PERFORMANCE CLASS 2 WITH DEFINED LIMITED EXPOSURE FOR OFFSHORE OPERATION: USE CASE AND PERSPECTIVES

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Abstract: Originally devised for offshore helicopter operation and with the objective to improve global safety (and not only the consequences of an engine failure), Airbus has developed the Performance Class 2 Defined Limited Exposure concept (PC2 DLE). PC2 DLE uses simple, robust and short take-off and landing procedures, associated with a given take-off and landing weight to calculate the exposure time and the objective risk in case of engine failure. The paper details some of the methodology developed for flight testing, tools developed for Flight manual documentations and customer use (PC2DLE iPhone/iPad applications). The H145 case will show the homogeneity developed between PC1 and PC2 DLE, with the goal of simplifying procedures and assure standardization for take-off and landing. It concludes by demonstrating how the PC2 DLE concept is a means to objectivize and reduce catastrophic risk – a key to flight safety! …and a concept that could be expanded to other types of operations.

1 SYMBOLS AND ABBREVIATIONS

AEO	All Engines Operating
EASA	European Aviation Safety Agency
HEC	Human External Cargo
HEMS	Helicopter Emergency Medical Services
HP	Pressure altitude
JAR	Joint Aviation Requirements
MTOW	Maximum Take-Off Weight
OAT	Outside Air Temperature
OEI	One Engine Inoperative
OPS	Operational regulations
PC1	Performance Class 1
PC2	Performance Class 2
PC2 DLE	Performance Class 2 with Defined Limited Exposure
PC2e	Performance Class 2 Enhanced
RP	Rotation Point
SFL	Safe Forced Landing
SMS	Safety Management System
TDP	Take-off Decision Point
VTOSS	Take-off Safe Speed
VY	Best rate of climb speed (kts)

2 CONTEXT AND PERFORMANCE CLASS

Passenger transportation, from an onshore base to an offshore elevated helideck is mostly performed with helicopters. The offshore industry is very concerned about the safety of its workers being transported by helicopter and is fully aware of the harsh operating environment that is inherent to operations over sea. Consequently, the safety standards for offshore transportation are very demanding.

The engine failure has been perceived as a major contributor to potentially unsafe conditions, even for multi-engine helicopters. During take-off and landings, the highest predicted risk is an engine failure, which could lead to a deck strike (typically a catastrophic event), or ditching (which is not necessarily catastrophic), see Fig. 1.

Once the aircraft has reached V_Y, the main risk following one engine failure is the inability to maintain level flight.

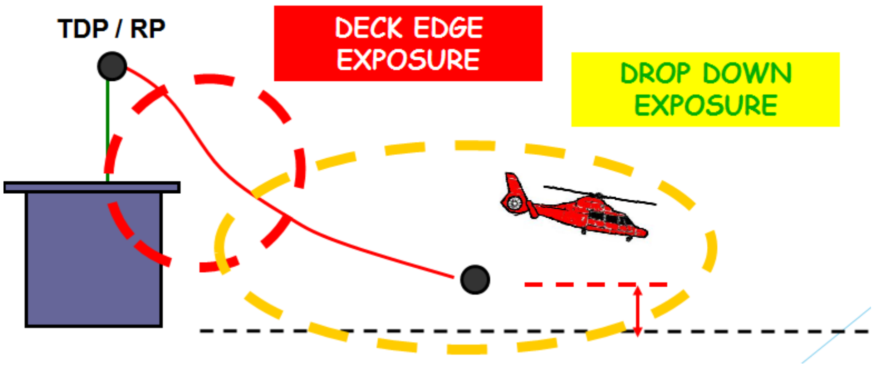


Fig. 1: Risks in case of engine failure during take-off

In Europe, offshore operations have been supervised by the aviation authorities as JAR OPS at the beginning and EASA OPS now, through the notion of Performance Classes and they have imposed the use of multi-engine aircrafts with some Cat A characteristics (certification criteria) for engine installations.

2.1 Performance Class 2

Operation in Performance Class 2 means an operation that, in the event of failure of the critical engine, sufficient performance is available to enable the helicopter to safely continue the flight, except when the failure occurs early during the take-off maneuver or late in the landing maneuver, in which case a forced landing may be required.

The PC2 concept has seen evolutions and sub-definitions.

2.2 Pure Performance Class 2 : safe forced landing instead of forced landing

To address the potential engine failure at the beginning or at the end of the mission, the notion of pure PC2 has been introduced, which means: Full engine failure accountability enroute (which corresponds generally to Cat A clear area second segment performance), and Safe Forced Landing during the take-off and landing phase.

Where Safe Forced landing (SFL) is defined as: Unavoidable landing or ditching with a reasonable expectancy of no injury to persons in the aircraft or on the surface.

The direct consequence is a payload reduction compared to PC2.

2.3 Performance Class 2 with Exposure Time : forced landing acceptable through a accepted low risk

The performance reduction induced by pure PC2 and engine reliability statistics have led to building a probabilistic approach to address the case of engine failures with catastrophic consequences.

At this stage, a notion of acceptable catastrophic risk of $5*10^{-8}$ had been proposed for offshore operations in Europe taking into account already available figures. (The acceptable catastrophic risk for certification purposes was already established at $1*10^{-9}$).

At this period, the ratio of one catastrophic event every 20 millions of take-off or landing has been pragmatically accepted by the offshore community: The PC2 Limited Exposure concept was born.

Taking into account the engine power-loss rate of 1 per 100,000 engine hours (established through a 5 years moving average) for each engine type, the maximum permitted exposure time has been set to 18 s for single engine and 9 s for a twin engine.

The typical flight profile for PC2 with Exposure Time is shown in Fig. 2.

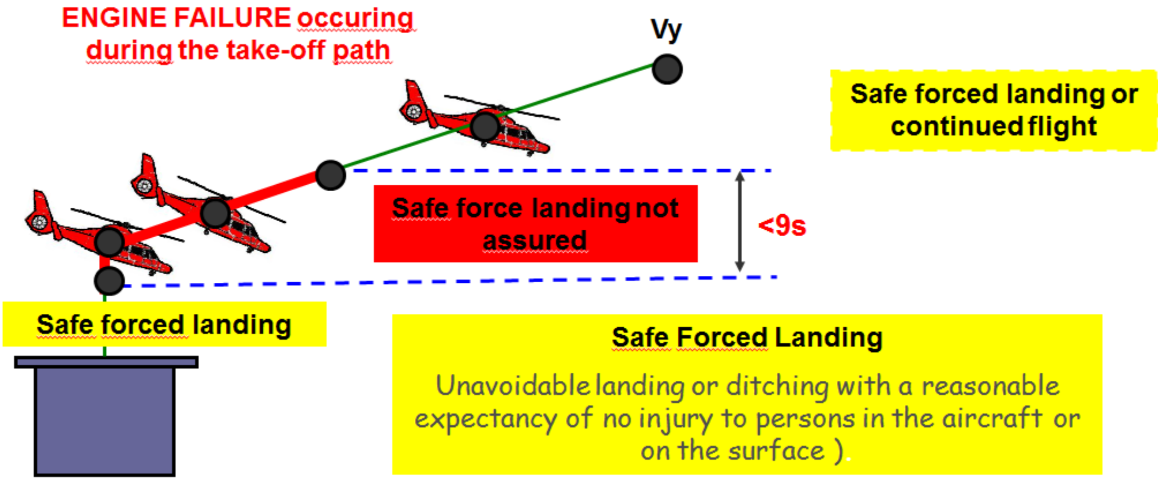


Fig. 2: PC2 with exposure time – take-off profile

2.4 Performance Class 1

In parallel, PC1 performance was also developed for other than offshore operations. PC1 requirements have to be compared with the certified Cat A performance standard.

