” OD and any other typical wire or slickline or control line
- Up to MYS 165ksi Material Grade

Figure 1~~Figure 1~~ shows the 18 ¾” 15 ksi K-BOS installed on a subsea BOP. Figure 2~~Figure 2~~ shows the simulation model results vs actual shear samples.

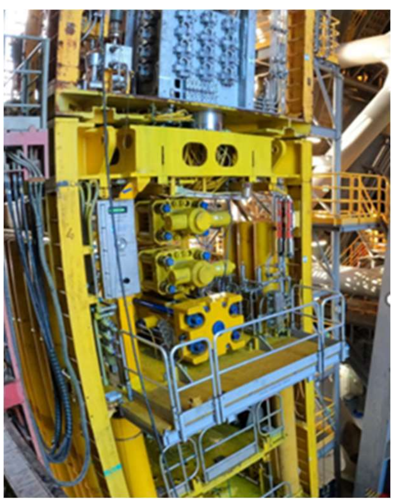

Figure 1- K-BOS Subsea BOP retrofit

Figure 2- K-BOS shear modelling and shear samples

With the K-BOS being able to shear and seal in <1 second it is possible to optimize the EDS sequence on BOP stacks equipped with K-BOS. EDS timing of as little as 9 seconds is possible with an optimized sequence. Important consideration in optimizing an EDS sequence include, using fast closing gate valves (under 2 second close), using LMRP connector with low opening volume and reviewing stack piping to ensure unrestricted flow to functions.

Study Approach – DP Simulator

A vessel DP Simulator (K-POS desktop simulator) was run for a Gusto P10000 design. In this simulation the drilling riser is not included. A blackout was simulated for a typical GOM weather with Hs=2m and a mean wind speed 10m/s. The purpose of these figures is to give the operator a feel for the impact of watch circle and time for disconnect or recovery operation. See Figure 4~~Figure 4~~:

- 70s after blackout the red watch circle is reached for the EDS=73s case.
- 150s after blackout the red watch circle is reached for the EDS=9s case.
- (Note, in these simulations the watch circles are fixed, and values are not necessarily one to one with the SIMO analysis study)

