NATIONAL TECHNOLOGY PROJECT 'OUTCAST' ON UAS SENSE AND AVOID

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Abstract

To address the challenge of sense and avoid for Unmanned Aircraft Systems (UAS), the Netherlands' Ministry of Defense tasked the National Aerospace Laboratory NLR with the National Technology Project 'OUTCAST [1]'. The project objectives were to define the sense and avoid requirements and evaluate in flight tests a concept solution feasible for 2010.

NLR's Cessna Citation II laboratory aircraft was selected as the (manned) platform in which a demonstrator system was installed and certified. More than 30 test flights in Visual Meteorological Condition (VMC) were performed in which various air traffic situations were examined. Flight test data was recorded, and crew comments were captured. In post-flight analysis, the sense and avoid requirements and the feasibility of the concept solution were evaluated, and recommendations were made on how to adapt and improve them.

1 Introduction and background

Today, a large variety of Unmanned Aircraft Systems (UAS) exists, ranging from micro UAS that fit on a human hand until UAS with the wing span of a Boeing 737. The benefits of deploying UAS are generally found in missions that are dull, dirty or dangerous. Examples are long endurance (> 24 h) surveillance missions, missions in contaminated areas, military missions in enemy airspace or civil missions in a hazardous environment such as scientific data gathering in tropical storms.

So far, most of the UAS deployment has been in military applications. The recent and steep increase in military UAS deployment also leads to an increased demand for ferry and training flights outside the operational theatre, under peacetime conditions. Also, civil and commercial market opportunities have been identified (e.g. border surveillance, pipeline inspection). Thus, there is an increasing demand for access to 'civil airspace'.

UAS are currently only operated in segregated airspace, restricted to other airspace users. One of the key inhibiting factors for UAS flights outside segregated airspace is the lack of a capability to *Sense And Avoid* (SAA) nearby aircraft.

In 2004, the National Technology Project OUTCAST was initiated by the Netherlands' Ministry of Defense (MoD), in which NLR was tasked to explore a near-term (2010) solution for SAA. Several other important issues needed to be resolved as well but OUTCAST focused on the prevention of mid-air collisions, for Medium Altitude Long Endurance (MALE) UAS types.

The vision of the OUTCAST project was to safely fly (military) UAS outside segregated airspace under 'peacetime conditions' in 2010. 'Peacetime conditions' refer to conditions where the UAS is operated among other (civil) air traffic and where flight safety is prevalent over the efficient execution of the mission. In times of crisis or in conflict areas, UAS can be kept clear of collisions with other aircraft by procedural measures as it is done today, e.g. by blocking certain airspace or altitude bands. The main objectives of OUTCAST were:

- Define the SAA requirements
- Evaluate in flight tests a concept solution, feasible for 2010.

[1] Operations of UAV – Transition to Civil Air Space and Traffic environments

It was recognized that the 2010 solution would most likely not be a 'final' solution for all airspace, but it would be a first of a series of steps to safely integrate UAS operations among other air traffic.

2 SAA Requirements and Concept Definition

In Phase-1 of OUTCAST, a survey was performed of the operational and regulatory environment and feasible technological solutions for 2010. An initial set of requirements was defined.

2.1 Operational and Regulatory Environment

Because of the short timeframe to 2010, OUTCAST approached the problem in a pragmatic way. Major changes to the Air Traffic Management (ATM) system until 2010 were not foreseen. Therefore, the existing ICAO conflict management concept [1] for preventing collisions was used as a baseline, which has a three layered safety approach:

1. Strategic conflict management, (such as airspace structure, flight plan)
2. Separation provision
3. Collision avoidance ('safety net')

The nominal way of preventing collision in flight is by maintaining a safe separation distance from other traffic. Depending on airspace class and flight rules under which the flight is executed, either Air Traffic Control (ATC) or the pilot is responsible for this function. If separation provision fails, the collision avoidance function is required as a 'safety net' for which the pilot is responsible at all times (irrespective of ATC services).

