IMPROVING OFFSHORE HELICOPTER OPERABILITY & SAFETY

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Abstract

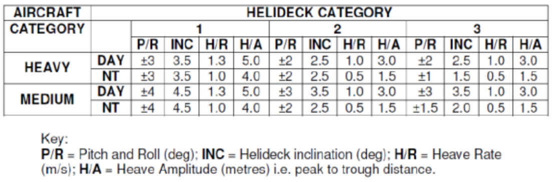
Helicopter services have been used by the offshore industry for decades. Traditionally offshore production platforms were fixed. For drilling, installation and work-over, large and stable semi submersibles were deployed. Nowadays helicopters have to operate on FPSO’s, drillships and relative small well intervention and installation vessels. In countries around the North Sea, Civil Aviation Authorities (CAA) and helicopter operators are operating under a strict regime; for “small” vessels helicopters are only allowed to land and remain on deck if pitch and roll angles are less than 2° and the average heave rate of the largest wave is less than 1m/s for the last 20 minutes.
MARIN technicians noted the sensitivity of offshore operations to these restrictions when they had to remain on standby at a Norwegian heliport for a week awaiting favourable landing conditions before flying to the destination vessel. The week wait sparked the incentive to investigate helicopter workability on ships and possibilities to extend that. A workability analysis for an 80 m light well intervention vessel operating offshore Norway, showed that the downtime for helicopter operations in winter time assuming good visibility may drop to 70 and 90% depending on the relative wave direction[1]. Helicopter availability is essential for an economic operation of these vessels as the alternative is to leave station and return to shore which can take days depending on the working area.

The Helicopter Operations for Offshore Ships (HELIOS) project aims on decreasing the ‘downtime’ for offshore helicopter operations while at least maintaining the present safety standards. This is achieved by at first finding options to improve and optimize operations inside the existing standards and secondly by researching available “new technology” to increase safety and operability. Important conclusions are that: 1) Helicopter operability is dominated by “stability on deck” considerations. 2) Recent incidents suggest safety will be improved mostly by improving the pilot’s situational awareness during approach and landing. 3) Many technical solutions are available to improve safety and operability of the isolated stages in a helicopter operation. 4) A formal regulatory framework for helicopter ship operations is missing, so introduction of dedicated new technology can be done as it can be in the regular aviation world. 5) Actual introduction of technology requires technology pull from offshore oil companies in order to start certification procedures, enter trial and acceptance procedures with pilots and adopt new technology in the standing procedures. This paper highlights how safety could improve directly by increasing situational awareness during approach and landing and how operability could improve by raising on deck stability with deck lock systems and easing landing limits to the actual touch down limitations.

1. INTRODUCTION

Ship motion impact on helicopter operations is obvious: The approach and set down at the centre of the heli deck is affected by horizontal motions; Vertical motion and speed can cause impact damage on the landing gear at touchdown; Variations in vertical and horizontal acceleration can trigger helicopter instability in tipping or slipping mode in combination with the moments from the turning main and tail rotor under acting wind load. Since there is no regulatory framework that sets any safety envelope, the Norwegian flight operators formulated practical limitations to ensure safety throughout the helicopter landing, on deck and lift off operation. This resulted in strict limitations on roll, pitch, heave amplitude and velocity. The actual values being dependent on helicopter size and agility, and ship type, dimensions and its heli deck details. The ship and helideck qualification and maintenance of the limits is handled by the Norwegian Helideck Certification Association or HCA.

Table 1 Helicopter landing limits



AIRCRAFT CATEGORY		HELIDECK CATEGORY											
		1				2				3			
		P/R	INC	H/R	H/A	P/R	INC	H/R	H/A	P/R	INC	H/R	H/A
HEAVY	DAY	±3	3.5	1.3	5.0	±2	2.5	1.0	3.0	±2	2.5	1.0	3.0
	NT	±3	3.5	1.0	4.0	±2	2.5	0.5	1.5	±1	1.5	0.5	1.5
MEDIUM	DAY	±4	4.5	1.3	5.0	±3	3.5	1.0	3.0	±3	3.5	1.0	3.0
	NT	±4	4.5	1.0	4.0	±2	2.5	0.5	1.5	±1.5	2.0	0.5	1.5

Key:
P/R = Pitch and Roll (deg); **INC** = Helideck inclination (deg); **H/R** = Heave Rate (m/s); **H/A** = Heave Amplitude (metres) i.e. peak to trough distance.

The limits have become a defacto standard since 2001. They are based on measured data over the past 20 minutes. Work of UK CAA since that time concluded that operational hazard is dominated by the on deck stage. The motion severity index and wind severity index (MSI/WSI) parameters were proposed for this purpose. Intention is to combine MSI/WSI alongside the existing HCA standards. The limits per helicopter type and the impact on operability is now being investigated by CAA but will always pose a further negative effect on helicopter availability. The Helios project thus set out to investigate options to improve operability and safety under existing standards, and in case current approach could be altered to adopt new insights.