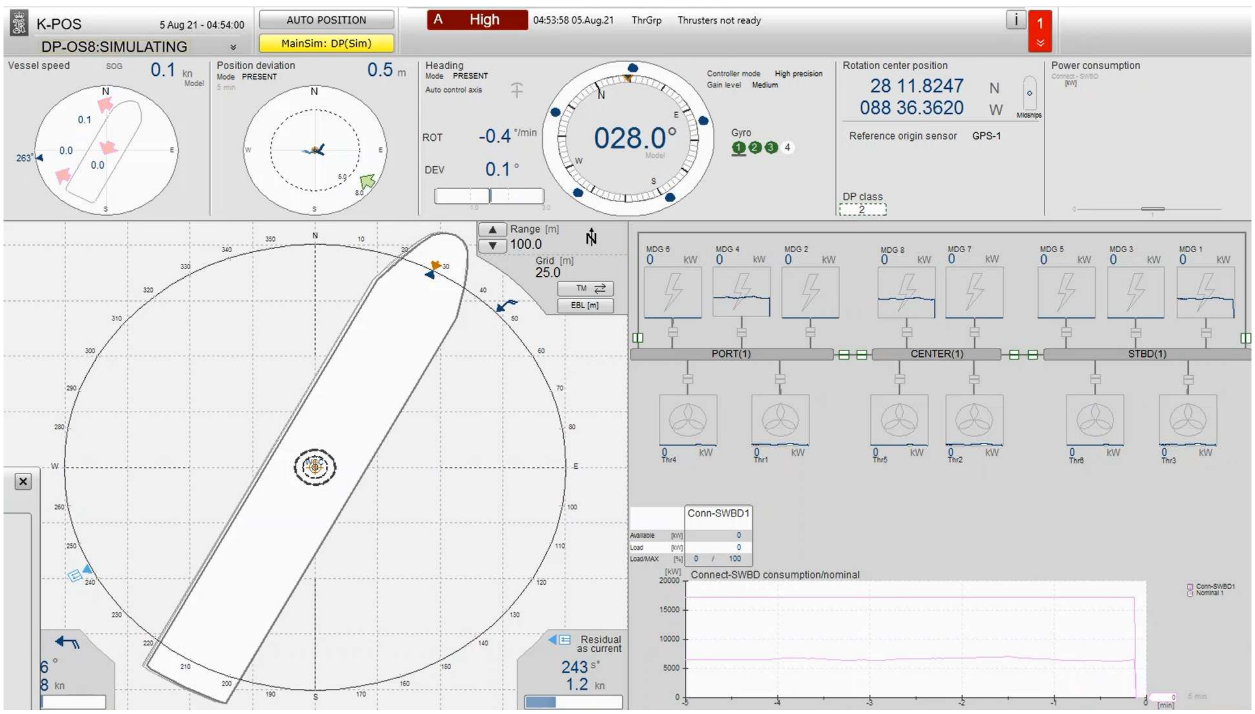

Figure 3- DP Simulator model

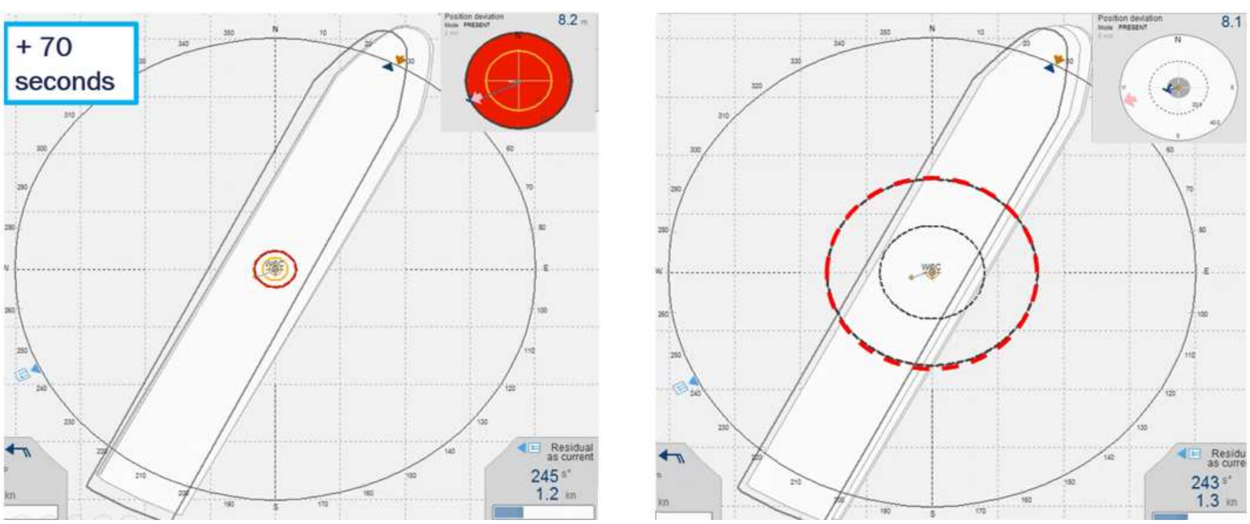

Figure 4- DP Simulator results – red watch circles for EDS=9s (right) and EDS=73s (left)

Study Approach – Simulation Model

Kongsberg's SIMA simulation model was used for the study. SIMA is a time domain fully coupled finite element model. The SIMA simulation for this study included riser and wellhead/casing models. The model used site specific P-Y curves for soil/conductor interaction. Two separate sets of analyses were conducted:

- On DP in operation, full operability analysis including the riser. Also investigating DP footprint and dynamic station keeping capability
- Blackout drift-off analysis

EDS times of 9 seconds, 32 seconds and 73 seconds were analysed for the blackout drift-off analysis. The 73 second EDS represents a typical EDS time where both a casing shear ram and a blind shear ram are activated prior to LMRP separation. The 32 second EDS represents a typical EDS time where only a blind shear ram is activated prior to LMRP separation. The 9 second EDS time represents a vessel with optimized EDS sequence including using a K-BOS as the shear/seal device prior to LMRP separation.

The study considered a drillship hull form for the GOM analysis, specifically a Gusto P10000. For the North Sea analysis, a Semi hull form was used, specifically a GVA 7500.

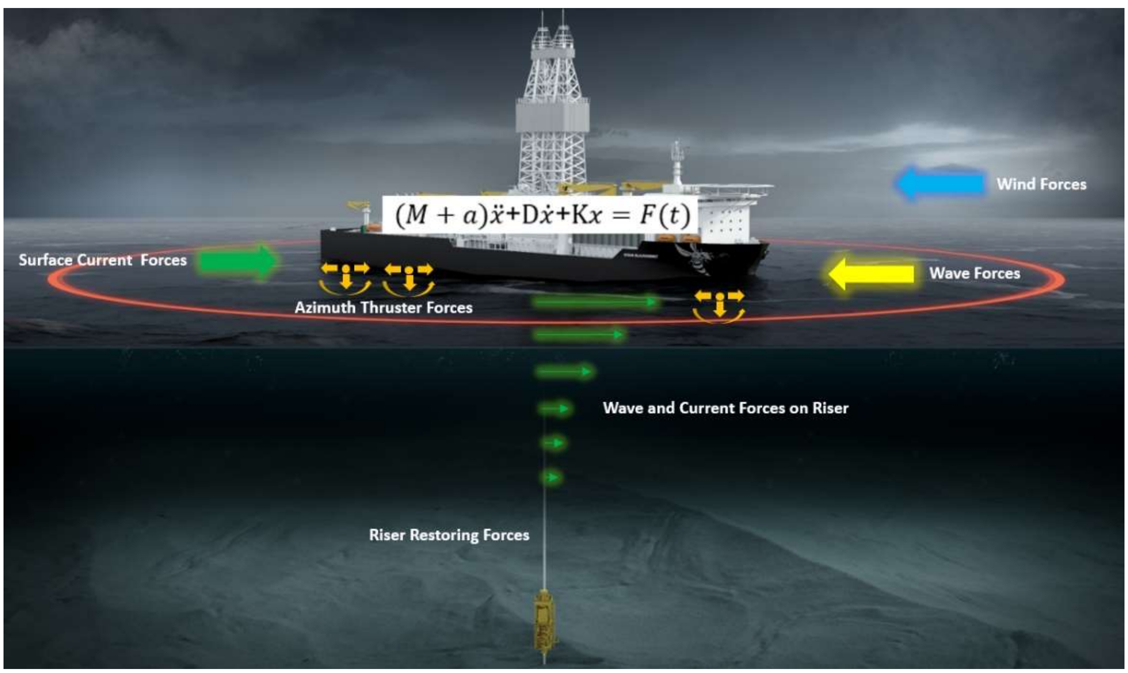

Figure 5- Operability Analysis - Simulation Model

Operability Analysis

When conducting the EDS assessment, it was important to consider vessel, BOP stack and wellhead/casing limitations. Vessel limitations related to EDS include upper flex joint angle and tensioner stroke. For the BOP stack the important limitations were lower flex joint angle, and stack bending moment capacity. Finally, the wellhead bending moment capacity and casing bending moment capacity needed to be considered. For the operability analysis (on DP) the limits shown in Figure 6~~Figure 6~~ were used. For the drift-off analysis the limits shown in Figure 7~~Figure 7~~ were used.

