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VALIDATION OF UNMANNED AIRCRAFT SYSTEMS' (UAS) INTEGRATION INTO THE AIRSPACE – THE VUSIL[1] PROJECT

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Abstract

Validation of Unmanned Aircraft Systems' (UAS') Integration into the Airspace (VUSIL) is a research project the German Air Navigation Service Provider (DFS Deutsche Flugsicherung GmbH) conducts on behalf of the German Federal Ministry of Transport, Building and Urban Affairs. The UAV manufacturer EMT and the German Military (Bundesamt für Wehrtechnik und Beschaffung BWB) are project partners. Also involved are the German Ministry of Defence and the German Aerospace Center DLR. The project was kicked of in November 2007 and will be accomplished in February 2009.

The paper defines UAS and the paradigm shift from "see and avoid" of pilots to "sense and avoid" in UAS with sensors onboard and "monitor and avoid" in UAS without sense capability but a ground operator who monitors the surrounding traffic on a radar data display. The latter could be one approach to integrate UAS into the airspace and is investigated in VUSIL. The methodology to validate this integration approach by a combination of simulated and real flight radar data is presented.

1. INTRODUCTION

UASs were developed during the last decades primarily for military use. Especially the US Army uses different UAS for reconnaissance purposes. The German Army makes also increasingly use of UAS in this area. Further analyses of UAV capabilities are currently conducted by several governments (e.g. [1]).

Unmanned Aircraft Vehicles (UAVs), the flying component of a UAS, are increasingly important for military missions which otherwise would expose human pilots to high risks. But also the civil use of UAVs, for example pipeline infrastructure monitoring [2], is increasing. Military UAVs can be used for combat or reconnaissance missions. They are currently flying only in temporarily restricted and restricted airspace. Aviation organisations recognized the importance of integrating UAVs into regular airspace ([3], [4], [5], [6], [7], [8], [9]). However, to date there are no approved operational concepts for the integration of UAVs into civil air traffic. It is the objective of VUSIL to provide empirical evidence about integration possibilities. This is achieved by a combination of simulation and field flight studies.

1.1. UAS Definition

A UAS consists mainly of three components:

1) The flying component or Unmanned Aircraft Vehicle (UAV). This component contains all necessary parts for flying and the payload.
2) The communication component maintaining contact to the Ground Control Station (GCS) and – in controlled airspace – to the responsible Air Traffic Control (ATC) unit.
3) The GCS in which human operators exert control over the whole system.

1.1.1. The flying component or Unmanned Aircraft Vehicle (UAV)

This component contains all parts necessary for flying, for example, the hull, the engine, and flight management and navigation systems. The UAV carries the payload, for example, reconnaissance sensory systems, like cameras.

1.1.2. The communication component

Depending on the UAS size and the airspace it is operating in, communication systems with the Ground Control Station (GCS) must be installed. Technically, this is a data link connection, which must be stable and interference proof. Moreover, the UAS needs radio transmission systems for the communication with Air Traffic Control (ATC). Depending on the distances between UAV, GCS, and the ATC unit in charge, relay stations are necessary to maintain communication. Relay stations might be satellites, aircraft, or a chain of ground stations.

1.1.3. The GCS

Here the UAS operator exerts control over the whole system. The size of the GCS can vary from a laptop computer to a stationary control centre. The most frequent form of a GCS is a mobile container. Usually, the data generated by the payload is also analysed here.

1.2. UAS Integration Problems

Currently, UAS flights are only permitted in restricted or temporarily restricted airspace, i.e. outside civil air traffic.

