PAVE: A Prototype of a Helicopter Pilot Assistant System

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Abstract: A functional prototype (figure 1) of a pilot assistant system for helicopter operations has been developed within the scope of an internal DLR project entitled PAVE (pilot assistant in the vicinity of helipads) under the management of the DLR Institute of Flight Guidance. PAVE concentrates especially on safe takeoff and landing phases even in very difficult visual conditions. Besides today's standard procedures or emergency procedures in case of an engine failure the research is also being done for the definition of noise abatement procedures and – for future ATM applications – time based procedures.

INTRODUCTION

The main function of the helicopter assistant system is the capability to generate an optimal plan according to different constraints like setting waypoints, defining speed, altitude, and time of arrival constraints at waypoints. A 4D trajectory planner generates an accurate trajectory which is based on the helicopter performance data, helicopter state, actual weather, and helicopter flight envelope. The trajectory planning module simulates the entire flight along the discretely defined route according to the altitude and speed constraints directly set by just clicking on the moving map. A precisely calculated trajectory is a precondition for time based flight guidance and for conflict detection with terrain, obstacles, other aircraft and helicopter flight envelope limits. The flight intention and the core information for further assistant driven processes like operator communication, Air Traffic Control by data link, and flight progress monitoring are also reflected by the trajectory.

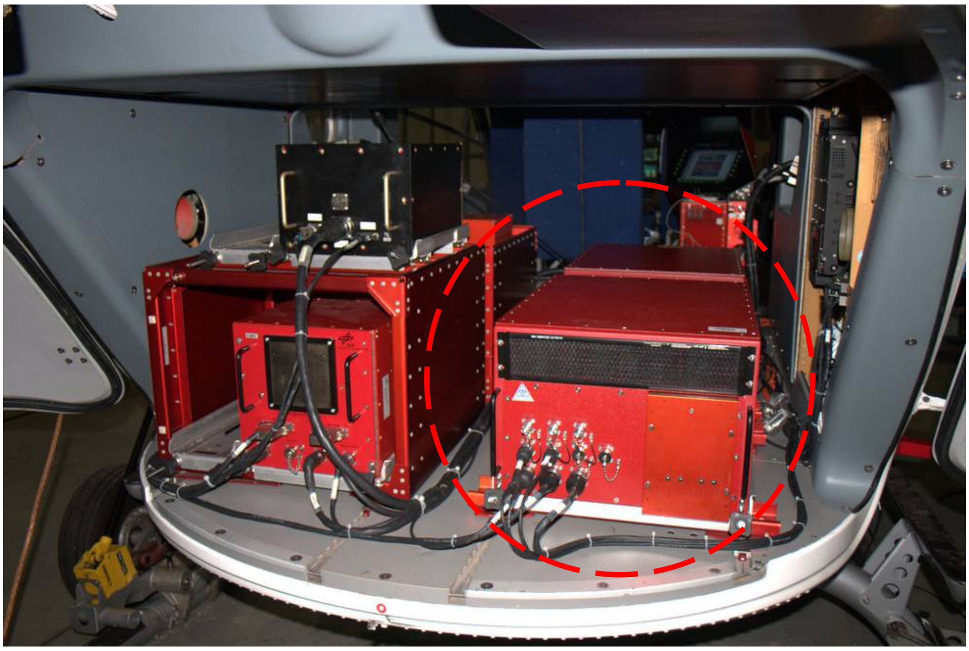

Figure 1: Prototype of a helicopter pilot assistant system

The focus of the pilot assistant is the assistance especially during approach and departure. The intention of the project is to improve situational awareness and offering human centred automation to one of the complex, work intensive and dangerous parts of helicopter missions.

The background is that helicopter landing sites are often located near buildings, close to terrain, or other obstacles. The pilot must orient himself on visual cues during approach and landing to conduct the flight safely. Bad visibility conditions makes it complicated to avoid collisions or even to fly and to land the helicopter. Helipads by their nature are situated close to populated noise sensitive places. On the other hand noise abatement procedures require a steeper approach exposing the helicopter closer to its flight envelope limits ([1],[2]). Additionally, emergency procedures in case of engine failure require very fast pilot decisions and actions. They are of vital interest especially during departure.