Limit	Unit	Drilling	Non-Drilling
UFJ (Mean)	deg	1	-
UFJ (Max)	deg	5	8.25
LFJ (Mean)	deg	1	-
LFJ (Max)	deg	5	9
LMRP-BOP Conn BM	kNm	3973	3973
BOP-WH Conn BM	kNm	5423	5423
WH_BM	kNm	5423	5423
Casing BM X80 - Above 32.3m BML	kNm	10422	10422
Casing BM X56 - Below 32.3m BML	kNm	5707	5707
Tens Stroke	m	4.96	4.96

Figure 6- Operability Analysis

Limit	Unit	Drift-Off
UFJ (Mean)	deg	-
UFJ (Max)	deg	8.25
LFJ (Mean)	deg	-
LFJ (Max)	deg	9
LMRP-BOP Conn BM	kNm	3973
BOP-WH Conn BM	kNm	7660
WH_BM	kNm	7660
Casing BM X80 - Above 32.3m BML	kNm	17166
Casing BM X56 - Below 32.3m BML	kNm	9689
Tens Stroke	m	5.06

Figure 7- Drift-Off Analysis

Environmental Model - GOM

For the study, an all year GOM Hs-Tp omnidirectional scatter diagram based on ISO 19901-1 was used and shown in Figure 8~~Figure 8~~.

Hs [m]	Tp [s]												Wind Speed	Probability
	1	2	3	4	5	6	7	8	9	10	11	12	[m/s]	[%]
0.5		0.16	1.99	4.26	5.67	2.74	1.05	0.67	0.05	0.01	0.02		2.5	16.62
0.8		0.04	1.22	3.39	7.78	6.62	1.84	0.53	0.13	0.01	0		4.3	21.56
1.1		0.01	0.35	1.41	4.8	7.84	3.14	0.61	0.08	0.03	0		6.1	18.27
1.4			0.07	0.27	1.97	5.89	4.78	1.5	0.08	0.01	0.01		7.0	14.58
1.7			0.01	0.05	0.49	3.02	4.28	2.32	0.14	0.03	0.01		7.9	10.35
2					0.13	1.16	2.87	2.37	0.23	0.03	0.01		8.9	6.8
2.3					0.03	0.36	1.54	2.05	0.39	0.08	0.02		9.8	4.47
2.6						0.11	0.62	1.46	0.39	0.1	0.02		10.7	2.7
2.9						0.02	0.2	0.88	0.37	0.11	0.02		11.5	1.6
3.2							0.06	0.46	0.42	0.08	0.02		12.3	1.04
3.5							0.02	0.2	0.25	0.1	0.03		13.1	0.6
3.8							0.01	0.12	0.17	0.13	0.03		13.9	0.46
4.1								0.08	0.12	0.13	0.04		14.6	0.37
4.4								0.02	0.05	0.08	0.03		15.4	0.18
4.7								0.01	0.03	0.04	0.05		16.2	0.13
5									0.01	0.03	0.05		16.9	0.09
5.3										0.01	0.05		17.4	0.06
5.6											0.04		18.0	0.04
5.9										0.01	0.04		18.5	0.05
6.3										0.01	0.02		19.4	0.03
	0	0.21	3.64	9.38	20.87	27.76	20.41	13.28	2.91	1.03	0.51	0		100

Figure 8- GOM Hs-Tp omnidirectional scatter diagram

The study considered collinear wave, wind and current. The following were also considered:

- Irregular Waves
- Wind spectrum NPD
- Rig/wave heading 15 deg
- Drift off performed for 10 wave realizations, 50% NE reported
- 3 hour time domain analysis in DP station keeping analysis
- Wind speed versus Hs as per scatter diagram
- Current speed of 0.4m/s assumed based on 1 year value in ISO 19901-1
- Note, hurricane events were excluded

US GOM Model Results

The results from the simulations conducted showed a vessel with a K-BOS enabled 9 second EDS could conduct DP drilling operations in 350ft of water with 100% uptime. Substantial gains were seen in red watch circle size and time to disconnect in 350ft water depth as compared to 73 second EDS scenarios. Figure 9~~Figure 9~~ illustrates that Red watch circles for 350ft water depth grew from less than 2m with 73 second EDS and 2.6m Hs to more than 12 m with a 9 second EDS.

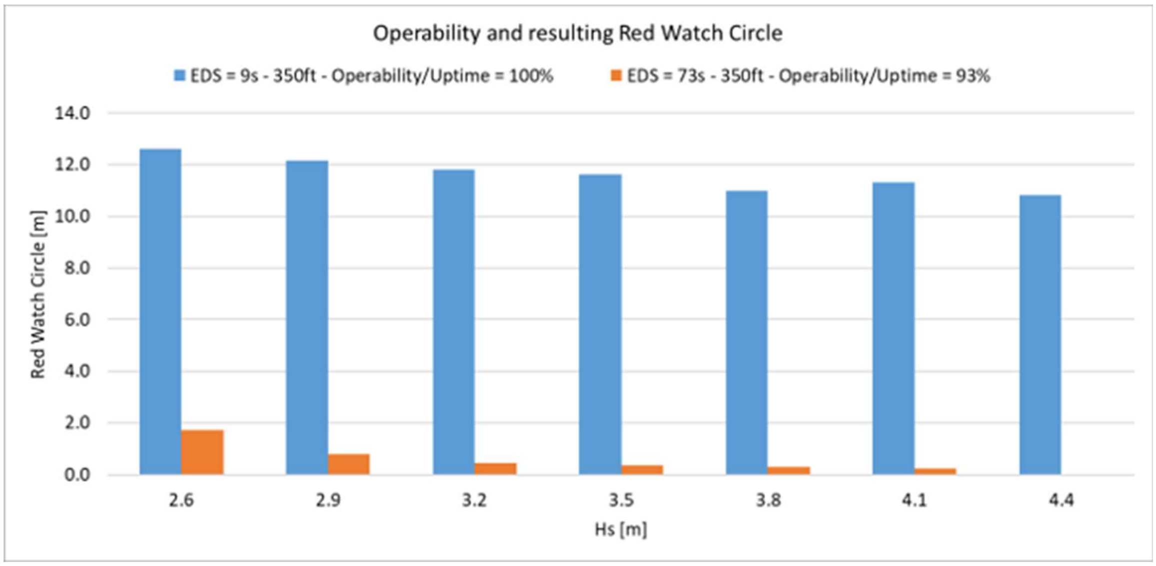

Figure 9- Operability and Resulting Red Watch Circles (US GOM)

Figure 10~~Figure 10~~ shows the improvement in time to red watch circle for the 9 second EDS vs the 73 second EDS for 350' water depth

