SURVEY REPORT: NAU-SR-SD-001 Rev 01_abridged

HULL STRUCTURAL VISUAL INSPECTION UTILISING DRONE (UAS)

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EXECUTIVE SUMMARY

A pilot survey by UAS (Unmanned Aerial System, or "drone") of the hull structure of a semi-submersible drilling unit was performed on 27th February, 2017 whilst the rig was moored inshore at Invergordon, awaiting mobilisation.

The motivation for the use of a UAS in this manner was to reduce the time taken to perform a visual inspection of the hull structure by minimizing (or removing) the need to mobilise rope-access personnel, or build scaffold platforms, to access the remote areas of the structure not visible from the rig. This not only improves survey efficiency but, more importantly, significantly improves safety as the rope-access and scaffold-build operations are both inherently hazardous.

The primary purpose of the pilot was to demonstrate that a survey performed utilising a UAS to obtain high-definition digital images can be of sufficient quality and detail to meet the requirements of Close Visual Inspection. This objective was successfully demonstrated.

The secondary purpose was to demonstrate that the survey could be performed from a survey vessel, without impact on the operations on-board the rig at the time of the survey. This objective was also successfully demonstrated.

The pilot survey also demonstrated that the team composition used (UAS Surveyor plus UAS pilot and co-pilot/camera operator) represented the ideal make-up to fully deliver a "dynamic" survey i.e. a survey in which the scope was modified during the survey in response to the results obtained as the survey progressed.

The pilot survey was performed in a manner that was fully compliant with the rig owners' Safety Management System and in accordance with the recently issued guidelines on the use of UAS's from Oil and Gas UK.

The pilot survey successfully demonstrated a technique that was fully aligned with the rig owners' high values in Safety Performance and Innovation.

1.0 INTRODUCTION

The prime objective for the pilot survey was to demonstrate the feasibility of using an Unmanned Aerial System (UAS) or "drone" to visually inspect in detail the critical areas of a drilling semi-submersibles' hull structure that would otherwise require rope access and /or scaffolding etc. to complete.

A secondary objective was to demonstrate that significant areas can be visually inspected without requiring access on to the unit, thereby reducing the impact on the day to day maintenance activities etc. of the unit.

To achieve these objectives, an inspection scope was developed, using as its basis DNV-OSS-101 Rules for the Classification of Offshore Drilling and Support Units; Chapter3 section 3: Periodical Survey extent for main class. October 2014.

Based on these, specific areas of the hull structure were identified (refer Targets list and images in Section 3.2.3) and a flight schedule developed to allow investigation utilising the drone (refer Section 2). The investigation was planned and executed solely from the deck of a workboat to deliver the secondary objective.

The survey was executed on 27th February, 2017 at Invergordon, Scotland, on a drilling semi-submersible moored inshore, preparing for mobilisation.

The survey was completed in 4 hours, and a total of 190 digital images were captured. Selected images are presented in this report to demonstrate that the requirements for Close Visual Inspection and the ability to examine in detail the areas under inspection, were met by the survey. These are presented in Section 4.

The survey was conducted in accordance with the requirements set out in the approved Survey Plan, document reference: NAU-SP-SD-001 Rev1, issued prior to the mobilisation to site.

The UAS team would like to thank the rig owner for allowing the access to the rig for this survey. Their support demonstrates their commitment to innovation and the promotion of and improvement to, safe working practices.

2.0 SCOPE OF SURVEY

2.1 PRE-SURVEY SCOPE IDENTIFICATION

In determining which areas to visually survey, Classification Rules were utilised as the guide. In particular, for this pilot, DNV-OSS-101 Chapter3 section 3: Periodical Survey Extent for Main Class is the guiding reference. This specifies areas requiring inspection, including critical areas and from this the following general locations were selected:

Horizontal bracings and connections (if accessible) – pontoon to pontoon

Vertical diagonal bracings and connections

Columns to deck connections

Main barge girder connections

Upper hull girders/bulkheads

Under deck coating condition (plus all exterior surface coating condition in general) – utilising the "look-up" camera facility.

Based on these requirements, the following specific locations for the pilot survey were selected (refer to Section 3.2.3) prior to the survey:

Key: T(x) – target (number)

In addition, the rig owner identified a particular location to be visually inspected. This is defined as Target (1) – T (1) on the mark-ups.