[1] The acronym refers to the original German title Validierung von UAS (Unmanned Aircraft System) zur Integration in den Luftraum

There are two main integration problems:

1) See and avoid: The basic safety regulation of the International Civil Aviation Organisation (ICAO) is the „see and avoid" principle. The pilot of any aircraft has the obligation to watch out for other aircraft and obstacles and to avoid them according to the currently valid procedures. The „see and avoid" principle is always in power, independent of the airspace category or the operational procedures that the pilot follows. Since a UAV is unmanned by definition, the „see and avoid" principle must be modified using an alternative to the human pilot. One alternative could be the development of sensory systems that together with electronic flight management systems replace the „see and avoid" of human pilots by "sense and avoid" by means of technology. Currently available approaches suggest integrating the sensory system and corresponding electronics into the actually flying part of the UAS, the UAV, making it able to "sense and avoid". An Equivalent Level of Safety (ELOS) is required which is at least as good as human „see and avoid". However, there is no defined „see and avoid" safety level yet, which could be used as a benchmark. Our approach is to make the traffic information available to the UAS operator at the Ground Control Station (GCS) by means of radar technology (FIG 1 and FIG 3). If the UAS operator on the ground receives sufficient radar information about the surrounding traffic, he/she can resume the „see and avoid" of the pilot in ordinary aircraft. The most appropriate description of this paradigm is "monitor and avoid". Thus, the complex and heavy sensor electronics onboard can be avoided.
2) Emergency procedures for disrupted data link between UAV and GCS: Since UAVs are controlled by distant operators via data link, it must be assured that a disruption of the data link connection does not result in an uncontrolled UAV and thus compromise safety. Internationally binding procedures must be developed that prescribe the safe termination of a UAV mission in uncontrollable situations like irretrievable data link; procedures could be, for example, UAV self-destruction or automatic landing at the next airfield.

1.3. Research objectives

Research objectives of VUSIL can be formulated with respect to function and work integrity (TAB 1):

TAB 1. VUSIL Research Objectives

Objective	**Operational definition**
Function	
The developed integration concept will be accepted by the responsible German authority	The German Federal Ministry of Transport, Building and Urban Affairs will approve the developed integration concept
The necessary technical and operational infrastructure for flight simulations and real flights will be made available	Simulations and real flights are successful, i.e. conducted without technical and without safety problems; the UAS operator has all relevant traffic information available for a safe conduct of UAV flight
The safety standards in Air Traffic Management are not violated by the UAV	– Number of separation infringements = 0 – Safety assessment by the involved air traffic controllers on a scale ranging from 1 safe to 7 unsafe in no trial > 3 – Safety assessment by the UAS operator on a scale ranging from 1 safe to 7 unsafe in no trial > 3 – No safety doubts in the debriefings of UAS operator and air traffic controllers
The integration concept will be assessed feasible	– Safety standards in Air Traffic Management are not violated – The task load of the UAS operator does not exceed 50% in established instruments like the NASA TLX [10] or ISA [11] [12] – No negative assessment of the concept in the debriefings of UAS operator and air traffic controllers
Work Integrity	
The UAS operator will be straining at an acceptable level	– Number of separation infringements = 0 – The task load of the UAS operator does not exceed 50% in the NASA TLX or ISA scales – No report of unacceptable stress and strain in the debriefings of the UAS operator

2. METHOD

The VUSIL project makes use of real and simulated flight data. The UAV „LUNA" with a Mode S transponder flying search patterns was made available by BWB and operated by EMT for the real flight trials. The mission area was and will be ED-R 138, the restricted airspace around the military airfield Manching, Bavaria, Germany. The UAV follows the national regulations [13] which are

