TWENTYFIFTH EUROPEAN ROTORCRAFT FORUM

PAPER E4

"IMPROVED METHODOLOGY FOR TAKE-OFF AND LANDING OPERATIONAL PROCEDURES

THE RESPECT PROGRAMME"

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Organisations: Eurocopter♦, GKN-Westland✧, Eurocopter-Deutschland■, DLR♠, Agusta□, CIRA✦, DERA●, NLR○, ONERA, CEV✲

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ABSTRACT

In passenger transport missions, rotorcraft are operated in accordance with air traffic procedures which have been established essentially for the needs and performance capabilities of fixed wing aircraft, i.e. which incorporate trajectories with long rectilinear legs, moderate turns and shallow slopes in climb or descent. The specific ability of rotorcraft to take-off and land vertically, and to perform terminal manoeuvres in a confined space, following routes which do not interfere with the other air traffic, makes much more efficient operations possible. Nevertheless the potential benefit of revised flight procedures (in terms of better integration with other air traffic and reduced noise impact) and the consequent development of intercity connections, will materialise only if such procedures can be shown to preserve or improve flight safety without degrading the vehicle performance in terms of its payload capability.

Since the end of 1997, all of the European helicopter manufacturers together with experts from European aerospace research establishments have been working on a joint programme supported by the European Commission in an effort to develop improved take-off and landing procedures for a wide spectrum of field configurations and operating conditions. The programme, called RESPECT, standing for Rotorcraft Efficient and Safe Procedures for Critical Trajectories, will demonstrate the feasibility and safety of the proposed manoeuvres, addressing in particular those critical flight conditions during which an engine failure could endanger the passengers and/or population on ground. A methodical approach is being pursued, with the three following major steps:

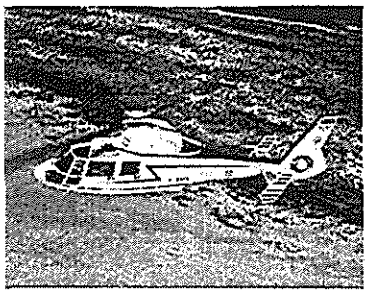
1. establish a common performance simulation code and validate it using existing flight data,
2. use this code to analytically optimise trajectories and propose improved manoeuvres,
3. substantiate the practical feasibility and usefulness of these new procedures by means of piloted simulations and demonstration flight tests.

This methodology and the first year activity is presented

A109K

BO105

W30



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1 THE RESPECT PROJECT

1.1 Industrial Objectives

The main objectives of the RESPECT project (Rotorcraft Efficient and Safe Procedure for Critical Trajectory) are:

- To determine for existing helicopters, how and by how much, terminal manoeuvres can be modified to improve mission effectiveness in terms of allowable payload and in terms of time necessary to take-off and depart or to approach and land whilst maintaining or improving the level of safety.
- To demonstrate the feasibility and error-tolerance of these manoeuvres taking into account all of the practical difficulties such as pilotability, crew field of vision, altitude and position cues, transient engine and rotor speeds, etc.., addressing in particular those critical flight conditions during which an engine failure could endanger the passengers and/or the population on the ground.

The helicopter industry as a whole would profit from the market growth triggered by improved flight procedures and by quieter heliport neighbourhoods, if it can be shown that flight safety is preserved or improved without degrading helicopter payload performances.

The time-to-market for the project results exploitation could take up to three years since it would be first necessary to convince the helicopter community (operators, airfield authorities, airworthiness authorities) of the advantages offered by the new approach.

These ambitious industrial objectives are naturally widely exceeding the framework of a 3-year programme. This complex problem must therefore be broken down to optimise the advantages of this co-operation and obtain results that are immediately applicable.

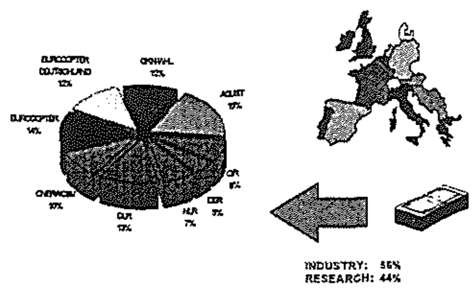
1.2 Partnership

This research programme is partially funded by the European commission and includes the following European manufacturers: Eurocopter (EC) - Eurocopter Deutschland (ECD),
GKN-Westland (GWHL) - Agusta (Ag)

As well as the following research agencies:

ONERA (associated to CEV for flight testing), DLR, CIRA, DERA and NLR.