> Note: For certification, the operating environment is not taken into account in developing the procedure and performance determination; Which could be a determining factor for Offshore operations.

To achieve good performance for take-off, this concept has led to impose a high Rotation Point (RP) associated with a dynamic take-off which consists to reach the max rate of climb before reaching the RP. PC1 requirements impose a minimum 15 ft deck edge margin and a 35 ft sea margin and a Cat A clear area continued flight profile. See Fig. 3.

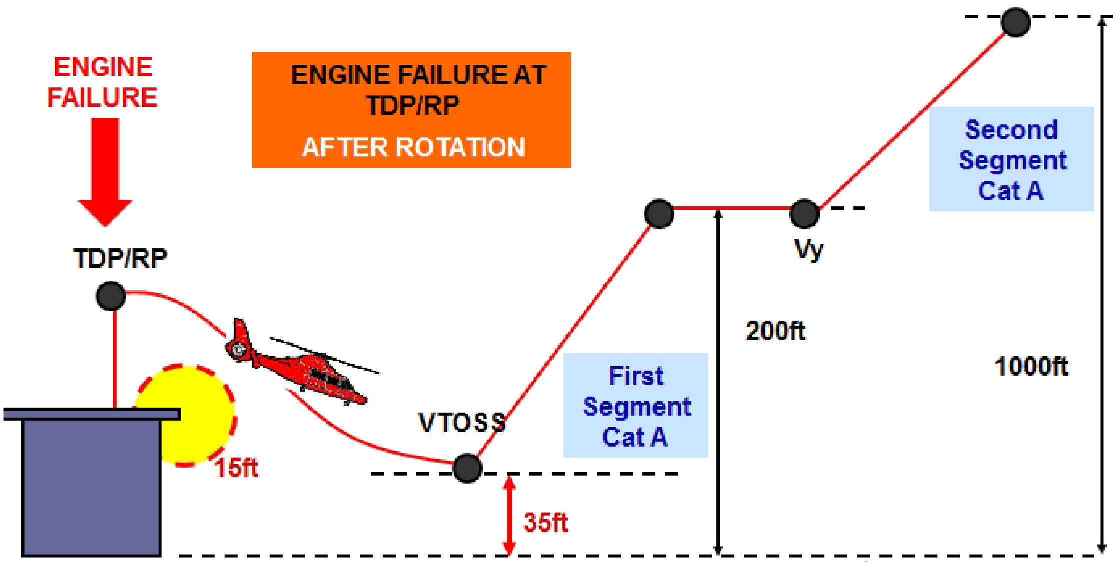


Fig. 3: PC1 - take-off profile

At the beginning, the payload reduction associated with the PC1 performance has been declared not economically feasible by offshore community.

2.5 Performance Class 2 Enhanced

JAR OPS3 (and then EASA OPS) has introduced a new type of PC2 performance: PC2 Enhanced with the objective to improve safety level and also take-off and landing payload.

> *"... the future requirement for PC 1 is replaced by the new requirement that the take-off mass takes into account: the procedure; deck-edge miss; and drop down appropriate to the height of the helideck. This will require calculation of take-off mass from information produced by manufacturers reflecting these elements. It is expected that such information will be produced by performance modelling/simulation using a model validated through limited flight testing."* (EASA-OPS [1], Part CAT, GM to Section 2, Chapter 3 Performance Class 2, § (g)(4)(ii))

> *"However, due to the severe consequences of an engine failure to helicopters involved in take-off and landings to helidecks located in hostile sea areas (such as the North Sea or the North Atlantic), a policy of Risk Reduction is called for. As a result, enhanced Class 2 take-off and landing masses together with techniques that provide a high confidence of safety due to: deck-edge avoidance; and, drop-down that provides continued flight clear of the sea, are seen as practical measures."*(EASA-OPS [1], Part CAT, GM to Section 2, Chapter 3 Performance Class 2, § (g)(4)(ii))

The PC2e concept could be based on the PC1 flight profile but with a variable margin regarding deck edge clearance (case of engine failure early on take-off) and a variable margin regarding fly away (Fig. 4).

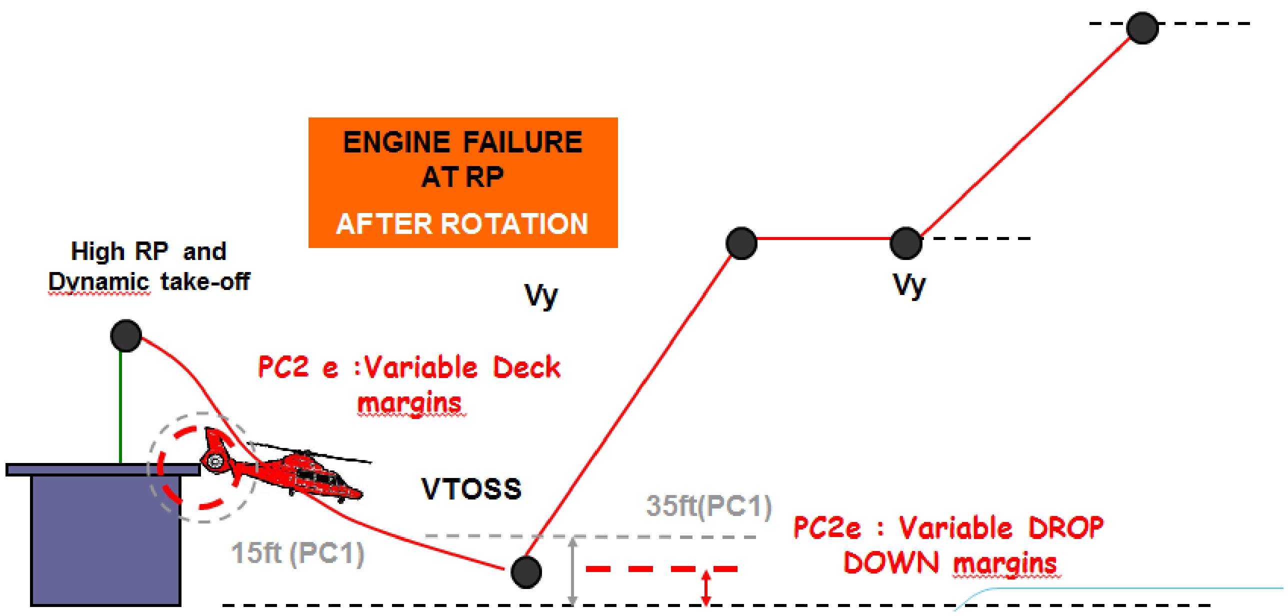


Fig. 4: PC2e Flight profile with margin reduction

2.6 Associated Take off procedures

Whatever the performance classes , to achieve good performance, the take off procedure to clear the deck edge et reduce the drop down in case of an engine failure are generally achieved by taking advantage of :

- kinetic energy through a initial vertical dynamic take off
- potential energy with a high Rotation Point above the take off surface (Rotation Point corresponds to the beginning of forward trajectory)

In fact, the typical offshore environment (obstacles near the deck, moving deck, low cues, turbulences …) associated with the dynamic take-off to reach a high RP and with the PC2 Enh reduced margin appeared not to provide the best safety compromise… This is the beginning of PC2 DLE.

