REAL TIME SIMULATION OF INTEGRATION OF UAV'S INTO AIRSPACE

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Abstract

Real time simulations for the integration of UAVs into non-segregrated airspace were carried out using DLR's air traffic simulator with air traffic controllers and UAV pilots. The workload for the controllers increased slightly in the beginning, however, it could be demonstrated, that UAVs can be integraded into airspace easily if they operate according the rules for manned aircraft.

1 Introduction

Unmanned Aerial Vehicles (UAVs) gain increasing attention in aeronautics, especially as also civil applications open up for their use. From the view of the design of unmanned aircraft, most problems can be solved as technology does not differ much from that of existing aircraft. However, the integration of UAVs into non-segregated airspace is a remaining important issue which has to be solved soon with highest priority. One tool to validate concepts for integration of UAVs into airspace are real time simulations.

2 Experimental Set-Up

2.1 The Need for Real-Time ATM Simulations

The reality itself will prove the usability and efficiency of new developments, new components or adapted traffic management procedures. However, because of the complexity of the air traffic system and its fragility when operated within small margins at the limit of its capacity, real life experiments or the non-validated implementation of any could have a crucial impact to the whole operating system with corresponding financial consequences and repercussions to airline operations, passenger comfort and customer satisfaction. Also safety reasons have to be kept in mind before such experiments could be carried out at a real airport. Therefore a general motivation for using real time Air Traffic Management / Air Traffic Control (ATM/ATC) simulation is the development and validation of new ideas and concepts in a virtual but realistic environment [1].

Depending on the specific topic, the use of real time simulation is normally embedded as one tool within a larger development and validation process. Often it is the second step, preceded by fast time simulation runs with many statistical variations covering topographical and topological aspects of the proposed modification to the existing system under investigation. By integrating the human operator into the development and validation process, real time performance and an adequate testing environment is necessary. The working environment of the human operator has to be modeled in a sufficiently realistic way to permit the transfer of simulation results to reality.

The spectrum of use for real time ATM simulation includes

- the use as a testbed during development of new ATM-Management systems or air traffic controller tools,
- in-flight simulation of new data links and flight management systems,

- testing of new procedures for ground traffic or approach and departure,
- the investigation of the influences of new airport infrastructure to the handling of air traffic,
- the demonstration of new tools in a realistic environment,
- human factors research for development and optimization of human machine interfaces (HMI) for air traffic controllers
- capacity testing of new or modified airports, and
- training of air traffic controllers on new systems, procedures, airport infrastructure or basic training of new controllers.

Especially when introducing completely new aircraft systems like UAVs into the system, a carefull modelling and simulation of the impacts is necessary. Within this paper the use of DLR's Air Traffic Management and Operations Simulator (ATMOS) for the simulation of UAV scenarios will be discussed.

2.2 Air Traffic Management and Operations Simulator (ATMOS)

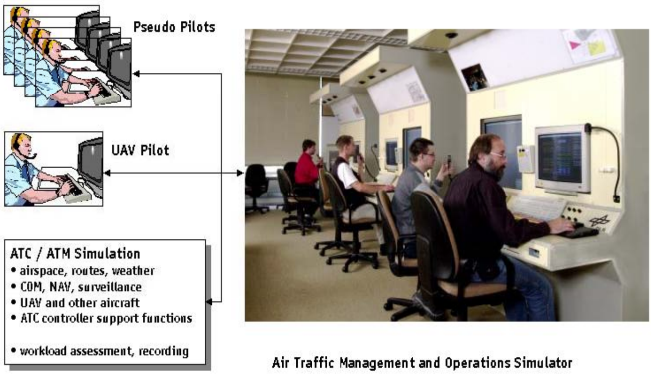

Fig. 1. Air Traffic Management and Operations Simulator. The simulation set-up includes pseudo pilots as well as an UAV ground station with an UAV pilot.

Fig. 1 shows the set-up of the simulation trials with the especially configured DLR Air Traffic Management and Operations Simulator. It represents an ATC radar simulator which allows to simulate the basic working environment of an 'air traffic control officer' (ATCO) whose task is to control the air traffic by means of radar situation displays, electronic flight strips (to visualize flight plan information), radio voice communication with aircraft, and telephone communication with neighboring control sectors or other ATC control centers. The simulated traffic in these two sectors is piloted by so-called pseudo pilots, who are navigating the aircraft according to predefined individual flight plans as well as to advisories or clearances given by ATC controllers in the respective sectors. To this system an UAV ground control station is added including a simulated data-link [2].