The Pilot Assistant PAVE addresses all these problems and takes into account the full complexity of the pilot work during these flight phases. Therefore it integrates single solutions of dedicated problems, using all available information onboard to improve safety and operability. In all weather conditions and 24 hours a day the pilot assistant system also covers assistance in situation assessment, flight planning, flight execution, and monitoring ([7]) during approach, departure and enroute. The technical approach is to develop, to integrate, and to test the research prototype and to evaluate it using ground simulations and flight trials. For future extensions the system architecture was kept open. Flight trials are carried out using the DLR research helicopter ACT/FHS EC 135 and the BO 105 for noise measurement trials. The goal of the project is to evaluate pilot assistance functionalities with respect to the objectives and to present possible solutions/results to the industry.

Within the first phase of PAVE (2003-2005) the system has been developed and integrated into the FHS (flying helicopter simulator, figure 1) and within a second phase (2006-2007) the system has been evaluated in real flight tests.

1. MISSION PREPARATION

With today’s conventional automation inside the cockpit, it is not easy to interact with the different stand alone systems. The resulting overall situation has to be combined in the head of the pilot. In dangerous situations, sometimes the interaction between human and machine is not quick enough and the quality of automation is not high enough. The PAVE system summarizes all information provided by different sensors to make clear the current situation.

The first step in mission preparation is to define the mission flight path by setting waypoints on a moving map. After a lateral description of the flight path each waypoint can be edited to define altitude and speed constraints. The pilot can also choose between predefined Standard Instrument Departures (SIDs) and/or Standard Arrival Procedures (STARs) according to Air Traffic Control constraints for a specific helipad or the pilot can select a flight path directly which he has defined before. The destination can also be defined by a WGS84-position. The system then works out an optimal plan according to these constraints and to predict the flight path accurately according to wind conditions. Conflict detection with terrain is made and the assistant recommends a solution in case of conflict ([3]). Optionally, the planning algorithm can take into account noise sensitive areas (figure 2) to minimize the disturbing influence of the noise emission of the helicopter in urban areas.

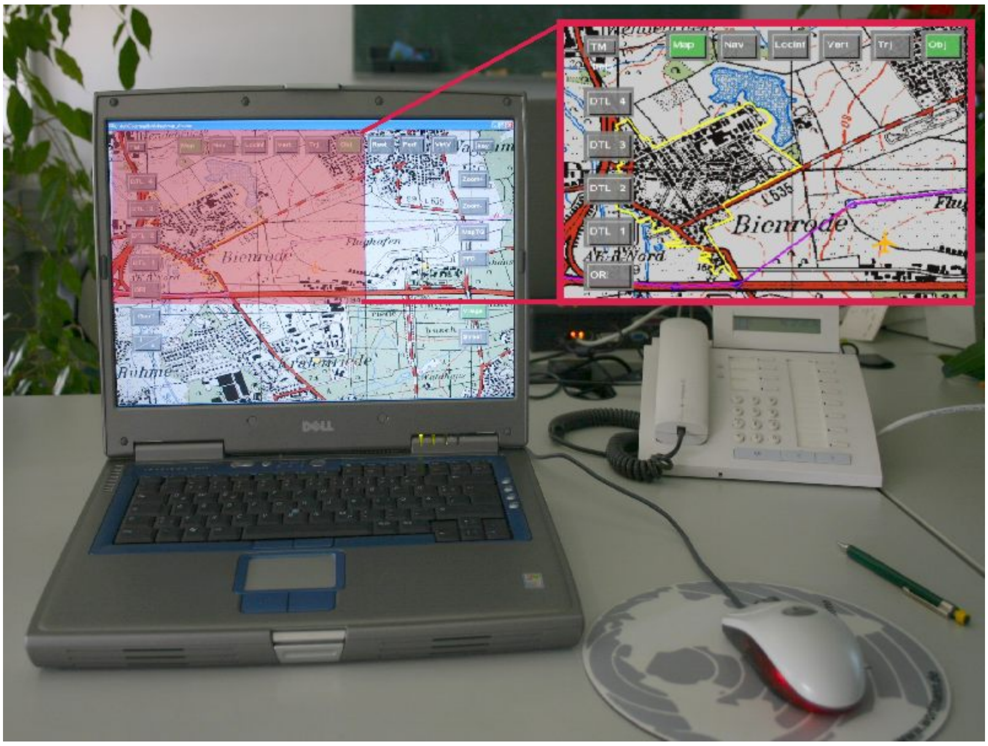

Figure 2: Flight Planning with consideration of Noise Sensitive Areas

The input environment of all mission parameters is not necessarily the helicopter and all data can be entered with the use of a laptop (figure 2) where the same version of the pilot assistant software is installed. The planned flight path can be transferred on a memory stick to the helicopter and can be reloaded into the system by the pilot.

