Integrating Unmanned Aircraft Systems

D.-R. SCHMITT, H. H. HESSELINK AND F. MORLANG OF AT-ONE* BRAUNSCHWEIG AND AMSTERDAM OUTLINE THE RESULTS OF TWO SIMULATIONS, WHICH SHOW THAT WITH SOME MINOR ADAPTATIONS, EMERGENCY PROCEDURES AND BACK-UP COMMUNICATIONS, UAS CAN BE SAFELY INSERTED INTO NORMAL DENSITY AIR TRAFFIC.

Unmanned aircraft systems (UAS) are presently deployed in segregated airspace; passage through controlled airspace is taking place only via segregated corridors. With the increased use and the growing size of unmanned aircraft (UA), the need for insertion in non-segregated airspace has increased, with first steps being taken in environments with air traffic control services in normal density traffic situations (en-route and not too busy terminal control areas (TMA)). Already, civil UAS are flying in segregated airspace to carry out maritime surveillance missions and their insertion in air traffic control (ATC) is soon to increase their operational scope.

The European Commission (EC), European Space Agency (ESA), and the European Defence Agency (EDA) established a European Framework Cooperation (EFC) in which UAS air traffic insertion was identified as a major topic to be addressed. We will describe the results of two experiments with real-time, man-in-the-loop air traffic control simulations to support UAS air traffic insertion.

1. INTRODUCTION

Several studies have investigated UAS air traffic insertion, mostly addressing detect and avoid, safety of the operations (related to the aircraft, other airspace users, and population on the ground), architectures for data link communication, and definition of standards for certification. However, little effort is currently dedicated to performing actual flight trials and preparatory simulations for actually achieving the ultimate goal: air traffic insertion.

The major work so far in air traffic insertion is the European Civil UAV Roadmap defined by the EC-funded UAVNet consortium [1]. A further roadmap was defined by a consortium called Air4All [2]. The document defines six consecutive steps until full integration is achieved in step 6, where civil-type certified UAS fly instrument flight rules and visual flight rules across national borders routinely in controlled and uncontrolled airspace (airspace classes A, B, C, D, E, F, and G). Based on the results from Air4All, a consortium of research centres (E4U), [7] set up a detailed business case for the prioritisation of actions for insertion of UAS in air traffic.

In this article we present the set up and results of simulations for UAS in order to prepare for full flights in the near future. Actual flights cannot be carried out before the full set of routine and emergency procedures is evaluated in a simulated environment [6].

In order to evaluate and validate routes, procedures, and emergency situations, we set up simulations in a real-time man-in-the-loop ATC environment, including UAS, which were piloted from a realistic remote pilot station (RPS). In two

A HERON UAS BEING PREPARED FOR LAUNCH (PHOTO BY SEBASTIAN WILKE/BUNDESWEHR)

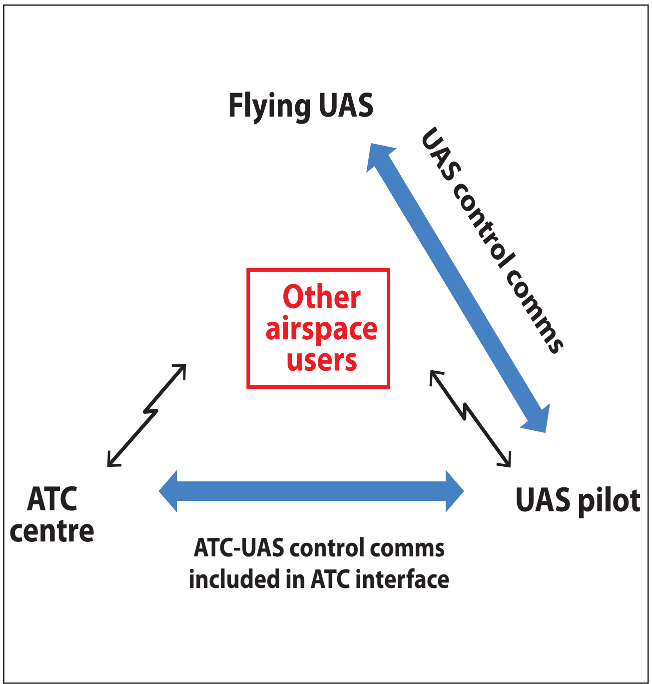


FIGURE 2: FUNCTIONAL SET UP

projects; USICO (UAV Safety Issues for Civil Operations), in 2004 and SINUE (Satellites enabling the integration in non-segregated airspace of UAS in Europe); simulations were organised where real air traffic controllers participated in experiments for the introduction of UAS in non-segregated airspace.

