

Validation of Unmanned Aircraft Systems' Integration into the Airspace (VUSIL I and II)

2011-01-2687

Published
10/18/2011

Andreas Udovic, Hans de Jong and Jürgen Vielhauer
DFS Deutsche Flugsicherung GmbH

Copyright © 2011 SAE International

doi:10.4271/2011-01-2687

ABSTRACT

The VUSIL program has developed a concept for the integration of unmanned aircraft systems (UAS) into non-segregated airspace, which is also used by manned civil aviation. For the integration of UAS it is necessary for the Unmanned Aircraft (UA) pilot to be aware of the surrounding traffic in order to recognise and resolve possible conflicts. Therefore the surrounding traffic was displayed in the pilot ground control station (GCS) based on Radar data provided by DFS Deutsche Flugsicherung GmbH (DFS). The pilot was supported in detecting potential conflicts by means of a "Sense and Avoid" tool provided by ESG GmbH. This tool shows conflicts and possible avoidance manoeuvres on a separate display. To validate the concept, two flight campaigns with two different UAS (LUNA by EMT GmbH and NEO by Swiss UAV) and several intruders were conducted. In the first flight campaign, the intruders for the real flying UAS were simulated. In the second flight campaign the intruder was a manned helicopter supplied and flown by the German Federal Police. The proof of concept has been validated by the results of both flight campaigns.

Additionally, a safety analysis was conducted, aiming at demonstration of safe integration of UAS. Especially the equivalent level of safety (ELOS) of "See and Avoid" in manned aviation and "Sense and Avoid" as developed in the VUSIL program was addressed. Based on the results of the flight trials, workshops with aviation experts and relevant literature, under some conditions and assumptions, ELOS of VUSIL's integration concept has been shown.

Collecting the ability requirements of unmanned aircraft pilots was also part of the program. To this end, the UA pilots filled in a job analysis questionnaire to gather first information about the required abilities. The results were

compared with the results from air traffic controllers and pilots.

INTRODUCTION

The two projects in the VUSIL program were lead and conducted by the Research and Development Centre of DFS. The first project (VUSIL I) was sponsored by the German Ministry of Transport ("Bundesministerium für Verkehr, Bau und Stadtentwicklung"), the second project was financed by the German Federal Police in cooperation with the Ministry of Internal Affairs ("Bundesministerium des Inneren"). Both projects would not have been realised without their support.

BACKGROUND

Unmanned Aircraft Systems (UAS) are new kinds of aircraft, which have great potential for conducting various kinds of tasks. In comparison to manned aircraft the pilot of a UAS is not onboard the aircraft. He is steering the Unmanned Aircraft (UA) from the ground. UAS have been mainly developed for the military environment to conduct Dull, Dirty and Dangerous (3D) missions. Therefore most of the civil UAS operations considered are spin-off from the military side, as for instance surveillance operations. In particular pipeline surveillance, border control and maritime or environmental observations are the most described applications. Also dangerous applications like flying into volcanic ash or radioactive contaminations for measurements are possible missions for civil UAS. The advantage of UAS for conducting 3D missions is at the same time the challenge for the integration of UAS into civil aviation. In manned civil aviation the pilot is sitting in the cockpit and not on ground. The pilot in the cockpit is responsible for the safe conduction of the flight and he has to avoid hazardous situations. All civil aviation regulations are based on this premise.

THE PROBLEM

Based on the pilot not being onboard the aircraft, various problems for integration into non-segregated airspace must be solved. The problems can be divided into three areas:

1. Technical problems: For steering an aircraft from the ground, a data link connection between the control station and the aircraft must be established. This data link connection must be stable, safe and secure. At any moment of time, the pilot must have the possibility to interact with the aircraft. To handle the aircraft safely he needs all relevant information in his ground station. In particular, the status of the aircraft, e.g. position, flight attitude, altitude, and status of the engine must be displayed. Therefore a two-way data link is required. To disburden the pilot, several tasks, such as stabilising the aircraft during flight, can be integrated into the avionics of the aircraft. Alternatively, a fully autonomous UA (in which all of the pilot's tasks have been taken over by onboard systems) can be designed. At the moment, such autonomous aircraft are not available.