3 Concept and Validation

3.1 Integration Concept

A concept for the integration of UAVs into civil airspace was developed. This is shown in Fig. 2. The unmanned vehicle is guided from a control station at the ground in which the UAV pilot is giving his advisories and constraints for the flight plan. It is to be noted that the UAV is operating autonomously on base of its flight control and flight management system and is not flying with the pilot in the loop for the flight controls. The integration in ATC/ATM is done via radio communication of the UAV pilot with ATC. For this, the UAV acts as transmission relay. Hence in this concept, the ATC does not observe any difference between an unmanned or manned aircraft.

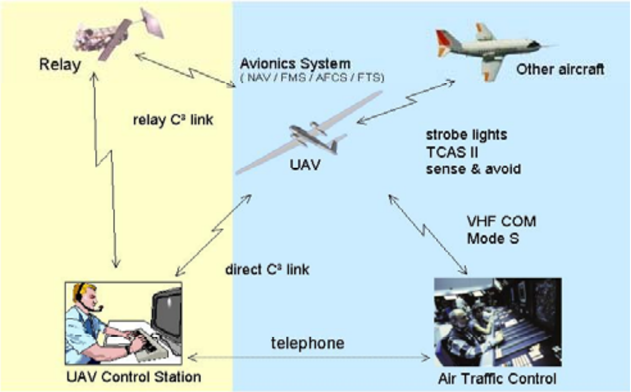

Fig. 2. Concept for integration of an UAV system in ATC/ATM

3.2 Simulation

For the simulation discussed in the following, the simulated airspace is the TMA Frankfurt controlled by Frankfurt Arrival and the western sector controlled by Langen Radar. Controller working positions of the ATC center (Frankfurt Arrival and Langen Radar) are provided by the employed ATMOS. The simulated traffic in these two sectors is piloted by the pseudo pilots. The traffic in the northern and southern sector is navigating fully autonomously, i.e. it is so called dummy traffic (Fig. 3).

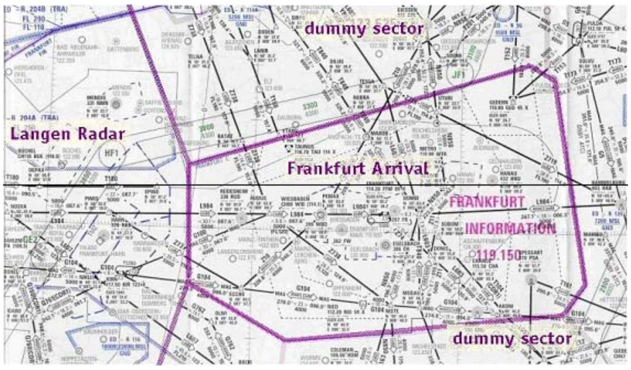

Fig. 3. Simulated airspace (modified TMA Frankfurt).

The simulated traffic comprises a mix of arrival and departure traffic of Frankfurt airport (EDDF) as well as some overflights. It consists mainly of a mixture of typical jet transport aircraft. One or two MALE UAVs are included in the simulation scenarios, which are assumed to be operated from Frankfurt-Hahn airport (EDFH) in the western sector. Runways in use at Frankfurt airport are RWY 25R and RWU 25L. Simulated arrival traffic appears on the radar screen a few miles inbound of the Metering Fixes GED (Gedern), PSA (Spessart), EPINO and ETARU. Arrival traffic via EPINO is also simulated in the west sector, controlled by Langen Radar. These aircraft appear a few miles inbound ARCKY or LUXIE. Simulated departure traffic is dummy traffic. These aircraft follow predefined departure routes from Frankfurt RWY 18. Overflight traffic is predominantly simulated in the western sector controlled by Langen Radar.

Apart from the background traffic there is included a simulated UAV. This UAV will flies a route as described in the scenario descriptions. A single turboprop engine MALE type UAV was chosen as representative for the purpose of these simulations for several reasons:

1. A surveillance mission in European continental airspace is a typical example of a future civil UAV mission. Such a mission will most probably be performed by fixed wing MALE type UAVs, which are operated from a regional airport.

2. MALE UAVs will operate in all classes of airspace to perform the surveillance mission, i.e. it is reasonable to assume that they will mainly fly in controlled airspace and that they also cross a busy TMA if their mission task requires it.

3. A single engine turboprop MALE UAV is cheaper to operate than a twin engine turboprop. The probability of total loss of thrust is higher than with a twin engine. Total loss of thrust is one emergency case to be investigated in the simulations.

The UAV is controlled by a pilot working in a UAV control station via direct (within LOS) or relay (beyond LOS) C^3 link. The UAV control station is emulated by a pseudo pilot working position of the ATC/ATM simulator. Control commands are fed into the autopilot or Flight Management System of the UAV. Two way voice communication between UAV pilot and ATC is realised by a voice link without delay or with a communication delay typical for a satellite relay link. A telephone link is available between UAV pseudo working position and ATC controller in case of contingency. ACAS or sense and avoid functionality is not included in this simulation experiment.