For the USICO project, a dense traffic sample of the Frankfurt flight information region was chosen. For SINUE, we set up a radar simulation facility, which was configured for running the scenarios round the Canary Islands in Spain. For this, the Spanish airspace was set up and a representative traffic sample with flights from and to Gran Canaria was implemented.

2. RESEARCH QUESTION

To bring air traffic insertion of UAS further, we started with simulating the environments in which the aircraft will fly. It is possible to set up the necessary architecture in a network of simulators for the air traffic control station, the unmanned aircraft and a communication link. In a real-time simulation environment, air traffic controllers will be able to experience, without risk, the aircraft in operation in their sector, the aircraft's characteristics, the use of emergency routes and procedures, communication with a remote pilot, and interaction with other traffic. Our research question was to:

1. Identify a suitable architecture for beyond line of sight (BLOS) operations with UAS.
2. Examine the effects on ATC of UAS in their airspace.

3. THE ARCHITECTURE SET-UP

In most scenarios, the aircraft will fly en-route their missions in a remote area, and will therefore be flying BLOS. Communication between the pilot and the aircraft will have to take place through satellite communication. Communication between the ATC centre and the RPS will be relayed over satellite. Therefore, the architecture proposed must at least enable the command and control (C2) link between the UAS pilot and the UA, and the ATC link between the UAS pilot and the ATC centre. You can see the functional decomposition in figure 2.

In the simulation experiment, the architecture as depicted in figure 3 was chosen. In the centre of figure 3, the UA is flying a mission in controlled airspace. The UAS pilot has no line of sight with the aircraft, so command and control will be relayed over satellite. This already is a standard operating procedure for UAS that fly BLOS operations.

Specific attention has been paid to VHF R/T communication between ATC and the UAS pilot. In our set up, the aircraft will receive all R/T on the frequency and relays this signal on a dedicated channel to the satellite. This set up requires significant bandwidth and operating costs, but our calculations do show that bandwidth does not form a limitation here. A back up for R/T communication is available through a standard telephone line.

A pseudo-pilot had to control the other traffic in the simulation. In a typical simulation, depending on the intensity of the required actions, pseudo-pilots are capable of dealing with 10 to 20 aircraft at the same time.

4. EMERGENCY SITUATIONS/PROCEDURES

The mission of the European Aviation Safety Agency (EASA) is to promote and maintain the highest common standards of safety and environmental protection for civil aviation in Europe and worldwide. EASA performed a study for an impact analysis on safety of communication for unmanned aircraft systems [5].

From this study, through a functional hazard analysis, the following list of relevant emergency situations needs to be covered during experimental simulations and flights:

- Loss of voice communications between UAV/S pilot and ATC
- Interruptions to voice communications between UAV pilot and ATC
- Intelligibility and latency of voice communications between UAV pilot and ATC
- Loss of command and control link between UAV and GCS
- Interruption of command and control link between UAV and ATC (due to system reliability or satellite communications coverage)
- Loss of surveillance information feed to ATC
- Interruption of surveillance information feed to ATC (due to system reliability or radar coverage)
- Loss of surveillance information to other airspace users
- Interruption of surveillance information to other airspace users (due to system reliability or coverage).

With the exception of the "loss of surveillance information," all events were considered in the experiments to cover all emergency situations emerging from the use of UAS. As the C2 and ATC signals are relayed through different channels on board the aircraft, the "loss of" emergency situations can occur for either one of them or for both simultaneously. For