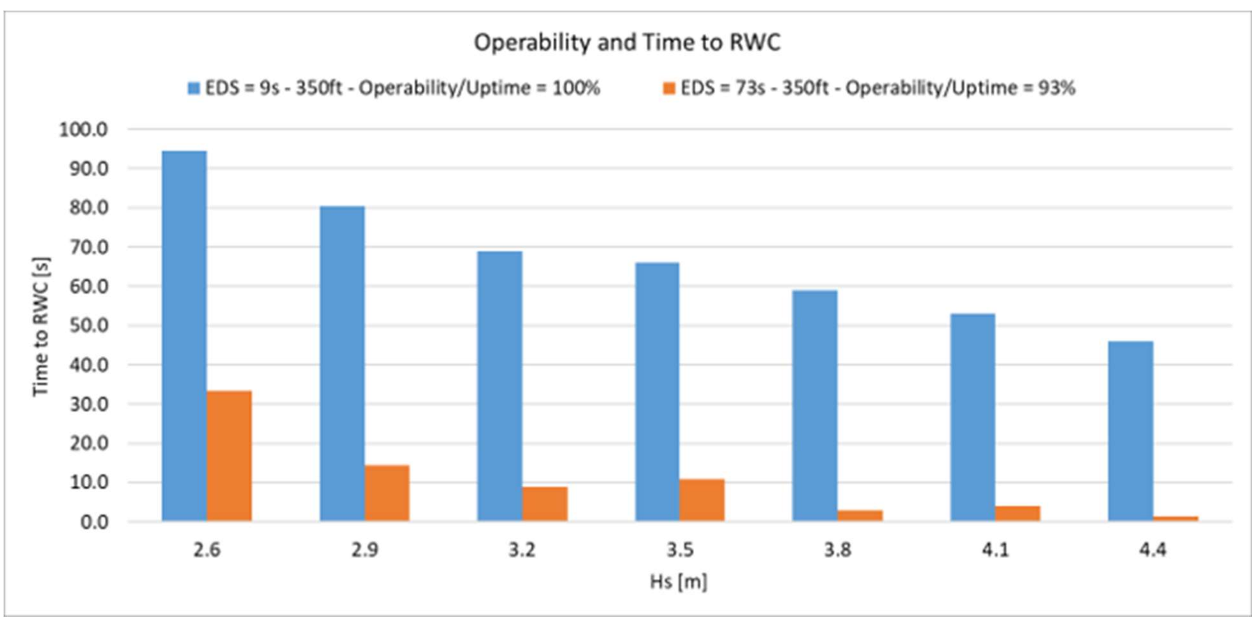

Figure 10 - Operability and Time to RWC (US GOM)

It should be noted that the point of disconnect remains at the same offset for both the 9 second and 73 second EDS scenarios. However, there is over a 10x increase in Red Watch Circle between the scenarios. This Red Watch Circle increase provides vessel operators with additional time and opportunities for restoration of performance capability following an upset, before reaching POD thereby allowing for predictable and safe DP operations. This can be seen in ***Error! Reference source not found.***~~Figure 11~~.

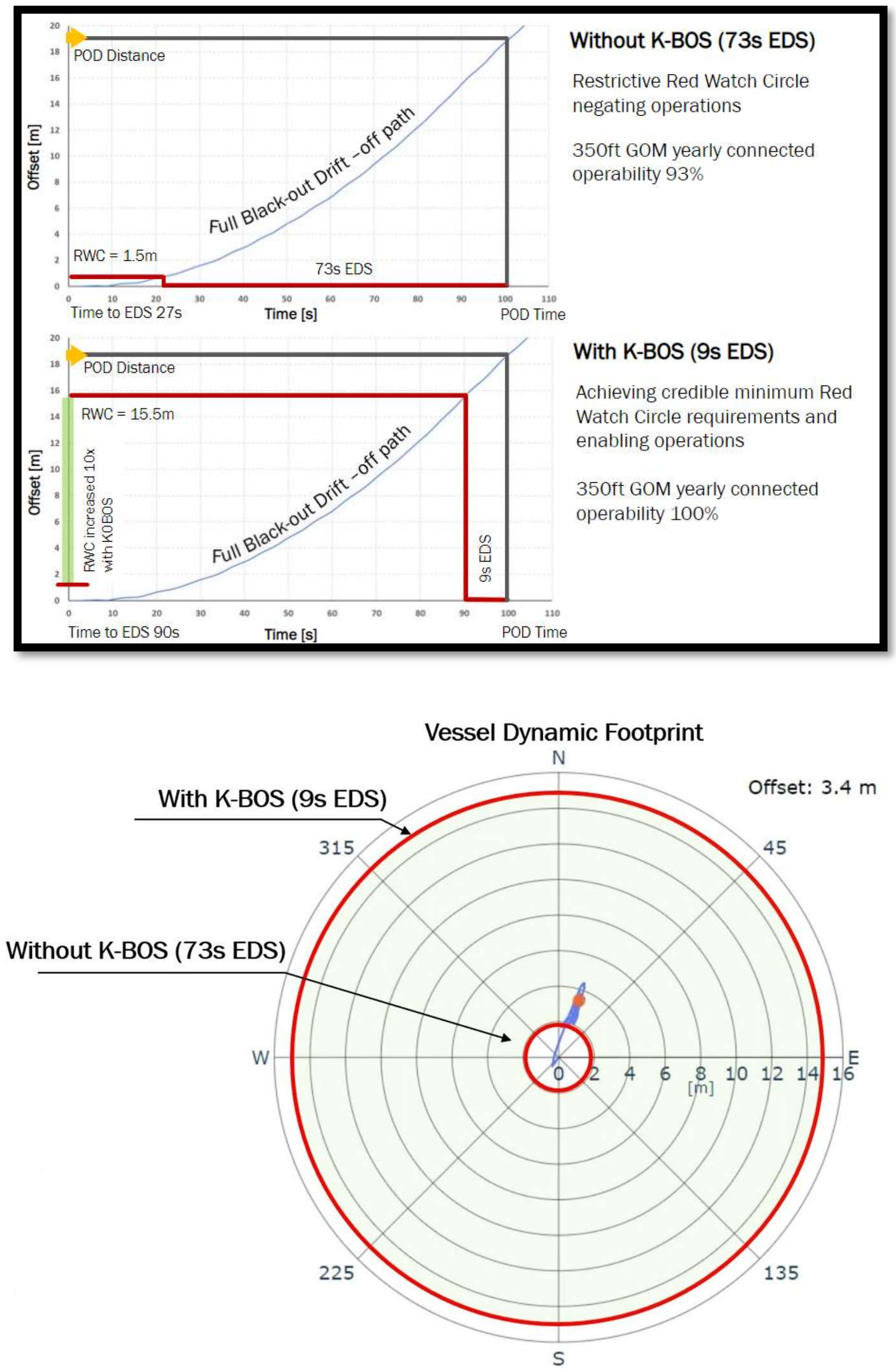

Figure 11 - POD Comparison (US GOM)

