DYNAMIC POSITIONING CONFERENCE
November 15-16, 2005

Risk Management

Safety of DP Operations on Mobile Offshore Drilling Units on the Norwegian Continental Shelf

Barriers to Prevent Loss of Position

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ABSTRACT

Barrier methodology is applied to safety modeling of DP operations on mobile offshore drilling units (MODUs). Based on the DP incident experiences on MODUs on the NCS, a critical scenario, i.e. a DP control system initiated drive-off due to erroneous position data from DGPS systems, is selected for modeling and analysis. In this paper ten barrier elements are identified in order to prevent this loss of position scenario from initiation. Deficiencies on these barrier elements are revealed based on the operational experiences on the NCS. Measures to strengthen these barrier elements are recommended. These findings and the methodology are believed to be of generic and practical values for loss of position preventions on offshore DP drilling units worldwide.

ABBREVIATIONS

BOP	Blowout Preventer
DGPS	Differential Global Positioning System
DP	Dynamic Positioning
DPO	Dynamic Positioning System Operator
DUBE	Driftsutvalg for offshore entreprenørvirksomhet i Norges Rederiforbund (In English: Operations committee of offshore companies in Norwegian Shipowners' Association)
EQD	Emergency Quick Disconnect
FMEA	Failure Modes and Effect Analysis
HDOP	Horizontal Delusion of Precision
HIPAP	High Precision Acoustic Positioning System
HSE	Health and Safety Executive
IALA	International Association of Light House Authority
IMCA	International Marine Contractor Association
MODU	Mobile Offshore Drilling Unit
NCS	Norwegian Continental Shelf
NMD	Norwegian Maritime Directorate
NPD	Norwegian Petroleum Directorate
NTNU	Norwegian University of Science and Technology
PSA	Petroleum Safety Authority (Norway)

1 INTRODUCTION

1.1 Background

A joint industry research project - safety of dynamic positioning (DP) operation on mobile offshore drilling units (MODUs) on the Norwegian Continental Shelf (NCS) has been on-going since autumn 2003. The main objective of this research project is to improve the safety of DP operations of MODUs on the NCS.

The project was initiated by the Centre for Ships and Ocean Structures at NTNU and the operations committee of offshore companies in Norwegian Shipowners' Association (DUBE) in late 2003. The sponsors include the former two organizations, Statoil, Hydro and Scandpower Risk Management. The research activities and results are subjected to reviews from a reference group which includes representatives from: Statoil, Hydro, Centre for Ships and Ocean Structures at NTNU, drilling rig owner workgroup at DUBE, Smedvig Offshore, Stena Drilling, Saipem, Fred Olsen Energy, Prosafe Offshore, PSA (former NPD in Norway), HSE (UK), NMD, DNV, Kongsberg Maritime, and Ship Maneuvering Simulator Centre in Trondheim.

This paper presents a part of the project findings which consists of:

- Overall safety modeling of DP operations on MODUs in light of the barrier methodology
- Identification of barrier elements, analyses of their deficiencies, and recommendations to strengthen them in order to prevent loss of position

1.2 Barrier Methodology

The background of using barrier methodology in this study comes from the regulations relating to management in the petroleum activities from NPD (Ref. /i/). The regulation states that barriers shall be established which a) reduce the probability that any failures and situations of hazard and accident will develop further, and b) limit possible harm and nuisance.

In this study barriers are decomposed into barrier function and barrier element. The working definitions are given below. They are taken from the definitions developed in the offshore industry in Norway (Ref. /ii/).

- **Barrier function**. A barrier function represents a function (and not an object), which can arrest the accident evolution so that the next event in the chain is not realized, or reduce the accident consequences.
- **Barrier element**. A barrier element is to achieve the required barrier function. Such element can be an operator, an instruction, an automatic device, or an emergency preparedness plan.

An overall illustration of the barrier methodology used in this study is given in Figure 1.

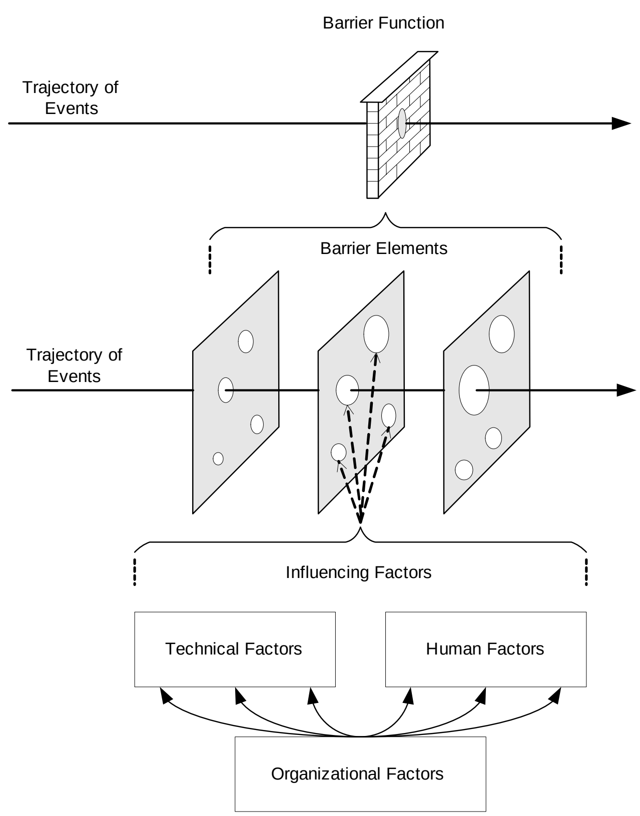

Figure 1: Illustration of Barrier Methodology

As illustrated in Figure 1, a barrier function is generally achieved by one or several barrier elements. No one barrier element is ever entirely intact. The barrier elements in real world have weaknesses and gaps - holes. These holes on barrier element may be influenced by several technical, human and/or organizational factors.