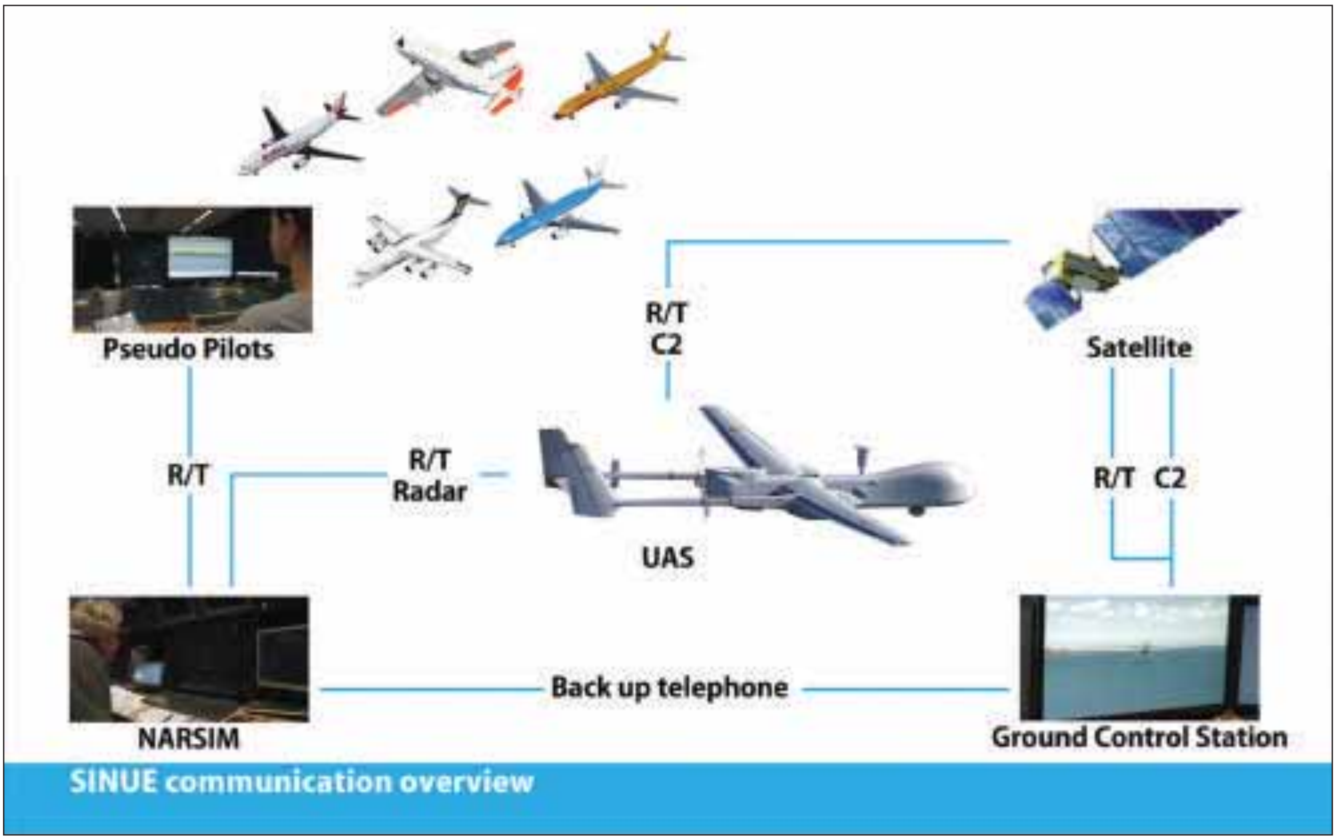


FIGURE 3: SINUE COMMUNICATION OVERVIEW

the design of emergency procedures, three aspects need to be considered: a home area; an emergency route, cleared from the other airspace routes; and a procedure to fly from the current location (where the emergency occurs) to the emergency route.

4.1. HOME AREA

The home area is a base where the UA will fly to when an emergency occurs. The aircraft will land there or perform a manoeuvre, which will destroy the aircraft without risk of casualties. For each flight and for each experiment, the home area needs to be defined, depending on the local situation. For the two experiments mentioned in this paper; USICO [4] and SINUE [3]; two distinct procedures were defined.

In the SINUE set up, a home area above sea was defined, where the aircraft would fly a circular pattern and be climbing in order to try and re-establish communication with a land-based station that was within the line of sight. In USICO, an emergency airport was identified.

4.2. EMERGENCY ROUTE

An emergency route must be designed that is fully separated from other air traffic routes so that the UA can follow a path separated from all other traffic. For every flight with a UAS, the route must be carefully evaluated in order to check whether it is easily and safely reachable from the mission area. In the Spanish experiments, one route was sufficient for all experiments performed. It was designed in cooperation with air traffic controllers and several entry points were defined towards which the aircraft would fly in case of an emergency. The points were chosen so that the aircraft would never fly over inhabited areas in case of an emergency and was vertically separated from other crossing air routes.