3 ORIGINS OF THE PC2 DLE CONCEPT

In 2008 (2 years before mandatory PC2e application), Airbus was not very confident with this new PC2e, built on margin reduction without a rational methodology given to operators to "manage" this margin reduction (the only way to increase the weight, if not : it is PC1 performance !). There were several reasons.

- There is not sufficient engine failure experience during take-off by a pilot or operators (several pilots) and also end users (several operators) to be able to state the right margin to be taken for each operation. The risk was to put responsibility on the crew.
- Secondly, the deck edge margin reduction was questionable when the take-off procedure to achieve increased performance, appeared more complex compared to the previous one used since decades by North Sea offshore operators
- Furthermore "*high confidence of safety*" expressed in the PC2e fundaments could be impaired by "*using a model validated through limited flight testing"* when we know the complexity to address "transient" performance which is multi parameters dependent.

In consequence, Airbus decided to launch a precise analysis of the actual situation with the present use of the PC2 Exposure Time (§2.3) by operators.

The objective was to not break decades of experience, but to have a better understanding of offshore operations taking into account the recent "engine failure" flight tests done for Cat A helipad and progresses done with updated numerical modelling already use for certification purpose.

The second objective was also to address the effect of take-off and landing procedure during every-day operations (i.e.: AEO operations): A way to improve the global safety and not only the case of engine failure during take-off or landing.

3.1 Hazards identification

The first step has consisted to do hazard identification:

- For AEO operation (hopefully the great majority of flight: every-day operation)
    - Loss of references due to poor cues (bad weather, small deck) or, due to procedure (very dynamic take off or crew focusing too much on instruments to the detriment of situational awareness, …)

- Payload reduction effect: For the same amount of passengers to transport from A to B, the payload reduction will impose more sorties and inevitably more risks (more take offs and landing, CFIT, …) and performance reduction could also put pressure on the fuel quantity to be taken on board…

  Note: the first studies conducted by operators to comply with PC2e requirements have revealed a 30 % average payload on their fleet operating in PC2 with exposure time.

- In case of engine failure occurring during take-off or landing, hazards are :
  - Deck edge strike
  - Sea strike
  - Loss of references…

All these risks are increased with moving deck (ship), bad weather, turbulences, night operations, and with low experienced crew.

3.2 The PC2 DLE objectives

The engine failure and its consequences are not the only risk to be addressed. The every-day operations represent the greater exposure time with potential catastrophic outcomes compared to the time exposure for take-off and landing.

The global safety has to be improved and for this, the following hazard mitigation has been implemented through PC2 DLE concept.

1. Take-off and landing procedure must be:

   SIMPLE, to be easily reproducible by the pilot community,

   ROBUST to normal piloting dispersion, and

   SHORT, to reduce the drift induced by time integration of dispersion.
2. A similarity between AEO and OEI procedures, to limit misunderstanding and to limit crew workload.
3. A means to have a performance calculation taking into account engine failure and giving a risk exposure for each risk (Deck strike, sea strike) with the associated exposure time.

4 PC2 DLE – APPLICATION TO AIRBUS FLEET

4.1 The helicopters fleet

Taking into account that the PC2 DLE concept is presently for Offshore operation, the most Airbus civil twin engine is relevant.

The first model was the Dolphin with the 365 N3 , followed by EC 155 B1 and then EC 225 and Super puma MK2.

Then light twin H135 haS been upgraded with PC2 DLE performances

H175 and H145 are the last airbus certified version taking advantage of PC2 DLE ; H160 which is the new product to come , is already prepared for .

4.2 Instrumentation and flight test tools

The aircrafts were fully instrumented for test campaigns. This included differential GPS and extensive on-board data monitoring capabilities.

For engine failure testing, special engine software was installed. This allowed simulating a failed engine while keeping both engines at 50% of the maximum single engine power. This engine software permitted adjusting the “power gap” (the characteristic behaviour of the power transient during engine failure) so that it would match the transient power behavior during a real sudden engine flame-out.

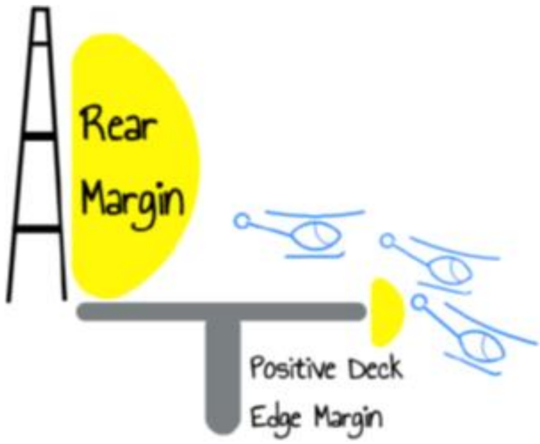
4.3 The take-off procedure

As previously explained, the PC2 DLE take off procedure needs to be SIMPLE, SHORT and ROBUST. For that, a low RP is essential to avoid the loss of references (AEO and OEI) and to be able to guaranty the rejected take-off (OEI). This is even more important for small helideck size and/or with poor cues.

To simplify the procedure, the RP has to correspond to the Take-off Decision Point (TDP), which minimizes actions (too many sequences can lead to pilot dispersion with the risk of unsafe trajectory). The unique RP=TDP point also limits the crew misunderstanding in AEO and especially in case of engine failure.

> Note: Some PC1 procedures (none AH Helicopters) have a high RP and a lower TDP: In case one engine failure occurring after TDP, the procedure is to continue to climb to reach the RP and then fly-away.

To reduce the procedure **duration** (from take-off to deck edge clearance), and by consequence the take-off trajectory drift potentially induced by dispersion during the sequence, the aircraft has to be positioned with the rotor tip tangent to the deck-edge. This ensures the largest deck edge margin in AEO and in case of engine failure. Furthermore it also gives the greatest margin regarding rear obstacles.



With the overall flight safety improvement objective, the first seconds of both procedures AEO and OEI are similar. (A way to reduce crew work load and misunderstanding)

For the last aircraft models , the most logical starting point for developing the take-off procedure was to use the experience gained from the EC225, the Dauphin and the EC175. This ensured that the procedure was based on long standing experience and that crews could easily transition from other Airbus helicopters. In addition, the PC2 DLE procedure would have to be largely identical to any offshore PC1 procedure.

The take-off procedure was therefore defined as follows (Fig. 5):

1. Start from In ground effect hover with the rotor blades tangent to the edge of the helideck;
2. Apply take-off power;
3. As soon as the radar altimeter indicates 20 ft, rotate 10° nose down and accelerate to V_Y.

In case of an engine failure before the Rotation Point (which is also the Take-off Decision Point), return vertically to land on the helideck.

