INNOVATIVE RPAS AIRSPACE INTEGRATION FOR COASTGUARD MISSIONS

Henk Hesselink (henk.hesselink@nlr.nl),
Jos Stevens (jos.stevens@nlr.nl),
Dennis Nieuwenhuisen, (dennis.nieuwenhuisen@nlr.nl)
Netherlands Aerospace Centre, NLR,
Anthony Fokkerweg 2, 1059 CM, Amsterdam, The Netherlands

Dirk-Roger Schmitt (dirk-roger.schmitt@dlr.de)
German Aerospace Centre, DLR,
Lillienthalplatz 7, 38108 Braunschweig, Germany

Abstract

The use of RPAS for coastguard operations rather than manned aircraft introduces several challenges, which will be addressed in this presentation. Typically the envisioned coastguard tasks involve low level flights Beyond Visual Line Of Sight (BVLOS). This requires the Remotely Piloted Aircraft to be equipped with appropriate sensors and on-board Detect and Avoid (DAA) capabilities. We will present a demonstration flight for the project AIRICA (ATM Innovative RPAS Integration for Coastguard Applications), where the detection and separation will be based on active Mode S interrogation and received ADS-B signals. A Detect & Avoid (DAA) system, *AirScout*, will be implemented and tested.

While operating the RPAS on a mission, different airspace environments will be encountered. ATM involvement is crucial, because of the envisaged take-off and landing at local airfields and the involvement of other (manned) aircraft in the mission. The proposed AIRICA flight will include demonstration of the RPAS under ATC and demonstration of the DAA function with planned intruder aircraft (manned).

To prepare the demonstration flights, a real-time man-in-the-loop simulation environment has been set-up, where real air traffic controllers, a real pilot (for other traffic), and a pilot at an RPAS ground control station (GCS) participated to evaluate the concept. The simulations paved the way for real flight demonstrations with a MALE (Medium Altitude Long Endurance) RPAS in non-segregated airspace for maritime surveillance missions.

1. INTRODUCTION

Within the foreseeable future, Remotely Piloted Aircraft Systems (RPAS) will operate in the airspace together with manned aviation. The RPAS will thereby be considered as much as possible to behave as manned aircraft. Similar to manned aviation, they will be capable of sensing/detecting and avoiding other traffic and be in contact with air traffic control to follow clearances and give information.

In this paper, we will focus on RPAS operations for coastguard operations, i.e. the RPAS will carry equipment for typical coastguard missions. The main payload therefore will consist of a sensor suite to carry out surveillance and search-and-rescue missions. Missions typically last several hours and will be performed over sea at low altitudes. RPAS technology and related sensor suites have now reached a level of maturity which can provide real added value to coastguard operations, notably through quicker deployment, greater autonomy, and the use of smaller aircraft. For these reasons, several government services have expressed interest in replacing (a part of) their fleet with RPAS applications.

The envisaged coastguard operations will take place Beyond Visual Line Of Sight (BVLOS) and will involve (low-level) flights in different airspace environments. Following take-off from an airport, the Remotely Piloted Aircraft (RPA) will fly towards some target area, perform its mission, and fly back to the same airport.

Up until now, the majority of unmanned aircraft have not been equipped with Detect & Avoid (DAA) systems, but given the envisaged coastguard operations and the non-segregated environment in which they will be performed, on-board DAA capabilities are essential. This paper presents a demonstration flight for the project AIRICA (ATM Innovative RPAS Integration for Coastguard Applications), where the detection and separation is based on active Mode S interrogation and received ADS-B signals. A DAA system has been implemented and tested. The aircraft used for the demonstration is an unmanned Schiebel S-100 Camcopter with a rotor diameter of 3.40m., typical weight of 200kg. and cruising speed of 100kts. Demonstration flights are planned for autumn 2015.

Chapter 2 of this paper will further indicate the issue of RPAS airspace integration. Chapter 3 will describe the typical coastguard mission that is envisaged to be flown in the AIRICA project, as described in chapter 4. Next, chapter 5 will give insight in the DAA function with first results from preparations through simulations to be presented in chapter 6.