Most recent incidents suggest helicopter safety for landing-ondeck-liftoff is mostly affected by the approach and touch down stage. NLR focused on that aspect. On Navy vessels, the helicopter deck is typically situated at the rear of the ship, enabling the helicopter crew to have a constant view on the ship. This visual reference offers the pilot situational awareness during the final stage of the approach and landing. On high level bow mounted helidecks, characteristic for offshore vessels, the pilot could suffer from a lack of view on the vessel's motions which makes the landing much more challenging. Even more, if the horizon is not clearly observable due to degraded visibility environment or at night the pilot's situational awareness is vulnerable.

Unfortunately there are several examples to illustrate this, for instance the crash with an AS365 on December 27th 2006 in Morecambe bay, UK. The AAIB report stated: "*the approach profile flown by the co-pilot suggests a problem in assessing the correct approach descent angle, probably, as identified in trials by the CAA, because of the limited visual cues available to him*" [2]) and the accident with a Super Puma on February 18th 2009, 125 miles east of Aberdeen. The AAIB report stated: "*The approach was conducted in reduced visibility, probably due to fog or low cloud. This degraded the visual clues provided by the platform lighting, adding to the strength of the visual illusions during the final approach*" [3]).

A study on the use of Helmet Mounted Display was performed to determine how this technology can assist the pilot during the approach and landing phase. Based on the results a simulation setup, consisting of a helicopter pilot station and research HMD, was furnished to demonstrate and evaluate HMD technology to and with three offshore pilots.

MARIN researched opportunities to improve the way motions are included in the present standards. The best way to describe motion climate in general, how to minimize the impact of uncertainty on future prediction of MSI, and options to navigate the ship for minimized motions altogether. The research was based on measured data on board an offshore service vessel operating off the Norwegian Coast.

2. REFERENCE VESSEL

Full scale data was obtained on an offshore service vessel. The same vessel was also used for numerical calculations and simulations by NLR. She is a light well intervention, and subsea support and construction vessel, see Figure 10. Operations are typically done at zero velocity, under dynamic positioning and pointing into the waves to minimize motions. She has a total length of 106.2 m and a width of 21.0 m (helideck width of 22.2m) [4].

3. MOTIONS

3.1 Motions in relation to wave climate

Around one year of data was used for the evaluations of ship motions. Data are not filtered in any way. It is the total record of the time at sea where the datalogger was active. It is noted that real extreme conditions are not included in the records as the vessel will then call into port. The resulting operational profile in terms of waves is shown in Figure 1. Typically wave conditions are dominated by 2.5m sea states and wave periods around 8 seconds.

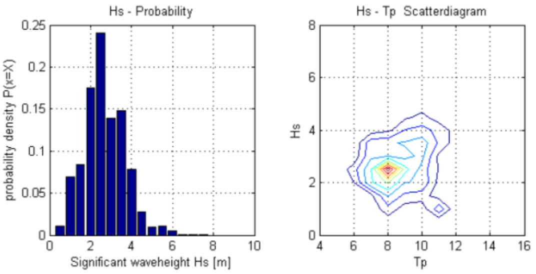


Figure 1 Wave conditions

The overall seastates were sorted in a range from 0-2m representing mild seastates, a range from 2 to 4 meters representing medium seastates, and a range above 4 meters representing heavy weather. Typical roll and pitch motions at these conditions are represented in Figure 2. A tabular representation of exceeding probabilities for these seastates is given in Table 2 and Table 3.

Table 2 Probability of exceedance for 3 degree inclinations for roll and pitch in varying wave conditions

P(x>3 deg) in 20 min	Roll	Pitch
H13 < 2m	1%	0%
2m < H13 < 4m	21%	45%
4m < H13	54%	89%

Table 3 Probability of exceedance for limiting criteria of 1 m/s and 3 m for Significant Heave Rate (SHR) and Maximum Heave Amplitude (MHA)

P(x>x) in 20 min	MHA > 3m	SHR> 1m/s
H13 < 2m	17%	2%
2m < H13 < 4m	99%	83%
4m < H13	100%	100%

Rolling motions are limited due to the operation in head waves and installed anti roll damping features. Operability for this vessel is dominated by vertical motions as shown by the 99% probability of exceedance for max heave amplitude when waves exceed 2 meters significant height. An interesting conclusion is that the transition from operable to downtime is just under the most prevailing wave condition which is 2.5m. Stretching operable limits could quickly yield in big increase in uptime due to the statistics of the sea state.

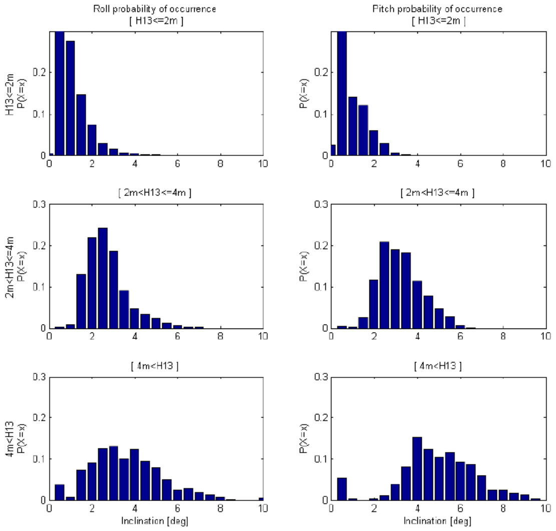


Figure 2 Long term distribution Roll & Pitch motions

3.2 Increasing operability

Operational limits are determined by an ultimate limit, in combination with the margin that is needed to ensure that limit will not be exceeded. If operability is to increase, then the options are to reduce the margin, or to shift the ultimate capacity upwards.

