ADVANCED PILOT ASSISTANCE TO PERFORM OIL RIG APPROACHES

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Abstract

This paper relates to the Navigation and Automatic Flight Control Systems modifications to automate the oil rig approach procedures in order to decrease the pilot workload as well as to increase the flight safety while following the civil regulations applied to RNP approaches. The following topics are addressed: operational needs, safety aspects, guidance concept, system design, automation of the IMC part of the approach, visual segment management up to the oil rig as well as certification aspects. RIG'N FLY is a highly integrated, quite intuitive avionic system providing significant value for the end users. It reduces the crew workload by 70% where the pilot has to tune the proposed path and to monitor the automatic guidance. The system, which has been certified on H225, is currently under deployment on other helicopters of the AH fleet.

1 ACRONYMS

ACAS	Aircraft Collision Avoidance System
AFCS	Automatic Flight Control System
AH	Airbus Helicopters
AHRS	Attitude and Heading Reference System
AIS	Automatic Identifier System
ALT	ALTitude hold mode
ALT.A	ALTitude Acquire mode
ANAV	Area NAVigation mode
APP	lateral APProach mode
CAA	Civil Aviation Authority
CRI	Certification Review Item
DA	Decision Altitude
DMAP	Digital MAP
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FND	Flight and Navigation Display
FPSO	Floating Production Storage and Offloading
FMS	Flight Management System
GA	Go-Around mode
GNSS	Global Navigation Satellite System
GSPD	Ground SPeeD mode
H/C	helicopter
HDG	HeaDinG mode
HSI	Horizontal Situation Indicator
IAF	Initial Approach Fix
IMC	Instrument Meteorological Conditions
IAS	Indicated Air Speed mode
LPO	Leveling POint
LNAV/VNAV	Lateral/Vertical Navigation – IFR approach minima
MAP	Missed Approach Point
MDA	Minimum Descent Altitude
MFD	Multi Function Display
MSA	Minimum Safe Altitude
NAVD	NAVigation Display
OSAP	Offshore Standard Approach Procedure
RIG'N FLY	Rig Integrated GPS approaches with eNhanced FLyability and safetY
RNP	Required Navigation Performance
SBAS	Satellite Based Augmentation System
TP	Turning Point
TPE	Target Position Error
TRC	Translational Rate Command
TTG	Time To Go
VAPP	Vertical APProach mode
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
WPT	WayPoinT
WXR	Weather Radar

2 INTRODUCTION

2.1 Background

Oil rig installations are often far from shores (possibly more than 250 NM) and located in areas where adverse weather conditions can be encountered: strong sea and winds, low visibility, low cloud ceiling. Due to distance and operational conditions, the H/C has been and remains the most suitable means for carriage of workers. This mission requires the H/C to approach and land on oil rig installations using specific procedures.

Oil rig approaches performed in IMC have started around mid 70's. As a reminder, navigation in IMC relies on onboard flight instruments only (without any external visual reference). Usage of airborne radar to perform oil rig approach was introduced in 1981, when GNSS navigation was not yet available. Hence, operational procedures have been based at this time on airborne radar.

In 90's, usage of navigation systems providing GNSS based navigation was introduced to perform oil rig approaches in IMC. The crew had to manually create the whole procedure within the FMS, function of the operational conditions (wind, obstacles). The rough trajectory to be flown was still to be monitored using the airborne radar.

Anyway, IMC oil rig approaches remain based on airborne radar as the primary navigation means to detect the oil rig installation to be approached and to ensure obstacle clearance during the final approach (final approach must be obstacle clear).

Such approach procedures were called ARA: **A**irborne **R**adar **A**pproach (refer to Figure 1).

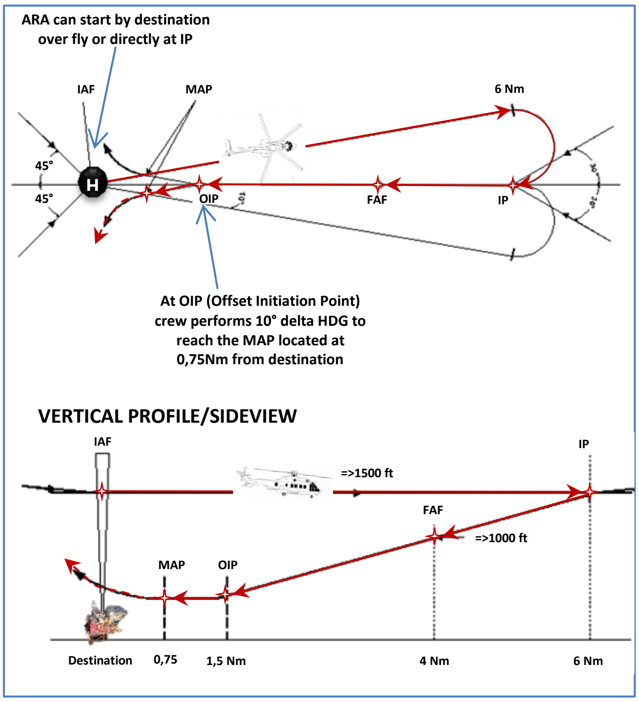

Figure 1 : *Historic **ARA*** **lateral/vertical profile**

Contrary to airport, no official published oil rig approach procedure exists.

It is the responsibility of each H/C operator to define its approach procedure accordingly to the applicable operational regulation and to make it approved by its local authority such as CAA for instance.

Basically the ARA procedure brings the H/C to a missed approach point (MAP) at low altitude level where a visual contact with the rig allows transitioning to the helideck. Otherwise a missed approach must be executed (refer to Figure 2).

In this paper, the term oil rig approach includes both:

- the descent to the MAP (the ARA procedure), that can be performed in IMC and
- the visual transition to the rig, that must be performed in Visual Meteorological Conditions (VMC) only.

Crew workload associated to performing an oil rig approach includes: the approach path preparation, the manual piloting along the defined path, the monitoring of the path clearance during the descent and the transition to the visual segment when the oil rig is in view.