These agencies have been working for many years with the industrialists on rotary wings. The breakdown is presented in Fig. 1.



All European Helicopter Industry and Major Resarch Institute are Present
Large Helicopter Performance Knowledge

Figure 1

RESPECT is really close as a research programme to the product in the wide sense of the word. It includes main helicopter operations and covers operating improvements by retaining or enhancing the safety levels that are accepted by the Airworthiness Authorities today.

1.3 Methodology: The RESPECT Project

The RESPECT programme is intended to set up a study framework which will help to improve helicopter safety and performance for a wide range of helicopter weights and an extensive range of operations. The study topics and the helicopters types are listed in Fig. 2 below:

Operation	Helicopter	Max. Weight (kg)
Unprepared and confined area EMS/SAR	BO105 A109K	2500 2720
Restricted Helipad	BO105 A109K 365N W30	2500 2720 3850 5800
Elevated Platform	365N W30	3850 5800
Clear airport City heliport	365N W30	3850 5800

Figure 2

The methodology that will be derived from the RESPECT programme is also the main thrust of this project and, in some respects, its first application. In applying the results of study, the RESPECT partners will work alongside helicopter operators as well as some European government agencies. In fact, a part of the programme is naturally dedicated to contacts with the operators' flying personnel as well as the agencies e.g. DGAC, CAA, LBA, JAA, EHA, IFALPA.

This methodology is well illustrated in Fig. 3 presenting the different tasks included in the RESPECT programme.

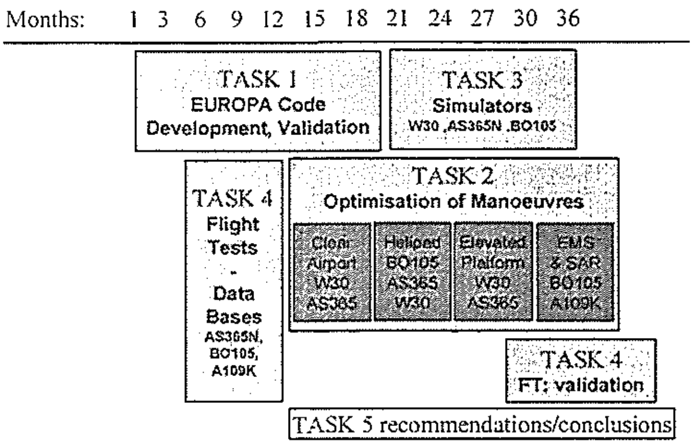


Figure 3

Task 1: Specification and development of a common computer code for the calculation of stabilised and non stabilised performance.

Task 2: Optimisation of procedures applicable for those cases and helicopters quoted.

Task 3: Piloted simulations to verify the optimised procedures for the respective helicopters.

Task 4: Flight testing: This part includes 'preliminary' as well as 'confirmatory' flight tests after the phase optimising procedures for the operations considered.

Task 5: Circulation of results. This involves not only communicating information regarding the RESPECT programme but also feeding this study with concrete cases close to the daily operating realities of the helicopters.

Most of the effort expended to data has been devoted to the development of a performance calculation code common to every partner.

2 EUROPA: PERFORMANCE COMPUTATION CODE – TASK 1

This chapter gives the design specification for the EUROPA (EUROpean Performance Analysis) software and the status of development achieved. The EUROPA code essentially consists of two elements: a helicopter performance simulation and the control logic required to run multiple performance simulations for:

1. manoeuvre optimisation,
2. research,
3. calculation of performance data for the generation of aircraft performance charts.

2.1 Uses for the code.

EUROPA is used in the BRITE EURAM "RESPECT" project, as a research tool for predicting the take-off and landing performance of helicopters operating in a variety of complex situations. The code is capable of accurate performance prediction and is suitable for the task of finding the optimum piloting strategy for each manoeuvre. The flight conditions which the model is able to analyse and the modelling accuracy are described.

Once fully developed, the code will be used by some of the partners (and possibly by other parties) for the estimation of helicopter performance for research, and the calculation of performance for certification and flight manual chart production. In this role the code must be capable of finding the limiting performance of a helicopter at each point in its operating envelope (both steady-state and dynamic performance).