The results show that a 9 second EDS provides operational gains not only in 350ft water depth but also in the 1000ft water depth scenario. This can be seen in Figure 12~~Figure 12~~ and Figure 13~~Figure 13~~.

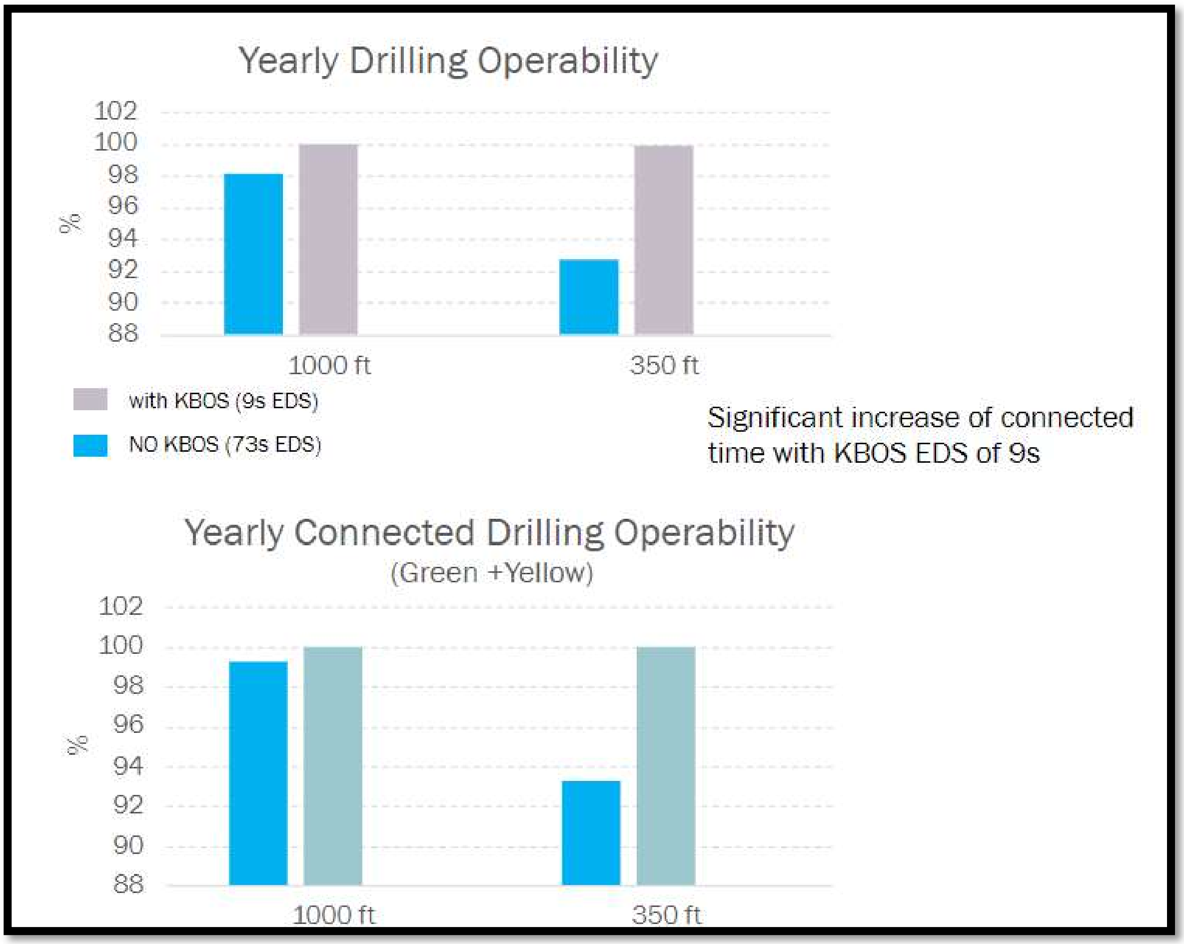

Figure 12 - Yearly Drilling Operability (US GOM)

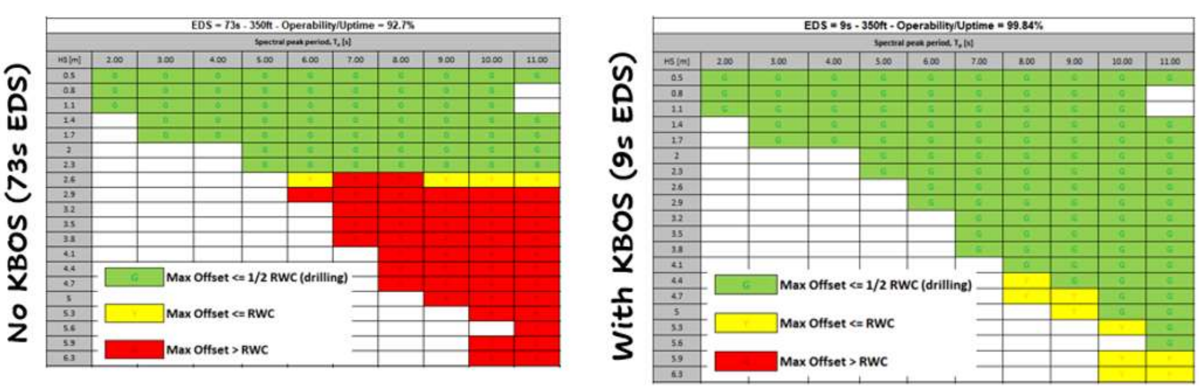

Figure 13 – Operability scatter diagrams (US GOM)

Environmental Model – North Sea

For the study an all year North Sea Hs-Tp omnidirectional scatter diagram was used and shown in Figure 14~~Figure 14~~.