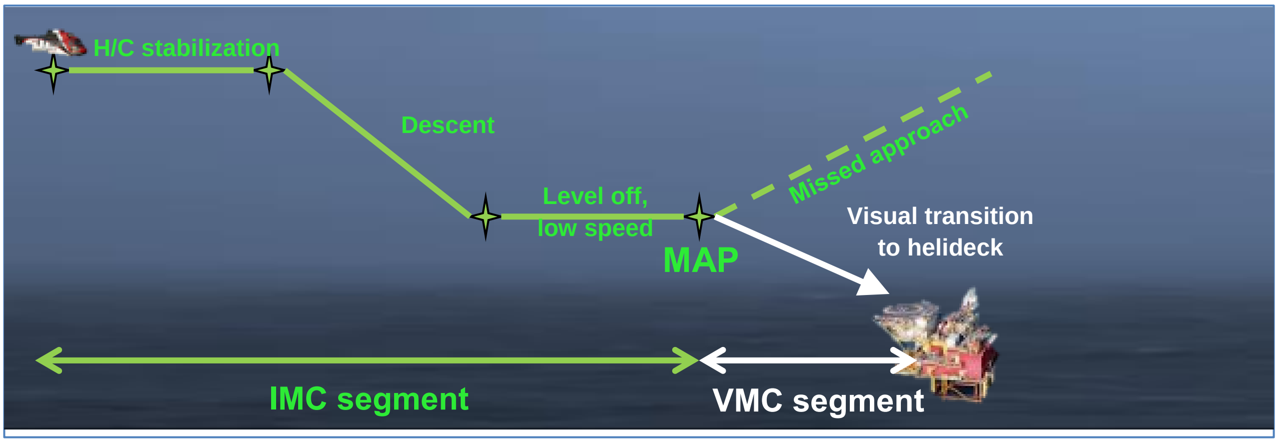

Figure 2 : Oil rig approach overview

2.2 Focus on AH Oil & Gas fleet

The main AH helicopters dedicated to Oil & Gas (O&G) operations are the H225 (19 pax, 11t MTOW, 250 Nm range) and the H175 (18 pax, 7,8t MTOW, 130 Nm range).

The previous avionics of those H/Cs did not propose any specific integrated features to perform oil rig approaches.

To insert an ARA procedure within the flight plan, the pilot had to mentally compute all WPTs part of the procedure relatively to the rig to be approached, with respect to headwind and obstacles around the path. Then he had to manually define those WPTs within the FMS.

Once the procedure built, crew was able to use existing upper modes (ALT, ANAV or HDG, and IAS) to follow the procedure.

Oil rig approach required many actions on push buttons: up to 14 actions were required to build the procedure and to activate the modes as well as associated display formats. This represented a high crew workload and safety of flight could be largely improved.

Beginning 2011, AH has initiated an avionics development to improve oil rig approach operations. The key driver of the project was to increase the safety of flight.

The new avionics capability is named Rig'N Fly: **R**ig **I**ntegrated **G**ps approaches with e**N**hanced **FL**yability and safet**Y**.

The design of the function required several phases:

- Needs capture in close cooperation with O&G pilots, using prototyping tools to support the preliminary definition and to validate the concepts;
- Certification baseline definition, shared with EASA;
- Avionics sub-systems design;
- Intensive bench tests on representative rig;
- Flight tests to check the function performances in representative operational conditions.

The function development lasted 5 years, up to its certification.

3 THE NEW AH SOLUTION: RIG'N FLY

3.1 Overview

Rig'N Fly function provides crew assistance at each stage of the oil rig approach, including its preparation (refer to Figure 2):

- **EnRoute** phase of flight which includes preparation, and creation of the approach procedure on the selected deck.
- **Approach** phase (IMC segment) during which: the autopilot provides H/C 3D steering along the path down to the MAP and also controls the H/C speed decrease. (Automatic steering is also provided along missed approach path).
- **Visual segment** to helideck (VMC segment) using advanced Automatic Flight Control System (AFCS) mode/laws.

Main features of the function are:

- Automatic approach and missed approach path construction;
- Easy tuning of the approach path parameters;
- Improved crew interface via graphical display;
- Automatic steering of the aircraft along the approach path (including speed reduction) with new dedicated AFCS upper modes;
- H/C control improvement at low speed using dedicated AFCS upper mode (to provide assistance during visual transition to the rig);
- New dedicated awareness functions to monitor the descent path and to improve the situational awareness.

For approach path construction, the function proposes 3 different ARA procedures:

- **Full lateral offset** (default one, refer to Figure 3, designed based on [3]
- ARA as defined by [1]
- OSAP DELTA30 as defined by [2]