2. RPAS AIRSPACE INTEGRATION

Many potential operations for RPAS exist and their use for video surveillance, monitoring and inspection and, in some cases, even for package delivery has been accepted by the authorities. Those operators fly the RPAS under agreed conditions, not over population, in segregated airspace, thus not interfering with other traffic. However, regularly reports from manned aviation appear that notice the infringement of airspace from an RPAS. Other reports mention the occurrence of an RPAS at locations where flights are not allowed.

In 2013, the Dutch news site “luchtvaartnieuws” [1] identified drones as a potential threat for commercial aviation. FAA reports a serious increase in the number of drone encounters from 238 in 2014 up to 650 already in 2015 (up to August 9th) [2]. Although most encounters have occured with a small RPAS, the impact of a collision can be catastrophic. None of the RPAS’s provided today is using an automated Detect & Avoid function.

With more envisaged BVLOS missions, the number of encounters between RPAS and other traffic can be expected to increase. This is where the AIRICA project comes in. Over the course of 2 years the project shows the feasibility of using RPAS for coastguard activities in non-segregated airspace. The AIRICA project is one of nine RPAS projects that have been selected for co-funding by the SESAR Joint Undertaking, with the goal of demonstrating the feasibility of integrating RPAS into normal air traffic by 2016.

3. TYPICAL COASTGUARD MISSION

A typical coastguard mission is performed over water and consists of flights with one or more aircraft and/or ships that make a survey of a large area. The task of the coastguard is to 1) ensure responsible use of the sea (e.g. no spillage), 2) ensure safe use of the sea (e.g. search and rescue) and 3) enforce international law (e.g. detect smuggling activities).

All coastguard missions will require the use of a camera and possibly other sensors to perform the requied surveillance tasks. Missions may last from one to several hours. Usually, coastguard aircraft fly specific patters that consist of one or more long or short legs, to allow extended surveillance of large parts of the water surface.

The use of RPAS for coastguard operations rather than manned aircraft introduces several challenges. Typically, the envisioned coastguard tasks involve (low level) flights in BVLOS conditions. This requires the RPAS to be equipped with appropriate sensors and on-board Detect and Avoid capabilities.

4. THE AIRICA PROJECT

The objective of the AIRICA project is to demonstrate a realistic coastguard mission executed by an RPAS in non-segregated airspace ensuring separation based on Mode S and ADS-B transponder Detect & Avoid functionality. The RPAS will operate in controlled airspace and demonstrate feasibility of communication with ATC. The project is carried out by the Netherlands Aerospace Centre, NLR, in cooperation with the Royal Netherlands Air Force and the Netherlands Coastguard. The RPAS that will perform the mission is a Schiebel S-100 camcopter, equipped with a specially developed DAA-function, integrated in an on-board system, which is linked to several aircraft systems. Additional sensors and software are integrated in a pod, which is mounted under the aircraft, as can be seen Figure 1.

Figure 1 Schiebel S-100 with DAA pod

4.1 The Mission

The demonstration flight will be performed from the military airport of De Kooy in the north of The Netherlands. The mission will be performed over sea, west of the coastline. Figure 2 and Figure 3 show the airport environment and the transition path from the airport towards this mission area.

Figure 2 Environment of De Kooy

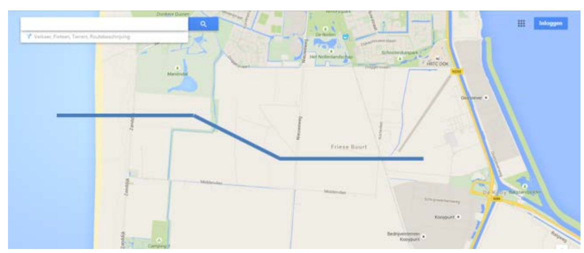

Figure 3 Transition path to the mission area

During its mission, the RPA will cross several different classes of airspace, where it will encounter different types of traffic.