In case of an engine failure after the Rotation Point, continue the take-off and increase nose down attitude to 15°.

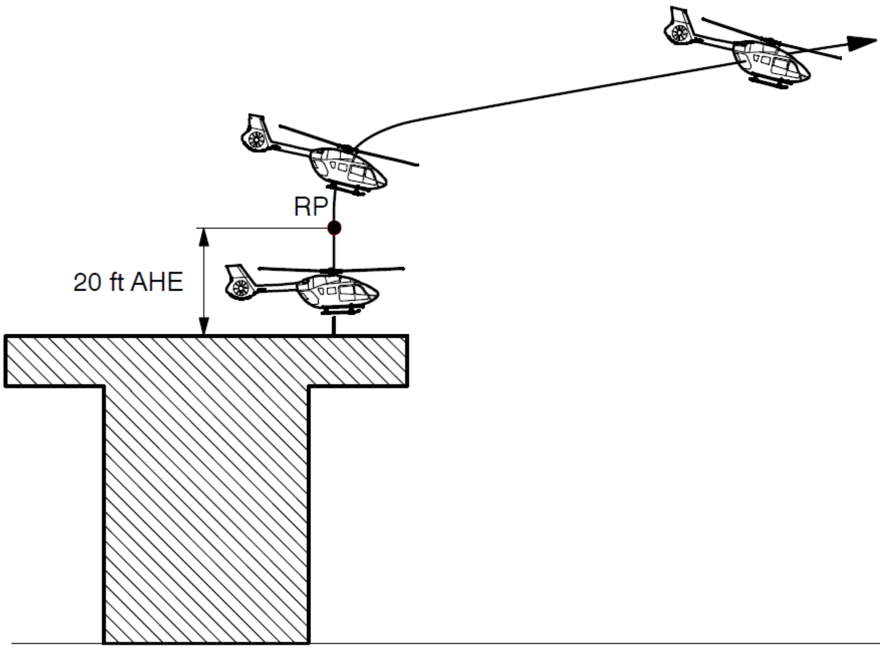


Fig. 5: Normal take-off procedure

4.4 The landing procedure

For the offshore landing procedure, the same general objectives as for the take-off applied with a focus not only on the commonality between the Airbus products, but also on the commonality between the PC2 DLE and PC1 procedures.

In case of engine failure before the LDP, set maximum OEI power and accelerate to V_{TOSS} (45 kt) and fly by the edge of the helideck.

In case of failure after the LDP, adjust maximum OEI power and continue along the normal landing path until touchdown on the platform.

5 BUILDING THE PERFORMANCE DATABASE FOR PC2 DLE

The goal of PC2 DLE is to objectivise the risk of engine failure compared to the other risks , to achieve the best safety compromise, taking into account the offshore environment.

During the last decades of off shore experience many collisions with obstacles on elevated Helideck have been inventoried during normal take off procedure . No catastrophic engine failure during take off has been reported .

In fact, to achieve this, a solid flight tests database is required.

5.1 Methodology

For performance determination, the philosophy has been to use tools, certification rules and experience already available.

In fact, the take-off weight for PC2 DLE is limited by the capacity to do a rejected take-off in case of engine failure occurring at the height of RP before rotation (worst point) or in case of engine failure occurring at aircraft rotation, by capacity to do the fly away depending on drop down available (height under platform level without obstacle) or capacity to execute a Safe Forced Landing or ditching (SFL).

– For each helicopter type, a test flight data base has to be built, with specific flight tests using already certified FADEC tools for in flight engine failure simulation (OEI 30s/2 and power gap).
– Certification criteria as normal reaction time before first pilot action.

For all Airbus products – the flight database was mainly constructed with certified Elevated Helideck Cat A (i.e.: PC1) tests and additional ones specific to PC2 DLE concept.

The aircraft data points were added to the fleet database which presently includes more than 2000 flight test points with engine failures, from light twin to heavy twin. This database includes tests over the entire offshore flight domain (Hp, OAT) to be able to demonstrate the rejected take-off (up to safe forced landing). Some test points were done on real elevated platform during day and night operations to check procedure prescribed and associated performance.

5.2 Helicopters flight testing

All flight testing for the development and validation of the PC2 DLE performance database were conducted onshore and in free air thank to specific flight test devices .Depending on the needs , results have been verified on actual elevated helideck . This significantly reduced the complexity and gives more opportunities with planning.

Flight testing for the validation of PC2 DLE offshore procedures could be divided into 4 different tests:

– Rejected take-off after engine failure
– Continued take-off after engine failure
– Balked landing after engine failure
– Continued landing after engine failure

Once the testing for these 4 cases was completed, the procedure and maximum gross weight for the normal (AEO) take-off and landing could be established and validated.

5.2.1 Rejected take-off after engine failure

Rejected take-off covers the case where the engine fails before the TDP. In this case, the aircraft must return vertically to the helideck. Testing for this failure case was performed on a surface level deck in zero wind conditions.

The test consisted of climbing vertically – just like for a normal take-off – until 20 ft. Then a simulated engine failure was introduced and the helicopter was lowered back to the deck while using the maximum OEI 30 sec power. On-board monitoring during the test allowed direct verification of the engine failure point and the subsequent use of power and rotor speed droop. This monitoring significantly increased the effectiveness of flight testing.

The test was conducted incrementally up to the 20 ft rotation point (with some margin for abuse) and up to the maximum achievable gross mass that would ensure a safe landing.

5.2.2 Continued take-off after engine failure

The continued take-off describes the case where an engine fails after the TDP/RP. In this case, the aircraft already is rotating nose down and safe return to the deck is no longer possible. To achieve maximum acceleration, the nose down attitude is increased to -15° while maximum OEI power is applied. This allows the aircraft to accelerate to 30 kt while giving up altitude. At 30 kt, a near level attitude is adjusted and the aircraft is accelerated to V_{TOSS}, from which a climb is possible (Fig. 6). In the context of PC2 DLE, an engine failure right at the RP should not lead to deck edge strike. In addition, the required dropdown height may be higher than the deck height above the water.

To test these conditions, the continued take was performed from a free air hover at 120 ft AGL. Just like for the normal take-off, maximum power was applied until the aircraft had climbed 20 ft and had initiated its rotation. At that point, a simulated engine failure was introduced and the procedure was completed.

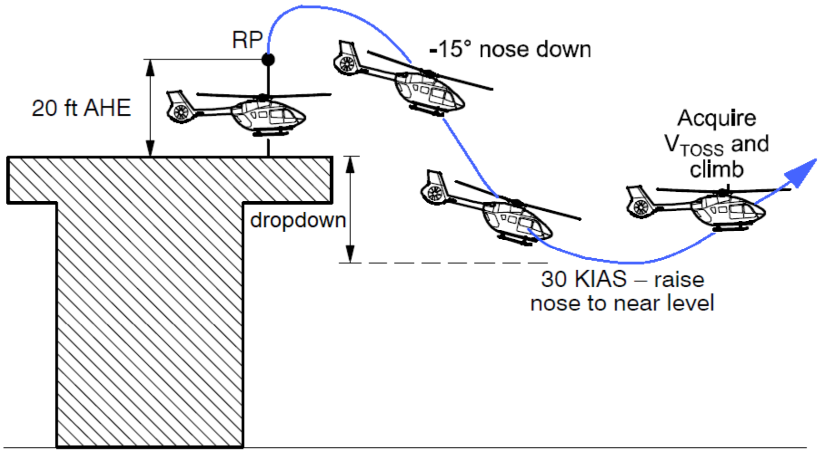


Fig. 6: Flight path after engine failure

To avoid long delays during post processing, on-board monitoring was established, which allowed the lead flight test engineer on board the aircraft to check the entire flight profile. This allowed an immediate assessment if the deck edge had been properly cleared and how much dropdown was achieved. It also permitted assessing if the engine failure had been inserted at the right moment and how much rotor droop had been encountered.