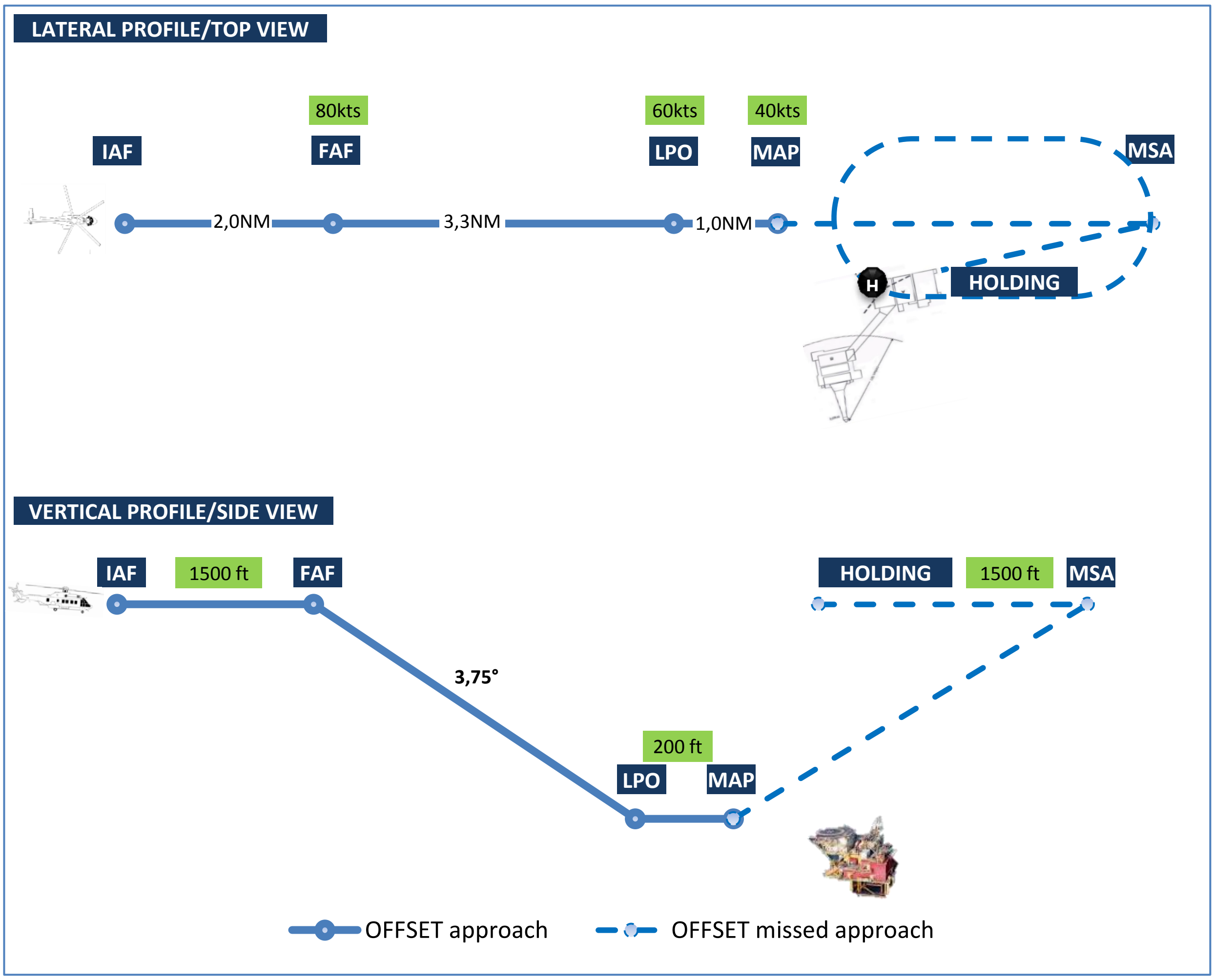

Figure 3 : Full lateral offset approach is proposed by default.

During the approach:

- Lateral guidance is based on GNSS. SBAS is used if available but is not mandatory.
- Vertical guidance is based on barometric altitude.

This design choice ensures worldwide availability of the function, independently of SBAS coverage and a safe vertical barometric sensor to control the HC vertically.

Finally the function does not modify the operational concept (still based on airborne radar, current approach minima remain unchanged), but provides an optimized automation of the approach, significantly decreasing the crew workload.

3.2 System architecture

Redundant avionics system architecture (refer to Figure 4) evolutions implemented to enable RNP approaches is used as basis. Rig'N Fly requires the modifications of the following avionic sub-systems operational softwares:

Systems	Intended function
Flight Management System (FMS)	Approach procedure creation, RNP monitoring
Automatic Flight Control System (AFCS)	Automatic guidance during approach procedure and assistance during visual segment
Flight Display System (FDS)	Guidance data display
Digital MAP (DMAP)	Graphical flight planning and improved situational awareness

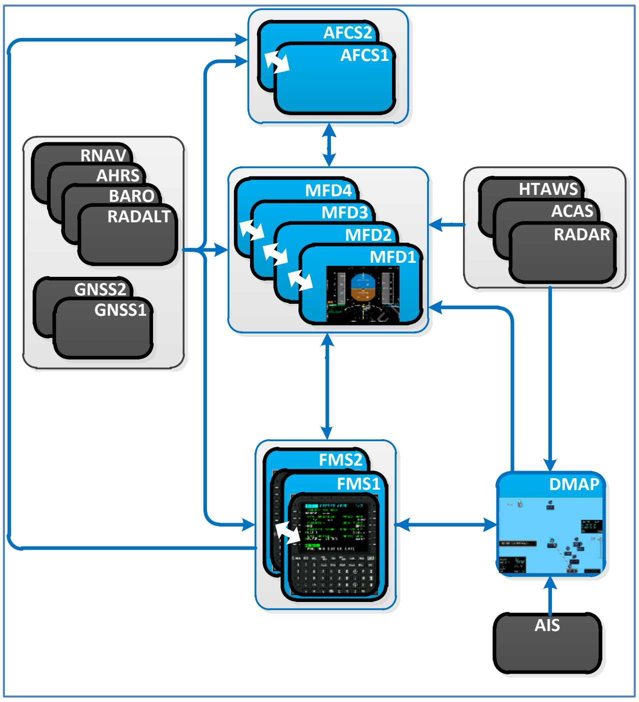

Figure 4 : Functional system architecture

4 OPERATIONAL CONCEPT

4.1 Mission preparation

The FMS embeds a dedicated database within which the oil rigs positions and their associated main characteristics are stored. Simple process has been established and enables O&G operators to feed this database from any data provider.

4.2 En-Route

4.2.1 Approach flight planning

The approach flight planning can be performed at any time but is generally done EnRoute at 20 to 30 Nm from destination.

Crew can select the destination oil rig either using the FMS or by interactive graphical designation on the DMAP (refer to Figure 5).

Some installations are mobiles (FPSO, floatel) and, by definition, cannot be stored within any database. For those cases (around 30%) the crew can define the destination by directly designating the associated AIS or any other position/object on the digital map or by manually creating a user WPT from known target coordinates.