The project will replicate a common coastguard operation in the North Sea area. This is an interesting demonstration zone consisting of nature reserves and areas of economic activity with daily low-level helicopter flights to and from oil rigs. The purpose of the demonstration is to show that the seamless integration of RPAS in non-segregated airspace is possible using relatively simple DAA system functionalities and straightforward communications with Air Traffic Control (ATC) with little or no impact on airport operations.

When performing surveillance operations within the mission area, the RPAS will be under the control of ATC. Intended intruders will be manned aircraft that will fly close by to trigger an on-board action by the RPAS.

The remote pilot will have full control over the aircraft and will be the pilot-in-command. Data links will be used to provide information exchange with ATC, both on the position of the RPA and on information that is presented at the remote pilot's Ground Control Station (GCS). The remote pilot will communicate with ATC through standard radio telephony and standard phraseology.

4.2 Simulations

To prepare for real flights, simulations in a realistic ATC environment have been carried out. We have set up a suitable architecture in a network of simulators, for the air traffic control station and the GCS. In a real-time simulation environment, air traffic controllers have been able to experience, without risk, the unmanned aircraft in operation in their sector and experience themselves the RPA's characteristics, the use of emergency procedures, communication with a remote pilot, and the interaction with other traffic. Our research question was to identify a suitable architecture for BVLOS operations with RPAS and to examine the effects on ATC of RPAS in their airspace [10], see Figure 4.

The results of the simulations proved that air traffic controllers were capable of handling the RPAS. They provided valuable feedback on the procedures for DAA and on contingency procedures (e.g. in the case of a lost link between the RPA and the ground pilot).

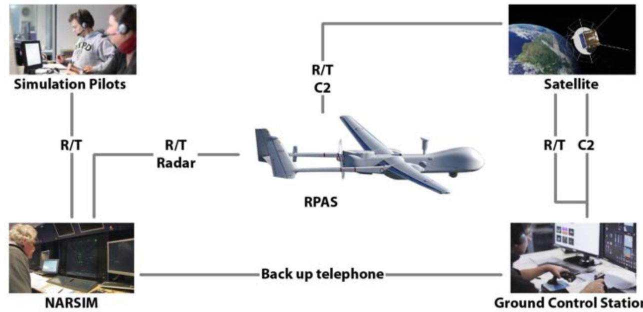

Figure 4 RPAS simulation architecture

5. DETECT AND AVOID

In the time-frame 2014 – 2018 progress is expected for IFR (Instrument Flight Rules) access of RPAS in class A to C airspace, thanks to a DAA system capable of interacting at least with cooperative traffic [2]. Following this, flights in other airspace classes, including VFR (Visual Flight Rules) with cooperative traffic can be tackled by the DAA system. This will require further research, which has been taken up by the AIRICA project.

As part of the AIRICA project, an RPAS will be equipped with an ADS-B transponder for detecting and locating other aircraft. It will also be equipped with a combination of active systems capable of interrogating Mode-S transponders. The signals will be processed on board the RPA, but will also be sent to the GCS. When the remote pilot does not take appropriate actions the RPAS will automatically take evasive action. This system is called *AirScout*.

5.1 AirScout

The AirScout DAA module ensures that the RPAS, called the *ownship*, is able to safely navigate through VFR airspace. It aims to detect other traffic called *intruders*. The following definitions are used:

- *Loss of separation (LOS)*: this is a state of the ownship in which it is closer to an intruder than some minimal lateral and vertical value at the same time.

- *Time to LOS*: the time it takes the ownship to enter a state of LOS. This time is calculated using an extrapolation of the tracks of ownship and intruders.
- *Well clear*: this is a state of the ownship in which the time to LOS has at least a certain value.