5.2.3 Balked landing after engine failure

A balked landing is executed when an engine failure occurs before the LDP – i.e. at 30 kt and 50 ft above the helideck (Fig. 7).

During flight testing, this maneuver was carried out in free air in order to avoid any ground effect during the acceleration phase.

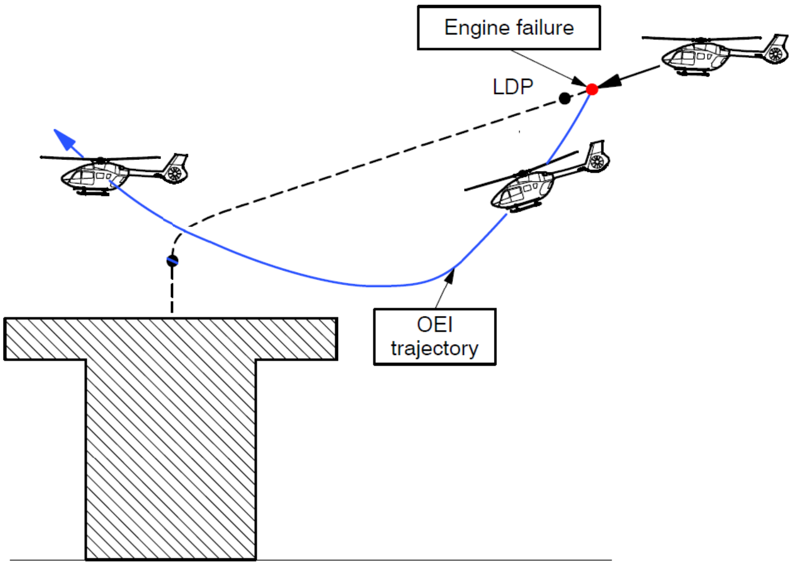


Fig. 7: Balked landing after engine failure

5.2.4 Continued landing after engine failure

Finally, continued landing after an engine failure was demonstrated to be possible for any point at or after the LDP. The same techniques and monitoring tools were used as before. Again, the maneuver was approached incrementally, by gradually increasing the gross mass that would still allow a safe landing.

5.3 Performance model and hypothesis

5.3.1 Simulation tool

The simulation tool used for PC2DLE assessment involves the AH unsteady performance model used for all OEI analysis (OEI model). This two-dimensional model (X axis and Z axis) is piloted with the following controls: collective pitch, pitch attitude and available power.

It calculates, at each time step of the maneuver, the different forces applied on the airframe and the resulting accelerations and velocities. Therefore it predicts the trajectory corresponding to a given maneuver.

For simulation purposes, the available power evolution is defined as follows:

- Engine Power
    - failed engine: instantaneous and total loss of power
    - operative engine: after a short reaction time, power increases up to the maximum OEI power consistent with the minimum guaranteed power provided by the engine manufacturer (depending on the pressure altitude/temperature conditions), and affected by the installation losses.

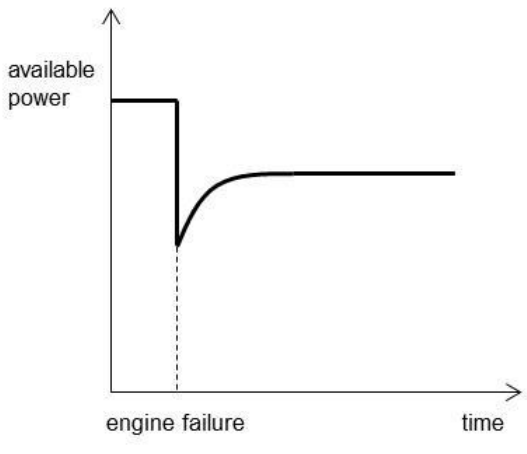


Fig. 8: Balked landing after engine failure

5.3.2 Model validation

The model validation consists in comparing the real trajectory of the helicopter as recorded during flight tests and the one computed by the OEI model with the same control variations (collective pitch, pitch attitude, available power).

Numerous flight test maneuvers dedicated to Category A certification are used to validate the OEI model. In particular, the model is tuned against helideck takeoff and landing maneuvers performed in flight in a large range of external conditions and weights.

5.3.3 PC2DLE simulations

Once validated against flight tests, simulations are performed to assess PC2DLE performance. For this purpose, the control variations applied during the simulated OEI maneuver are consistent with the PC2DLE procedure as defined with the Flight Tests Department.

All calculations are done according to FAR criteria:

- Total and sudden engine failure
- Factored wind
- No power margin on engine remaining at OEI rating.

5.3.4 Exposure time assessment at takeoff

Engine failures are simulated all along the normal takeoff trajectory (AEO takeoff).

Rejected takeoff maneuvers are simulated in case of engine failure before the Rotational Point (RP).

Continued takeoff maneuvers are simulated in case of engine failure after the RP.

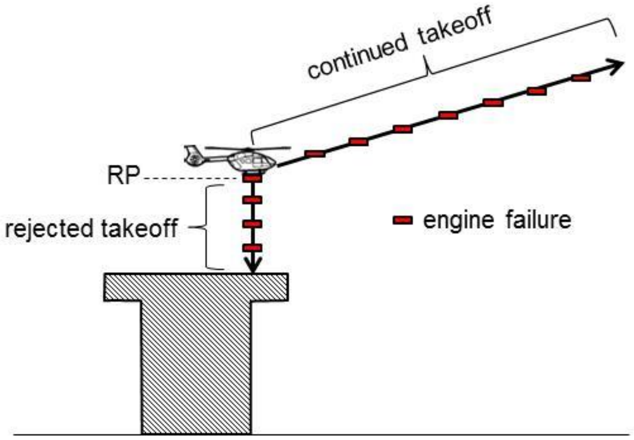


Fig. 9: Engine failure along the AEO takeoff trajectory

The Total Theoretical Exposure Time (TTET) is then determined by simulations:

- TTET begins at the last point of the AEO trajectory prior to the RP at which a an engine failure leads to a safe forced landing
- TTET ends at the first point of the AEO trajectory after the RP at which an engine failure leads to positive margins wrt deck edge and water level.