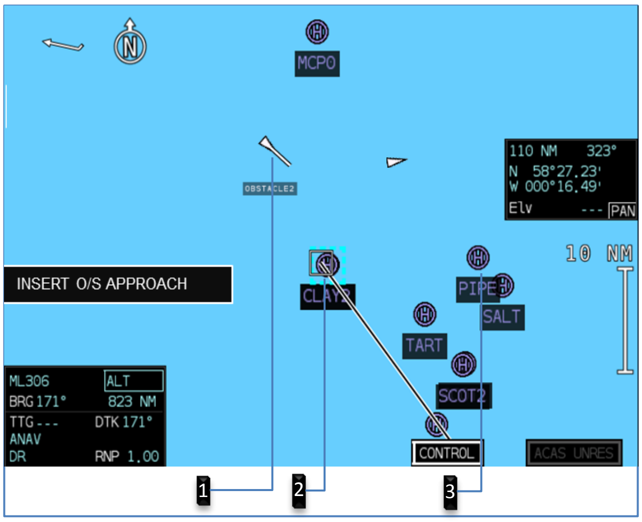

Figure 5 : Target graphical designation on digital map.
1/ AIS, 2/ Designation cursor, 3/ Oil rig retrieved from data base

Figure 6 : FMS centralized approach MMI
1/ Destination oil rig ID and complete name, 2/ Lateral offset side/value, 3/ Day/night predicted arrival, 4/ MDA value, 5/ Approach axis

For safety reason, the approach must be performed headwind (potentially variable), and the altitude minima of the MAP, varies with day/night operations and the deck height. In addition the obstacle situation is changing close to the oil rigs. So an oil rig approach has to be computed in real time.

From the position of the oil rig selected as destination and its associated characteristics stored within database, the FMS automatically computes a complete optimized approach path as follow:

- The approach axis is defined to be as much as possible headwind with respect to the authorized approach sector;
- The altitude minima is defined based on deck height and the day/night approach conditions accordingly to operational regulation.

All approach parameters are centralized within a dedicated FMS page where the crew can check, adjust (if any) and activate the approach (refer to Figure 6).

Crew can also adjust the approach parameters by graphical designation. This feature is particularly appreciable for course tuning since crew gets an immediate feedback of the tuning with respect to the horizontal situation (ship, obstacles and surrounding oil rigs).

Up to a very late moment, the crew can adjust the approach even if in progress. This permits to take into account maritime traffic around the destination oil rig or any wind evolution.

4.2.2 Approach clearance monitoring

The DMAP merges relevant onboard sensors data to provide a complete situational awareness on a single display:

- Weather radar (WXR)
- AIS
- ACAS
- Flight plan.

This allows efficient situational awareness monitoring with all relevant data displayed at a glance (refer to Figure 14).

Particularly, the crew can check:

- that the right oil rig has been selected as destination;
- that all positions associated to the destination oil rig are consistent: database, vs WXR vs AIS;
- the configuration of the surrounding destination area;
- the obstacle clearance along the approach path;
- the air traffic in the approach area.

The Automatic Identifier System (AIS) is a maritime transponder providing ships data via VHF range. AIS installation is mandatory on large vessels and it also trends to be deployed on oil rigs. The function uses AIS data to enhance the situational awareness.

The DMAP automatically monitors consistency of destination oil rig position by comparing the position retrieved from database against the one received from its associated AIS. When an alert is raised, the crew can easily adjust the position to be used as destination.

In addition, as soon as an approach is planned, the DMAP continuously monitors the AIS obstacle clearance along the approach and missed approach paths, taken into account the H/C speed, the active flight plan and the wind effect. Alert is raised when function predicts that obstacle clearance will not be ensured during the approach. This obstacle clearance anticipation helps the crew deciding to perform or not the approach and will reduce the number of missed approaches (refer to Figure 7).

If required crew can then easily adjusts the approach to recover safe approach conditions.

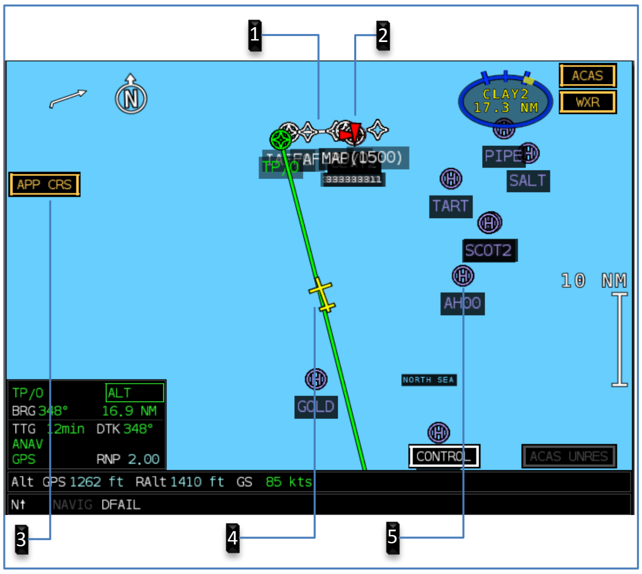

Figure 7 : Automatic approach path clearance monitoring
1/ Oil rig approach path, 2/ Red AIS=obstacle within the approach path, 3/ Approach clearance alert, 4/ Current H/C position, 5/ Surrounding oil rigs

4.2.3 Focus on lateral offset approach and RNP management

With full lateral offset approach, the whole path is laterally (left/right) offset versus direct track to the oil rig which ensures lateral clearance. When automatic approach is performed, the aim of the system is to ensure that this required lateral offset is respected along the approach path.

This is achieved by deriving standard RNP principles (generally used to approach on airport) to oil rig approach.

The distance between the lateral approach path and the direct track to the rig can be seen as a corridor split as follow (refer to Figure 8):

- A sub-corridor is used as a margin to handle destination position uncertainty: TPE (Target Position Error). TPE is increased for mobile destination.
- The remaining distance (lateral offset distance – TPE) is split in 2 sub-corridors. The width of each sub-corridor represents the value of the RNP to be managed during the approach.