5.2 Mission

The ownship is expected to have a mission that it needs to execute. The mission is a list of waypoints without time constraints. At each waypoint the altitude at which the ownship is supposed to pass it can be defined. AirScout supports two types of waypoint navigation: fly-by and fly-over. For fly-by waypoints, it is assumed that the ownship uses a circular arc-like trajectory to “cut the corner”. For fly-over waypoints it is assumed that the ownship starts turning only after passing the waypoint. It again uses a circular arc but needs a second circular arc to return to its intended trajectory. The radius of the arcs is defined by the aircraft’s speed and a nominal bank angle. Fly-by waypoints are normally used for flights that perform a transit from one place to another. Fly-over waypoints are typically needed for coastguard missions that require full parts of the sea to be surveyed and no points are allowed to be skipped. Figure 5 shows the different types of waypoint navigation.

5.3 Extrapolation of Tracks

While the ownship executes its mission, a *detect* function constantly calculates the expected time to LOS. This is done by using extrapolation of the trajectories of both intruders and ownship. Each time an update for the position of either the ownship or one of the intruders is received, their estimated track, speed and Rate of Climb/Descent (ROCD) are calculated using linear regression. With the estimated track, speed and ROCD it is possible to extrapolate their positions for some time in the future.

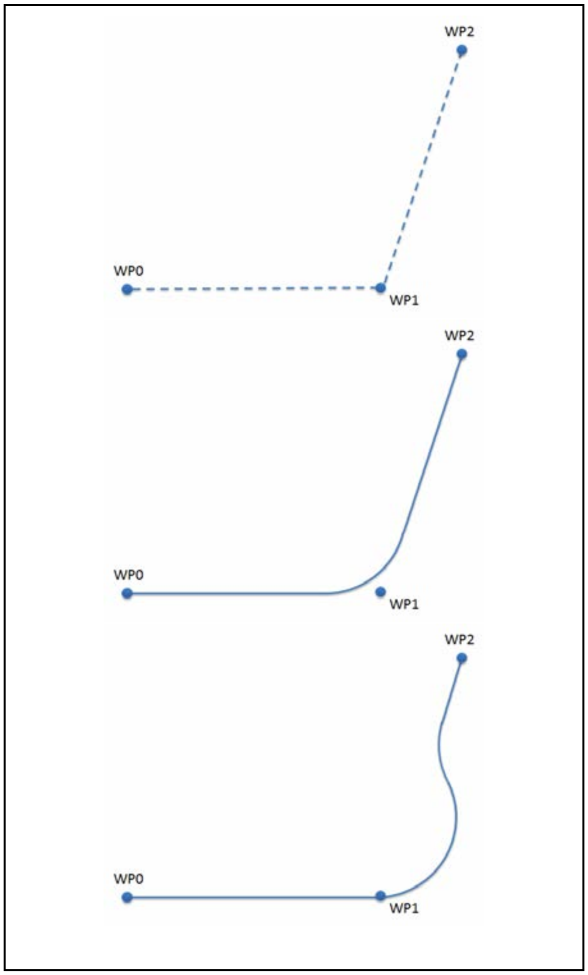

Figure 5 (a) Intended mission. (b) Mission flown with fly-by strategy. (c) Mission flown with fly-over strategy.

5.4 Detection Module

Using the extrapolated positions of ownship and intruders, the time to LOS for the ownship is calculated. If this drops below a certain threshold (the *detection horizon*), proper action is taken by calling the avoid module. The avoid module generates a solution that prevents the LOS of occurring. While executing the solution, the detect module continuously monitors progress by updating the time to LOS. If a new LOS is predicted to occur (e.g. because an intruder does not follow the predicted trajectory), a new solution may be generated.

5.5 Avoid Module

The avoid module is invoked when a LOS is expected to occur within the detection horizon. The goal of the avoid module is to generate one or more waypoints that prevent the expected LOS, ensure that there will be no new LOS within the *detection horizon* and bring the ownship back to its mission trajectory. The avoid module uses several strategies to generate a long list of candidate solutions. Each strategy has the same goal: connect the current position of the ownship to a resume point, which is a point on the mission that has not yet been passed by the ownship. The result is a "deviation" from the mission to prevent a LOS from occurring followed by a safe return to the mission. Each strategy results in a number of solution candidates, which are all added to the candidate list. After each strategy has finished, the "best" solution is selected (using a set of criteria) and returned as a result.