Other areas that were considered for visual inspection should time permit were:

Crane pedestals and top flange attachments

Anchor bolsters and fairleads

2.2 IN-SURVEY SCOPE ADDITIONS

During the survey, additional area were identified by the rig owner representative and the UAS Surveyor on board the workboat. These were examined in detail and are identified on the Target image as T (a1) etc.

The flexibility inherent within the operating methodology (refer Section 4) allowed for this “dynamic” scope development and was demonstrated powerfully during the survey.

3.0 OPERATING METHODOLOGY

3.1 PRE-SURVEY

Prior to commencement of the survey, the following activities were completed

i) The pilot survey UAS-specific risks were assessed and reported in document: RA353 ***** **** Structural inspection utilising drone (UAS) which was included in the Survey Plan.

ii) Prior to the commencement of the survey, at the time of the pre-survey briefing, an on-site review of the risk assessment was conducted to ensure that the risks remain relevant and to allow any other, location and time - specific risks to be identified and evaluated.

iii) Equipment preparation: the UAS team checked and prepared the UAS for flight prior to boarding/loading the survey vessel.

iv) Pre-survey briefing (Tool Box Talk -TBT) involving Surveyor (UAS Operations Manager & PTW Performing Authority); UAS team (pilot and co-pilot); Stena Safety Representative; Survey Vessel captain and crew.

In this all aspects of the survey were discussed and explained including scope (flight schedule), risk assessment/PTW, intended areas of UAS activity, potential operating effects (exhaust, turbulence etc.), operational requirements on-board (launch/capture arrangements, deck space restrictions, emergency landing requirements etc.), weather forecast, potential sources of disruption, marine deconfliction arrangements, survey vessel operating characteristics and limitations, safety briefings.

References:

Survey Plan: NAU-SP-SD-001 Rev1

DNV-OSS-101 Rules for the Classification of Offshore Drilling and Support Units; Chapter3 section 3: Periodical Survey extent for main class. October 2014

Oil & Gas UK UAS Standards and Guidelines Issue 1 January 2017

3.2 SURVEY OPERATIONS

3.2.1 TEAM COMPOSITION

The team for the survey comprised three, as follows:

Surveyor/Operations Manager: directs survey; monitors results in-survey; adjusts scope as necessary

UAS Pilot: operates the drone to requirements of Surveyor

UAS co-pilot: supports pilot, assists in launch recovery; observes flights (safety); operates camera under instruction of pilot

This team composition is considered as “exemplar” and vital to deliver the full flexibility of the UAS survey process. Direction of the image capture by the UAS by an experienced rig/ship surveyor ensures that the correct images are captured and that the scope of the survey can be managed “dynamically” and modified in-survey to ensure that all areas of interest are captured without the need for additional mobilisations.

This was demonstrated comprehensively during the survey, as Targets were identified that were additional to the areas identified pre-survey, following review of the images captured on-board the survey vessel.

3.2.2 FLIGHT OPERATIONS

Flight operations were performed in accordance with the Operations Plan defined by the UAS team – Document Title AMS Vol1 Operating Manual – submitted as attachment to the Survey Plan.

In addition, the following vessel operating procedures were followed:

Communications with the rig were conducted by the Survey vessel Captain, at the request of the UAS Surveyor on board the survey vessel.

Weather monitoring: was conducted by the Survey vessel Captain and crew

Survey Vessel station-keeping monitoring was under the control of the Survey Vessel Captain

Marine traffic monitoring was under the control of the Survey vessel captain but with support from the Surveyor and the rig Control Room.

For the pilot survey, a conservative “offset” (i.e. physical distance between UAS and asset) of 3 to 4 metres was maintained. The pilot survey confirmed, however, that in similar conditions, a minimum “offset” of 1.5 to 2 metres was achievable without compromising the UAS or asset under examination.

3.2.3 FLIGHT SCHEDULE

The flight schedule/record is included below:

Flight Number	Target Number *	Vessel Location *	Duration	Data Record Storage Folder Reference	Comments
1	T1,Ta1,Ta2	V A	10	Flt1AOI	3-4m offset
2	T1,Ta3,Ta4	V B	10	Flt2AOI	3-4m offset
3	T4,Tb1,T2	V B	10	Flt3AOI	3-4m offset
4	Tb2,T2,Tb3	V C	10	Flt4AOI	3-4m offset Plus Fairleads
5/6	T5,T6	V D	3&10	Flt5&6AOI	3-4m offset Battery alarm
7	Helideck	V B	5	Flt7AOI	3-4m offset GPS Reset
	DEMO	V B	10	General PR Complete	400'>20m offset
Total Elapsed Time				[Total 190 images]	4 hours on board survey vessel
Date					27.02.17

FLIGHT RECORD: SURVEY SD1 – HULL STRUCTURAL INSPECTION (PILOT)

*Refer Target and Vessel Location images below.