Hs [m]	Tp [s]																			Wind Speed [m/s]	Probability [%]
	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5		
0.5	0.005%	0.228%	0.964%	1.984%	2.586%	1.720%	1.059%	0.801%	0.537%	0.307%	0.194%	0.100%	0.050%	0.030%	0.026%	0.009%	0.005%	0.002%	0.001%	3	10.61%
1.5		0.044%	1.270%	3.917%	6.057%	7.656%	6.763%	4.658%	3.275%	2.264%	1.518%	0.906%	0.496%	0.329%	0.198%	0.091%	0.076%	0.038%	0.039%	5	39.60%
2.5			0.011%	0.362%	2.522%	3.780%	4.126%	4.173%	3.351%	2.536%	1.942%	1.354%	0.702%	0.466%	0.308%	0.139%	0.102%	0.044%	0.056%	9	25.97%
3.5				0.004%	0.139%	0.897%	2.080%	2.148%	1.984%	1.664%	1.292%	0.944%	0.549%	0.367%	0.208%	0.110%	0.073%	0.025%	0.027%	11	12.51%
4.5					0.001%	0.029%	0.399%	1.056%	1.241%	1.052%	0.764%	0.592%	0.391%	0.229%	0.132%	0.069%	0.051%	0.009%	0.012%	13	6.03%
5.5						0.001%	0.026%	0.202%	0.564%	0.732%	0.541%	0.321%	0.182%	0.113%	0.067%	0.039%	0.028%	0.003%	0.003%	15	2.82%
6.5								0.010%	0.112%	0.313%	0.402%	0.255%	0.133%	0.068%	0.033%	0.016%	0.012%	0.001%	0.001%	17	1.36%
7.5								0.001%	0.010%	0.062%	0.155%	0.198%	0.097%	0.048%	0.024%	0.005%	0.005%	0.001%		19	0.61%
8.5										0.010%	0.038%	0.103%	0.079%	0.046%	0.011%	0.006%	0.002%			19	0.30%
9.5											0.003%	0.025%	0.040%	0.028%	0.010%	0.004%	0.004%			23	0.114%
10.5											0.001%	0.002%	0.015%	0.015%	0.011%	0.003%	0.001%			25	0.047%
11.5													0.004%	0.005%	0.005%	0.004%	0.001%			27	0.019%
12.5													0.002%	0.001%	0.005%	0.001%	0.003%			29	0.013%
13.5														0.001%	0.001%	0.001%	0.002%			31	0.004%
14.5														0.001%		0.001%	0.001%			33	0.002%
Sum	0.005%	0.272%	2.246%	6.268%	11.305%	14.082%	14.454%	13.049%	11.076%	8.941%	6.851%	4.801%	2.740%	1.746%	1.040%	0.499%	0.366%	0.122%	0.138%		100.00%

Figure 14 – North Sea Hs-Tp Omnidirection Scatter Diagram

The study considered collinear wave, wind and current. The following were also considered:

- Irregular Waves
- Wind spectrum NPD
- Rig/wave heading 0 deg
- Drift off performed for 10 wave realizations, 50% NE reported
- 3 hour time domain analysis in DP station keeping analysis
- Wind speed versus Hs as per scatter diagram
- Current 1 year profile is applied to all runs (conservative)

North Sea Results

The North Sea results include 9 seconds, 32 seconds, and 73 second EDS scenarios. The 32 second EDS represents a typical EDS time where only a blind shear ram is activated prior to LMRP separation.

Figure 15~~Figure 15~~ shows the results from the simulations conducted showed a vessel with a K-BOS enabled 9 second EDS could conduct DP drilling operations in 350ft of water with 95.3% uptime. This is an improvement from 10.5% uptime with a 73 second EDS and 75.8% uptime with a 32 second EDS. It should be noted that all year weather conditions were used for the study. It would be reasonable to assume even higher uptime results could be achieved if operations were scheduled to avoid harsh winter weather.

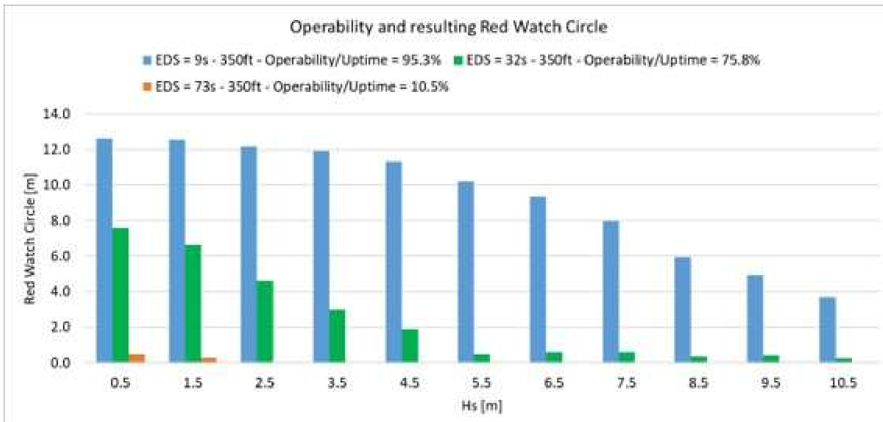

Figure 15 – Operability and RWC (North Sea)

Figure 16~~Figure 16~~ shows substantial gains in red watch circle size and time to disconnect in 350ft water depth as compared to 32 second and 73 second EDS scenarios. Red watch circles for 350ft water depth grew from less than 5m with 32 second EDS and 2.5M Hs to more than 12m with a 9 second EDS.