5.6 Solution Selection

The avoid module generates a set of potential solutions to prevent a LOS from occurring. As the RPAS operates in (non-segregated) VFR airspace, it is assured that the final solution respects the Rules of the Air and behaves in a way that is natural to a VFR pilot. Finally, it is ensured that the selected solution is efficient and that the solution has minimal deviation from the mission. In very rare circumstances a lateral solution may not exist, in which case AirScout is able to generate a solution that uses altitude as a means to prevent the LOS. If (despite the execution of a solution) the ownship enters a LOS with an intruder (e.g. because the intruder does not respect the rules of the air), a *traffic alert* will lead to an immediate solution that consists of either a climb or descent command, in line with current regulations, so that the RPAS performs a predictable action for the intruder. The choice for climb or descent depends on the current Rate of Climb Descent of the ownship and the intruder and their altitudes.

6. RESULTS

Results until now have been gathered from simulations. Fast-time simulations have been performed to validate the AirScout algorithms. Real-time simulations add provide an opportunity to examine procedures concerning the RPAS flights in controlled airspace.

6.2 Fast-time Simulation Results

AirScout has been evaluated through a series of fast-time simulations, with increasingly complex scenarios. In total 40 scenarios have been defined, where the ownship and intruder have different relative positions. In the example of Figure 6, the ownship (in blue) is on a converging course with an intruder (in red). A series of waypoints, indicated as stars, is included in the flight track of the ownship to avoid the LOS.

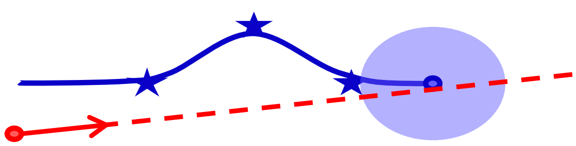

Figure 6 AirScout LOS scenario

Different types of scenarios (head on, converging, overtaking) have been assessed with one or two intruders simultaneously. The results of the simulations have been sufficiently convincing to take the next step: on-board evaluation of the system in a live demonstration flight.

6.1 Real-time Simulation Results

In the real-time simulations, air traffic controllers in all cases indicated they felt comfortable with the procedures defined, even where the emergency situation would occur at the "most inconvenient moment". In our case an RPA was flying without control trough an arrival stream and in another situation straight towards two low flying aircraft. As long as emergency situations are defined similar to those of manned aircraft, controllers are well trained for emergency situations.

The air traffic controller will need to know that he is dealing with an unmanned aircraft in an instance. The label at his display must indicate the fact that the aircraft under control is an RPA.

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. There is a need for a good common situational awareness for air traffic controllers, RPAS pilots, and pilots of other traffic.

7. RELATED WORK

Several projects for RPAS integration in the airspace, with both simulations and real flights have been carried out in Europe.

USICO (UAV Safety Issues for Civil Operations) [4] was one of the first large projects in Europe on RPAS airspace Integration. The project that ran from 2002 to 2004 was funded by EC and identified the major issues concerned with RPAS integration. Several real-time simulations have been performed.

Currently, the major project to identify issues and provide solutions for the DAA function is MIDCAS. MIDCAS (Mid Air Collision Avoidance System) is carried out by a European consortium [5]. The aim of the MIDCAS program is to propose a baseline of solutions for the "Unmanned Aircraft System Mid-air Collision Avoidance Function" acceptable by manned aviation. The MIDCAS DAA-function has to:

- Detect (or sense) aircraft in the vicinity of the RPAS.
- Maintain situational awareness of the human pilot in control of the RPA.

SINUE (Satellites enabling the Integration in Non-segregated airspace of RPAS in Europe) [6] was an ESA (European Space Agency) funded feasibility study, carried out in 2010. Within this project, real-time simulations have been performed with air traffic controllers. Simultaneously with the SINUE-project, another project was carried out for the preparation of a real RPAS mission in Europe. This IDEAS (Integrated Deployment of RPAS in the European Airspace using Satellites) [7] project was funded by EDA (European Defense Agency) and also carried out in 2010 with similar objectives but more focus on military operations.