The flight path data for the generation of noise abatement approach/departure procedures are derived from the evaluation of recorded noise data which are acquired on the basis of multiple approaches and departures with different descent rates, airspeeds and flight path angles. The idea behind noise abatement procedures is to fly the helicopter in those regimes of the flight envelope that produce less noise than others. A number of 43 microphones are arranged on the Cochstedt airport for the acoustic data recording process. These data are synchronized with the GPS-position of the helicopter. The calculated noise model shows the connection between flight condition and noise emission and permits the regulation of noise-optimized approach and departure procedures ([1],[2]).

After all necessary mission information are entered by the pilot, the trajectory generator calculates a flyable trajectory with consideration of the performance data of the helicopter and according to current wind conditions. The trajectory has a high level of detail and covers typical helicopter maneuvers, e.g. backwards flight, turns, etc. The flight intention is reflected by the trajectory and is the core information for further assistant driven processes like operator communication, Air Traffic Control by datalink, and flight progress monitoring.

The assistant is designed to limit the necessary inputs to a minimum. Another option under investigation is Direct Voice Input (DVI, [10]). All interface solutions have to be considered in the light of the challenging environment of the helicopter cockpit which can be noisy and have vibration and restricted space for additional devices and large size screens.

2. IMPROVEMENT OF SITUATION AWARENESS

The pilot's situational awareness onboard the helicopter can be increased by displaying aerial photos and a virtual landscape in conjunction with the planned trajectory. A detailed visual impression of the geographical environment also supports the mission planning process, and gives for example a first impression of unknown helipads. This increases the confidence in proper planning because planning mistakes are obviously visible. Inside the project PAVE two main aspects will be addressed: Providing a cockpit view along the planned trajectory and drawing the planned trajectory into the virtual landscape.

Figure 3: HRSC-AX camera

The data for the visualization were generated by a High Resolution Stereo Camera – Airborne (HRSC-A, figure 3) developed by the DLR institute of planetary exploration. This camera is a further developed airborne version of the HRSC, which was designed for the exploration of planet Mars by the international space mission MARS96 and one HRSC-A is currently flown on the European Mars Express mission. In combination with the photogram metric processing system, HRSC-A provides image and 3D-data products with relative accuracies of about 10-15 cm and absolute accuracies of about 20-25 cm from a flight altitude of 3000m [[8],[9]].

In order to guarantee reliability regarding to the accuracy of the data, it is necessary to know the exact orientation of the sensor. For this purpose a GPS-receiver as well as a measuring sensor for the determination of the orientation of the camera are connected with the HRSC-AX, so that the proper motion of the aircraft can be reconstructed during the photographs and can be recorded to each picture simultaneously.