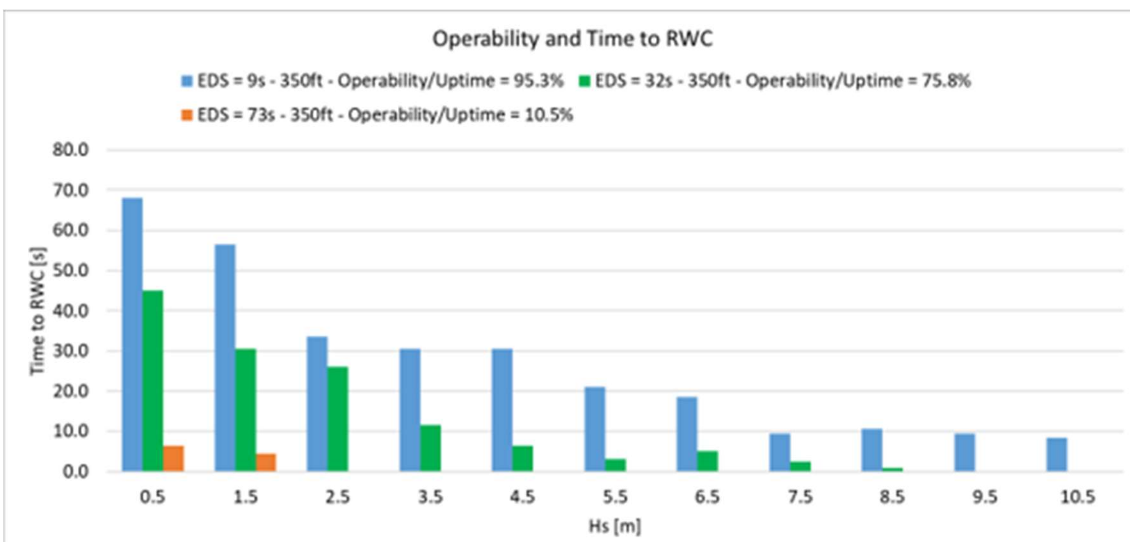

Figure 16 – Operability and Time to RWC (North Sea)

Figures 17 provides an overview of the yearly drilling operability improvement for 9 second EDS vs. 32 second EDS for North Sea conditions. For 350' and 1000' water depth respectively.

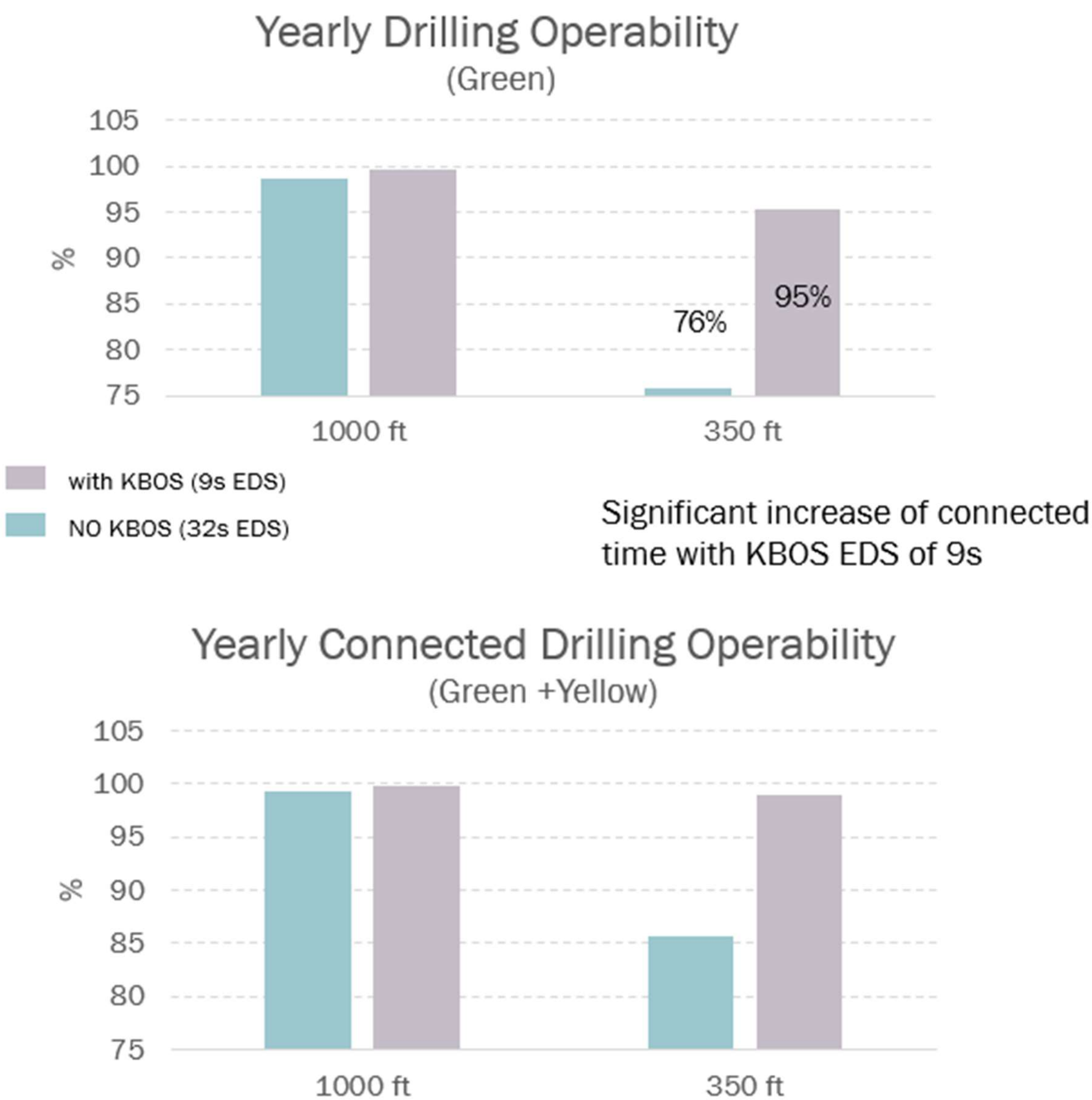

Figure 17 – Yearly Drilling Operability (North Sea).