1.3 Structure of Paper

The contents in this paper are structured as follows.

In Chapter 2 an overall barrier model is presented. It consists of three main barrier functions that are crucial to the safety of DP drilling operation.

In Chapter 3 a barrier model to prevent a critical scenario, i.e. drive-off initiated by DP control system due to erroneous position data from DGPS, is developed. It consists of two barrier functions in order to 1) prevent erroneous position data from DGPS, and 2) prevent DP controller using erroneous DGPS data for positioning.

In Chapter 4 and Chapter 5 barrier elements to achieve the two barrier functions identified in Chapter 3 are identified systematically. Deficiencies are revealed based on the operational experiences on the NCS. Recommendations to strengthen these barrier elements are given.

In Chapter 6 conclusions are given and further work is also outlined.

2 BARRIER MODEL IN DP DRILLING OPERATION

2.1 Background

A dynamically positioned MODU performing drilling operation (termed as DP drilling operation in this paper) on the NCS is illustrated in Figure 2. The MODU is positioned within a green zone inside the yellow limit. Various excursion limits (advisory, yellow, red and physical) are illustrated in the figure.

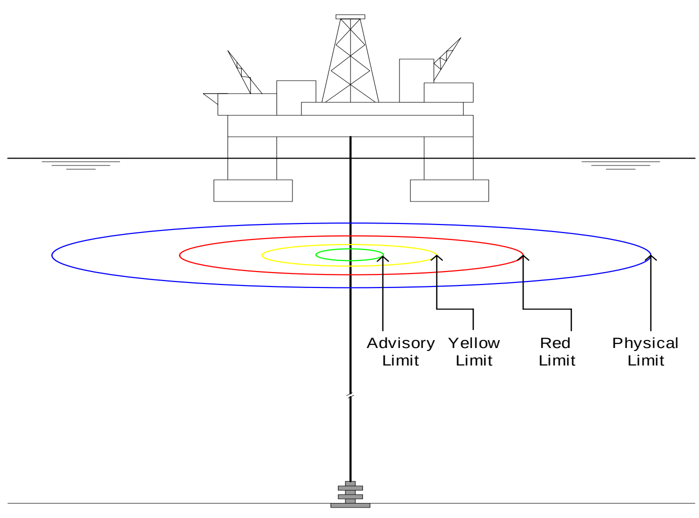

Figure 2: DP drilling operation on the Norwegian Continental Shelf

We need to emphasize that the *loss of position* defined in this study is: MODU loses, either temporarily or for an extended time, the capability to maintain its position by means of thruster force, and consequently has a position excursion which is beyond the yellow limit.

2.2 Barrier Model for Safety of DP Drilling Operation

According to the barrier methodology discussed in Chapter 1.2, the following three main barrier functions that are critical to the safety of DP drilling operation are identified:

- Barrier function 1: to prevent loss of position
- Barrier function 2: to prevent critical loss of position, given a loss of position
- Barrier function 3: to prevent loss of well integrity, given a critical loss of position.

An illustration of these three main barrier functions in relation to the horizontal excursion that a MODU may have, and failure events defined at various stages in this study, is given in Figure 3.

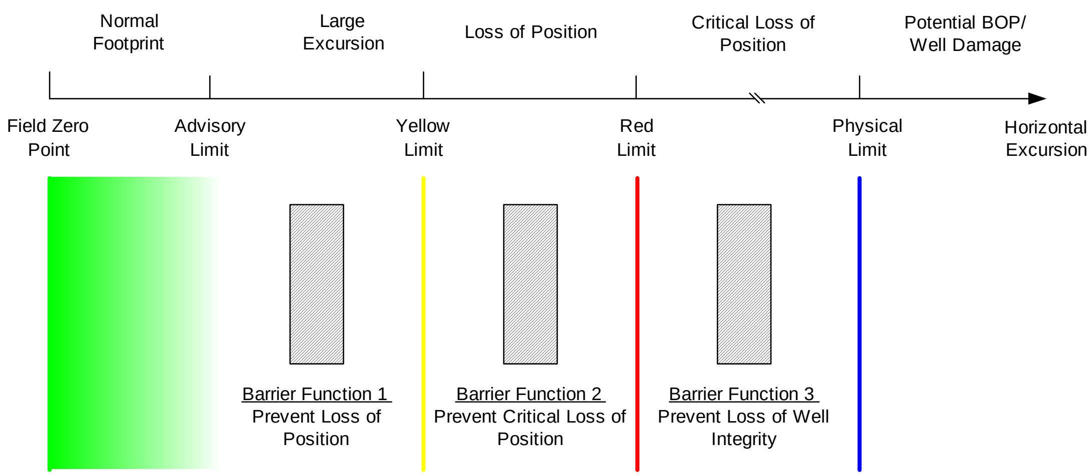

Figure 3: Three Main Barrier Functions with Respect to the Safety of DP Drilling Operation

The analyses of barrier function 1 are presented in Chapter 3-5 in this paper.