internationally harmonised [8].
Technical details of the real/simulated flight trials and the layout of the infrastructure are given at the end of the paper (FIG 1, FIG 2, FIG 3). Four radar stations track the LUNA and provide radar data: Munich South, Nuremberg, Mittersberg, and Großhagener Forst. The bottom right box of FIG 2 shows how the live radar data are submitted via the DFS radar network and UMTS to the field LAN in Manching. The simulated radar data of aircraft following visual and instrumental flight rules (VFR/IFR) are fed in by the DFS NEWSIM ATC simulator (top right box in FIG 2). Both, real and simulated radar data are displayed on the ATC system Phönix (PHX) which is a DFS developed operational system (left side of FIG 2 and FIG 3). Two containers are located in Manching during the real flight field trials (FIG 1). The UAS container hosts the GCS and the interface to the PHX system. In the ATC container the ATCO coordinating the UAV real flight and the simulated VFR/IFR flights is located as well as the ATC supervisor and pseudo pilot controlling the simulated VFR/IFR flights.
The DFS Advanced Function Simulator (AFS) will be installed next to the UAS GCS and feed in the radar data of simulated civil air traffic in this area.
The study design will incorporate twelve trials which are combinations of traffic load and traffic modes, as displayed in TAB 2. VUSIL investigates mainly the integration of the UAV in conventional VFR traffic for two reasons: First, the previous projects WASLA/HALE I to III ([14], [15], [16]) focussed on the integration of UAV in conventional air traffic under instrumental flight rules (IFR). Second, one result of these previous projects was that a slow UAV like LUNA would rather be avoided by fast surrounding IFR traffic than vice versa; the research objective to show that LUNA is able to avoid other traffic can thus better be achieved in surrounding VFR aircraft.

3. CURRENT PROJECT STATUS AND OUTLOOK

The VUSIL Project has been kicked-off in November 2007. Since then the operational concept of integrating UAS in unrestricted airspace has been developed. Test trials were conducted at DFS Headquarters in February 2008. First real flight trials in Manching were started in June 2008 in Manching and continue during the summer 2008. So far, five UAV flights have successfully been conducted, i.e. one test flight, three with low and one with high VFR traffic load (TAB 2). A presentation of the first results will be given at the DGLR Conference in September 2008. An analysis with a focus on safety assessment is planned for November 2008. The final project report is due in February 2009. The project will be considered successful if the operational targets as described in TAB 1 will be fully achieved.

4. ACRONYMS

AFS	Advanced Function Simulator
ATC	Air Traffic Control
ATM	Air Traffic Management
ATCO	Air Traffic Controller
BWB	Bundesamt für Wehrtechnik und Beschaffung, German Military Entity
DFS	Deutsche Flugsicherung GmbH, German Air Navigation Service Provider
DLR	Deutsches Zentrum für Luft- und Raumfahrt, German Aerospace Center
ELOS	Equivalent Level of Safety
EMT	UAS Manufacturer
GCS	Ground Control Station
HALE	High altitude and long endurance
ICAO	International Civil Aviation Organisation
IFR	Instrumental Flight Routine
ISA	Instantaneous self-assessment
NASA TLX	NASA Task Load Index
PHX	Phönix, DFS developed, operational ATC system
RTCA	Radio Technical Commission for Aeronautics
UAS	Unmanned Aircraft System
UAV	Unmanned Aircraft Vehicle
VFR	Visual Flight Routine
VUSIL	Validierung von UAS (Unmanned Aircraft System) zur Integration in den Luftraum
WASLA	Weitreichendes abbildendes signaler-fassendes luftgestütztes Aufklärungssystem, long-range monitoring signal-receiving air based reconnaissance system