2. Operational problems: One of the major operational problems is that the pilot of the UA is not onboard the aircraft. Therefore he cannot look outside to avoid conflicts with other traffic or obstacles according to the "See and Avoid" principle. Also it is not possible for the pilot to see signals from other aircraft such as Anti Collision Lights (ACL) or signals from the ground (e.g. from Tower Controller by means of runway lighting). At the moment no technical equipment is available to support the pilot on the ground with this information. If such equipment were available its certification for use in aviation is another hurdle. This leads to the third problem.

3. Regulatory problems: Rules and regulations for the safe integration of UAS into civil airspace do not exist at the moment. Building rules for UAS, requirements for a safe and secure data link or rules for the necessary information exchange between ground station and UA are not defined yet. Neither are requirements for a "Sense and Avoid" system comparable to the "See and Avoid" principle in manned aircraft available. The International Civil Aviation Organization (ICAO) is addressing these problems. On a national level, only some high level requirements are available in certain states. For example in Germany flying UAS outside the Visual Line of Sight (VLOS) of the pilot is prohibited. Only in segregated areas flights can be conducted.

Both VUSIL projects focused on the operational problem of "See and Avoid". In addition, some regulatory problems related to legal aspects and safety analyses were addressed.

THE VUSIL IDEA

To solve the "See and Avoid" problem for the UA pilot the Radar equipment from DFS is used. These Radar data are available within DFS and can be presented to the pilot of the UA in the control station. [Figure 1](#) shows the principle of the solution.

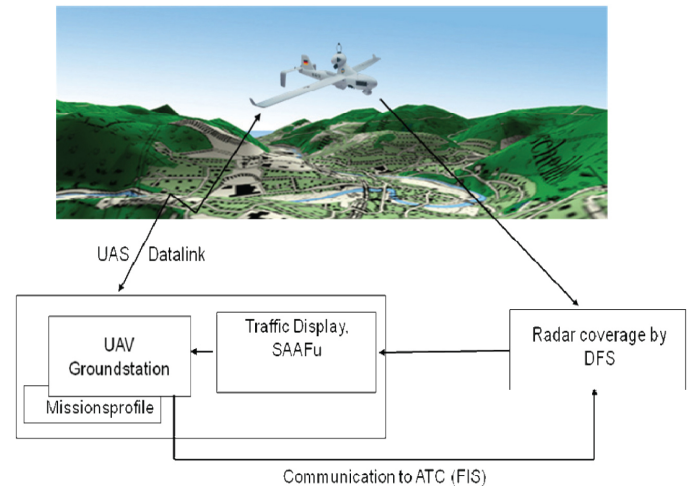


Figure 1. Principle of the "Sense and Avoid" solution developed by VUSIL

The UA is equipped with a common transponder. DFS can detect the UA and the surrounding traffic with normally used Radar equipment. These data can be sent via a landline to the control station of the UA. In the control station the traffic can be displayed on a Radar screen comparable to those used by Air Traffic Controllers. Also a "Sense and Avoid" tool (SAAFu) can be fed by the Radar data. Based on this information the pilot can avoid the surrounding traffic and the UA can be safely integrated into non-segregated airspace. The applied principle is that UA are separated from other traffic by at least 0.5NM laterally and/or 500ft vertically (these values were based on considerations involving inter alia Radar accuracy).

[Figure 2](#) shows the traffic display based on the Phoenix Air Traffic Management system of DFS and the "Sense and Avoid" display "SAAFu" developed by ESG.

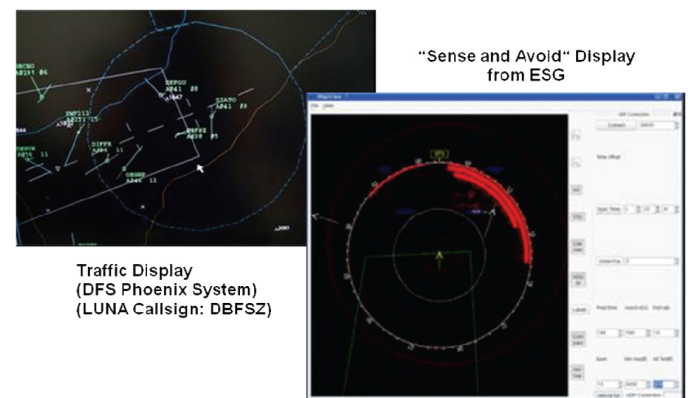


Figure 2. Traffic Display and "Sense and Avoid" Display (SAAFu)