The analyses related to Barrier 2 & 3 are briefly described below, and will hopefully be summarized into a paper for a future MTS DP Conference.

2.3 Barrier Function 2

Barrier function 2 is primarily achieved by DP operator. In a loss of position scenario, it is the DP operator (not automatic technical systems) that performs recovery actions to arrest vessel movement.

A three stage reaction process model is established to model the DP operator's recovery action initiation process in the drive-off scenario. The DP operator's performance is influenced by five identified performance shaping factors, i.e. bridge ergonomics, alarm system, procedures, competence and training, and operational management. Deficiencies in these factors are identified, and recommendations to strengthen the human barrier element are proposed.

The research work is carried out based on 1) extensive DP operational data collected from the rig owners involved in this project, and 2) recognized principles of human factors in design and operation, i.e.

ergonomic design of bridge (Ref. /iii/ & /iv/), human information processing theory (Ref. /v/), and situation awareness theory in automation (Ref. /vi/). Proposed measures cover technical, organizational, as well as human factor domains in order to strengthen the human barrier element.

2.4 Barrier Function 3

Barrier function 3 is achieved by performing successful BOP emergency quick disconnect (EQD) prior to the vessel passing the physical limit.

The physical limit is operation specific, influenced by, e.g. water depth, riser design, etc. For shallow water, the physical limit is often a circle with rather limited diameter. The EQD process may be similar among MODUs. It will typically involve an operation of 15 to 20 (or more) functions, and the whole sequence may take about 30-90 s to finish. However, with respect to the way that the EQD process being initiated, there are two concepts currently existing on the NCS: 1) Automatic concept, i.e. EQD will be automatically initiated if certain design parameters are not satisfied, irrespective of driller actions; and 2) Manual concept, i.e. EQD will be initiated by driller pushing EQD button (the decision to activate the EQD due to loss of position is made by the DPO).

Physical barrier element, such as Auto EQD, Safe Disconnect System, and non-physical barrier element, e.g. teamwork between DP operator and driller, are identified and assessed in this project. Recommendations are made based on the identified potential weakness during operations on the NCS.

3 BARRIERS TO PREVENT LOSS OF POSITION

3.1 Incident Experience on the NCS

DP incident data analyses (Ref. /vii/ & /viii/) were performed in the beginning of the project. Definition of loss of position is made based on (relatively narrow) yellow and red limits from the DP requirement documents issued by oil companies on the NCS (Ref. /ix/ & /x/). There are two failure modes defined for loss of position, i.e. drive-off and drift-off.

The drive-off is defined as: there is abnormal thruster force so that vessel is driven away from the target position, and has an excursion beyond the yellow limit. Drive-off may be further divided into two types, one is thruster related - due to thruster control failure of one or several thrusters, and the other is DP control system related - due to erroneous position data (e.g. from DGPS, wind sensor, MRU, etc.) being used by DP controller so that the controller demands thrust from one or several thrusters.

Based on our definitions, we found six DP incidents on MODUs on the NCS that can be classified as drive-off since 1997 (up to May 2004). All drive-offs were *DP control system* related. Notably, five of these six drive-offs were initiated due to wrong position data associated with DGPS. Thruster related drive-off had not been reported for MODUs on the NCS, though it had happened on MODUs in other areas.

Drive-off due to erroneous position data from DGPS are hence selected for barrier modeling in this study. Analysis of this failure scenario could identify pertinent measures for MODUs on the NCS to prevent loss of position. The findings could also provide useful lessons to MODUs, which work in other parts of the world. Other types of drive-off scenarios (e.g. thruster related) and other types of loss of position scenarios (e.g. drift-off) are not included in this paper. However, it is believed that the methodology presented in this paper could be applied to analyze those scenarios too.

3.2 Barrier Function Identification

The event sequence of DP control system initiated drive-off due to erroneous position data from DGPS may be characterized by the following three main events:

1. DGPS's generate erroneous position data simultaneously or almost simultaneously, the erroneous position data are sent to DP software
2. DP controller takes in the erroneous DGPS data for positioning, the drive-off is initiated
3. MODU is driven to a wrong target position, and there were no timely and successful recovery actions taken by DPO. Eventually MODU passed the yellow limit, resulting in a drive-off incident.

The barrier functions along the event sequence are identified as the following three:

Barrier function 1.1 to prevent DGPS generating erroneous position data

Barrier function 1.2 to prevent erroneous position data being used for positioning by DP controller

Barrier function 1.3 to arrest MODU movement before MODU reaching the yellow limit, given a wrong target position being used by DP controller

An illustration of these three barrier functions in the selected drive-off scenario is given in Figure 4. Note that the numbering of above barrier functions indicates that they are actually "sub barrier functions" to the main barrier function 1 - to prevent loss of position. Given the hierarchical numbering, the term "sub barrier function" is not used in the following text of the paper.