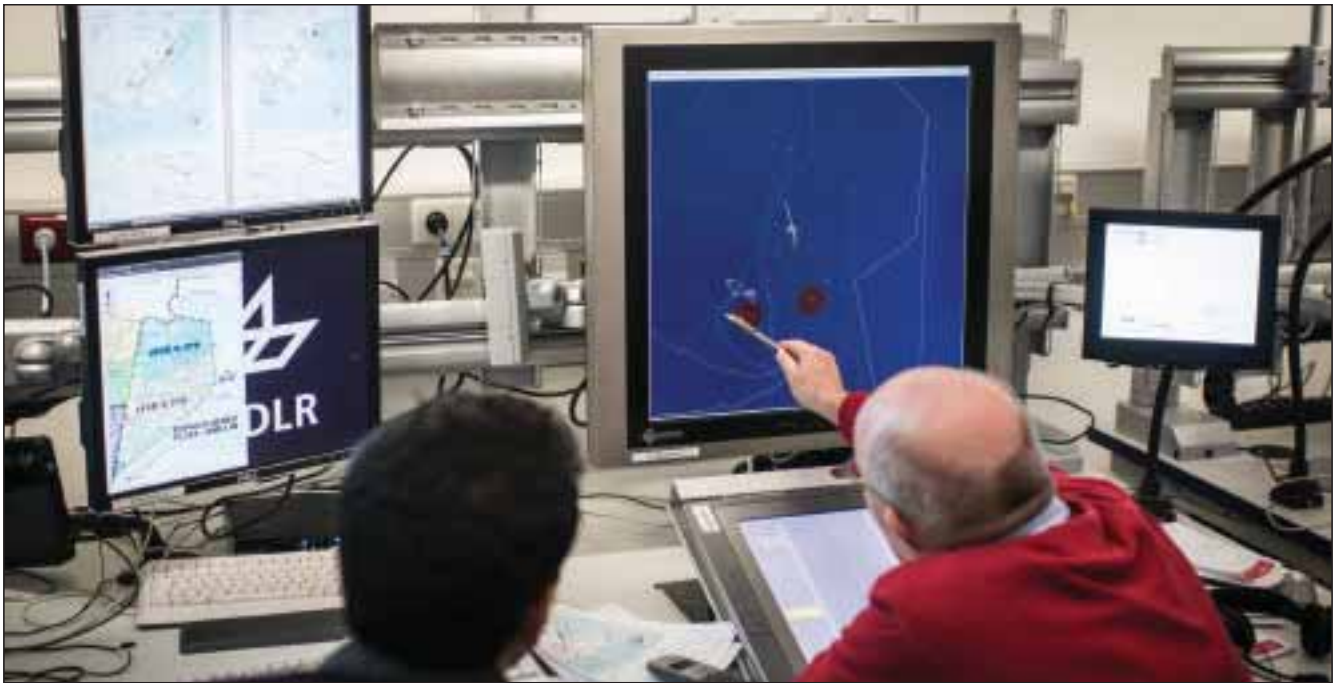
One special situation is when the aircraft is on final approach. In this case, the UA would fly the standard missed approach procedure to avoid it flying through other aircraft on approach.

For USICO, 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 centre (Frankfurt Arrival and Langen Radar) are provided by the employed Air Traffic Management and Operations Simulator.

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; it is so-called dummy traffic. For emergencies, the airport of Hahn was planned as an alternative.

4.3. TOWARDS THE EMERGENCY ROUTE

To reach the emergency route, the UAS follows a standard procedure, which is known to the controller and the remote pilot. The procedure chosen in the SINUE study follows the procedure that has to be followed by other aircraft as well. The UA will abort its flight path by turning towards the closest way point on the emergency route and maintain its current altitude for two minutes. After the two minutes the aircraft would climb or descend towards the altitude of the closest way point on the emergency route.



An Air Traffic Controller at his working position controlling an RPAS/UAV

5. EXPERIMENTS

In the simulations we carried out experiments in air traffic control simulation facilities where real air traffic controllers participated and evaluated the proposed concept and procedures. We used an air traffic control simulator, which resembles the airspace where the aircraft is flying as much as possible. An experienced air traffic controller and pseudo-pilots ran the experiments. They were briefed at the beginning of the day and were given the possibility for training.

A direct list of questions was handled through questionnaires distributed directly after each run and at the end of the simulation day. At the end of the day, a discussion session was also held with all participants of the simulations.

6. RESULTS

The goal of the two studies was to examine the effects on ATC of UAS in their airspace. From the simulations, questionnaires and debriefings, we obtained results for the sessions that were held.

Separation and collision avoidance: In the simulations, we did not use different separation criteria than those currently in use. The aim was to see if current separation can be maintained, even though there is no pilot on board the aircraft. We instructed controllers to use current separation criteria for the UAS, which they were able to maintain. In initial practical trials with real aircraft, for safety, the separation between a UA and a piloted aircraft will be increased in actual air traffic insertion experiments. The exact separation will need to be decided by the regulatory authority.