Finally the RNP to be used is computed as a function of the lateral offset distance:

$$RNP = \frac{Lateral\ offset\ distance - TPE}{2}.$$

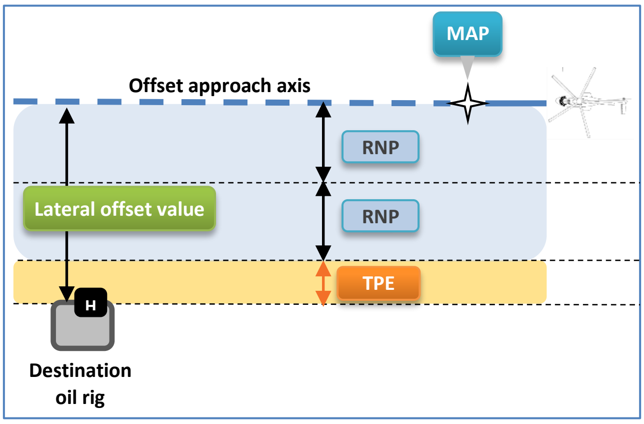

Figure 8 : Lateral offset approach and RNP principle

A low lateral offset distance brings the H/C at the closest of the destination and increases the probability to get visual contact but it implies the capability of the system to manage a low RNP value.

The system is currently certified down to 0,5NM lateral offset leading to RNP=0,175 (The system has been successfully tested down to RNP=0.05 which basically corresponds to 0,25NM lateral offset).

If a lateral offset approach is used, prior entering into approach (refer to position integrity check period on Figure 9), the FMS checks if the required positon integrity will be available during the approach to satisfy the computed RNP. If needed the FMS automatically increases the lateral offset value to a value associated to a larger RNP and thus requiring lower position integrity performance (refer to Figure 9).

By automatically anticipating the feasibility of the approach (from position integrity performance point of view), this feature increases approach success rate.

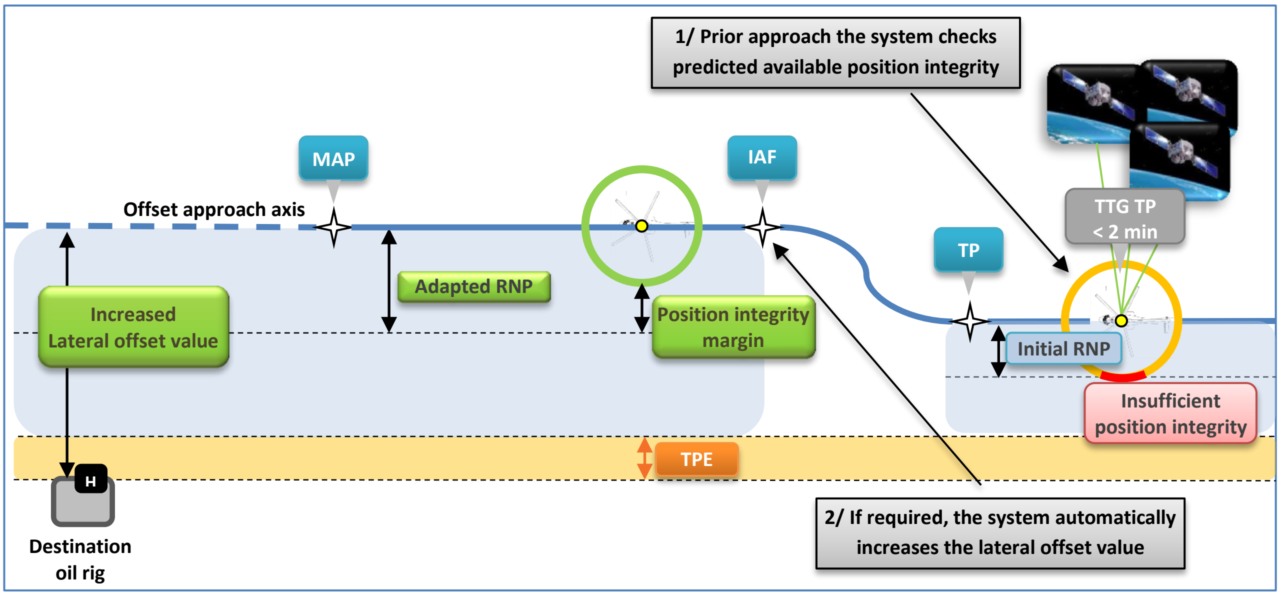

Figure 9 : Position integrity check prior approaching and associated automatic lateral offset value management

4.3 Automated approach

4.3.1 Automatic transition to approach

Once the approach has been inserted in the flight plan, the FMS computes transition trajectory including a TP (Turning Point) that ensures being aligned to the approach course at the approach entry point (IAF). Crew can use AFCS ANAV mode providing lateral guidance along this transition trajectory.

3 minutes prior the IAF if all required conditions are satisfied:

- Provided ANAV mode is engaged, the AFCS automatically arms its approach modes APP/VAPP (refer to Figure 10);
- The MFD automatically displays the TP altitude constraint and crew can use AFCS ALT.A mode to reach it.

Upon IAF sequencing, if all required conditions are satisfied (e.g. especially if the required position integrity level is achieved), the system enters into oil rig approach phase of flight and the AFCS automatically engages its approach mode and the IAS mode to provide 3D guidance as well as automatic speed decrease along the approach path.