Other uses of the code are:

- To define the **safety criteria** (necessary performance margins) for existing and future procedures.
- Analysis of manoeuvres and modelling of flight test events for parameter identification.

The validation of the model for each task will always be the responsibility of the user.

The work required to create this useful tool falls into two categories:

- Creation and validation of an accurate vehicle performance simulation.
- Development of an easy to use performance prediction tool, which uses

the vehicle simulation as a "performance calculation engine".

2.2 The EUROPA model.

The code includes models for the vehicle, the pilot, the environment and the control logic. For some helicopter components, there are several models or options from which the most appropriate to a given helicopter type can be selected. For example, a conventional rotor or a shrouded fan of the "fenestron" type can be used for the tail rotor. For the main rotor, a blade element integration, an analytical model in closed form and a flight test power identification can be selected according to the available aerodynamic data and the constraints on computation time. Engine models range from elementary time constant response to a thermodynamic description of engine components. A specific helicopter model is constructed by specifying appropriate modelling options as part of the input data files.

The pilot model and the control logic allow off-line simulation of various piloting strategies, generating realistic flight control activity and following a pre-selected schedule of fuselage attitude, airspeed, engine limitation, RPM, etc... according to the procedure under study. The effect of pilot abuse and errors such as reaction times, overreaction, etc... and the repeatability of manoeuvres can be parametrically investigated, making it possible to assess precisely the safety margins.

The required features of both elements of the model, their validation method and the accuracy requirements are outlined below:

2.3 Accuracy requirements.

The accuracy requirements can be divided into several categories:

Firstly the vehicle simulation is able to predict both the power required and attitude required to trim, to a high degree of accuracy. Although "factors" can used to refine the power match these factors are small. Users have a high degree of confidence in the fidelity of the basic aircraft model.

The accuracy of the vehicle manoeuvre simulation is also be of a high order. With any performance model, it is normally not possible to match any one flight test event to a high degree of fidelity due to un-modelled factors, such as small variation in the wind speed etc. However if a number of similar events are matched, the performance simulation must not show any trend in the errors (i.e. the predicted height loss during a hover flyaway may sometimes be less than measured, sometimes more, but a consistent trend is not acceptable).

When run to produce data for flight manual charts, the scatter between the predicted and measured performance is a combination of the accuracy of the simulation, and the repeatability of the manoeuvre. Margins are required to account for the worst possible combination of piloting errors. One of the uses of the code will be to predict the consequences of piloting abuse on performance. The Task 2 work to optimise performance must bear this in mind. If the optimum manoeuvre is difficult to fly, and the worst of the likely abuse cases is found to seriously degrade the performance, then the margins required to ensure safety may overwhelm the performance gains which accrue from optimising the technique! The accuracy of the code (in this case the modelling of the piloting technique) is verified by confirming that there is no consistent error, that is to say, the predicted performance should lie close to the centre of any measured performance scatter.

2.4 Development status

The EUROPA code has been compiled and run at each of the partner sites (on a variety of types of computer) and the same benchmark results have been obtained.

The EUROPA vehicle simulation has been shown to predict both the steady-state (trim) and dynamic (manoeuvre) performance of variety of helicopter types to a good degree of accuracy.

We have demonstrated that performance data can recorded for each simulation run (or trim condition) and that the output can be plotted to produce performance charts (H/V diagram, takeoff and landing charts (WAT) etc.).

To speed up the production of performance data, the simulation is able to iterate manoeuvres (e.g. critical engine failure point) and is able to cycle through multiple cases (i.e. run a series of cases automatically, varying the aircraft mass, pressure altitude, OAT, wind speed, etc.).

2.4.1 Steady-state (trim):

The code is capable of being run in a "trim only" mode. The utility of the code is of course improved by the addition of a "cycle" subroutine which permits the user to run multiple cases, for example over a range aircraft weights and speeds, so as to automatically produce a "predicted" power carpet. For validation purposes the performance-simulation output is stored in a file for comparison with flight test data.

The ability to run multiple cases is used to produce the stabilised performance data found in the Rotorcraft Flight Manual.

For performance prediction work, the basic power prediction is refined by the use of small "correction factors", which are normally applied to the predicted profile power, in order to produce a perfect match to the measured aircraft power carpet. The basic helicopter performance-simulation is made as accurate as possible, so that the factors required to produce a perfect match are small.