5. REFERENCES

[1] Park, R. (2008). MoD/industry UAS capability investigation. UVS Unmanned Aircraft Systems: The Global Perspective 2008/2009, June 2008, Paris, France.
[2] Kaldaev, A. (2008). Pipeline infrastructure monitoring with UAS. UVS Unmanned Aircraft Systems: The Global Perspective 2008/2009, June 2008, Paris, France.
[3] Radio Technical Commission for Aeronautics RTCA Special Committee 203 (2005). Summary of the Fourth Meeting on Minimum Performance Standards for Unmanned Aircraft System and Unmanned Aircraft. RTCA Paper No. 203-05/SC203-009. Washington DC: RTCA.
[4] Eurocontrol (2007). Eurocontrol specification for the use of military unmanned aerial vehicles as operational Air Traffic outside segregated airspace. Brussels: Eurocontrol.
[5] FAA (2007). Unmanned Aircraft Systems Operation in the U.S. National Airspace System. Interim Operational Guidance Ver. 1.1. UAPO Guidance Document 07-01. Washington DC: FAA.
[6] Jane's Airport Review (2007). FAA eyes safer UAV operation. November 2007.
[7] Jane's Airport Review (2007). UAVs close in on civil space. March 2007.
[8] ICAO (2008). Unmanned Aircraft Systems Study Group (UASSG). Montreal: ICAO.
[9] Radio Technical Commission for Aeronautics RTCA Requirements and Planning Work Group (2008). Airspace considerations for UAS Integration in the National Airspace System. Washington DC: RTCA.
[10] Hart, S. G. & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), Human mental workload (pp. 139-183). Amsterdam. North-Holland.
[11] Tattersall, A.J. & Foord, P.S. (1996). An experimental evaluation of instantaneous self-assessment as a measure of workload. Ergonomics, 39(5), 740 – 748.
[12] Leggatt, A. (2005). Validation of the ISA (instantaneous self-assessment) subjective workload tool. In P.D. Bust, P.T. McCabe Contemporary Ergonomics (pp. 74-78). Oxford: Taylor & Francis.
[13] DFS Deutsche Flugsicherung GmbH (2002). Betriebsanweisung Flugverkehrskotrolle. Langen, Germany: DFS.
[14] DLR, DFS, EADS, ESG, WTD61 (2000). Final report on Wasla Hale – techniques and procedures for unmanned flight in controlled airspace. Langen, Germany: DFS.
[15] Udovic, A. (2003). Unmanned Aerial Vehicles (UAV) - Simulation von Verfahren bei TE, TE im Fokus 2/2003. Langen: DFS.
[16] Udovic, A. (2007). UAS – Unmanned Aircraft Systems: Systemüberblick und DFS-Aktivitäten. TE im Fokus, 02/2007, 14-19.