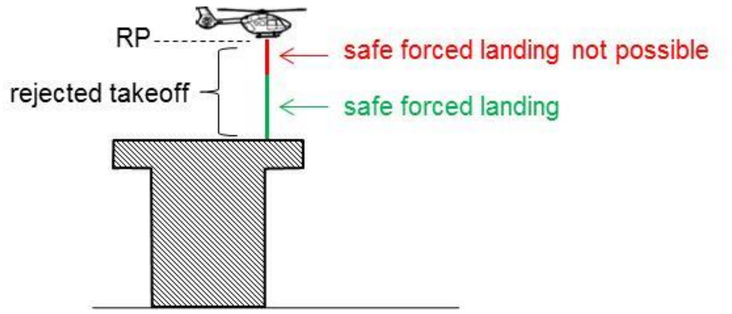


Fig. 10: Exposure time prior to the RP

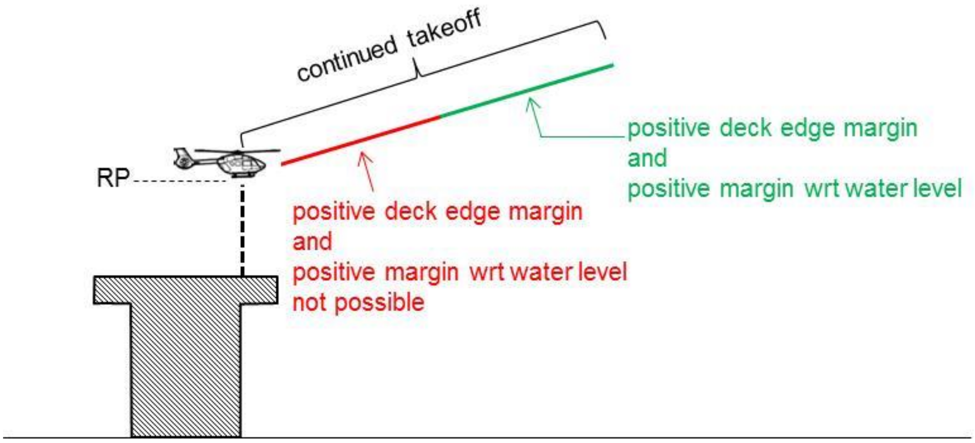


Fig. 11: Exposure time after the RP

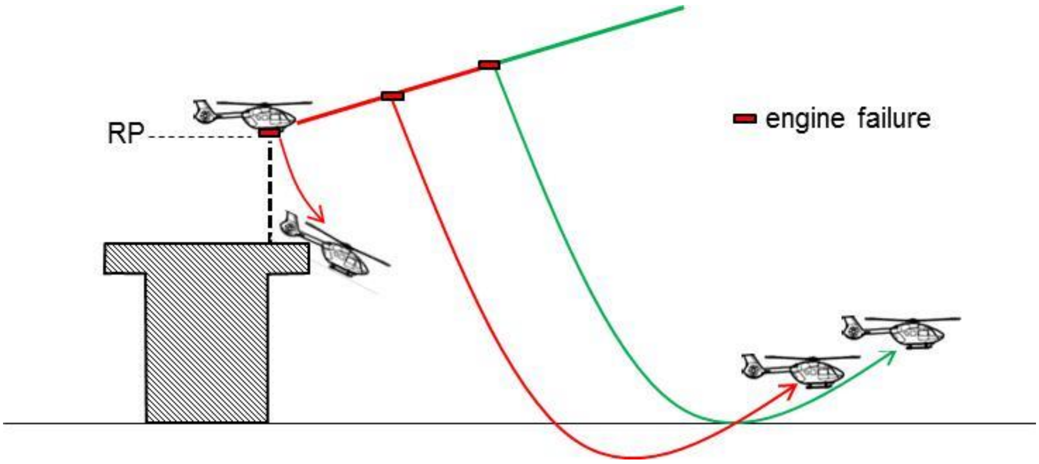


Fig. 12: OEI trajectory (engine failure after the RP)

<u>Note:</u>

- it can be demonstrated that the TTET coincides with the RP (no exposure time at rejected takeoff)
- a positive deck edge margin can be guaranteed even in case of engine failure at the RP; in such a case the exposure delay is exclusively due to a excessive drop down.

5.3.5 Exposure time assessment at landing

Engine failures are simulated all along the normal landing trajectory (AEO landing).

Aborted landing maneuvers are simulated in case of engine failure before the Committal Point (CP).

Continued landing maneuvers are simulated in case of engine failure after the CP.

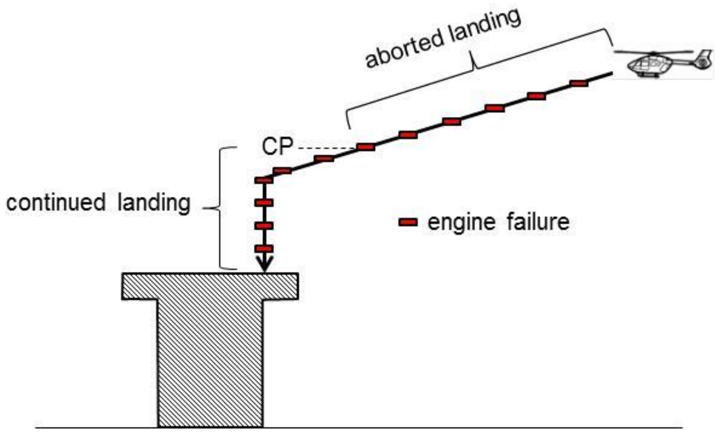


Fig. 13: Engine failure along the AEO landing trajectory

The Total Theoretical Exposure Time (TTET) is then determined by simulations:

- TTET begins at the last point of the AEO trajectory prior to the CP at which an engine failure leads to a positive margins wrt deck edge and water level
- TTET ends at the first point of the AEO trajectory after the CP at which an engine failure leads to a safe forced landing on the helideck.