EUROPA can be run in the "trim only" mode to predict the ability of the helicopter to hover in winds from any quarter. For this, an accurate tail rotor model and control position prediction capability were developed both for Fenestron and classical tail rotor.

The good level of correlation with flight test is illustrated in fig. 4 for hover and fig.5 for forward flight. Figure 6 shows the differences between predictions and measurements from figure 5.

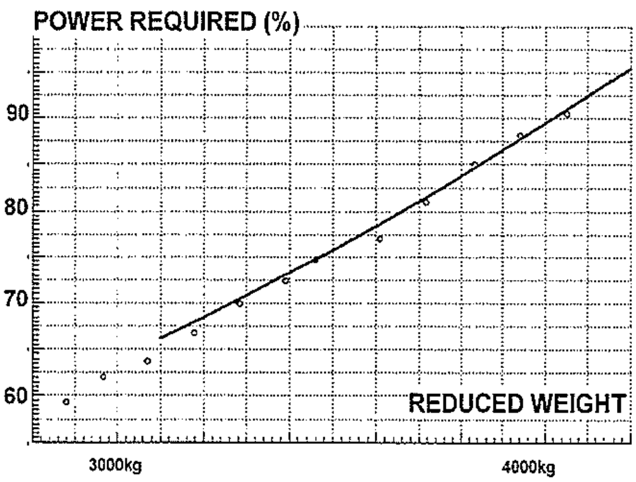


Figure 4: Hover out of ground effect

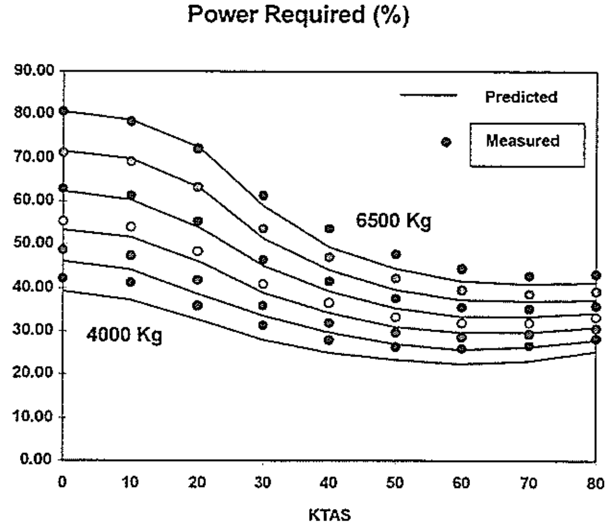


Figure 5: EUROPA/flight test comparison

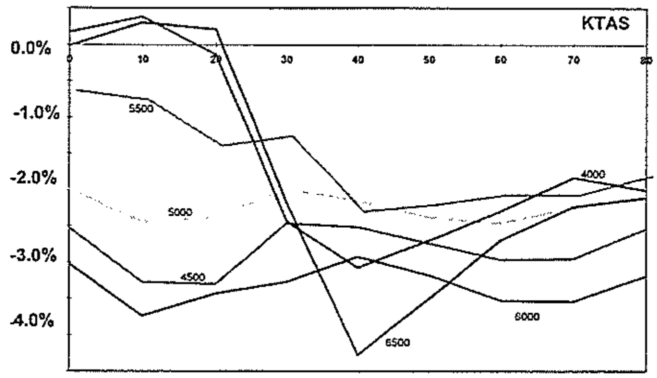


Figure 6: EUROPA/flight test - Accuracy

2.4.2 Dynamic performance (manoeuvre simulation)

Once the steady state performance of the simulation had been verified, the model was validated for the prediction of manoeuvres. As this is not a handling qualities code, only performance criteria are considered. To validate the vehicle model a "flight test manoeuvre matching" subroutine was created. The pitch and roll attitude time history from a measured flight test event is used as the "target attitude" and feedback controllers are used to generate the control inputs required to make the performance-simulation follow the measured aircraft attitude traces. Similarly, the collective is adjusted either to "follow" the flight test height trace or to match the measured movements of the collective stick. The yaw pedals are moved either to match the heading (low speed) or centre the slip-ball (high speed).