[Note: The Data Record Reference refers to the folders in which the survey images are located for detailed reference. These are issued separately to this report due to their size.]

TARGET LOCATIONS: PRE-SURVEY IDENTIFICATION

TARGET LOCATIONS: IN-SURVEY IDENTIFICATION

VESSEL LOCATIONS DURING SURVEY

3.2.4 AFTER ACTION REVIEW

Upon return to the shore base, a post-survey review was performed with all the on-board team to capture lessons learned from the survey and to determine the need for a follow-up survey utilising the contingency day.

Following review of all the images it was concluded that the survey objectives had been achieved and that a further day was not required. The rig and workboat owners/operators were advised accordingly.

4.0 RESULTS

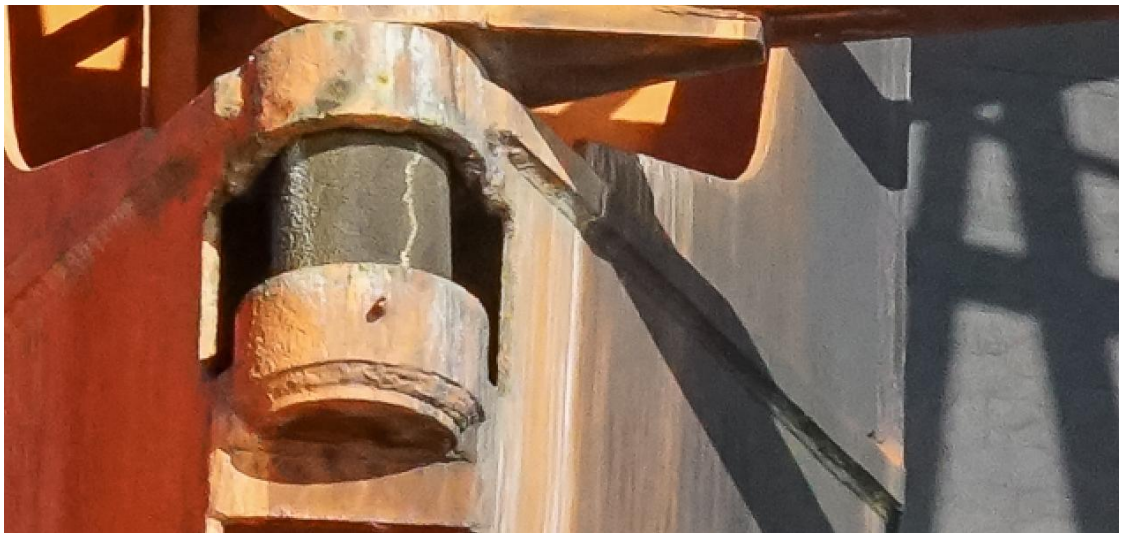
4.1 PRIMARY OBJECTIVE: CLOSE VISUAL INSPECTION (CVI) DEMONSTRATION

The following, selected, images demonstrate the degree of resolution obtainable after post-processing. This delivers a level of detail which is equivalent to observation with the naked eye at a distance of 1-2m and so meets the generally accepted criteria for CVI.

DIAGONAL BRACE JOINT DETAIL

ANCHOR FAIRLEADS – "POCKET" DETAILS

FLARE BOOM SUPPORT PIN DETAILS



Note: reference should be made to the images on www.nauticuas.co.uk as image quality is superior to that possible in the transposed, printable, versions above.

4.2 SECONDARY OBJECTIVE

The survey was completed without disruption to the rigs' operations from the workboat pictured below. The drone (UAS) was hand-launched and retrieved from the deck of the vessel. No intervention from the rig was required.

SURVEY VESSEL – PICTURED FROM THE UAS

The vessel utilised represents the minimum size required to safely perform the survey, assuming a UAS team of 3 plus one client representative on-board in addition to the crew of two.

4.3 SURVEY EXTENT ANALYSIS

The following table summarises the % completion achievable utilising the survey technique demonstrated in this pilot survey.

The extent required is as defined in the DNV Rules specified earlier in the report. The coding highlights the proportion of the visual inspection requirements which can be completed without the need for remote access arrangements, based on a detailed review of the results of the pilot survey (captured images and post-processing results).