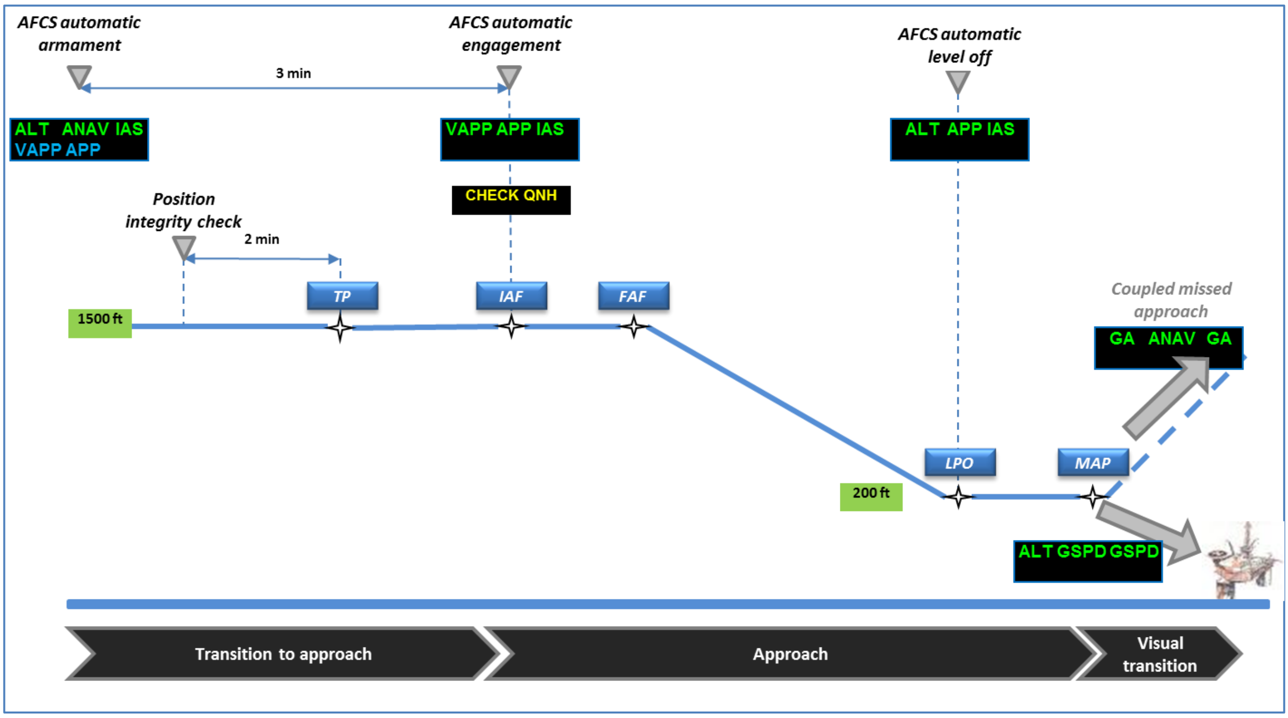

Figure 10 : Automated approach sequence

4.3.2 Automatic guidance during approach

Dedicated oil rig approach upper modes (APP/VAPP/IAS) perform full 4D aircraft control (lateral, vertical and speed reduction) along the FMS-computed approach path.

The oil rig approach modes can provide guidance along any of the 3 approach procedures proposed by the FMS (Full lateral offset, ARA OPS, Delta 30 OSAP). The approach procedure consists in a succession of waypoints provided by the FMS with their associated characteristics (3D position + maximum ground speed objective).

The 3 approach procedures have in common an entry point, called the Initial Approach Fix (IAF) starting a level-off segment at a Minimum Safe Altitude (MSA), then a descent phase followed by a level-off at a Minimum Descent Altitude (MDA). The last waypoint is called the MAP (Missed Approach Point).

Hence, provided that the crew has inserted an approach towards an oil rig in the active flight plan and the FMS navigation source is coupled, dedicated oil rig approach modes automatically arm 3mn before reaching the IAF waypoint. APP & VAPP modes automatically capture upon IAF sequencing while IAS mode automatically engages if not previously activated by the pilot. The first segment of the approach (from IAF) is used to stabilize the H/C. In case the initial H/C trajectory would deviate from the approach path, the upper modes will manage to acquire the MSA and to decelerate the H/C w.r.t. the ground speed target associated to the next waypoint.

The APP mode aligns the aircraft along the horizontal computed approach path.

The VAPP mode acquires and holds the vertical path by providing automatic guidance along the vertical trajectory defined by the waypoint altitudes in the baro-corrected altitude scale as transmitted on the FMS flight plan. Prior starting final descent to MDA, the crew should preset ALT.A mode reference to MSA value so that, in case of GA mode activation, the AFCS will automatically acquire the MSA to perform the missed approach procedure.

The VAPP mode automatically reverts to the ALT mode to level-off the H/C when reaching the LPO altitude. In addition, a safety mechanism is implemented to level-off the H/C at 150ft above the sea in case it would descent too low. The VAPP mode only controls the collective axis since the air speed control is performed on the pitch axis to achieve the maximum ground speed objectives associated to each waypoint. The baro-setting selected by the crew is consolidated with the radar height when valid to prevent the aircraft from descending too low above the sea.

The maximum ground speed constraint associated to each waypoint is controlled through the IAS mode for which the air speed reference is computed from the ground speed objective in considering an estimation of the actual wind. The IAS reference bug jumps when the deceleration starts in order to reach the objective ground speed 0.1 NM before the next waypoint. The pilot can adjust the air speed reference but it is upper limited to the next waypoint maximum ground speed objective.

During the approach:

- The FMS continuously monitors the actual position integrity vs RNP;
- As basic piloting task, the pilot monitors the cross track error on HSI with scale factor set to RNP;
- The Decision Altitude (DA) alarm is automatically slaved to the MDA value (MAP altitude) as set on the FMS.

In case of total GNSS outage during the approach, the system provides time limited autonomous dead reckoning navigation computed from the inertial sensor of the AHRS, enough to perform a missed approach with a good performance of track keeping

4.4 Visual transition to rig

The MAP is the last point where a landing manoeuver to the platform can be performed if the visual contact with the platform has been established; otherwise, a missed approach must be performed.

In case of missed approach activation i.e. GA mode engagement on collective stick dedicated push-button while AFCS ALT, APP & IAS modes were engaged, the APP mode automatically reverts to ANAV mode to follow the FMS missed approach trajectory. In case of previous ALT.A reference preselection to MSA, the h/c will automatically climb and acquire the preselected altitude. By a single action on FMS, the crew can resume the approach to perform it again.

In case the pilot has visually acquired the platform, once at MDA level, and up to the MAP, he can typically engage HDG mode so as to reach the platform in 4-axis operation with ALT/HDG/IAS modes. Upper modes references can be adjusted through beep trims while maintaining visual cues allowing transition to manual flight for a safe landing.

On H225, as an alternative to HDG mode, the pilot can engage the enhanced GSPD mode upon double click on the dedicated push button on the cyclic stick and act on the pedals to acquire the relevant track to go to the platform thus performing a flat turn at low ground speed (typically 40kt). Double click action actually triggers the automatic acquisition of the hover with longitudinal & lateral ground speed references set to 0 and the pilot can then adjust the longitudinal reference (typically 10kt) through beep action on cyclic stick. Advanced control laws enable the pilot to modulate the deceleration rate trough longitudinal stick inputs while holding the current track direction thus modifying the deceleration distance. Once the ground speed reference is reached, the pilot can directly control in hands-on flight a ground speed shift around unchanged reference speeds through longitudinal or lateral stick inputs (Translational Rate Command response type feature). TRC response significantly decreases the pilot workload while enabling easy and accurate ground speed/positioning adjustments thus allowing transition to manual flight for a safe landing.