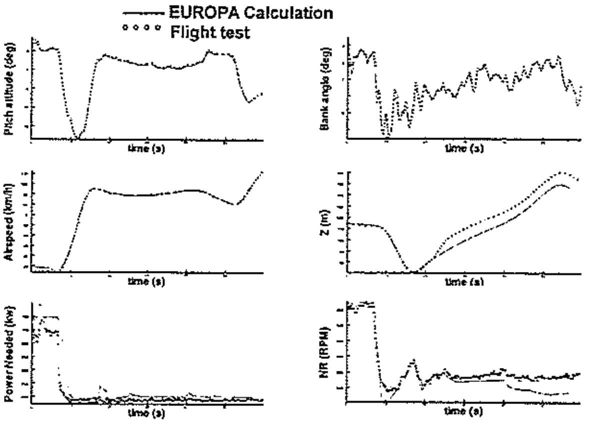


Figure 7 : Matching logic – Engine failure in descent flight 9° slope

The accuracy of the performance simulation is checked by comparing the "free" simulation parameters with flight test (torque, rotor speed, control positions, airspeed, aircraft position, etc.).

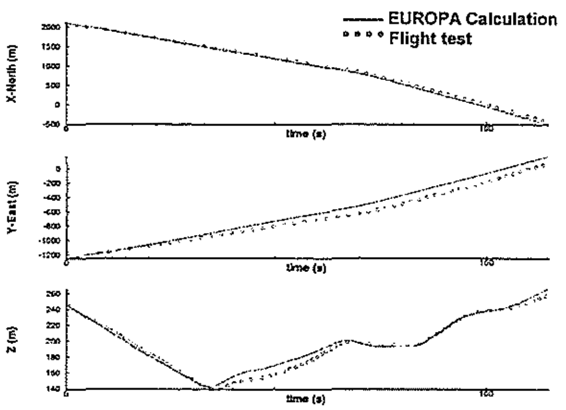


Figure 8 : Matching logic – Aircraft position (X,Y,Z)

Because some flight test parameters are not modelled (e.g. variations in vertical air mass motion and wind speed), validation tends not to be an exact science! It is normally necessary to model a number of similar flight test events and look for trends. The performance simulation is deemed to be valid if all of the predicted parameters sit close to the centre of the flight test "scatter".

When the basic vehicle model has been validated, the ability of the code to generate accurate performance predictions is checked by programming the performance-simulation to "fly" an idealised version of a number of measured events. The code is validated by comparing the predicted performance with the measured performance (e.g. rejected takeoff distance, distance to Vtoss, H-V limits, etc.).

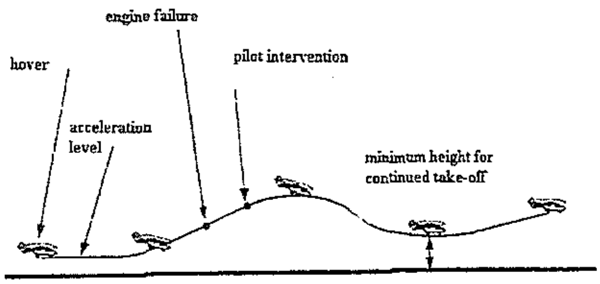


Figure 9 : Continued take-off scheme

In order to "fly" many of the critical flight manual manoeuvres, an "automated iteration" method is required. For example, when flying a Category A takeoff, the takeoff decision point (TDP) may be defined in terms of radar altitude (e.g. 35 ft). The critical continued takeoff case is an engine failure recognised by the pilot at the TDP. But, if the engine failure recognition time is one second, it will be necessary for the simulation to iterate on the engine failure time so that the required TDP is reached one second later.

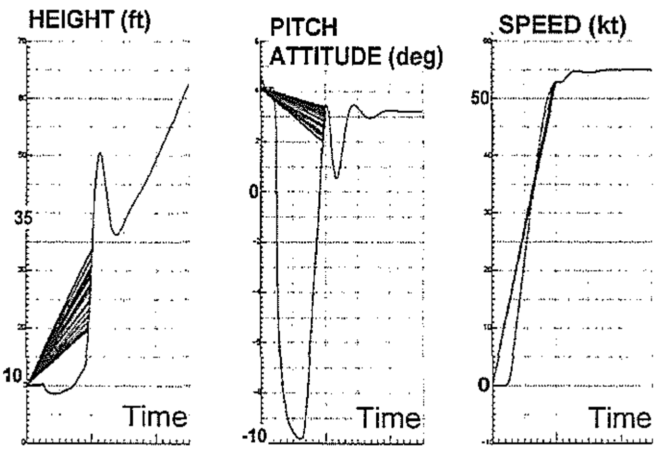


Figure 10 : Take Off Decision point calculation

Similarly, the limiting altitude for a vertical reject can be found only by iteration; starting at a low altitude and working up in height until a touchdown is made at the limiting rate of descent and Nr.