For the successful application of the VUSIL concept some preconditions have to be fulfilled:



- All traffic must be equipped with transponder, as for example in a Transponder Mandatory Zone (TMZ);
- The whole concerned airspace is covered by secondary Radar (in the concept developed, primary Radar is not applicable due to missing altitude information and insufficient accuracy);
- Separation minima of 0.5 NM horizontally, and/or 500 ft vertically;
- If possible, collision avoidance based on existing VFR rules;
- A traffic display is available in the control station; and
- A “Sense and Avoid” assistance system is available.

The preconditions show that the concept is only valid for some special areas, such as TMZs. However it can be used to gain experience with UAS to develop solutions for safe integration into a wider subset of non-segregated airspace.

STRUCTURE OF THIS PAPER

The VUSIL programme contains two closely linked projects. In the VUSIL I project, the VUSIL idea was validated using a real flying UA in combination with simulated surrounding traffic. VUSIL I is described in the following section.

In the VUSIL II project, the concept was validated with a real flying UA in combination with real intruders. Approach and results of this project are provided in the third section, except for the safety analysis, which is reported in the fourth section.

VUSIL I - FIRST VALIDATION EXERCISE

Partners in the VUSIL I project were:

- DFS Deutsche Flugsicherung GmbH (DFS);
- ESG GmbH (responsible for the SAAFu);
- Federal Office of Defence Technology and Procurement (BWB); and
- EMT GmbH (manufacturer of the UAS “LUNA”).

The project was kicked off in November 2007 and finished in February 2009. The aim of the project was defined as follows:

- Development of a UAS integration concept based on the DFS ground Radar infrastructure;
- First validation of the integration concept by flight trials (using certain procedures to maintain separation between the UA and surrounding aircraft);
- Preparation of the necessary infrastructure (Radar data, simulated surrounding traffic, traffic display, “Sense and Avoid” assistant); and

- Conduction of an analysis to identify and assess safety relevant differences between the UA flight trials with normal manned flights in similar circumstances.

REALISATION OF THE PROJECT

Four work packages were defined to realise the project:

1. Preparation of the flight trials: In this work package the integration concept was developed. The core elements were defined:

- Separation between the UAS and the surrounding traffic shall be based on minimally 500 ft distance vertically and/or 0.5 NM distance horizontally.
- All traffic in the area must be equipped with a transponder.
- Radar coverage in the area must be 100%.

The necessary infrastructure was defined. As test area the restricted area 138 (ED-R 138) near the military airfield Manching (in southern Germany) was selected. The Radar data from DFS was sent via UMTS to the UAS ground control station. As experimental vehicle, the UAS “LUNA” from EMT was provided by the BWB. The LUNA was equipped with a transponder. The infrastructure was built up in Manching. For the data collection, questionnaires, interviews and a structured debriefing were prepared. Furthermore the Radar data and the simulated traffic were recorded and analysed after the flight trials were finished. For a detailed description of the infrastructure and methodology see Reference 1.

2. Performance of the flight trials: In June and July 2008 the flight trials were conducted as planned in ED-R 138. 13 flights were performed in this period. Radar data and data from the interviews and discussions were collected. As an example, [Figure 3](#) shows the flight track of the LUNA from flight number 5.