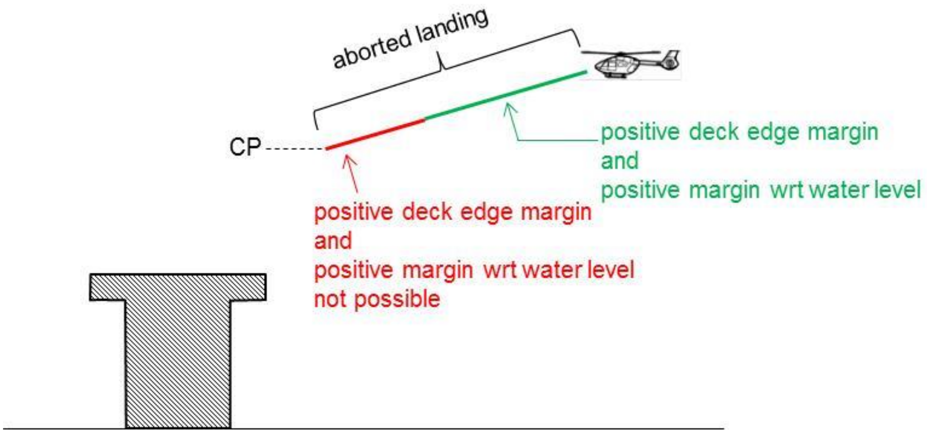


Fig. 14: Exposure time before the CP

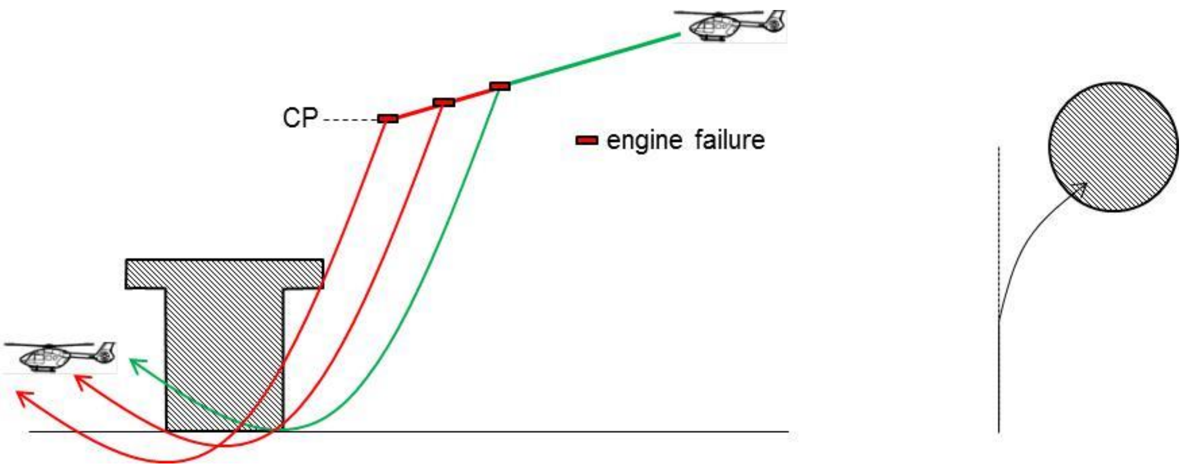


Fig. 15: OEI trajectory (engine failure before the CP, offset appraoch)

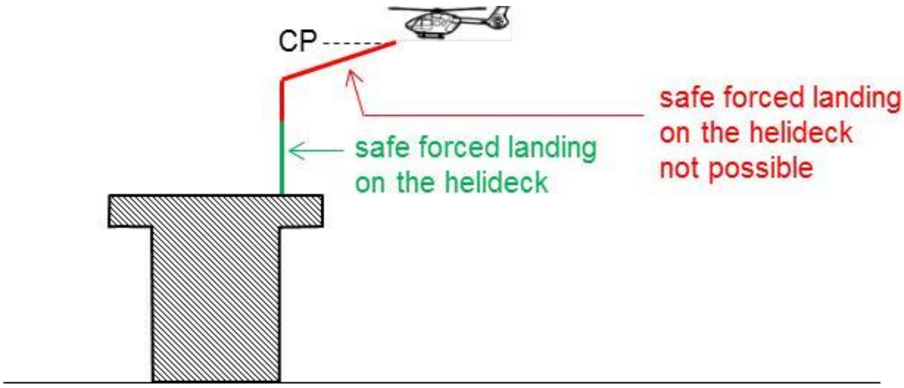


Fig. 16: Exposure time after the CP

5.3.6 Flight Manual PC2DLE performance information

In order to cover the PC2DLE target domain, engine failure simulations are performed at take-off and landing in a limited range of pressure altitude, temperature, wind and weight conditions.

For each condition, simulations aim at computing the following parameters:

- rejected takeoff: vertical speed at touchdown
- continued takeoff: deck edge margin and drop down (loss of height below the helideck level)
- aborted landing: drop down
- continued landing: vertical speed at touchdown.

Once the numerous data issued from simulations recorded, a post-processing is necessary to turn them into accessible Flight Manual and performance applications information.

The pilot can use this information:

- either to determine the Total Theoretical Exposure Time (TTET) at takeoff or landing as a function of: Pressure altitude, Temperature, Wind, Weight and helideck height
- or to determine the Maximum Take-Off Weight or Maximum Landing Weight as a function of: Pressure altitude, Temperature, Wind, TTET and helideck height.

As a synthesis of these studies, a take-off profile with one engine failure occurring at different moment is shown on the time scale (Fig. 17),

– The left green zone corresponds to normal OEI landing. In case an engine failure occurs during the vertical take-off: rejected take-off.

– The blue zone represents the Safe Forced Landing in case of rejected take off, where aircraft damage are accepted – at this time aircraft is operating out of exposure time.

– The red spot correspond to deck edge exposure – this event has a catastrophic outcome which have to be managed as during certification – the risk should be lower than 1/1000 million.

– The orange zone is the ditching exposure – the extreme right point, corresponds to the end of exposure time, this risk is manageable according to SMS.

  (Remember the very conservative hypothesis used: Exposure stops when aircraft the is able to continue to fly !).

– The right green zone represents the OEI fly away with no risk.

Fig. 17: Elevated Helideck take-off profile with an engine failure

5.4 Flight manual and performance tools

Through the flight tests done and with the already certified model it was possible to determine the take-off weight as a function of: Hp, OAT, available drop down and accepted risk or accepted exposure time.

Performance data has been included in the H145 flight manual in a special PC2 DLE appendix. The charts are easily useable (and somewhat conservative.

In addition to flight manual additions, Airbus has developed for iPhone its first application for performance calculation: Dauphin N3, EC 155 and EC 225 have optimised PC2 DLE performances (compared to flight manual charts) thanks to the “smartphone display” giving with same methodology and same hypothesis (Fig. 18).

For the EC175, this application was embedded in a more encompassing performance tool for the iPad (Fig. 19).

For the H145, the iPad performance tool will also be used.

Fig. 18: PC2 DLE iPhone application

Fig. 19: PC2 DLE iPad application

5.5 Calculating performance and exposure risk

Through these applications, it is possible to determine depending on H_P, OAT, drop down available, factored wind:

1. the take-off (landing) weight corresponding to a selected exposure time or
2. the exposure time for a selected take off (landing) weight.

For each performance calculation, the exposure time and associated risk exposure is determined:

- For deck edge exposure: **As it is is a catastrophic eventuality, risk exposure has to be kept lower than 1/ 1000 million.**
- For ditching exposure: this risk exposure has to be managed in accordance with environment, and operators and end users through the Safety Management System (SMS).

  Note: The time exposure and risk exposure which depends on the actual engine failure rate (5 years moving average) is automatically updated in the application.

Risk exposure provides a means to objectivise the risk. Time exposure is a way for crew to know when exposure stops.

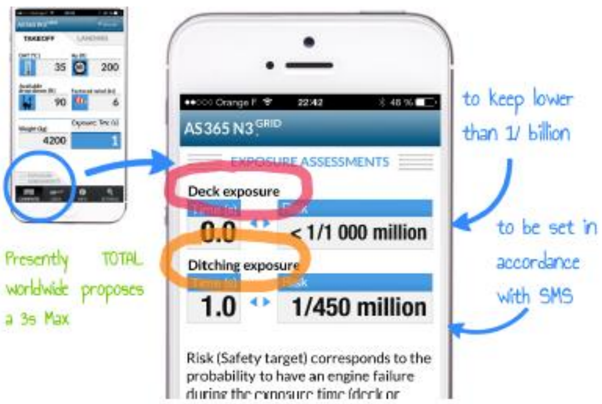


Fig. 20: iPhone application exposure tab.