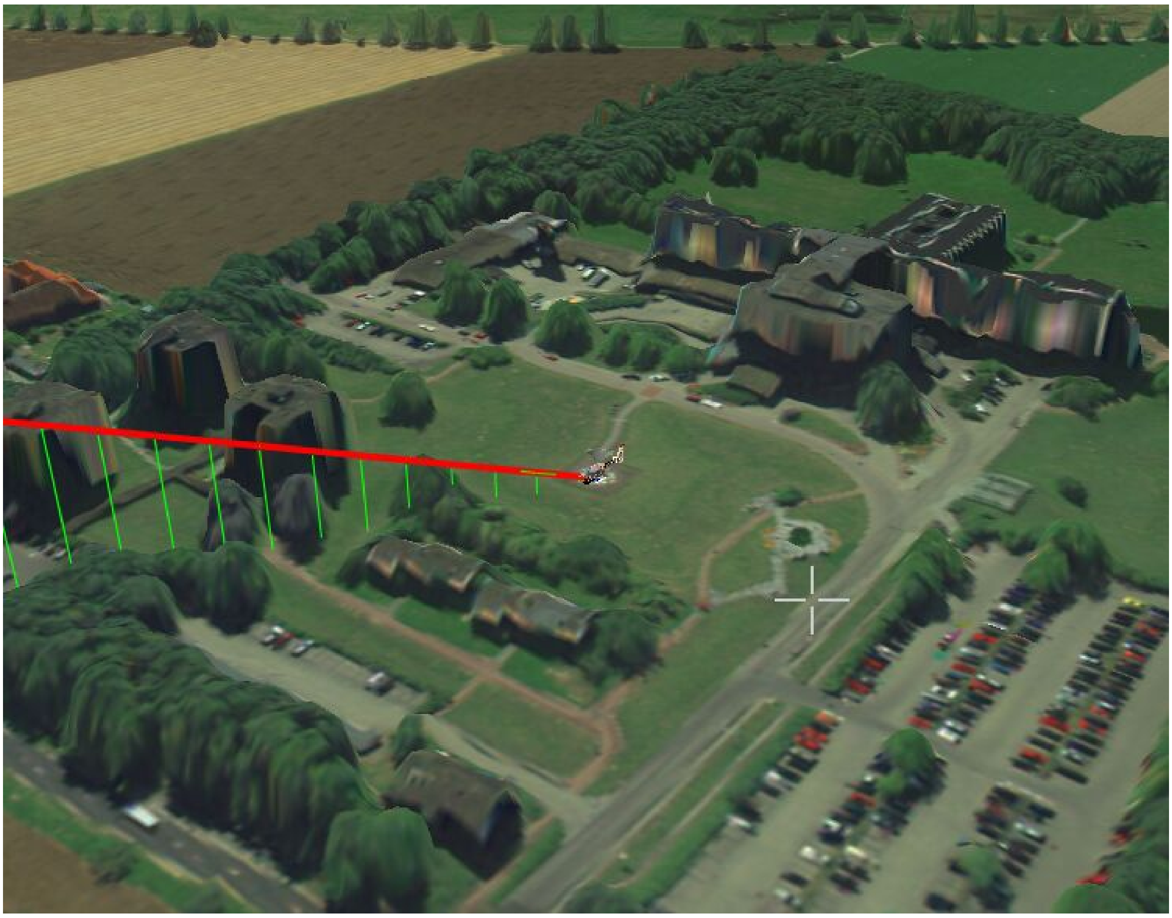

Figure 4: Example of a HRSC-Image with an embedded departure route

The high resolution HRSC-A data have been flown within a flight campaign for the project PAVE. The overflights aim an acquisition of highly accurate terrain data and aerial photos in the proximity of 5 helipads around Braunschweig. This is the region intended for flight tests in 2006.

Figure 4 shows an example of the virtual landscape superimposed with the planned departure path. Zooming, moving, and rotating functions of a virtual camera with the helicopter as the center point give the flexibility to get an idea of the current situation. The side walls of the buildings do not correspond to nature appearance. This fact explains itself by the use of the available data, because the virtual landscape is realized by a combination of the elevation data and the corresponding orthographic photos as textures. No information about the condition of the side walls exists. Nevertheless it helps the pilot to orient in the vicinity of the helipad.

3. FLIGHT EXECUTION

In 2006 and 2007 the pilot assistant system was tested in the scope of some flight test campaigns under real flight conditions and continuously improved by pilot comments and test data evaluation. The assistant guides the helicopter along a preplanned trajectory by switching autopilot modes. The Institute of Flight Systems is developing a model following control system with full authority for the FHS. The assistant enables an autonomous flight mode and provides adaptive flight control laws to improve handling qualities in degraded visual conditions for the manual flight mode. The FHS system also consists of a ground based system simulator. The simulation reproduces the flight characteristics of the EC 135, and the simulator experimental hardware is made as an exact copy of the FHS flying hardware. This ground simulator is the test platform for the intensive analysis of the complete functional range of the pilot assistant before going into real flight tests.

In order to compute the guidance parameters both for the automatic and for the manual flight mode, a comparison must sequentially be done between the current variables of state of the helicopter (position, orientation, speed, …) and the planned trajectory. The pilot assistant receives new variables of state at 30 Hz which are transmitted over a UDP connection. These parameters are written into the shared memory by the communication module. The guidance module reads the data out of the shared memory and calculates the guidance parameters on the basis of the new data. The result is sent back to both the primary flight display for the guidance in manual flight mode and the autopilot for the automatic flight guidance. Due to safety aspects, the pilot can change at any time from automatic mode into the manual flight mode by direct intervention of his flight stick.