4.5 Associated displays during approach

During oil rig approach, the MFDs provide FND (refer to Figure 11) and NAVD (refer to Figure 12) formats offering similar symbology as for RNP approaches with same data displayed at same locations: deviations, level of service, same AFCS approach modes labels…

Same alerting concept than for RNP approach is also used to manage degraded cases.

The following supplemental data have been displayed on FND to ease system monitoring:

- Active target IAS managed by AFCS for automatic speed reduction
- Active altitude target associated to active approach WPT
- Active MDA (level-off altitude to MAP)

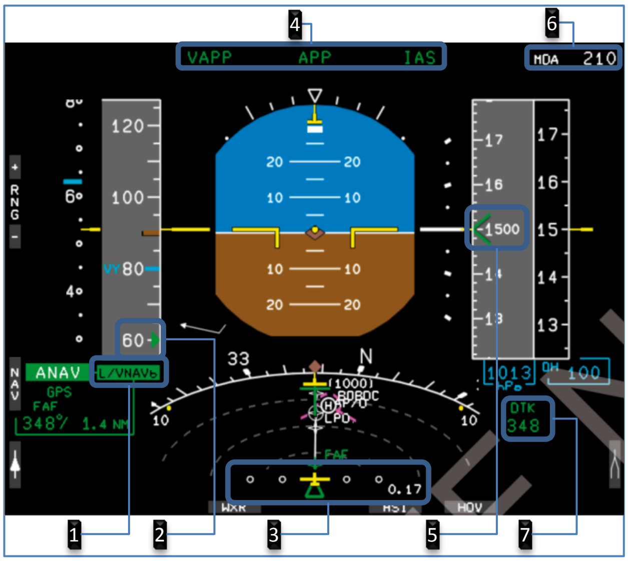

Figure 11 : FND view

1/ Level of service, 2/ Active target IAS, 3/ Lateral deviation, 4/ AFCS upper modes, 5/ Active target altitude, 6/ Active MDA, 7/ Approach axis

The indicated level of service is barometric LNAV/VNAV (L/VNAVb) since vertical guidance is based on baro-corrected altitude.

The following supplemental data have been displayed on NAVD to ease situation monitoring:

- Destination authorized approach sector (see also Figure 13);
- Nearest oil rigs;
- Active ARA pattern;
- Distance/bearing to destination (for cross-check with radar echo);
- Lateral offset side/value.

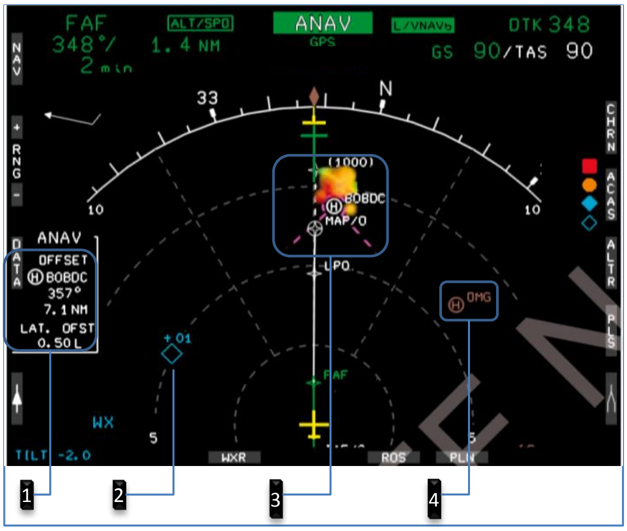

Figure 12 : NAVD view

1/ Active ARA pattern – Destination ID – BRG/Dist to destination – Lateral offset value/side, 2/ ACAS, 3/Enhanced destination symbology, 4/ Nearest oil rigs

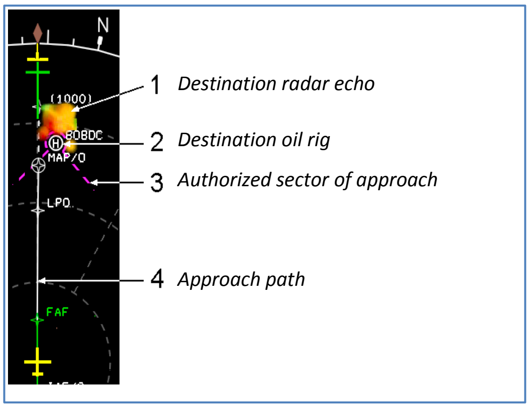

Figure 13 : Enhanced destination symbology

The DMAP reinforces the flight safety by displaying the following data on a single view which provides a complete situational awareness (refer to ***Figure 14***):

- Flight plan and navigation data
- Surrounding obstacles (radar, AIS, ACAS, nearest oil rigs)
- Target locator providing visual bearing/distance indication of the destination oil rig
- Safety box materializing next 60s flight area

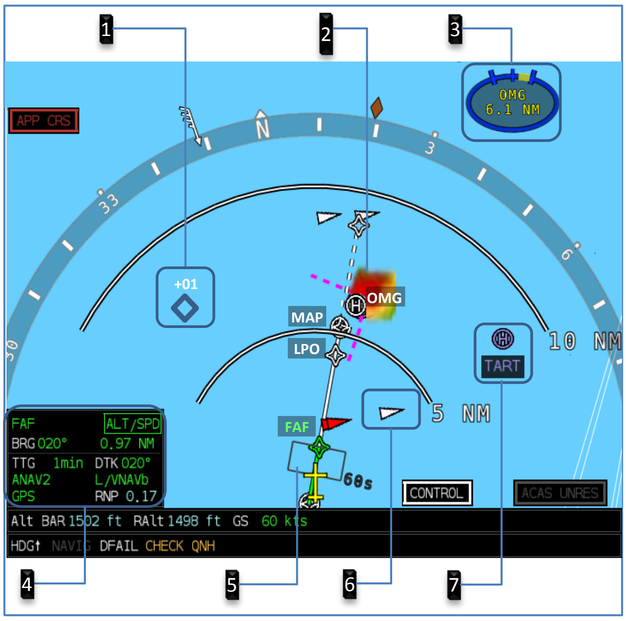

Figure 14 : DMAP: complete situational awareness at a glance

1/ ACAS, 2/ Destination radar echo, 3/Target locator, 4/ Complete navigation data, 5/ Safety box, 6/ AIS, 7/ Nearest oil rigs

5 TESTS & RESULTS

A full systems integration bench and a dedicated AFCS bench have been developed and extensively used (thousands of tests hours have been performed).