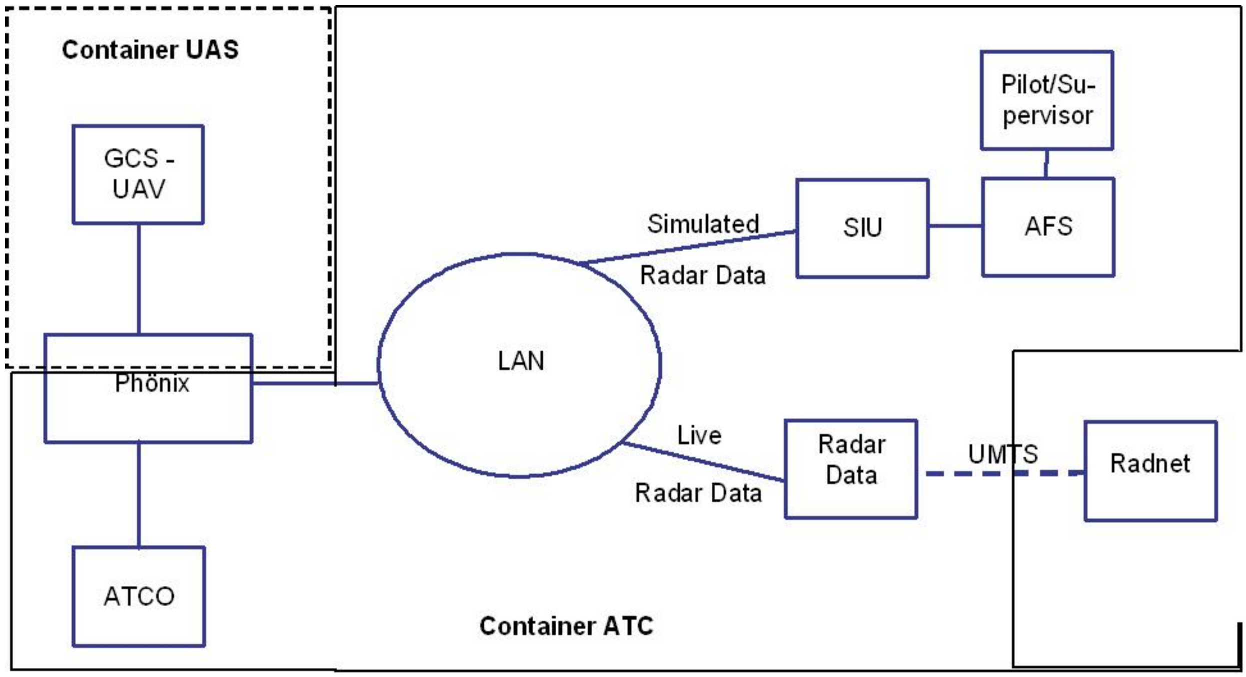

FIG 1. Layout of the VUSIL simulated/real flight infrastructure

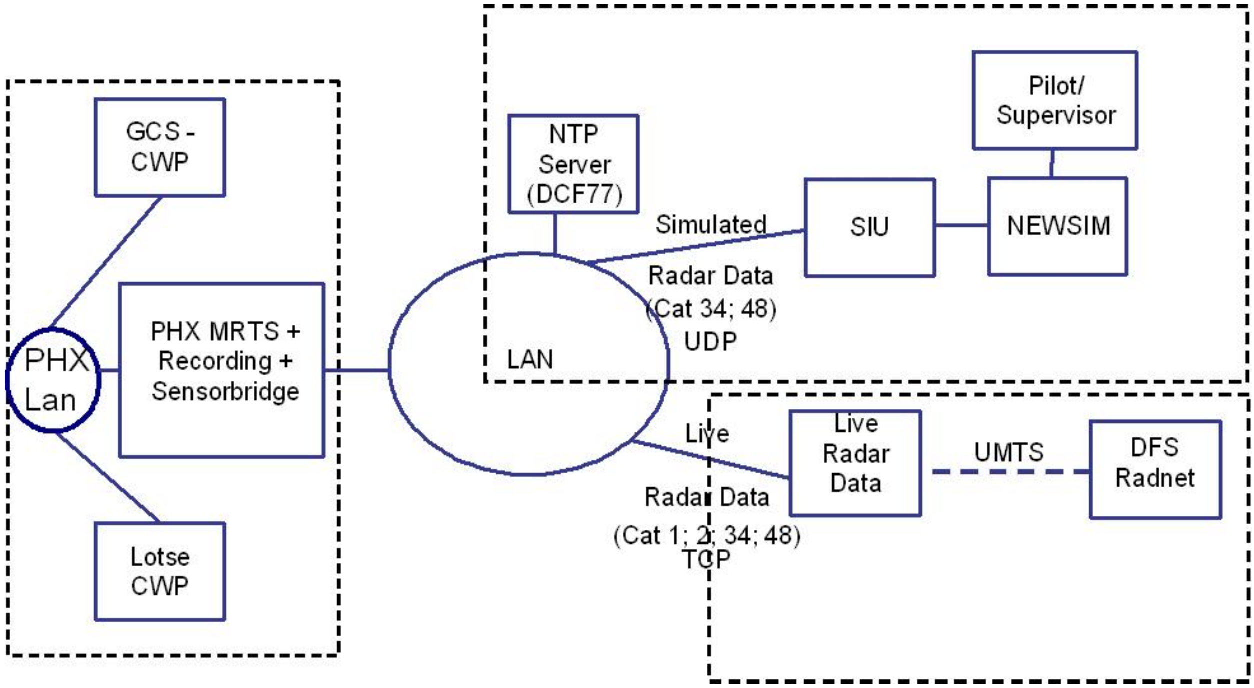

FIG 2. Technical realisation of the VUSIL simulated/real flight trials

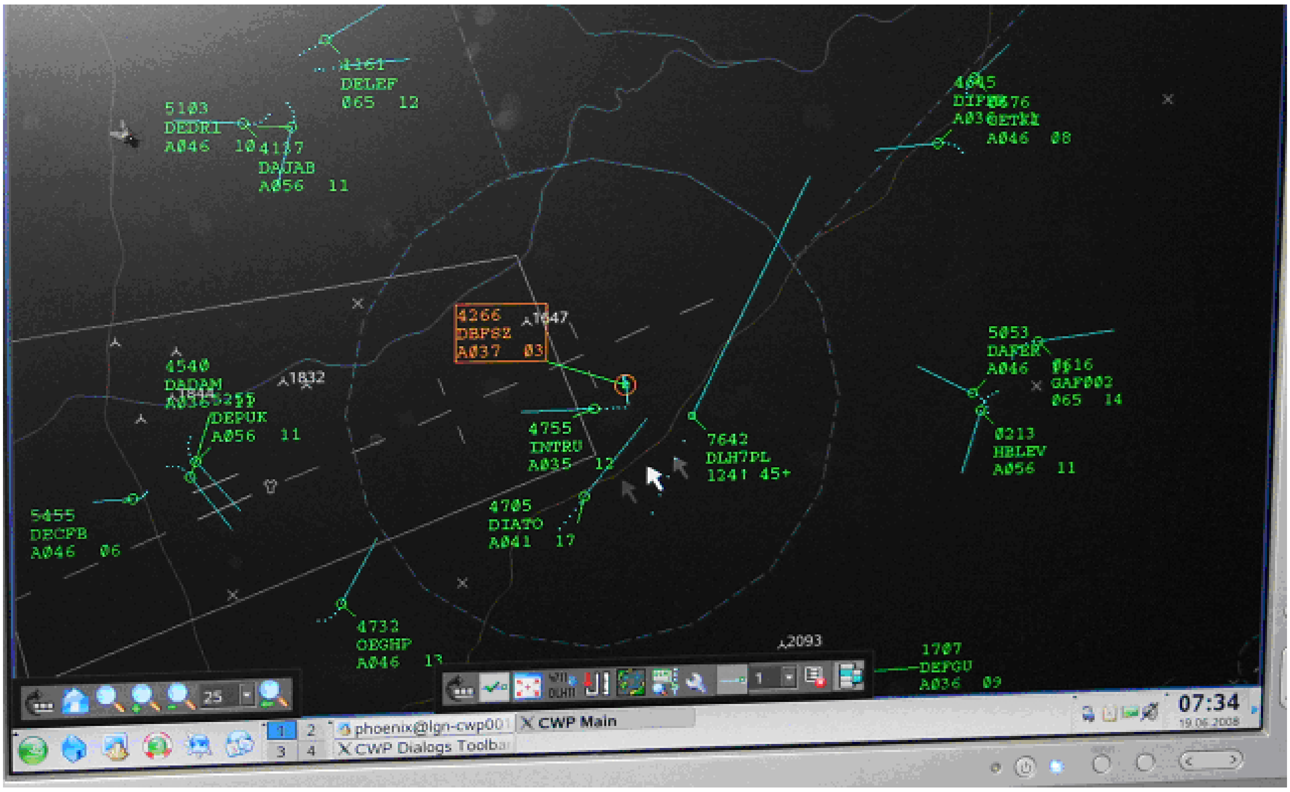

FIG 3. DFS developed Phönix display with LUNA UAV (red, framed) and simulated surrounding traffic (green) in restricted airspace (central circle)

TAB 2. VUSIL study design with six combinations of the independent variables "traffic load" and "traffic mode"; the cells show the number of trials in each condition and in brackets the number of already conducted trials beyond testing

Traffic Load	Primary Radar Display	VFR-Traffic	VFR/IFR-Traffic
Low	1	4 (3)	1
High	1	4 (1)	1
Separation Responsibility	Pilot	Pilot	Pilot/ATCO