		TYPE OF SURVEY											
		AS				*IS*				*RS*			
		INT		*EXT*		*INT*		*EXT*		*INT*		*EXT*	
		V	*NDT*	*V*	*NDT*	*V*	*NDT*	*V*	*NDT*	*V*	*NDT*	*V*	*NDT*
Special Areas for Inspection [1] *(SP) – Connections;*													
SP1	Horizontal bracing	A				A			A 7)	A	A	A	A
	Pontoon to pontoon	A				A				A	A	A	A
SP2	Vertical diagonal bracing	B				A				A	A	A	A
SP3	Columns to pontoon	X				C				A	X	A	C 3)
	Column to deck	X				C				A	X	A	C 3)
SP4	Main Barge girder/bulkhead.	X		X		X		X		A		A	X 8)
Attachments of:													
SP5	Crane pedestals and top flange	A		A		A	X	A	X	A	A	A	A
SP6	Anchor windlasses	X		A		X		A		A		A	C4)
SP7	Anchor chain fairleads and anchor bolsters	C		X		B		C		A		A	C4)
SP8	Helideck, derrick and drill-floor support	X		X		X		C		A		A	X
SP9	Other attachment/support connections, e.g. flare and life boat support structures	X		X		X		X		A		A	X
Primary Areas for Inspection (PR); [2]													
PR1	Horizontal bracings	A				A				A		A	
PR2	Vertical diagonal bracings	C				C				A		A	
PR3	Column and pontoon shell	X				C				A		A	
PR4	Upper hull girders/bulkheads	X		X		X		X		A		A	
PR5	Drill floor with substructure	X		X		X				A		A	
PR6	Crane/gangway pedestal	X		A		A		A		A		A	
PR7	Lifeboat platforms support			A				A				A	
PR8	Helideck support structure	X		X		X		A		A		A	

PR9	Other support structures	X		X		X		X		A		A	

A = 100% [6)]

B = 50% [5)]

C = 25% [5)]

X = Spot check 2-5% [5)]

V = Visual Inspection including Close Visual Inspection of Special Areas

NDT = Non-destructive Testing, normally Magnetic Particle Inspection (MPI) and/or Eddy Current (ECI) of selected stress concentrations and fatigue sensitive details

Notes

1) *Special Area for Inspection (SP)* is those sections of the Structure which are in way of critical load transfer point, stress concentrations, often special steel selection etc. see listing in [4.3.2].
2) *Primary Area for Inspection (PR)* are elements which are essential to the overall structural integrity of the unit. See listing in [4.3.2].
3) As a minimum centre bulkheads and corners to be covered.
4) May be waived if unit operating on DP.
5) - of the total number of these parts.
6) The inspection extent might be reduced (be less than 100%) if based on design documentation, see [1.2.6] above.
7) External NDT may be waived at IS if the unit has an approved leakage detection system according to guidelines issued by the Society.
8) Area adjacent to column connection to deck.

Code:

Survey extent % achievable	>90%	
	>70% <90%	
	>20% <70%	
	<0% <20%	

APPENDIX A – IMAGES (DATA RECORD STORAGE FOLDERS issued separately)

Refer to following table to cross refer images to targets etc.

Flight Number	Target Number *	Vessel Location *	Duration	Data Record Reference	Comments
1	T1,Ta1,Ta2	V(a)	10	Flt1AOI	3-4m offset
2	T1,Ta3,Ta4	V(a)	10	Flt2AOI	3-4m offset
3	T4,Tb1,T2	V(b)	10	Flt3AOI	3-4m offset
4	Tb2,T2,Tb3	V(c)	10	Flt4AOI	3-4m offset Plus Fairleads
5/6	T5,T6	V(c)	3&10	Flt5&6AOI	3-4m offset Battery alarm
7	Helideck	V(b)	5	Flt7AOI	3-4m offset GPS Reset
	DEMO	V(b)	10	General PR Complete	400'>20m offset
Total Elapsed Time				[Total 190 images]	4 hours on board survey vessel
Date					27.02.17

FLIGHT RECORD: SURVEY SD1 – HULL STRUCTURAL INSPECTION (PILOT)

*Refer Target and Vessel Location images in Section 4.3

T1: Connection PVD23 T2:PDV2, SDV2

T3: SC1 T4:H1

T5:TG2 T6: Under deck general condition

Ta1:PC1 Ta2:SVD12 Ta3:H2, SC2

Ta4:PC3 Tb1:SC1 Tb2:SC2 Tb3:PVD1, SVD1