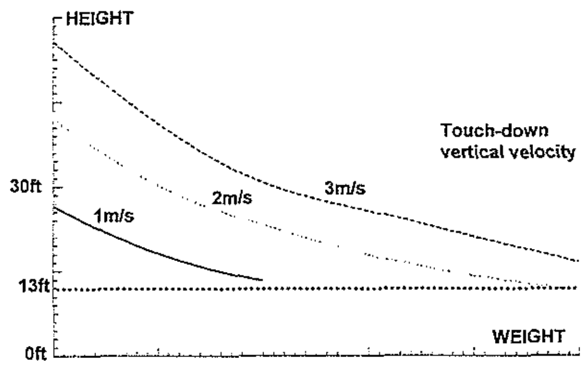


Figure 11 : H/V Diagram Low point calculation

The same type of "automated iteration" may also be used to vary the piloting technique, so as to achieve the optimum performance. The optimisation logic and the feedback parameters required, are the province of the RESPECT Task 2 partners, but the ability to undertake this type of modelling has been built in from the start.

To turn the simulation into a useful performance prediction tool, the "cycle logic" must allow a number of events to be simulated and the required performance data to be recorded and output. For example, the variation of the limiting vertical reject height with aircraft weight and wind speed; or the data required for the production of a Category A takeoff distance chart as a function of aircraft weight, pressure altitude, OAT, and wind speed. The accuracy of the performance output will be checked by comparison of the predicted "chart data" with measured flight test data.

At the end of RESPECT, EUROPA will only be a useful tool if the charts which are produced from the simulation output can be used to predict performance.

In practice, EUROPA must be able to quickly and accurately generate all of the dynamic performance data which is normally found in a Rotorcraft Flight Manual.

2.4.3 Visualisation

A visualisation post processing software using the VRML language is being developed in order to check the pilot visual cues with glazing surfaces corresponding to the actual cockpit.

This software provides animated visualisations of the particular helicopters used in the project and shows manoeuvres calculated by the EUROPA code. The results of off-line computations are easily interpreted and this visualisation technique will be used for the briefing of crew before piloted simulations and flight tests.

2.5 Conclusions.

A new code has been developed in common: EUROPA (European Rotorcraft Performance Analysis). Written in FORTRAN and meeting stringent standards for documentation and software quality, the code runs on desktop computers. Good portability has been shown. It can simulate steady state performance and complex 3D manoeuvres, such Cat A take-off and landing with lateral offset and turns with effects of wind. Manoeuvres can iterate for optimisation or chart production, so as to generate H-V diagrams, take-off decision point, exposure time, etc...

The EUROPA code is more than just a helicopter performance simulation. It is also a performance prediction tool which is quick and easy to use, and which produces output that can easily be plotted to produce accurate performance charts.

EUROPA can be run in two modes.

1. The steady-state (trim only) is used to produce power carpet data, and to analyse hover performance in any relative wind conditions.
2. The dynamic performance (manoeuvre) is used to analyse engine failure, takeoff, landing, and other such cases.

The EUROPA code is being validated in several stages. First the steady state trim has been validated by comparing performance-simulation with flight test. Next the manoeuvre capability of the vehicle model was verified by matching flown events, i.e. by comparing predicted and measured time history traces. Then the ability of the simulation to predict performance was confirmed by using EUROPA to predict the performance for a number of specific flight test events, and checking that the predicted performance is close to the centre of the flight test scatter. Finally the ability of EUROPA to produce valid charts will be checked by producing example "flight manual" charts and seeing how well they predict the performance flown during the RESPECT piloted simulation and flight trials.