The margin to the ultimate capacity may be reduced if the uncertainty in the predicted extreme reduces. In that case safety will not be affected but operability will increase. The question is thus to reduce uncertainty in the estimator for extreme motion levels.

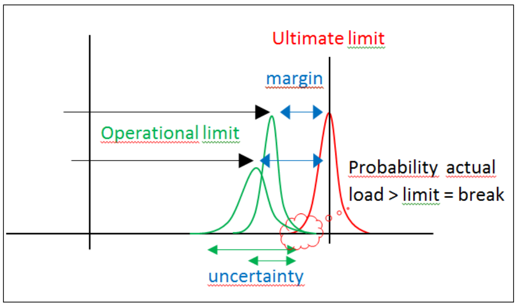


Figure 3 Safety margin vs uncertainty

3.3 Motion statistics

Current practice in helicopter landing limit assessment is based on 20 minute extreme values. Wave and ship motion extreme values however are Weibull distributed and in effect there is a very low probability for extremes in subsequent periods of time to be the same. A margin is needed to predict the larger extremes from the smaller ones. Typically that margin is represented by the factor R in the formula for MSI as proposed by UK CAA.

$$MSI = MMSmax(t - 20\,min, t).R \qquad (1)$$

Where MMS is measured motion severity over the last 20 minutes, being 10 times the apparent gravity angle as below.

$$MMS = 10 * atan\left(\frac{\sqrt{{ac_x}^2 + {ac_y}^2}}{ac_z}\right) \qquad (2)$$

The magnitude of the margin R is determined by the variation of subsequent extremes. If the highest extremes should be inside the predicted values in 95% of all cases, then the factor R will magnify the “upper half” of the extremes resulting in average overestimation. This obviously introduces unnecessary down time. This problem is basically caused by the variability of the extreme value parameter that is used for the prediction.

In marine engineering the extreme values are predicted using more stationary stochastic indicators. Gaussian, Rayleigh and Weibull distributed variables are known to be related to variability of the signal as described by the standard deviation. An example of the extreme value distribution of transverse acceleration as function of standard deviation is shown in Figure 4.

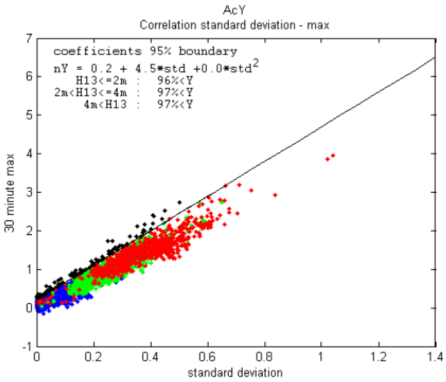


Figure 4 Extreme values vs standard deviations

A linear trend line is fitted to envelope 95% of the extremes. It is a linear trend with slope of 4.5 and a limited offset of 0.2 in m/s^2. It is not far off the prediction for short term extreme values for normal distributed signals which is:

$$mpm = 4.\sigma \qquad (3)$$

This again is explained by the fact that ocean waves can be shown to follow Normal distributions and ship motions are linear related to the waves in mild sea states and fixed wave headings. The MSI parameter however is a non linear combination of horizontal and vertical accelerations. The trend of extreme values as function of standard deviation is thus nonlinear as can be recognized in Figure 5.

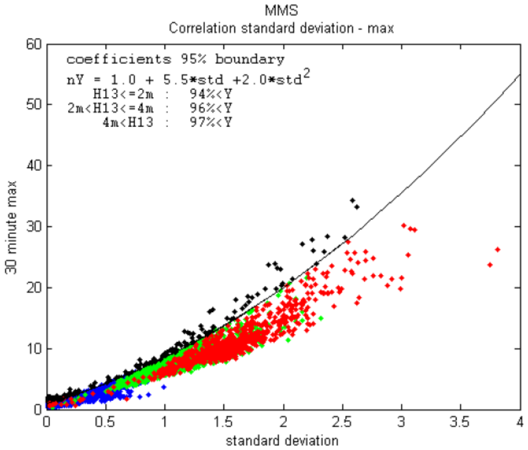


Figure 5 Extreme values vs standard deviations

A quadratic trendline is fitted to include 95% of the extremes. The trend is much steeper than the ones for the separate motion components. It demonstrates the feasibility however to predict extremes for non linear MSI based on the stationary standard deviation of the signal. A comparison of predicted MSI extreme values based on previous extreme value, and the standard deviation with same confidence for non-exceedance of 95% is shown in Figure 6.