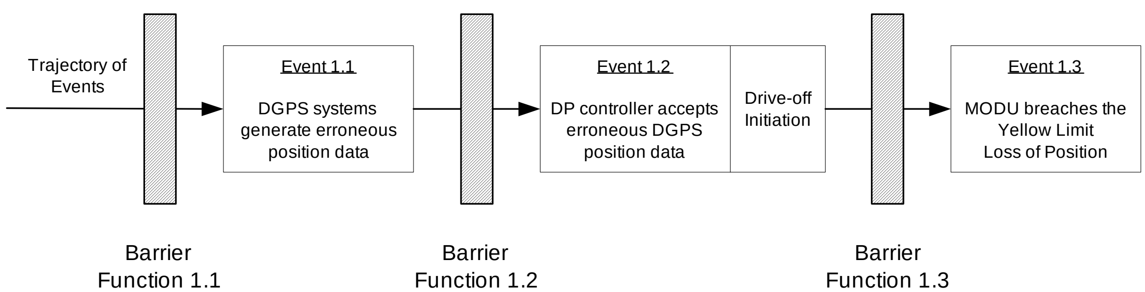

Figure 4: Three Barrier Functions to Prevent the Loss of Position Scenario

Analyses of barrier function 1.1 and 1.2 are presented in this paper. These two barrier functions largely cover the initiation of drive-off. The barrier function 1.3 is similarly to the barrier function 2 (Ref. Chapter 2.3), and both are achieved by DPO. Analyses and findings related to the barrier function 3 will be integrated in a future paper, which deals with the main barrier function 2.

4 BARRIER FUNCTION 1.1 - TO PREVENT DGPS GENERATING ERRONEOUS POSITION DATA

4.1 Incident Experience on the NCS

An overview of critical DGPS system failures on DP MODUs on the NCS is given in Table 1. These failures are considered as critical DGPS failures, since they all eventually led to incidents that are classified as drive-off in this study. There are in total five such incidents.

Table 1: Critical DGPS Failures on MODUs on the NCS

Incident	1	2	3	4	5
Failed DGPS's	2	2	2	2	2
Erroneous position data	Jump 65 m	Rapid drift 18/13 m	Rapid drift 18/12 m	jump[1)]	Slow drift
Satellite condition	Low number, poor constellation	-	-	Low number, poor constellation	-[2)]
Diff link condition	-	-	-	-	-
GPS equipment *	-	-	-	-	GPS antenna masking[3)]; Or noise/ disturbance of the signal in the coax-cable from the GPS antenna to the DGPS unit[3)]
Diff link equipment **	-	Wrong differential correction signal from a diff link Diff links are inter-connected with all DGPS units	Wrong differential correction signal from a diff link Diff links are inter-connected with all DGPS units	-	Wrong differential correction signal from a diff link[3)] Diff links are inter-connected with all DGPS units
DGPS unit ***	Incorrect system configuration (HDOP limit) vulnerable for position error tens of meters Monitor screen setup	HDOP limit[4)] Monitor screen setup[5)]	HDOP limit[4)] Monitor screen setup[5)]	-	-
Underlying causes	Service engineer changed DGPS unit configuration during maintenance	Diff link antenna location	Diff link antenna location	-	DGPS antennas location
Final event outcomes	Drive-off, 29 m excursion	Drive-off, 15 m excursion	Drive-off, 19 m excursion	Drive-off, 12 m excursion	Drive-off, 74 m excursion

1) Position data jump distance was not reported.
2) The investigation report did not provide satellite status during the incident. However at the time of incident, both "invalid satellite" warnings were given to both DGPS's. Other MODUs working on the NCS at the same time did not report any DGPS failures. This may imply that GPS satellite condition was not the cause. There could be common mode failures affect GPS equipment for both DGPS's
3) The failure was suspected, but was not concluded in the report
4) HDOP limit was found not correct. The DGPS system was open for position errors in 10-15 m given poor satellite constellation. However, when the incident happened, the satellite condition was normal. This implied that the failure causes could not be related to the HDOP limits, though it was not correctly set up.
5) This influences the DP operator's capability to detect if there is a position jump. However, it did not cause the failure data from DGPS
- No failure or abnormal situation, or lack of information in the report.

Definitions:
* The GPS equipment mainly includes GPS antenna, GPS receiver, and associated cables and amplifiers.
** The diff link equipment mainly includes diff link antenna, demodulator, and associated cables. There are typically three diff links used for operations on the NCS, i.e. Inmarsat, Spot beam, and IALA (International Association of Light House Authority) radio beacon. Splitters are used in order to connect one diff link signal with several DGPS units.
*** The DGPS unit includes DGPS computer with associated hardware and software, monitor which present DGPS data to DP operator, keyboard, and associated power supply (UPS).

Based on a cross-examination of these five DGPS incidents, we identify a critical DGPS failure, i.e. simultaneous or almost simultaneous erroneous position data from both on-line DGPS systems. The erroneous position data from two DGPS systems manifested in three types in those critical DGPS failure events, i.e. position jump, rapid drift and slow drift.