Figure 18 shows the operability scatter diagrams for 9 second EDS, 32 second EDS, and 73 second EDS, respectively.

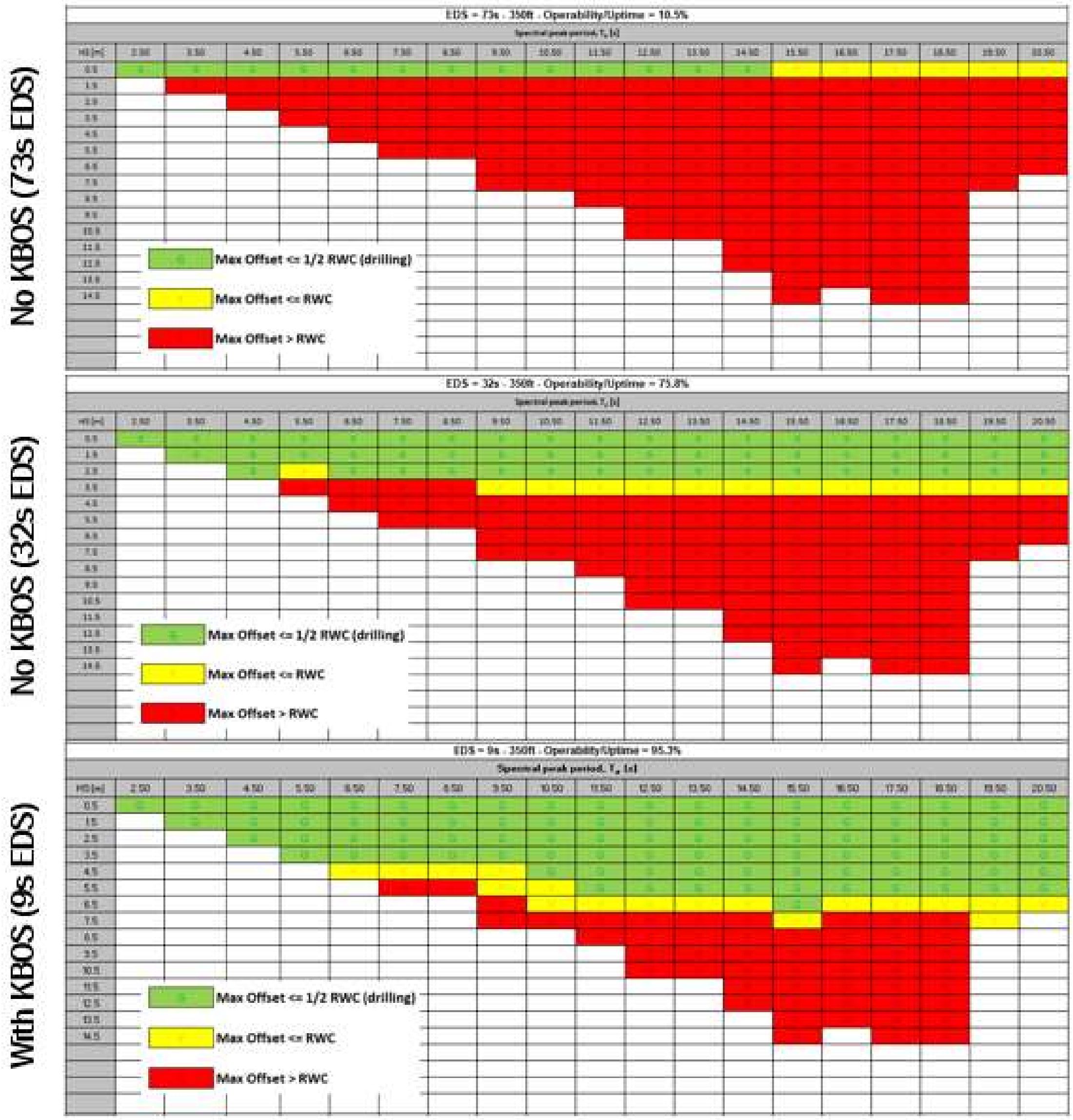

Figure 18 – Operability Scatter Diagrams (North Sea)

Reduced Bending Load

The 9 second EDS can result in a significant reduction in bending moment on the wellhead foundation system vs a 73 second EDS. This provides opportunities to optimize rig selection for a range of activities. These include:

1. Ability to use DP vessels vs moored rigs
2. Eliminate need for BOP tethering system
3. Allow DP operations in shallow water for reentry of older wells with lower strength foundation systems

Value Summary

The capabilities of K-BOS to shear/seal instantly provides the capability to significantly reduced EDS time and enable improved DP operability in shallow water and harsh environment scenarios. This provides the following benefits:

1. Operational benefits including improved DP operability and reduced Non-productive time.
2. Wells Process safety risk reduction
3. Alternative to moored vessels

The reduced EDS time enables contracting flexibility in areas where operators have deep water and shallow water operations, allowing a DP drilling vessel to operate in shallow water can result in complete asset coverage and the need for contracting multiple vessels. The advantages of using a DP rig vs. and anchored rig include:

1. Operational Time Savings
   - DP vessels can transit faster between operational sites.
   - Upon arrive at site, DP vessel can begin operations quicker.
2. Anchoring Savings
   - Eliminate time & cost associated with running/retrieving anchors and prelaid mooring system.
3. Tethering Savings
   - By reducing the time to disconnect is possible to reduce /remove the need for tethering BOP stacks.
4. Reduced Auxiliary Vessel Need
   - Auxiliary vessel for running pre-laid mooring and tethering may not be needed for operations

Conclusion

Utilizing K-BOS technology to complete an EDS sequence in as little as 9 seconds significantly widens the operability window for DP drilling vessels in shallow water and/or harsh environment. This study has shown that operating a DP drilling vessel in 350 ft water is possible to operate with 100% uptime in the US GOM and >95% uptime in the North Sea.

The K-BOS technology provides an improvement in wells process safety risk and allows DP operations in shallow water/harsh environment scenarios.

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