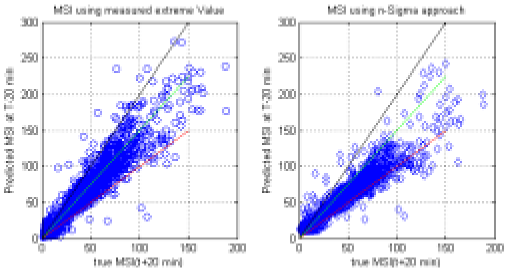


Figure 6 Extreme value predictions for MSI

Both approaches perform with 95% confidence not to under predict actual MSI. The spreading when using extreme values however is much worse than when using n-sigma resulting in overestimations up to 100%. The n-Sigma approach performs better and will improve workability with respect to the existing approach. Still however the spreading remains in the order of 50% of the nominal value. A typical finding also is that the fitted MSI as shown in figure 5 does not start at 0. The initial value has a big effect on the distribution of the cloud of points at lower amplitudes. The difference between the two methods is small at these lower motion amplitudes. It is considered that noise explains the non Gaussian noise at lower amplitudes. In any case, it is concluded that better prediction methods can improve operability to some extent, but will have limited benefit since a substantial safety margin will always remain for the normal variability of extreme values.

3.4 Shifting ultimate limits.

As mentioned a more structural approach would be to shift the operability all together. This will firstly increase safety to begin with, and secondly open up the opportunity to adopt to higher criteria and thus increase operability.

On deck stability was listed as the most hazardous stage in the helicopter operation. It is noted that helicopter are not restrained on the deck in offshore operations to avoid hazard for ground crew and allow pilots to lift off if need be. NATO uses pilot controlled deck lock systems to secure helicopter to the deck. The systems are in use for decades and have excellent track records. The issue of on deck stability is basically cancelled and flight operations are determined only by approach and touch down criteria. The technology appears to be mature, but its introduction in the offshore industry will require certification and further testing.

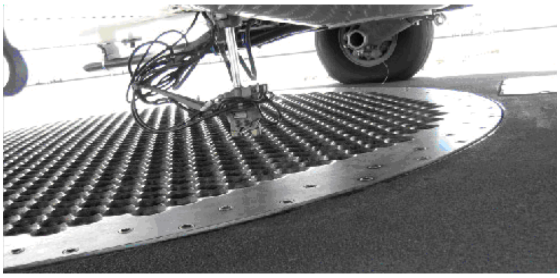


Figure 7 Harpoon locked to deck grid

“If” the safe envelope for the on deck stage can be extended then the touchdown phase will become the overall limiting factor. Landing limits are determined by helideck motions. An appealing option is thus to improve landing conditions by means of active motion compensation. Motion compensation of heavy equipment is commonly adopted in offshore industry for instance heave compensation for drilling and dredging operations and motion compensated platforms for ship to fixed structure crew transfers. Application on helideck’s is less common but also being applied. The seismic survey vessel “PGS Ramform Sovereign” is equipped with an Uptime helideck motion compensation system for roll induced transverse motions. It was approved by the HCA and resulted in the vessel being classed for less strict landing limits which improved operability. It must be noted though that motion compensation systems are still not widely accepted. Pilot comments as “like landing on a flying carpet” illustrate the mixed feelings. The compensated platform provides a stable landing area, but it requires confidence before setting down on something not rigid.

In conclusion:

- Extended helicopter operability is needed to support increasing offshore operations in remote and harsh offshore environment.
- Helicopter operability is limited by helideck motions during touch down and on deck stages.
- It is technically possible to increase safety and consequentially extend operability without doing concessions to safety.
- Legislative entities do not push technologic innovations aimed at increased operability.
- Technology pull is needed from the industry to start wider efforts for certification and actual implementation in the air and sea fleet by helicopter manufacturers, vessel operators, and helicopter operators.

In the meantime focus is on improvement of safety inside the existing standards. Optimizing the approach and assisting with the landing phase are the most feasible in that aspect. NLR used their simulation to investigate various opportunities.

4. SIMULATION SET-UP

4.1 Helmet mounted display

A fully colour-capable research-HMD with line-of-sight sensor and eye tracking capability (see Figure 8) has been used during the simulation trials. Imagery and symbology from a colour matrix display is projected on a reflective patch on the transparent visor in front of the pilot’s right eye. The HMD symbology itself can be freely and rapidly defined on a standard personal computer with graphics capabilities.

Figure 8 NLR Research HMD

The HMD can also present simulated sensor imagery, either on itself or blended with simulated symbology. For example, it is possible to add sensor data (e.g. infrared) to the database used for the outside world presentation and define a specific sensor channel in the Vega visual software. The characteristics of the simulated sensor output can be tuned to resemble an actual sensor. The simulated viewpoint and viewing direction can be coupled to the HMD position and line-of sight, and optionally an optical parallax can be introduced to mimic offset sensor placements such as on a turret below the cockpit. The electro-magnetic head-tracker used for the research-HMD is found in many HMD systems and is a requirement for presenting world-conformal, scene-linked symbology.