4.2 Barrier Elements Identification

In order to prevent the potential failures causing erroneous position data from one or both DGPS systems, the following six barrier elements (illustrated in Figure 5) are identified:

- Barrier element 1.1.1 - Type and independence between 2 DGPS's
- Barrier element 1.1.2 - Appropriate antenna locations
- Barrier element 1.1.3 - FMEA and performance assessment
- Barrier element 1.1.4 - DP operator
- Barrier element 1.1.5 - Signal input validation
- Barrier element 1.1.6 - DPGP position quality control (QC).

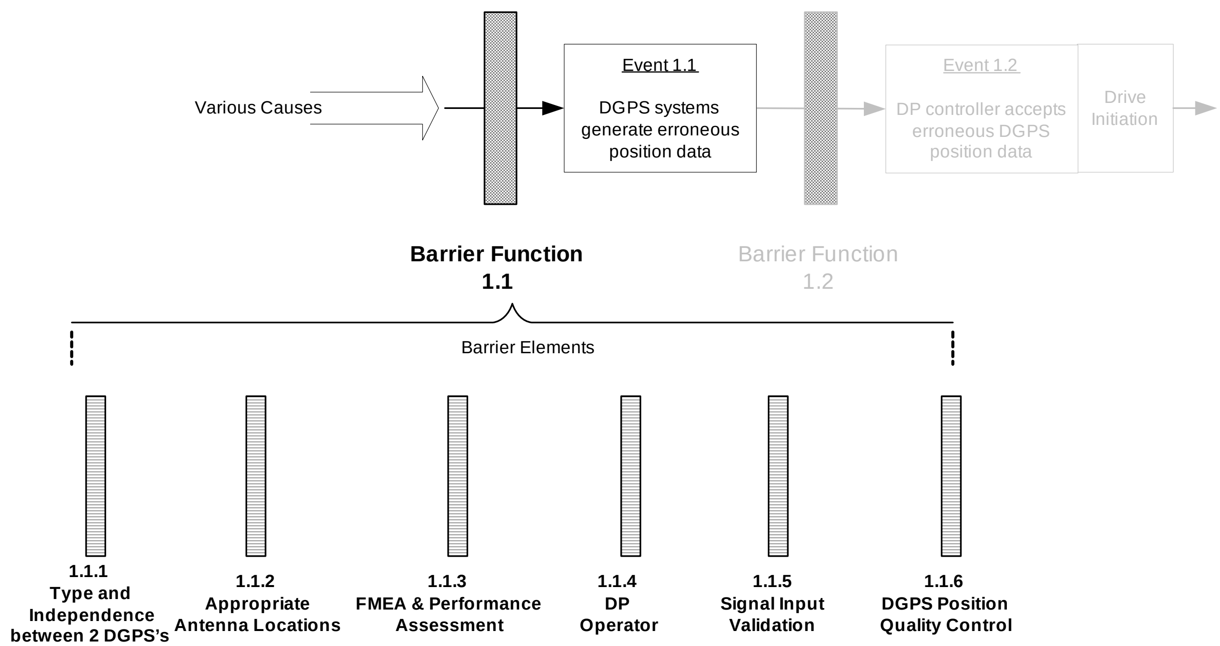

Figure 5: Barrier Elements to Prevent Erroneous Position Data from DGPS

A few more words about these identified barrier elements. There are in general many existing barrier elements, such as design reviews, FMEA, FAT (factory acceptance test), CAT (client acceptance test), sea trial, annual trial, maintenance programs, and so forth. They may appear at various stages in a life cycle of DGPS system. For a comprehensive coverage of these general measures (barrier elements) to eliminate various failures in a life cycle of DGPS system, reference is made to IMCA M141, Ref. /xi/, Chapter 3 and 4.

The IMCA M141 was issued in October 1997. Since recent, DP incidents found in this study have highlighted several failures (see Chapter 4.1) that nevertheless happened, and caused simultaneous erroneous position data from two "independent" DGPS systems onboard. The barrier elements in Figure 5 are identified so that these causes could be eliminated or minimized. Efforts are also made to arrange the barrier elements in sequence from a life cycle point of view.

Descriptions of basics of each barrier element and analysis of its deficiencies were performed in the project. The contents are lengthy and hence not detailed in this paper. The recommendations made for each barrier element are summarized below.

4.3 Recommendations

4.3.1 Barrier Element 1.1.1 - Type and independence between 2 DGPS's

The independence between two DGPS systems has been highlighted by the incidents. An immediate recommendation is that one diff link should not be used by more than one DGPS unit at one time. This measure could correct the lack of independence between the two DGPS systems. There could be other latent causes that may damage the independence between two DGPS systems. For example, software failure and/or human failure, both could affect two DGPS systems even though two independent sets of equipment are provided. We also have to note that possible external causes (such as satellite condition) could anyhow affect two DGPS systems. A second recommendation is hence to rig owners. They preferably need to perform vessel specific inspections and analyses to ensure the independence between DGPS systems. If the independence is somehow found not satisfactory, or loss of independence is inevitable, either due to internal or external reasons, use of two or more DGPS inputs to main DP control system at all times should be re-evaluated or revised.