Following SINUE and IDEAS, ESA and EDA joined forces (through the so-called European Framework Cooperation, EFC, together with the European Commission) and started a project that would demonstrate the integration of RPAS in the airspace through flying a real MALE mission. This DeSIRE (Demonstration of Satellites enabling the Insertion of RPAS in Europe) [8] project demonstrated operations through satellite communication. Demonstration flights took place in 2013 at the civil/military air base of Murcia in Spain, where a surveillance mission was carried out outside the coast of Spain. Take-off and landing took place from the airport that still operated other traffic, using increased separation criteria. The aircraft was under control of Barcelona ATC and one intruder aircraft was present to generate controlled conflicting situations. No on-board DAA system was used: ATC was responsible for separation insurance and conflict resolution.

ASTRAEA (Autonomous Systems Technology Related Airborne Evaluation & Assessment) [9] is a U.K. project focusing on technologies, systems, facilities, procedures and regulations for RPAS operations. The project aims to enable the routine use of RPASs in all classes of airspace without the need for restrictive or specialized conditions of operation. The project performs demonstrations.

8. CONCLUSIONS / RECOMMENDATIONS

By performing coastguard operations previously executed by manned aircraft, AIRICA aims to address remaining operational and technical gaps regarding the integration of complex RPAS operations into non-segregated airspace.

Through performing common missions with manned and unmanned aircraft, benefit can be achieved from both systems, where the long endurance and small size of RPASs will provide new possibilities for coastguard operations. The character of flights performed above water will help to convince authorities in allowing more flights without risk of a crash in urban areas.

We have demonstrated through simulations that a realistic RPAS mission can be performed in cooperation with manned traffic and that LOS and lost link situations can be dealt with by the RPAS pilot and air traffic controller.

The proposed cooperative DAA function, based on Mode-S and ADS-B, offers a valuable contribution to the work in separating RPAS from other traffic in VFR conditions and in lost-link situations. The planned AIRICA demonstration flights are expected to show that RPASs can be operated safely in coastguard operations.

It is recommended to further develop DAA functions and to consider implementing this for different RPASs in different weight categories. The AirScout system weights about 20kg. at the moment, but further miniaturisation will enable applicability of a ruggedized system for smaller RPAS. DAA technology on board of most RPASs will eventually lead to a reduction in encounters between RPAS and manned aircraft. Together with other technology such as geo-fencing, this will lead to a safer airspace shared by RPASs and manned aviation.

9. REFERENCES

[1] Luchtvaartnieuws, 23 August 2013, http://www.luchtvaartnieuws.nl/nieuws/categorie/72/algemeen/reeel-gevaar-drones-voor-commerciele-luchtvaart

[2] https://www.faa.gov/news/updates/?newsId=83544

[3] European RPAS Steering Group, Roadmap for the integration of civil Remotely-Piloted Aircraft Systems into the European Aviation System. Final report from the European RPAS Steering Group: main report, Annex I and Annex II. June 2013.

[4] Lemmers, A. et.al, *USICO (Unmanned Aerial Vehicle Safety Issues for Civil Operations), Evaluation of ATC/ATM Integration Concept for Civil UAV Operations,* D4.1/WAP4100 Report, 2009

[5] www.midcas.org

[6] Indra, *SINUE: Satellites for the Integration in Non-segregated airspace of UAS in Europe*, *Final Report, version 1.2*, SINUE_EID_00035_FINAL REPORT, January 2011

[7] IDEAS, *Integrated Deployment of UAS in the European Airspace using Satellites*, ESA/EDA Workshop May 11/12th, Noordwijk, 2010

[8] DeSIRE, *Demonstration of Satellites enabling the Insertion of RPAS in Europe*, Final Report, 2013

[9] www.astraea.aero

[10] Hesselink, H.H. and D.-R. Schmitt, *UAS Air Traffic Insertion Starts Now (Real-time simulation of UAS in ATC)*, 3rd, CEAS Air & Space conference, Venice, 24-28 October 2011