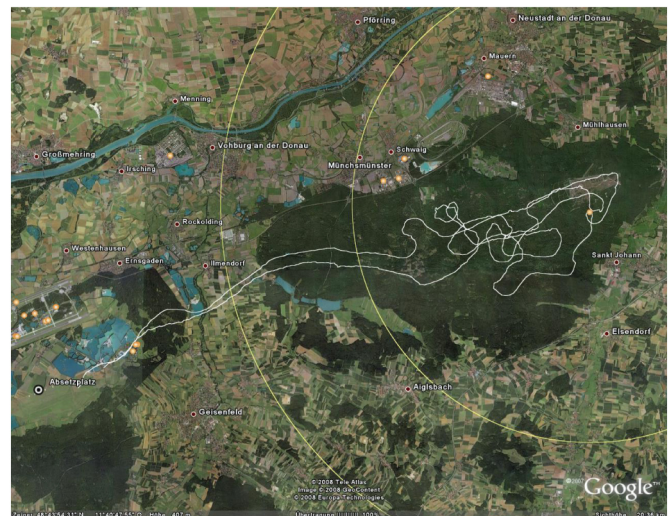


Figure 3. LUNA flight track, flight number 5

3. Safety analysis: Based on the results of the flight trials, a workshop was conducted with the participants of the flight trials to identify and assess differences between the UA flight trials and VFR flights in a comparable context from a safety point of view. UA pilots, UAS technicians, engineers, involved personal from ATC and safety specialists participated in the workshop.

4. Analysis of the integration concept: The last work package contained the analysis of the integration concept. Based on the results of the flight trials and the results of the safety workshop the integration concept was evaluated.

RESULTS

Some highlights of the results from the flight trials and from the safety workshop are presented here.

The analysis of the Radar data showed a shortfall in the separation between UAS and surrounding traffic in five cases (see Table 1).

Table 1. Separation shortfall between UAS and surrounding traffic

Flight trial	3	6	9	9	13
LUNA	DBFSZ	DBFSZ	DBFSZ	DBFSZ	DBFSZ
Call sign simulated a/c	DECBO	DIFFR	HBLEV	GAF002	DIATO
Time of the closest distance	13:03:41	07:57:10	12:55:13	13:21:34	07:23:34
Vertical distance (ft)	275	250	350	0	75
Horizontal distance (NM)	0.27	0.43	0.36	0.47	0.24

In most of these cases the traffic density was very high (see Figure 4). During flight number 3, 34 simulated aircraft and during flight number 9, 30 simulated aircraft were in the test area. In flight number 6, the amount of traffic was high as well (24 aircraft). During flight 13, technical problems were the reason for the shortfall of the separation. Therefore the flight was aborted.

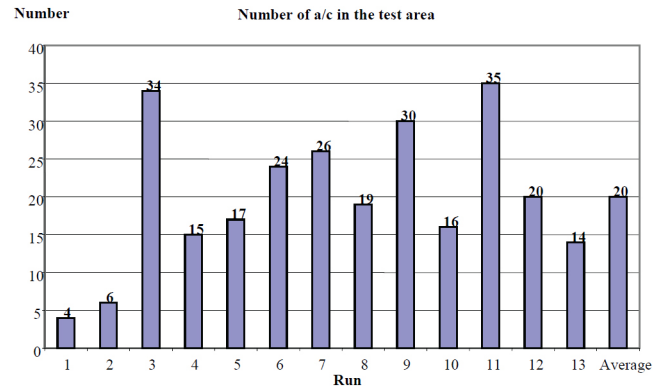


Figure 4. Number of simulated aircraft during the flight trials

Discussions with the UAS pilots and the participants in the flight trials yielded the following results:

- The traffic display with the surrounding traffic was rated as very helpful for the situational awareness. It was however not easy for the pilots to interpret the information on the display. To fulfil this task more extensive training is needed;
- The “Sense and Avoid” assistant was also rated as helpful. Especially for the avoidance manoeuvre this assistance was considered very supportive. Possible solutions to avoid the conflict are displayed to the UAS pilot. The software could however be enhanced by integrating vertical avoidance manoeuvres. More training could also enhance the effectiveness of the assistant;
- The combination of both support tools was rated as very helpful. A better integration into the UAS ground equipment could further enhance their effectiveness;
- The necessary instruction and training of the UAS pilot based on the investigated integration concept was discussed. The participants agreed on a combination of a pilot licensing and elements of air traffic controller training; and
- All in all, the tested integration concept was rated positively. The participants agreed that the concept could be a way to integrate UAS into non-segregated airspace. However, training of the pilots must be taken into account and the technical integration must be enhanced.

The results of the safety analysis workshop supported the results of the interviews and discussions. In addition, the following results were obtained:

- Compared to common manned aircraft, detection of a UA by a pilot of the surrounding traffic was rated negatively by the participants. UA may be very small and therefore their visibility is poor. This could generate problems if the pilot of the surrounding traffic is responsible for conflict avoidance; see the Rules of the Air - Reference 2. Special lights or a special colour could increase the visibility of the UAS.