Last but not the least, both DGPS systems' correct functioning will depend on the external GPS satellite conditions, if two DGPS systems are both based on GPS. Use of GPS and GLONASS combined DGPS system could increase the available positioning satellites. It reduces the system's dependency on GPS satellite conditions. The MODUs should preferably use one GPS and GLONASS combined DGPS system, and one GPS based DGPS system. This may also bring the advantage of different hardware and software in two DGPS systems.

4.3.2 Barrier Element 1.1.2 - Appropriate Antenna Locations

The recommendation is to rig owners. They should preferably check the current status of all antennas' locations in DGPS system. The IMCA M141 (Ref. /xi/, Chapter 3.4.3 and 3.4.5) gives a few principles regarding appropriate antenna locations. If antenna locations are found not optimum, and are confirmed by the degraded quality of signals in operation, corrections need to be planned. If non-optimum antenna locations are inevitable, key DP personnel need to be aware of the potential consequences, and have remedy measures in the operation, e.g. avoid certain vessel headings.

4.3.3 Barrier Element 1.1.3 - FMEA and Performance Assessment

Firstly, the quality of DP system FMEA with respect to DGPS failures should be improved. It should not be only failures such as loss of signals or loss of hardware that are considered. Failures where system behaves reasonably but position data are erroneous should be identified, highlighted and analyzed. The following generic failure modes may be considered for DGPS systems when performing a vessel specific FMEA:

1. Loss of GPS signal
2. Error in GPS signal
3. Loss of diff link signal (Inmarsat, spot beam or IALA radio link)
4. Error in diff link signal (Inmarsat, spot beam or IALA radio link)
5. Loss of DGPS unit equipment
6. Error in position data due to DGPS unit
7. Error in GPS signal due to external conditions

8. Loss of diff link signal due to external conditions
9. Error in diff link signal due to external conditions

Secondly, DP system FMEA alone is probably not a sufficient solution for DGPS failures, due to the level of detail in such study. In addition, failures could appear in any stage in a life cycle of DGPS system. The recommendation is hence to perform a dedicated DGPS performance assessment. The DGPS performance assessment could identify various failures and operational limitations of DGPS systems. These are valuable inputs to safe DP operation on existing MODUs, as well as to design of new MODUs.

The proposed DGPS performance assessment may consist of:

1. Vessel-specific risk analysis of DGPS system based on the current design, installation, configuration and operation of the system
2. Field assessment of DGPS failure and performance which covers hardware, software, configuration, operational procedures, operator knowledge and external conditions.

The proposed DGPS performance assessment may be carried out in a similar approach as the TTS (teknisk tilstand sikkerhet[1]) assessment which is developed by Statoil. The TTS methodology (Ref. /xii/) was developed in the light of the barrier requirement after NPD's management regulations (Ref. /i/) came into force. And TTS assessments are being carried out for key technical systems on offshore installations on the NCS and onshore plants by several oil companies.

4.3.4 Barrier Element 1.1.4 - DP Operator

DPO has the access to various kinds of information in order to prepare himself for the possible external causes that could affect all DGPS's, e.g. forecasts related to GPS and GLONASS satellite availability (e.g. SATVIZ) from the Internet, warnings and updates of diff link status from service providers, etc. It is, however, a question of how to gather and integrate all available information for better planning in daily operations. Who, when and how to gather the information should be clarified, and guidance of how to use the gathered information should be provided to DPO.

4.3.5 Barrier Element 1.1.5 - Signal Input Validation

The signal input validation is designed by algorithms in the DGPS software. Given certain external conditions, one or several signal input validation parameters could be out of limits, and the DGPS system may stop delivering position data to DP software. The recommendation is that there should be management measures in place for setup and maintaining correct signal input validation functions in DGPS system configurations. Further discussions are referred to Chapter 4.3.6.

4.3.6 Barrier Element 1.1.6 - DGPS Quality Control

In general, the DGPS QC parameters, together with many other functional parameters, are not supposed to be "driven" by DP operators, as errors are assumed to be proportional to hands-on intervention. This is a principle recommended in IMCA M141 (Ref. /xi/). However, there should be management measures to maintain correct DGPS configuration. The measures should address, for example:

- Who should be responsible for maintaining and updating DGPS configuration,
- When should DGPS configuration be set up and be checked, e.g.:
  - on-arrival at field

[1] Technical Condition Safety

    - daily operation
    - after maintenance and upgrade
    - and other possible operational situations
- How frequent the configuration should be checked
- What are optimum configurations for various operational conditions.

Afterwards, there should be proper operational procedures and checklists in place to facilitate the operator to carry out the above tasks. There should always be competent personnel to carry out these tasks. If the tasks should be carried by key DP personnel onboard, they need to have proper competence by, e.g. equipment specific course, and other educational and training activities.

5 BARRIER FUNCTION 1.2 - TO PREVENT DP CONTROLLER USING ERRONEOUS DGPS DATA FOR POSITIONING

5.1 Incident Experiences on the NCS

After DGPS generating erroneous position data, information from the five critical DGPS failure incidents is further collected and summarized in Table 2.