3 ANALYSIS AND OPTIMISATION OF MANŒUVRES – TASK 2

Based on existing rules, recommended practise, flight manuals or information collected from operators, unambiguous and simple criteria are being defined in order to provide either objective functions or constraints for optimisation. They fall into four categories:

safety criteria, esp. considering the consequence of engine failure and with provision for pilot abuse and obstacle avoidance in degraded visual conditions (when applicable);

performance criteria, which are combinations of the technical factors impacting profitability or efficiency of operations: payload, time...

noise criteria, which take into account the favourable or unfavourable flight conditions in the Vh-Vz diagram;

air traffic criteria, which indicate compatibility with alternate approach/take-off paths avoiding interference with fixed-wing airport traffic and the possibility of freeing runway slots for this traffic (applicable to airports only).

4 PILOTED SIMULATIONS DEMONSTRATION OF NEW PROCEDURES – TASK 3

An engineering department obviously does not have the same knowledge and appreciation as the crew. After the off-line studies, the optimisation manoeuvres established with the EUROPA code shall be applied to undertake piloted simulations to present and have the procedures evaluated by the pilots. It is evident that those procedures are set up in close co-operation with the test crew but the risks inherent to the flight testing for such procedures calls for preliminary evaluation in the simulator which could also be used as a training platform.

For the piloted simulations, three helicopter types will be implemented: AS365N, BO105C and Westland 30. Later, the new procedures developed during the RESPECT study will be demonstrated in flight on the AS365N, BO105C and A109K2.

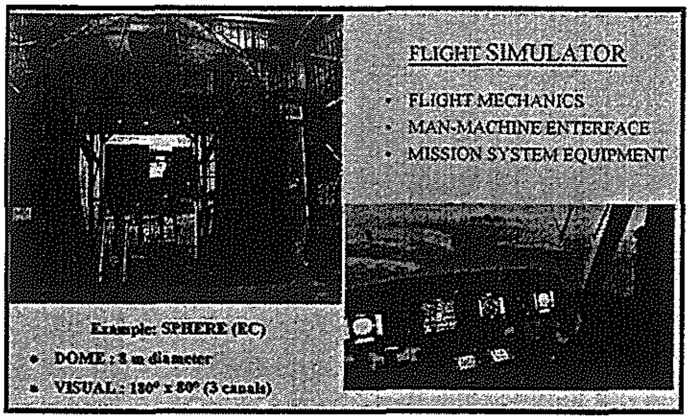


Figure 12

5 FLIGHT DATA - TASK 4

One needs reliable flight tests to validate or reject the analysis tool. These tests should be representative of the helicopter's behaviour in the emergency phases but shall not necessarily be performed in extreme conditions. The proximity to the ground or a rig , in particular, is not essential to compile the data bank needed to validate the helicopter's and/or the engines' behaviour in the acceleration, deceleration, climb or descent phase with or without engine failure. Some of these tests can be representative of the procedures scheduled but may also be limited to procedure sequences.

The dynamic performance studies are being conducted on a representative range of twin-engine helicopters: Dauphin AS365N, Westland 30, BO105C and A109K2 whose operations cover a wide spectrum of missions: passenger transport linking airports, heliports and offshore platforms; EMS to and from unprepared landing sites and hospital rooftop platforms; and mountain rescue.

Substantial data bases were available for all four helicopters. For the validation of the EUROPA code in manoeuvring flight, it was nevertheless found necessary to collect additional flight data: H-V diagrams, Cat A manoeuvres with simulated OEI situations. In 1998, complementary flight tests were performed with a Dauphin 365N operated by CEV and a BO105C operated by DLR. Similarly, tests with a A109K2 operated by Agusta were performed in 1999.

These tests were performed with well-instrumented helicopters. DGPS positioning is available for all manoeuvres.

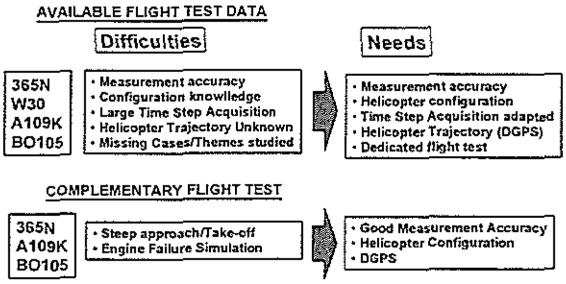


Figure 13

An additional flight test phase is scheduled for each of the 3 helicopters for which complementary flight tests have been performed in the second half of the RESPECT programme to check the results of the optimisation study off line and in the simulator.