Via a data interface between the experimental system and the PAVE hardware the important sensor data in combination with the calculated flight guidance parameters are recorded. This allows to produce significant quickplots during or shortly after the flight tests. Theses plots are then the basis for improving and tuning the installed algorithms.

A telemetry, data and speech downlink from FHS to the ground station is existing to allow supervising by quick look essential sensor signals during the flight tests. By this also structural loads can be monitored, in case of critical excitation the crew can be informed via the VHS radio link. An adaptation of this ground based software was performed to give both the airborne crew and the ground crew extended monitoring options. The sensor signals received by telemetry are transferred by a network connection to a laptop, also running the PAVE software. By also transferring the mouse position and the mouse switch operations of the flight test engineer, an image of the activities on-board can be generated.

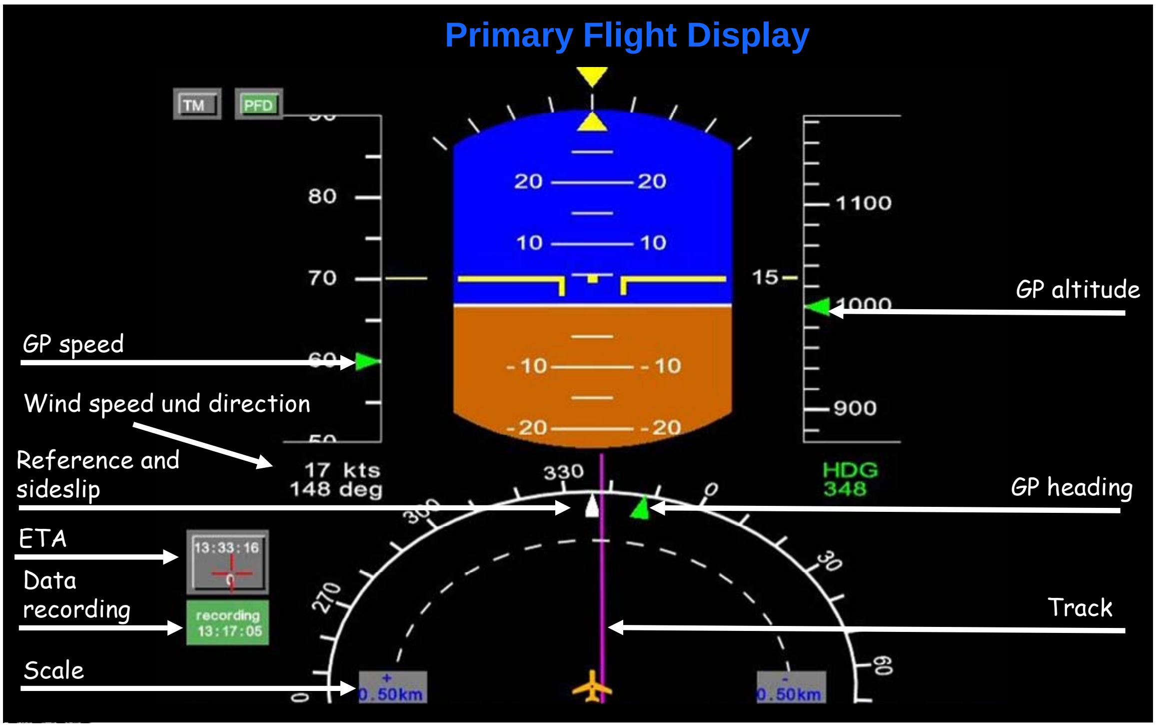

Figure 5: Primary Flight Display (PFD) extended by green triangles for the display of guidance parameters, e.g. speed (left), heading (down) and altitude (right).

In co-operation with experienced helicopter pilots the display of the standard primary flight display was extended and optimized with flight director functions to present the necessary guidance parameters for following along the planned trajectory. Three “so-called” bugs (green triangles) for speed-demand (left, figure 5), height-demand (right) and heading-demand (bottom) in combination with the pre selected trajectory are displayed to the pilots. In manual flight mode the pilot has to follow these values constantly to remain on the flight path. Deviations regarding speed, altitude, or heading are fast recognized by him if the green triangles move out of the range of the current variables of state. The actual wind is determined by the different on-board sensors, integrated into the calculation of the trajectory and displayed in terms of magnitude and direction.