4.2 Helicopter pilot station

The Helicopter Pilot Station (HPS) is NLR's fixed-base reconfigurable rotorcraft simulator for real-time, pilot-in-the-loop simulation purposes. The HPS has been operational since early 2001, with a major update at the end of 2009. Representative cockpit displays are built into front and side panels, attached to the structure of the helicopter control loading device. To a large extent use is made of commercial-off-the-shelf application software. The HPS offers a reconfigurable (two crew stations, one of which has controls) glass cockpit environment with instruments and rotorcraft flight controls. On the front and side cockpit panels the actual instruments are simulated by multi-function colour touch screens, allowing all the different buttons and switches to be functionally used. The current baseline cockpit lay-out is representative in terms of shape and volume for a medium size helicopter. The HPS is supported by a generic high fidelity four-axis electric flight control loading system, with force feedback, developed by Fokker Control Systems. The outside world is displayed by four projectors on a cylindrical screen providing a total field of view of 180° horizontally by 70° vertically.

Figure 9 Helicopter Pilot Station

4.3 Offshore vessel

The simulations were done with a typical high end offshore service vessel. It is a light well intervention, and subsea support and construction vessel, see Figure 10. She has a total length of 106.2 m and a width of 21.0 m (helideck width of 22.2m) [4]. The vessel was selected for modelling in the helicopter pilot station because of the high level bow mounted helideck which is characteristic for offshore vessels. Due to this location the pilot can suffer from a lack of view on the vessel's motions making the landing more challenging as compared to a lower located helideck on the stern. Twenty minutes of simulated vessel motions around the CoG (based on bow waves, Hs=2.0m) has been used for the dynamics in the HPS. The maximum roll motion was 1.9 degrees and the maximum pitch motion was 1.7 degrees.

Figure 10 Light well intervention vessel

5. HELMET MOUNTED DISPLAY SET-UP

5.1 Flight phases

The flight has been divided into three phases, transit/cruise, initial approach and the final approach phase, see Figure 11. The first phase of transit/cruise starts at take-off and ends when the helicopter is within the data link range of the vessel. During this phase the HMD will be used to assist the pilot in locating the vessel and to avoid obstacles like windmill farms during the flight. When the helicopter is within the datalink range of the vessel the initial approach phase starts. During this phase the HMD will be used to set the approach direction. When the helicopter is within the 0.75 NM range of the vessel the pilot starts with the final approach. During the last phase of the flight, the HMD will assist the pilot to ensure a stable approach, avoid vessel structure or any other no fly zone (hot gasses, turbulence) and a safe landing.

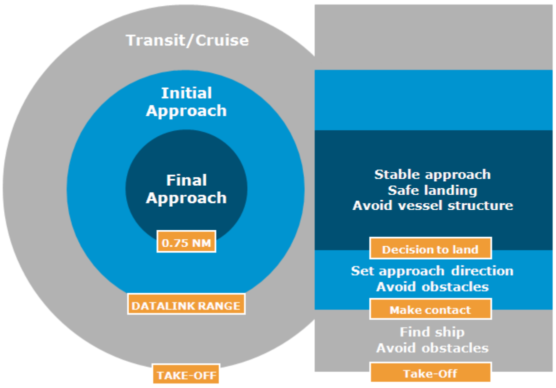


Figure 11 Definition different flight phases

5.2 Helmet mounted display symbology

For the HMD a combination of both 2-dimensional and 3-dimensional symbology will be used, the combined effect is represented in Figure 12. On the top the compass can be found which provides the heading and course information. On the left side the groundspeed scale is presented (units: knots) and on the right side the altitude scale (units: feet). The groundspeed is also presented numerically in the left upper corner (in this example 17 knots groundspeed). The altitude scale normally shows the barometric pressure altitude but for the trials it has been replaced by the radio altimeter height (RHT) which is the standard instrument used for the approach and landing. On the middle bottom position the RHT is also presented numerically. In the right upper corner the bearing and range towards the predefined waypoint has been depicted; respectively 267 degrees and 0NM. In the center a visual display of the aircraft's attitude around the longitudinal (pitch) and lateral (roll) axes is presented to the pilot. The 2-D symbology is always visible to the pilot, independent of the viewing direction.

The 3-D symbology is fixed to the outside world and will be only presented to the pilot when looking towards a certain direction. In the figure below the simulated helideck is presented and will therefore only be visible for the pilot when looking towards the vessel's helideck. The presented helideck in the HMD will exactly overlap the real vessel's helideck and follow the 6-dof motions of the vessel's helideck.

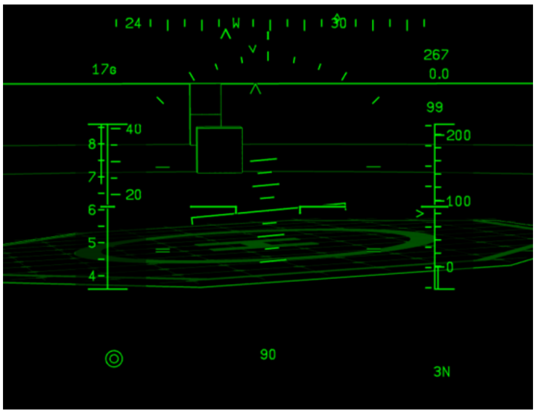


Figure 12 HMD visualisation of combined 2-D and 3-D symbology

To control the HMD symbology the pilot has to use three different buttons on the cyclic, see Figure 13. The operation of the controls is relatively simple. The coolie hat switch is used to "make contact" with the vessel by pushing it upwards (if the helicopter is within the datalink range of the vessel). This will show (among other information) the lead-in line which is orientated towards the vessel based on the current wind direction. The lead-in line represents the ideal approach path to land nose into the wind. When the "confirm" button is pushed the lead-in line will be directed towards the helicopter. This can be done repetitively if necessary. At any moment the pilot can remove the symbology and return to the initial situation (before making contact with the vessel) for which the "cancel" button can be pushed.