Those benches were key tools for function maturing and provided agility during system and function development.

The flight tests were performed in a zone close to Airbus Helicopter premises, a few kilometres from the shore. It permitted to perform oil rig approaches in tests conditions close to the reality (using buoys and lighthouses).

Thanks to test effort done on benches, only 30 flight test hours were necessary, essentially dedicated to:

- Evaluate the dynamic aspect and adjust AFCS trajectory control;
- Check track keeping accuracy, especially by strong wind conditions;
- Check H/C attitudes and associated visual contact achievement by poor visibility;
- Check HMI in real operational conditions;
- Evaluate passenger comfort during the approach.

Figure 15 illustrates a full lateral offset approach coupling with a course set to 340 (i.e -20 in the +/- 180° range) and a MDA equal to 400ft. APP mode acquires & holds the desired track and keeps the cross-track distance (Xtk parameter) below a few meters while VAPP & IAS modes manage the associated waypoints constraints (altitude/maximum ground speed) i.e. IAF (1500ft), FAF(1000ft/80kt), LPO (400/60kt) & MAP(400ft,40kt).

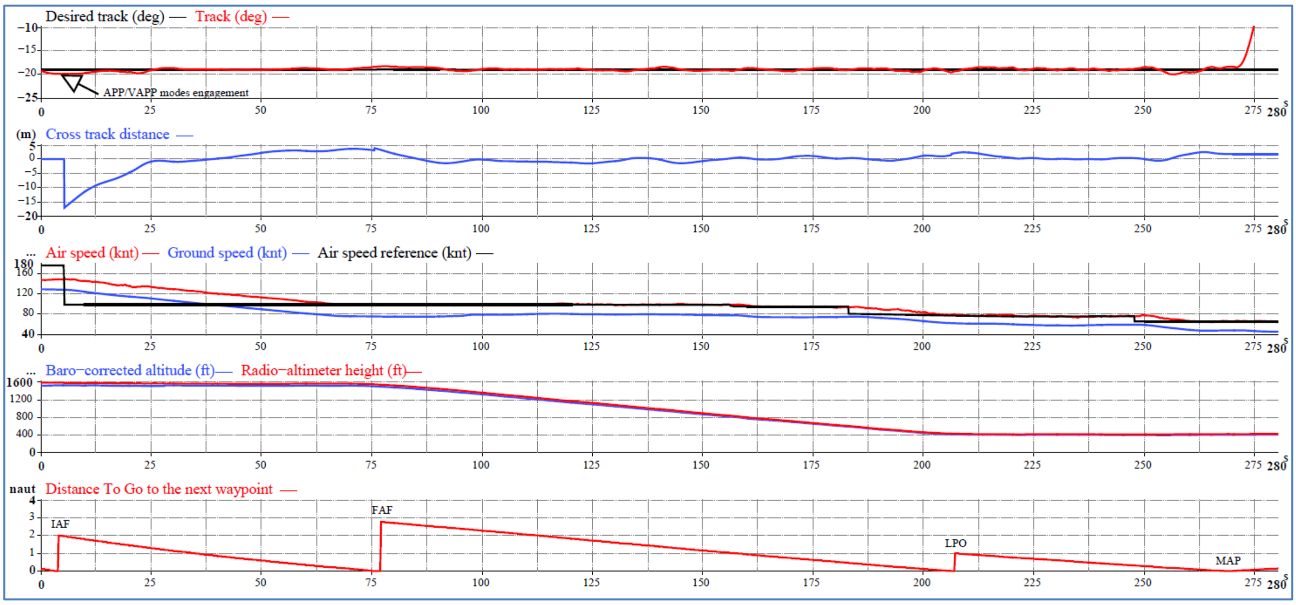

Figure 15 : Flight test results during "full lateral offset approach"

6 CERTIFICATION ASPECTS

A certification baseline was initiated by Airbus Helicopters and shared with EASA. The CRI (Certification Review Item) covers several topics

- The database integrity which is delivered by the operator;
- The approach definition and associated alerting close to an IFR approach.

and merges some requirements from airworthiness regulations applicable to RNP approaches [4] with operational regulation [1] and [2].

Demonstration has been made that the system provides efficient assistance to the crew to perform oil approach while it increases the safety level of approach, compared to previous method of operation.

7 CONCLUSION

RIG'N FLY is an integrated, quite intuitive system that drastically decreases the crew workload thanks to high automation and significantly enhances the situational awareness to perform an offshore procedure. It therefore largely improves the flight safety. The system has been certified on H225 on December 2015 and is currently being deployed on other helicopters of the AH fleet such as H175 for which certification is planned in the second part of 2017 with the HELIONIX avionics suite. Crew training is moreover eased since the function keeps unchanged the operational concept that remains based on airborne radar and uses the same principle, symbology and alerting concept than for other RNP approaches.

8 REFERENCES

[1] EU-OPS (AMC1 CAT.OP.MPA.120 & GM1 CAT.OP.MPA.120)

[2] FAA Advisory Circular AC90-80B; "Approval of Offshore Standard Approach Procedures, Airborne Radar Approaches, and Helicopter En-Route Descent Areas"

[3] CAA paper 2010/01 "The SBAS Offshore Approach Procedure (SOAP)"

[4] AMC 20-27 "Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV BAROVNAV Operations"

[5] Airborne radar approach FAA/NASA Gulf of Mexico Helicopter flight test program (January 1980)