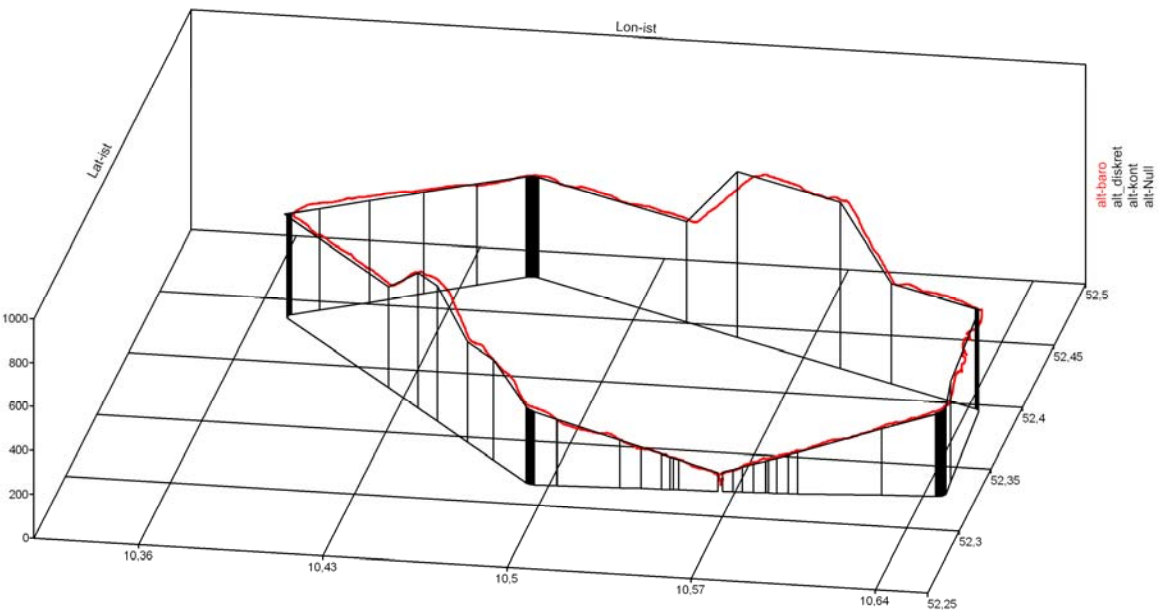

Figure 6: Comparison between preplanned trajectory and manually flown path (3D)

A flight path in terms of an aerodrome circuit has been defined for the flight test campaign to analyse both the flight path performance and the flight technical error especially for horizontal turns. Figure 6 shows a 3D diagram of both recorded tracks: the planned trajectory and the actual flight path. The horizontal deviations depend on the speed, the radius of the horizontal turn, the wind conditions and the kind of realisation of the guidance algorithm. The principle of the flight guidance goes as follows: A so-called prediction length factor (PLF, [11]) multiplied by the current speed of the helicopter defines the length of a heading vector. From the current position of the helicopter the algorithm then finds a new position on the trajectory which is as far distant as the length of the heading vector computed before. The angle between this heading vector and geographic north is the new guidance parameter according to the heading. Under disregard of wind influences the helicopter should normally follow the trajectory if it flew into this direction. Horizontal turns represent a special role: If the value of the PLF is too small, the real flight path of the helicopter overshoots the planned trajectory. Otherwise, if the value is too high, the real flight path cuts the curve. Figure 7 shows the comparison between the variables of state and the guidance parameters. After the system is in steady state, only very short delay times can be observed between the computation of the reference and the actual value. Especially for horizontal turns it is still investigated how to optimize this method under consideration of the latency time of the flight controller in order to get a smaller flight technical error.