Figure 13 Cyclic buttons to operate 3D symbology

During the transit/cruise phase the pilot is flying toward the vessel and his primary goal is to find the vessel and avoid any obstacles. The expected location of the vessel is made visible to the pilot by means of a sector waypoint symbol; see Figure 14 (marked by a red circle). If the pilot is not looking into the direction of the vessel the sector waypoint won't be visible. In that case a marker will be shown on the artificial horizon and on the compass to indicate the direction of the vessel, see Figure 15 (left upper corner).

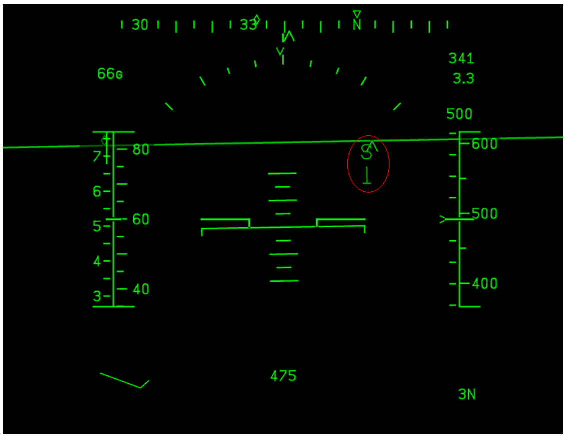


Figure 14 Location of the vessel displayed by sector waypoint symbol

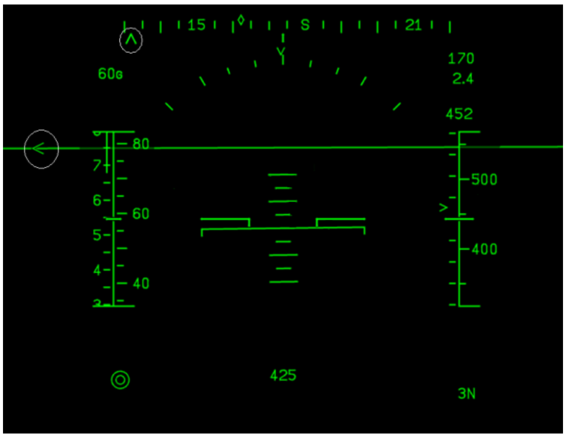


Figure 15 Location of the vessel displayed by markers

Obstacles, for instance a windmill farm for which the exact gps location is known, can be presented to the pilot by green cylinders, see Figure 16. This improves the pilot's awareness and gives the pilot a clear overview of the situation, especially during Degraded Visual Environment (DVE).

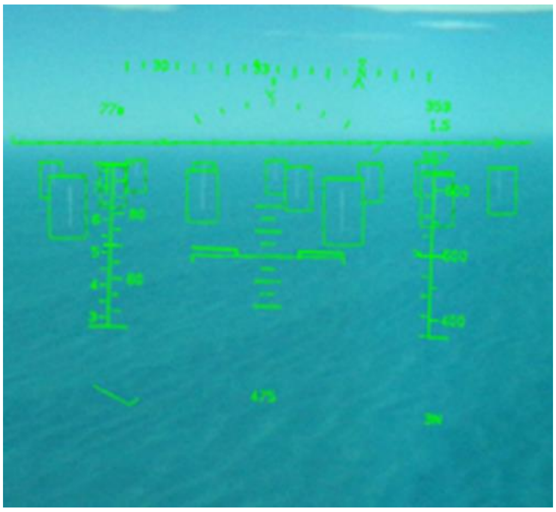


Figure 16 Obstacle warning symbology

Once the pilot is within the data-link range of the vessel the pilot can make contact and the HMD symbology will change according to Figure 17. The location of the helideck is given by a marker with the symbology IF (Island Frontier) on top. The no-go zone (for example due to presence of hot gasses, turbulence or structure of the vessel) is indicated in red to the pilot. This also gives the pilot an indication of the orientation of the vessel. Furthermore a horizontal dotted lead-in line is shown towards the landing point (LP) showing the ideal approach path in order to land nose into the wind.

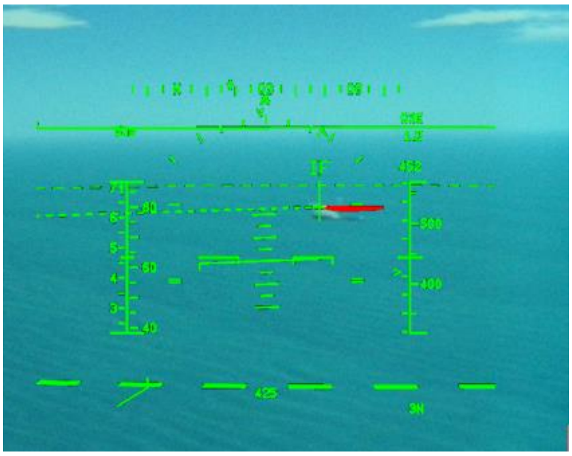


Figure 17 Presented symbology when making contact with the vessel

The wind direction is also presented to the pilot by means of a wind symbol in the lower left corner. If no wind is present the dotted lead-in line will orientate for a landing heading north. Finally a circle is also presented at 0.75NM around the vessel. When reaching this 0.75NM circle the vessel should be spotted by the pilot or else a go around for a next approach has to be initiated by the pilot.