Communication: Communication delay because of the satellite connection will not be an issue when high-quality bands are used. For SINUE we chose to perform the mission round the Canary Islands where coverage of the Hispasat satellite system is assured. The satellite gives a delay in voice communication of around two seconds. In the scenario (no dense traffic), this was rated acceptable by the air traffic controllers.

ATC interface: We investigated the interface with ATC with respect to these aspects. New special squawk codes were proposed:

7600: comm loss
7660: data link loss, proceed as planned
7661: data link loss, return home
7662: data link loss, fly to emergency field
7700: emergency

Although controllers indicated that they did not particularly require specific terminology or symbols for UAS guidance, either they do not feel comfortable with more information or they expect that more information will not help them in solving the issues at hand.

Dependable emergency recovery: In the simulations, we defined a “home” zone to which the aircraft will fly following a standard route, which is separated from other airspace routes. The procedure for flying towards the standard route follows common practice.

Controllers in all cases indicated they felt comfortable with the procedures defined, even where the emergency situation occurred at the “most inconvenient moment.” In our case, an UA was flying without control through an arrival stream and in another situation straight towards two low-flying IFR aircraft. As long as emergency situations are defined similar to those of manned aircraft, controllers are well trained for emergency situations.

Situational awareness: It is important for all parties to have a good overview of the traffic situation and to have the same mental picture of a traffic situation. This implies that there is a need for a good situational awareness for air traffic controllers, UA pilots, and pilots of other traffic.

The air traffic controller will need to know that they are dealing with an unmanned aircraft in an instant. Already at any existing ATCo's (air traffic controller's) display, the aircraft type is indicated in the aircraft label. The aircraft types need to be known to controllers. Other options to give more recognition to the UAS could be:

- A special convention for the use of call signs can be arranged for UAS
- A dedicated UAS symbol can be used to depict the aircraft
- The UA label at the ATCo's display can be made more explicit, for example, by the use of a special colour.

The unmanned aircraft must be easily visible to the eye for controllers in the control tower, which implies that the colour coding of the aircraft bodies and liveries must be carefully designed. During the introduction phase of UAS into air traffic control, other pilots will need to be aware of the flying objects around them. Air traffic control must play a role in this through informing pilots that an unmanned aircraft is flying ahead of them. This can be quite easily accommodated through informing other traffic over the R/T that a special aircraft is flying in their vicinity. This is already common practice, for example, with hot air balloons and glider traffic. Just like for air traffic controllers in the tower, the aircraft must be easily visually recognisable for other pilots.

Emergency procedures: In the experiments, all emergency situations as identified by EASA were tested. We observed that controllers were not always fully aware of the aircraft's behaviour at the moment that it was flying towards the emergency route. This was partly due to the fact that they used it for the first time.

From the discussions with controllers, it was suggested to define and discuss the emergency routes in advance of any simulation or real flight trial, based on the planned flight of the UA. The altitude of the points on the route must be defined such that the aircraft will make, as little as possible, a vertical movement on its way towards the route. The route must also be defined as high as possible, to increase the possibility for re-establishing communication either through satellite or via direct line of sight. The emergency route can be displayed at the controller's display, either at all times or only at the request of the controller.

Back up phone: One specific back-up element was introduced in the experiments. The air traffic controller was able to contact the UAS pilot directly by phone. This possibility is especially interesting in the case of R/T failure between ATC and the UAS.

RECOMMENDATIONS

We asked the controllers whether they would assign a different priority to unmanned aircraft over manned traffic. Interestingly, they considered UA traffic lower priority than commercial traffic and would treat it as small VFR traffic. This needs to be taken into consideration with assigning routes and sequences to the UA. From the results of the simulations, the following recommendations were given:

- When operating over satellite, keep the UAS on the party line. The UA pilot and the pilots of other traffic must be able to hear each other and hear the instructions given to each of them.
- Dedicated R/T must be developed or existing R/T must be adapted to inform other pilots of the UA in their vicinity.
- The UA does not require new symbology on the ATCo's display, but the ATCo must be able to see at a glance that the aircraft on his display is unmanned. A simple indication by using a dedicated type of call sign will do.
- The ATCo does not require more information on emergency transponder codes.
- ATCo's need good training of emergency situations.
- Benefit can be taken from the fact that communication with the UA pilot can be established over a high-quality landline.

Besides the existing progress with the concept of UAS insertion in non-segregated airspace, two further goals have to be solved: The detect and avoid function, as well as the certification of the UAS according to aviation standards. ■

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