Table 2: Incident Information in Five Critical DGPS Failure Events on MODUs on the NCS

Incident	1	2	3	4	5
Position references used prior to Incident	2 DGPS's 1 HiPAP	2 DGPS's 1 HiPAP	2 DGPS's 2 HiPAP's	2 DGPS's 1 HiPAP 1 HPR 1 Taut Wire	2 DGPS's 1 HiPAP
DP Operator Action	-	-	-	-	-
DGPS input validation	DP software did not have DGPS input validation function	DGPS input validation was not able to prevent the errors in this incident	DGPS input validation was not able to prevent the errors in this incident	Lack of info	DGPS input validation was not able to prevent the errors in this incident, or not configured correctly
PRS data error testing	Failed. 2 DGPS's were rejected initially. But shortly after, they were taken in automatically when position data were still erroneous	Failed. 2 DGPS's were rejected one by one initially. But shortly after, they were taken in automatically, when position data were still erroneous	Failed. 2 DGPS's were rejected one by one initially. But shortly after, they were taken in automatically, when position data were still erroneous	Failed	Ambiguity info.[1)]
Final event outcomes	Drive-off, 29 m excursion	Drive-off, 15 m excursion	Drive-off, 19 m excursion	Drive-off, 12 m excursion	Drive-off, 74 m excursion

1) The investigation report states that two DGPS had flashing lights when incident started. Based on DP vendor's info, flashing lights means DGPS's were rejected from the DP software. However, the investigation report draws conclusions on MODU in drive-off following 2 slowly drift DGPS's

\- Lack of information in the report.

5.2 Barrier Element Identification

In order to prevent DP controller taking in the erroneous DGPS data for positioning, the following four barrier elements (illustrated in Figure 6) are identified:

- Barrie Element 1.2.1 - DP operator
- Barrie Element 1.2.2 - DGPS input validation in DP software
- Barrie Element 1.2.3 - Adequate Position reference systems

- Barrie Element 1.2.3 - Position reference system (PRS) error testing in DP software.

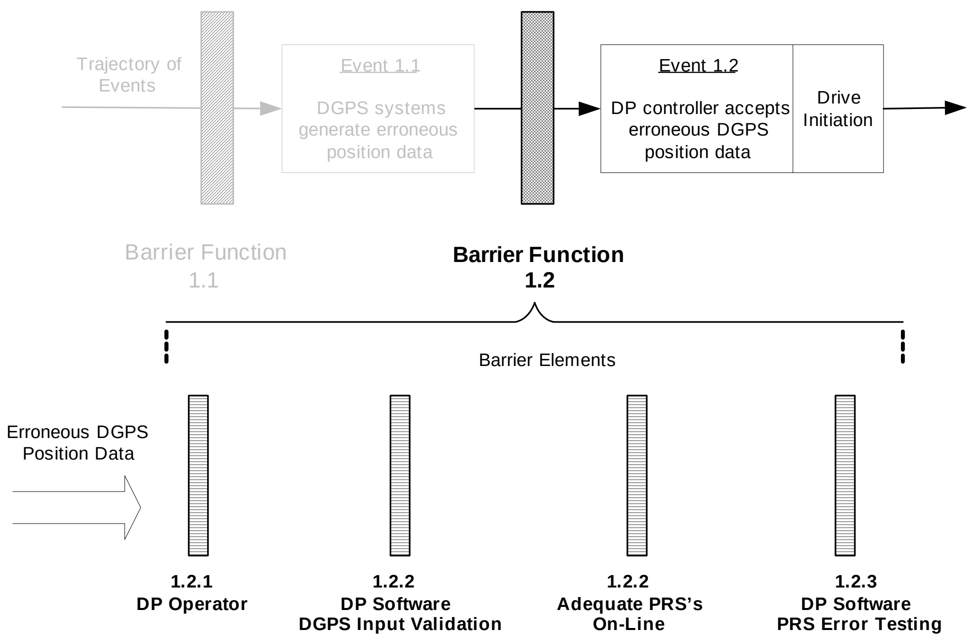

Figure 6: Barrier Elements to Prevent DP Controller Using Erroneous DGPS Data

The four barrier elements are inter-related instead of independent. DPO is viewed as the most important barrier element for barrier function 1.2. In normal operations DPO maintains optimum setup of DP software and uses adequate position reference systems. When encountering abnormal situations, DPO may be able to prevent erroneous DGPS position data being used by DP controller, irrespective to the other barrier elements. If this barrier element - DPO, has weaknesses, the following three barrier elements are vulnerable to various failures.

5.3 Recommendations

5.3.1 Barrier Element 1.2.1 - DP Operator

There should be proper operational procedures and checklists in place to facilitate DPO to carry out optimum configuration of DP software, as well as how to use the available position reference systems in a best way, and how to deal with abnormal situations which involves erroneous position data from DGPS (and other PRS).

The competence of DPO should also be improved via:
1. Equipment specific courses
2. Theory and simulator training

5.3.2 Barrier Element 1.2.2 - DGPS Input Validation

There may be a DGPS input validation check in some types of DP software. (But not all types of DP software!) It is to check if DGPS position data satisfy certain validations. The rationale is that if the valid satellite or diff link conditions are not maintained, the DGPS data should be excluded from further use in DP software, or be used cautiously.