Note that, for the RESPECT flight trials, there are likely to be various flight testing constraints (for example it may be necessary to use less than maximum engine power, etc). The flight trials will be used to check the optimised computed conditions, sufficiently far from the ultimate performance of the helicopter.

This involves performing the flight demonstration with an extensive knowledge of the safety procedures as well as a preliminary sensitivity study. The development efficiency shall be enhanced, the number of flying hours shall be reduced and so will the risks incurred by the aircraft and their crew.

6 RELATIONSHIPS WITH OPERATORS AND AUTHORITIES – TASK 5

The RESPECT team has established contacts with airworthiness authorities and operators, esp. via the JAA/OPS Helicopter Sub-Committee. HSC observers are invited to some RESPECT workshops and are scheduled to participate in piloted simulations. After thorough validation, the EUROPA code and the general methodology developed in RESPECT is expected to be used for developing operational procedures and limitations in a more accurate and less expensive way. On the other hand, the feedback from operators is helping RESPECT to concentrate on missions and operating conditions where the need for an improved methodology is most acute.

A web site is being maintained by the RESPECT team for the information of interested organisations. This site incorporates general information on the project and several pages for each active task, with a description of what is being done, photographs of the test helicopters and a short sample movie in synthetic images to illustrate one type of manoeuvre computed with the EUROPA code.

http://www.nlr.nl/public/hosted-sites/respect/

As the phases described above are completed, the safety procedures of each helicopter are extensively studied upon engine failure . The study and the related results are to be presented objectively to the certification agencies (European agencies first) as for a "conventional" certification process. Those products to which this process demonstrating safety margins or performances shall have been applied will naturally prove beneficial to the operators.

7 CONCLUSION

The RESPECT project aims to develop improved rotorcraft terminal procedures and airfield operations (i.e. take-off and landing manoeuvres) for a wide spectrum of field configurations, including, but not limited to, airports (freeing-up valuable runway slots), city centre heliports, and offshore platforms. The project will demonstrate the feasibility and safety of the proposed manoeuvres, with regard to the performance capabilities of existing helicopters, addressing in particular those critical flight conditions during which an engine failure could endanger the passengers and/or the population on the ground.

The approach to be used to reach this objective is threefold:

1. To establish a common performance simulation code and to validate it using flight data.
2. To use this code to analytically optimise trajectories and to propose improved manoeuvres.
3. To substantiate the practical feasibility and repeatability of these new procedures by means of piloted simulations and demonstration flight tests.

This paper reports on the work done and results obtained during the first project year. So far on-going activities concern the first step mentioned above, that is the development of a common simulation code named EUROPA (EUropean ROtorcraft Performance Analysis) able to predict helicopter performances in typical take-off and landing conditions.

For most of the partners the EUROPA software developed provides a new tool for the analysis of helicopter flight and the prediction of dynamic performance. This is also the first time that all of the European helicopter manufacturers and many of the European helicopter research organisations have shared a common performance prediction computer code. This by itself is considered to be a significant achievement.

The performance/safety methodology to be developed and demonstrated in the project has a **prenormative character**: it is expected that future airworthiness or air traffic regulations, advisory circulars and local heliport rules will refer to the methodology developed during this study to quantify and validate the take-off and landing performance of rotorcraft, either as a complement to, or a substitute for, earlier less accurate methods.

For the project partners, the creation of a common European helicopter performance prediction tool will improve their ability to work together on future rotorcraft programmes.

For the helicopter manufacturing industry a potential improvement in the take-off performance, without any additional production cost, should result in a decrease of operational cost margins. A more rigorous assessment of safety margins and safety enhancements, without performance penalties, should also give a significant marketing advantage to European manufacturers before the new methodology can be fully recognised and applied by overseas competitors.

For helicopter operators, increased profitability can be expected from improved payload performance and a more general public acceptance of helicopter operation.

Concerning Safety and Environmental Impact, the outcome of the project will contribute to the development of the public transport helicopter as a dependable and safe vehicle which can effectively complement the existing transportation infrastructure by providing an air link to any medium size city within a range of 150 km of a major airport.

The main benefit will be to ensure a high standard of safety, both for the passengers, and for people living in the vicinity of heliports.

8 ACKNOWLEDGEMENTS

The authors wish to thank the European Commission for the partial funding of the RESPECT project.

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