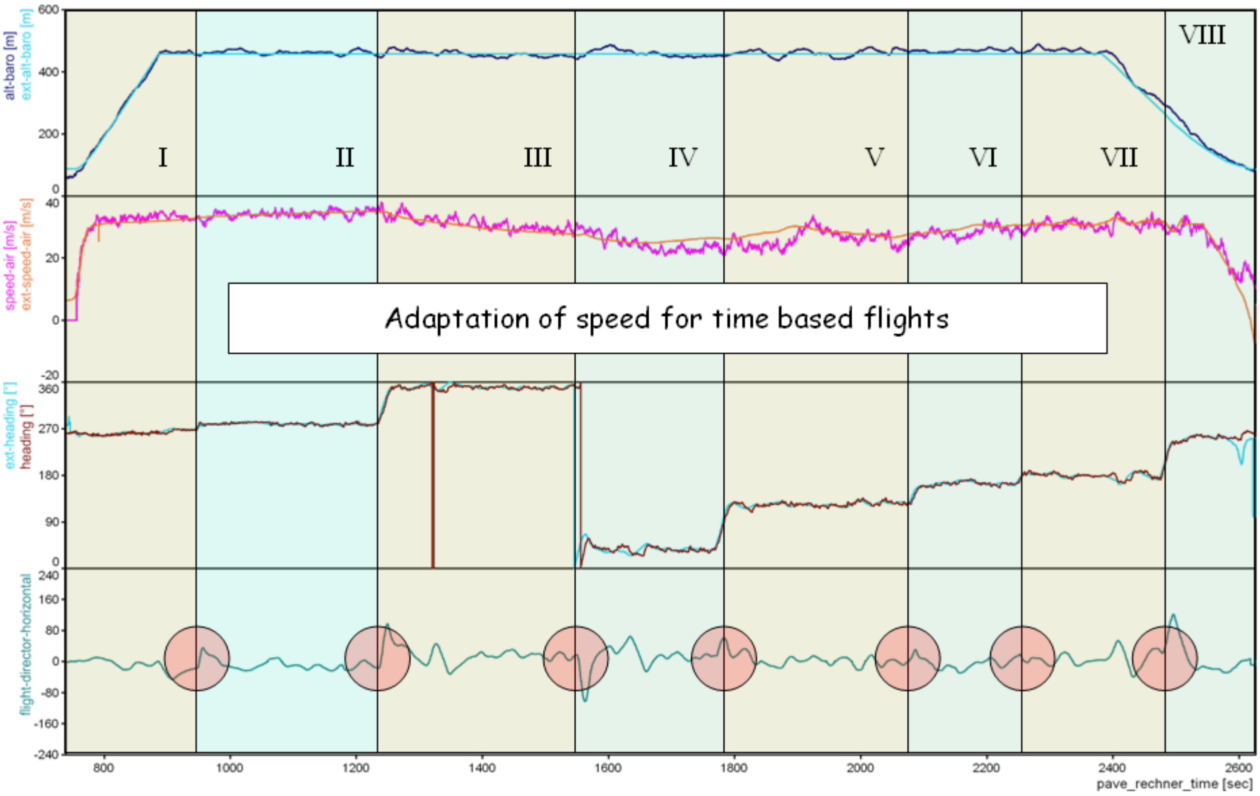

Figure 7: Comparison between variables of state and guidance parameters (altitude, speed, heading, lateral deviation to preplanned flight path) subdivided into different flight phases (after each phase a curve is following)

In addition to the computation of the heading-demand, the guidance module computes also the guidance parameters regarding altitude and speed (see the first and second row in figure 7). For time-based flights the speed-demand value is adapted continuously if the speed of the helicopter is too slow or too fast during the flight. The last row in figure 7 shows the distance in meter between the real position of the helicopter and the trajectory. Particularly with regard to horizontal turns the lateral deviations end up with values of about ± 100m. In level flight lateral deviations of about ± 25m could be achieved with the existing system. Concerning the altitude the pilot was able to follow the altitude-demand with deviations of about ± 10m.

4. SUMMARY AND OUTLOOK

PAVE is a project for the development of a prototype of a helicopter pilot assistant system in which numerous experts in different areas are involved. The pallet extends from flight control, acoustics, aerial photograph processing, and human factors up to data processing and structure of hardware and integration. 4 institutes of the DLR and the French research establishment ONERA are involved in this project. A substantial part of the development and pre-working was accomplished. Some flight tests take place in 2006 and 2007 on the FHS in the environment of Braunschweig. The validation of the automatic flight guidance with the use of noise abatement procedures is one of the objectives in the context of the flight campaign.

In the European Union project OPTIMAL, the helicopter pilot assistant will also be used to accomplish time-exact approaches and will be extended functionally in this year. One of the objectives in OPTIMAL is an investigation how helicopters can be merged into the airport traffic management in the future.

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