The market situation is that not all DGPS system has a QC function (Ref. Chapter 4.3.6), just as not all DP software has a DGPS input validation. It is therefore important to ensure that at least one barrier element is available. The best is to have them both. These two barrier elements should be configured together, in a human centered and operational specific way. Below is a proposed example:

<u>DGPS QC function in DGPS software</u>

1. DGPS QC function could be configured with the minimum criteria for DGPS system to function correctly on a specific field. If the minimum criteria are not satisfied, DGPS system should stop delivering position data to DP software
2. The configurations of DGPS QC function are viewed field-specific, and should be set up and maintained when arriving at a new field. They are not subjected to changes by DPO on a daily bases.

<u>DGPS input validation in DP software</u>

3. Warnings are given to alert DPO as early as possible for degrading external conditions
4. Alarms are given and DGPS inputs are rejected when external conditions are deemed not suitable for the operation
5. Different criteria for warning and alarm could be specified, and could be tuned based on actual operational context, DPO's preference, forecasted satellite information, and so on.

5.3.3 Adequate PRS On-Line

Adequate position reference systems should be used at all times during the operation. A recommendation is to use enough position reference systems with <u>three</u> different principles, instead of only three independent reference systems. Position reference inputs with three different principles could improve the current imbalance weighting between DGPS and acoustic systems in the DP software.

The recommendation is possible mainly for shallow waters, where DGPS, acoustics, and taut wire could be used. For deep waters where taut wire is not possible, design and use of new position reference system, such as HAIN (HiPAP Aided Inertial Navigation system, Ref. /xiii/)), should be investigated.

5.3.4 Barrier Element 1.2.3 - PRS Error Testing

If DGPS inputs are viewed valid by DP software, the next step in DP software is to check if all valid PRS inputs are correct. There are a number of PRS error tests being performed by DP software, and the algorithms for these tests may vary among different DP software.

Firstly, there are two recommendations from an operational point of view to facilitate position reference error testing in DP software. Use these recommendations could improve the chance that two erroneous DGPS inputs are detected and rejected by DP software.

1. Re-evaluate using two DGPS inputs. Taut wire is generally not possible for water depth over 500 m. In that case only DGPS and acoustics are available currently. Use two DGPS inputs combined with one or two acoustics in DP software may be avoided, or at least should be subjected to further detailed evaluation. The current weighting imbalance between DGPS and acoustics in DP software is the main background reason.

2. Optimum configuration of DP software. Error testing in DP software needs to be configured for specific operational conditions. For example, DP operator has the possibility to adjust DGPS weighting in DP software, in order to let acoustic systems have higher weighting. The optimum configuration of DP software demands competence from key DP personnel, as well as guidance of how to configure those position reference error testing parameters, procedures of when to do it and who to do it, and so on. These guidance and procedures should be vessel specific and operation specific.

Secondly, a principal recommendation is to improve DP software design, so that DP software could effectively detect and reject erroneous DGPS inputs, and correctly re-enable them when DGPS data are back to normal. Two preliminary ideas are given below in the light of this recommendation.

1. Improve weighting of DGPS. Weighting of DGPS inputs in DP software needs to be reviewed. The DGPS inputs should not have significantly higher weight than other position reference inputs.

2. Design of DGPS data error testing. The design may be improved so that erroneous DGPS position data will be detected more effectively. This may include improving existing PRS error testing algorithms or introducing new PRS error test functions in DP software. The DP software should also be subjected extensive test by being given as many possibilities of erroneous DGPS data as possible. Such test could reveal possible weakness in software algorithms related to DGPS input error testing. The hardware-in-the-loop test developed by Marine Cybernetics (Ref. /xiv/, and HIL test certification by DNV in Ref. /xv/) is viewed as an effective solution in this area.

6 CONCLUSIONS AND FUTURE WORK

Barrier methodology is applied in this paper. Three main barrier functions that are critical to the safety of DP drilling operation are identified. The main barrier function 1, which is to prevent loss of position, is further analyzed in this paper. Based on the incident experiences on DP MODUs on the NCS, a critical scenario, i.e. DP control system initiated drive-off due to erroneous position data from DGPS systems, is selected for modeling and analysis. The analyses identify the involved barrier elements, highlight deficiencies based on NCS experiences, and provide recommendations to strengthen each barrier element. The recommendations may also be applicable to DP drilling operations conducted in other parts of the world.

A possible future work is to summarize the project findings related to the main barrier function 2 and 3 into papers at a future MTS DP Conference.

7 ACKNOWLEDGEMENT

The authors would like to thank the five sponsors, Statoil, Norsk Hydro, Norwegian Shipowners' Association, Centre for Ships and Ocean Structures at NTNU, and Scandpower Risk Management AS, that made this study possible, and for their permission of publishing this paper. The author would also like to acknowledge the following two individuals for their supports on the barrier concept and methodology: Prof. dr.ing. Jan Erik Vinnem (Preventor AS, University of Stavanger), Gerhard Ersdal (PSA). The valuable inputs from Torbjørn Hals in Kongsberg Maritime AS regarding DGPS and DP software are also very much appreciated.

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