The same situation in a degraded visual environment is shown in the following figure. As can be seen the HMD symbology is especially useful to improve the situational awareness during DVE.

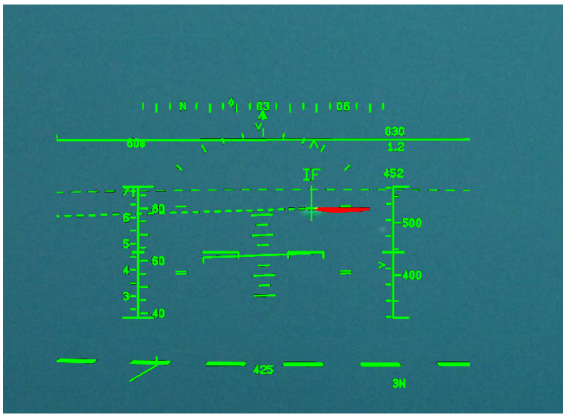


Figure 18 Helicopter degraded visual environment

Once contact has been made with the vessel the pilot can push the “confirm” button and the lead-in line will be orientated towards the helicopter, see Figure 19. The orientation towards the helicopter can be repeated by the pilot if necessary.

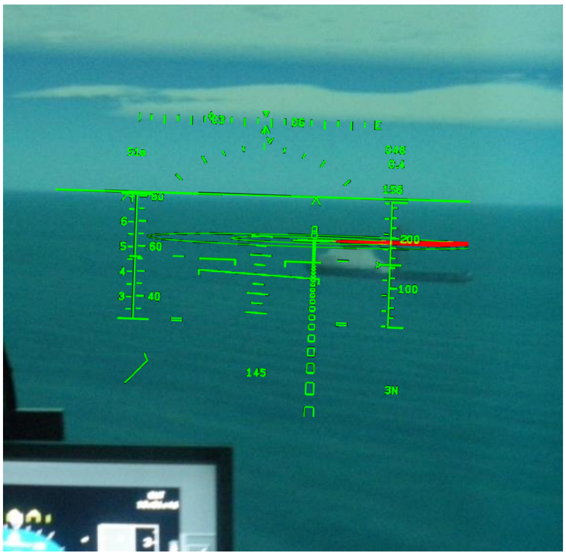


Figure 19 HMD symbology once “confirmed”

Close to the platform two cubical blocks/towers are displayed which follow the motion of the helideck platform to provide the pilot with additional cues to better judge the helideck motions, see Figure 20.

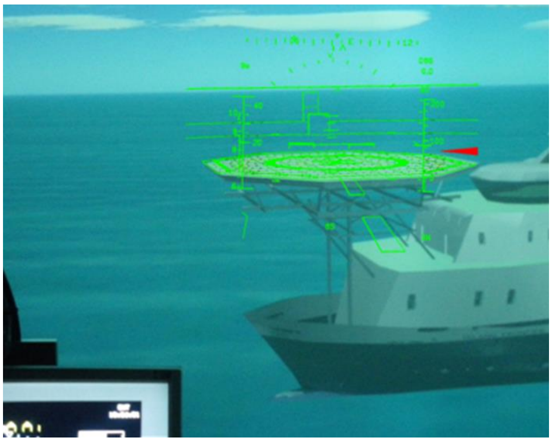


Figure 20 Position of the blocks/towers

As an alternative for the dotted lead-in line, which appeared to be too sensitive when flying close to it, a tunnel in the sky has been developed during the simulation trials, see Figure 21 and Figure 22. The tunnel is set under a 3 degree glide slope and in the right upper corner of each tunnel segment the distance towards the landing point has been stated in NM which helps the pilot to judge the closure rate and the required airspeed.

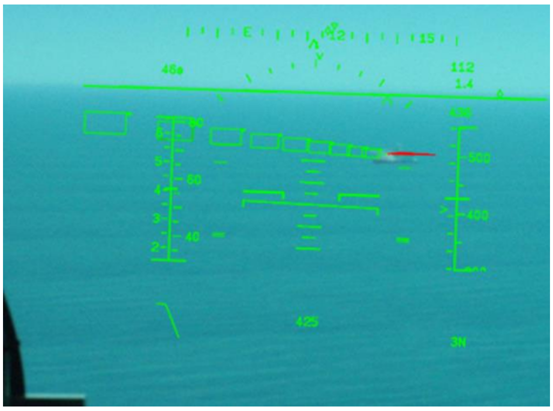


Figure 21 Tunnel in the sky at 3 degree glide slope

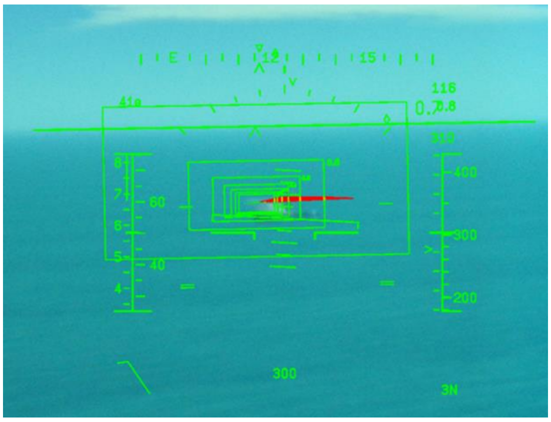


Figure 22 View when flying inside the tunnel

6. KEY-CONCLUSIONS AND RECOMMENDATIONS

Based on the simulation trials it is concluded that:

- With the lead-in line it is more difficult for the pilot to gradually decrease the altitude and groundspeed when approaching the vessel as compared to the tunnel in the sky concept. This can be seen in Figure 23 where the radalt [m] and groundspeed [kts] are plotted against time [s] (the vertical jump in the radalt is the moment that the helicopter is above the helideck). With the tunnel in the sky concept the approach path is much smoother.
- The HMD was stated as useful during the day but not enough to be actually considered using by the pilots if made available to them.
- According to all three pilots the workload decreased with HMD during DVE or night approaches (for tunnel in the sky concept). The HMD should therefore be specialized for DVE and night approaches.

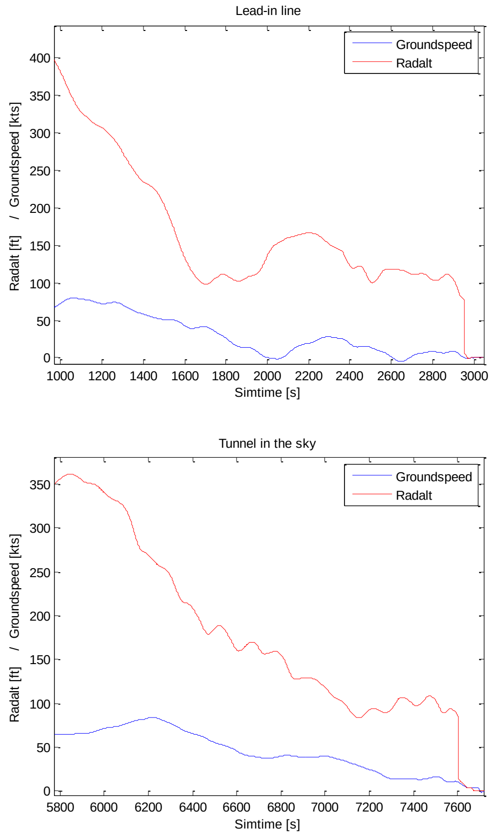


Figure 23 Flight path with lead-in line concept (upper figure) and flight path with tunnel in the sky concept (lower figure)

- Apart from the approach phase the landing phase with the added cubical blocks/towers (see Figure 20) was not considered beneficial. This because the blocks/towers were not visible anymore for the pilot when flying near or above the platform and looking down towards the platform. This was very likely due to the limited FOV of the HMD (the 20°x15° is more suited for fighter applications, for helicopter operation it should be at least around 40°x30°, similar to HMD's used in Royal Netherlands Air Force). A new HMD with more capabilities and a much larger FOV is being purchased by NLR.
- The HMD might also be useful for search and rescue (SAR) missions at sea because the pilot has very limited reference of his position in reference to the vessel.

In the light of the conclusions drawn, the following (summarised) recommendations are made:

- The trials should be repeated with a HMD with a larger FOV (approximately 40°x30 to investigate if this improves the landing phase.
- A comparison should be made between a HMD and a multi-function display (MFD) to see if a MFD could be used as an alternative solution.
- Investigate if the landing limits can be increased (at night) when using a HMD.

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REFERENCES

[1] S. Sprenger, “Development of Operational Strategies for a Save Helicopter Landing on the Flight Deck of Different Ship Types”, March 2010.

[2] AAIB - Report No: 7/2008 - Report on the accident to Aerospatiale SA365N, registration G-BLUN, near the North Morecambe gas platform, Morecambe Bay on 27 December 2006.

[3] AAIB - Report No: 1/2011 - Report on the accident to Eurocopter EC225 LP Super Puma, G-REDU near the Eastern Trough Area Project (ETAP) Central Production Facility Platform in the North Sea on 18 February 2009.

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ACRONYMS

AAIB	Air Accidents Investigation Branch
CAA	Civil Aviation Authority
CoG	Center of Gravity
DOF	Degree of Freedom
DVE	Degraded Visual Environment
FOV	Field of View
GPS	Global positioning system
HELIOS	Helicopter Operations for Offshore Ships
HCA	Helideck Certification Association
HMD	Helmet Mounted Display
HPS	Helicopter Pilot Station
IF	Island Frontier
LP	Landing Point
MFD	Multi-function display
MHA	Maximum Heave Amplitude
MPM	Most Probable Maximum
MSI	Motion Severity Index
NM	Nautical Mile
SAR	Search and Rescue
SHR	Significant Heave Rate
WSI	Wind Severity Index