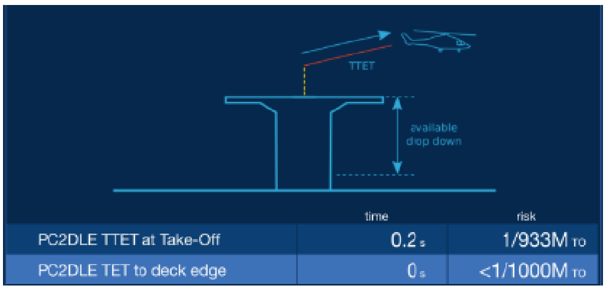


Fig. 21: EC 175 iPad application details

5.6 Interpreting the exposure risk

In fact, by using certification criteria (Total and sudden engine failure (the failed engine goes down suddenly to 0%); Factored wind ; No power margin on engine remaining) the figures given in the flight manual or through the smartphone application correspond to the worst case: theoretical exposure time or exposure risk .

nota : theoretical because actual situation will conduct to lower exposure.

Taking into account that the deck edge risk is a catastrophic eventuality, it has to be kept lower than 1/ 1000 million (which is the accepted risk in certification for catastrophic event) .

The sole residual risk is ditching exposure.

Few figures will help understanding :

For an EC225 in North Sea operation at MTOW, ISA, with 100ft drop down and zero wind, the theoretical (worst case) time exposure is lower than 3s which correspond to a ditching risk of 1/90 million (the deck risk is always lower than 1/1000 millions.)

With a 10 kt factored wind, the theoretical exposure time becomes 1 s and associated exposure risk is 1/225 million.

But the actual risk is much lower considering that :

- a wind 10 kt greater than the factored wind, reduces the exposure time by 2s.
- if the failed engine goes down suddenly to 10% instead of 0% (total power loss), exposure time is also reduced by 2.5 s.

In fact, the actual risk of a catastrophic event due to an engine failure occurring at the worst point on the take-off trajectory remains very, very small.

6 PC2 DLE SYNTHESIS: NOTHING IS REALLY NEW, EXCEPT THAT RATIONALE IS USED INSTEAD OF A FEELING …

6.1 PC2 DLE versus PC2 Limited Exposure

Factually, PC2 DLE is an enhanced version of PC2 Limited Exposure, with the enhancement coming from a prescribed procedure for each helicopter and clear exposure time and exposure risk calculation associated with take-off weight. This allows an objective assessment of the associated risk.

Note: The initial PC2 Limited Exposure wasn’t fully documented by aircraft manufacturers except for data coming from an approve flight manual (H-V diagram, AEO Hover Out of Ground Effect, and enroute Cat A charts).

- No take-off (landing) procedures were described (each operator procedure proposed was approved by its own authority. Operator’s procedures for same operation were often very different).
- No take-off (landing) performance charts were available to determine the exposure time: in case of engine failure, the crew was not really able to predict if aircraft could fly or not !

6.2 The tool box: a means to objectivize and also to reduce catastrophic risk

PC2 DLE is a toolbox to reduce the global risk during take-off and landing for offshore operations. This risk consists of much more than just the consequences of an engine failure.

This is achievable through:

- Defined, simple and robust flight manual procedures.
- A set of tools (charts) or a smart application with optimized performance, providing weight determination and risk assessment calculation for deck risk (lower than 1*10-9) and ditching risk (to be managed) which is consistent with operators SMS.

By knowing the actual risks associated to engine failures, operators can focus on other safety issues and put these in the proper perspective, e.g. workload, field of view, cockpit HMI, crew training, etc…

6.3 Standardization

The globalisation has conducted pilots and operators to have a worldwide "office" with the need to standardise. Furthermore, end users have contributed to spreading the latest Europeans rules worldwide.

The PC2 DLE brings this necessary standardization and the last improvements offers the possibility to have the same procedure for PC2 DLE and PC1 (with a low RP to take advantage of safety case analysis).

6.4 Compliance with EASA OPS regulations

The PC2 Enhanced requirements CAT.POL.H.310 (take-off) and the identical CAT.POL.H.325 (landing) are part of CAT.POL.H.305 "Helicopter operations without an assured safe forced landing capability", as shown hereafter (from [1]):

CAT.POL.H.305 Operations without an assured take-off and landing capability
(a) Operations without an assured safe forced landing capability during the take-off and landing phases shall only be conducted if the operator has been granted an approval by the competent authority.

CAT.POL.H.310 Take-off Operations
(c) for operations in accordance with CAT.POL.H.305, in addition to the requirements of (a)
(2) for operation from a helideck
(i) with a helicopter that has an MOPSC of more than 19,or
(ii) any helicopter operated from a helideck located in a hostile environment,
the take-off mass shall take into account: the procedure; deck edge miss and drop down appropriate the height of the helideck with the critical engine(s) inoperative and the remaining engines operating at an appropriate power rating .

According to EASA-OPS, the so-called PC2 Enhanced requirements aim at minimizing the exposure time in case of one engine failure, while this exposure time is still allowed in order to cope with the other risks present on helidecks:

- collision with the helideck obstacles due to human error (main hazard according to in-service history),
- moving decks
- sea level (tide)

PC2 DLE indeed gives the operator a tool to minimize the exposure time, while offering a simple and reproducible procedure as recommended by JAR-OPS 3 ACJ (used by the North Sea operators for decades).

PC2 DLE is consequently compliant with the EASA-OPS requirements in the offshore helideck environment.

7 CONCLUSIONS AND OUTLOOK

7.1 Conclusions

The concept of Performance Class 2 with Defined Limited Exposure is an advanced method of defining helicopter performance for offshore operations. PC2 DLE presents the operator and end users with some significant benefits over less stringent methods.

Flight testing was conducted to apply PC2 DLE to the Airbus H145 helicopter. The unique capabilities of the H145 resulted in a PC2 DLE take-off procedure with zero exposure to deck edge strike up to the aircraft's MTOW, and with limited time exposure only for helidecks with low available dropdown heights. The H145 PC2 DLE landing procedure is completely exposure free up to the aircraft's MTOW.

An H145 flight manual appendix for PC2 DLE has been published and is currently in used with offshore operators. An iPad application for PC2 DLE is currently under development. In the near future, the PC2 DLE data will also be available for an all up gross mass above 3700 kg. The associated PC1 data and procedures will also be available shortly.

7.2 The future of PC2 DLE

The PC2 DLE concept provides a risk based approach to dealing with the consequences of an engine failure. Rather than making "theoretically absolute" safety requirements ("an engine failure at any moment must be totally safe"), PC2 DLE offers the pragmatic possibility to weigh the risk following an engine failure against other hazards and to define the risk one is willing to accept.

Currently, this concept has already been adopted by the offshore community. It could, however, be easily expanded to other types of operations, such as HEMS, HEC, etc.

7.3 New technology

For very low drop down available (small ship), aircraft performances are generally limited except if the risk accepted for ditching is increased.

For future developments, the use of advanced autopilot modes and cockpit displays may allow increasing the RP height without having to keep sight of the helideck. In addition, automation could reduce the reaction time and typical pilot dispersion for the normal take-off and in the event of an engine failure.

8 REFERENCES

[1] European Union, Commission Regulation (EU) No 965/2012 on air operations and related EASA Decisions (AMC & GM and CS-FTL.1), Revision 10, March 2018.