To weeks of simulations were carried out with air traffic controllers from Eurocontrol, form Germany and France. Different trails with one or two medium Altitude Long Endurance (MALE) UAVs flying in the Frankfurt airport area have been carried out. The scenarios included emergency procedures including emergency landing in Frankfurt. The UAV-pilot to ATCO interactions have been investigated by Instantaneous Self Assessment questionnaires as well as by NASA Task Load Index methodology.

4 Experimental Results

The simulation environment was working quite well. After adequate training of controllers during the warm-up runs the controllers felt that the simulation set-up represented quite well a real working environment of ATC controllers. Hence there is evidence that the obtained results are representative for a real ATC/ATM environment.

The trials started with the baseline of the normal traffic. Later on, 2 UAVs have been added into the airspace. It could be shown, that the workload increased, which was due to the "new" behavior of the type of aircraft. Fig. 4 shows an example of the results of NASA TLX workload determination of the controllers for those different trials [3].

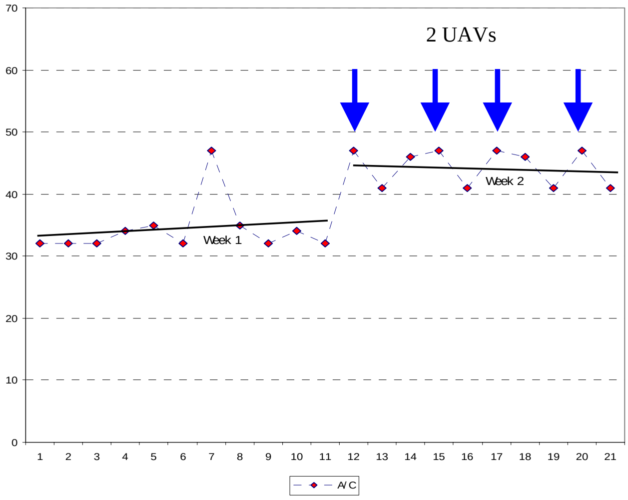

Fig. 4. NASA TLX workload vs. trials without (left) and with UAVs (rigth) included in airspace

One integration concept proposes to apply the standard emergency codes 7600 (communication loss) and 7700 (emergency situation) as for manned aircraft, but to introduce additional extended emergency codes for the case of data link loss to give additional information on the further intent of the UAV, i.e:

7660 for data link loss, proceed as planned, 7661 for data link loss, return home, 7663 for data link loss, fly to emergency field

- After having simulation runs with the extended emergency codes the controllers came to the conclusion that the standard codes 7600 and 7700 are appropriate also for UAVs. The extended codes are a nice idea, but it would implicate that they need to be implemented world-wide thus requiring additional effort for implementation and training of controllers. The simulation runs showed that a UAV emergency can be handled as easy as an emergency of a manned aircraft.
- 7700 shall be used only in emergency cases where the behavior of the UAV is not predictable at all and an immediate change of flight path i.e. to an emergency landing field is necessary.
- 7600 for communication loss shall be used as long as the behavior of the UAV is predictable.
- It is not necessary to distinguish between the classical communication failure in which there is no more radio telephony possible between aircraft and ATC and a failure of the datalink of the command & control link from the UAV control station to the UAV. As long as the UAV on-board system pro-vides a predictable flight path (i.e. proceed as planned, return home, fly to alternate) the code 7600 is appropriate.

A benefit would be to have a telephone available at the UAV control station and the phone number included in the ICAO flight plan. The telephone line may be used by the supervisor controller to ask the UAV pilot for fur-ther in-formation on the UAV flight intentions, especially in case of communication or data link loss. This possibility is even a benefit of a UAV compared to a manned aircraft.

Some problems which occurred in the airspace of TMA Frankfurt were only due to the slow cruise speed (110 KIAS) of the simulated MALE configuration compared to normal jet transport aircraft approaching Frankfurt. These problems are not typical for a UAV but would show up also with any other slow flying propeller aircraft.

There was also the time delay which may occur via a satellite communication link simulated, for each direction 1.5 s. Consequently, the controllers experienced a total time delay of 3 s. This delay was not considered to cause any problems.

4 Discussion

A major objective of the integration concept for UAVs in ATC/ATM was to show that UAVs can be treated like manned aircraft. It was proven that standard procedures for manned aircraft were also applicable to a UAV. No specific problems with a UAV in controlled airspace were observed.

However, one major topic for the integration of UAVs is to solve the problems on See & Avoid. An idea could be to introduce the concept of Sense & Avoid, which does not fully copy the human behavior of viewing. It incorporates other means by use of different sensor types including non-cooperative and cooperative ones like ADS-B.

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