A SAA capability should thus facilitate two functions: separation provision where ATC is not responsible, and collision avoidance at all times, in all airspace classes. These two functions may be executed by two separate (sub-) systems.

2.2 Sense and Avoid Requirements

During Phase-1 of OUTCAST, initial requirements for SAA were derived by analyzing regulations, historical data and collision geometries. Also requirement documents from EUROCONTROL [2] and NATO [3] working groups were taken into account. The key requirements are listed in Table 1. They were an integral part of the evaluations during the flight tests.

Sensor Coverage	
Azimuth	+/- 110°
Elevation	+/- 15°
Detection range	90 sec before CPA[2]
Separation Minima [2],[3]	**Collision Avoidance miss distance [2],[3]**
Hor: 0.5 Nm Ver: 500 ft	Hor: 500 ft Ver: 350 ft
Other requirements	
UAS shall adhere to ICAO right of way rules	
SAA shall not compromise safety margins of ACAS equipped aircraft	

Table 1: OUTCAST Initial SAA Requirements

2.3 OUTCAST Sense and Avoid Concept

In terms of sensors, two types of solutions exist: cooperative sensors and non-cooperative sensors. Cooperative systems require dedicated broadcasting equipment on board of aircraft to aid their detection. Such equipment needs to be available (mandated) on all aircraft in the same airspace in order to base a solution on it. The only feasible cooperative solution available in 2010 is the Mode S transponder as it is widely mandated by ICAO on all aircraft by April 1, 2008 although not for all airspace. This mandate will be implemented in a phased approach for most of the airspace in the Netherlands above 1200 ft altitude. The surveillance function of the civil Airborne Collision Avoidance System (ACAS) can detect and track aircraft that are equipped with transponders.

Non-cooperative sensors do not require dedicated equipment onboard other aircraft and detect these by e.g. visual light, heat (infrared) or radar. The challenge for such systems is achieving a high reliability, at sufficient range and coverage, with acceptably low false alert rates. It was considered infeasible in light of the

[2] Closest Point of Approach

2010 timeframe to develop a mature, reliable and certifiable SAA solution based on non-cooperative technology. It was recognized however that electro optical/infrared (EO/IR) cameras are available on many UAS as a mission payload. OUTCAST considers flights in ‘peacetime conditions’, where flight safety is prevalent over the use of the payload for the mission. In case of a pending conflict, the EO/IR payload could complement the ACAS surveillance function by providing accurate bearing and information on the class of and intentions (turning, level flight etc) of surrounding traffic.

In conclusion, OUTCAST investigated the feasibility of a ‘sense and avoid’ system based on existing and proven ACAS surveillance technology as a primary sensor, and the EO/IR mission payload as a secondary sensor. Because the concept is built on the ACAS/ Mode S backbone, it is only a suitable solution for transponder mandatory airspace.

3 Demonstrator Development

In Phase-2 a concept demonstrator was developed with the purpose to be able to evaluate the OUTCAST concept by flight trials.

3.1 OUTCAST Sensors

The NLR Cessna Citation laboratory aircraft is equipped with a Honeywell CAS67A TCAS[3] system. More sophisticated TCAS systems are available on the market, but the objective was to evaluate the concept of ACAS surveillance as a primary sensor for SAA, and not to evaluate the best available ACAS system. As the CAS67A does comply with the ACAS Minimum Operational Performance Standards it is representative for the ACAS concept.

In addition to the surveillance functionality, detecting and displaying nearby traffic to the pilots to enhance their situational awareness, ACAS systems comprises an alerting and advisory functionality. The alerting algorithms are designed specifically for manned aircraft, and are as such not suitable for UAS. A key reason for this that most (long endurance) UAS do not have sufficient performance to comply with the resolution advisories, and since ACAS may coordinate resolution advisories with other ACAS equipped aircraft, this may compromise the safety of other airspace users.

Therefore, the surveillance functionality is primarily used for OUTCAST as a means to detect other aircraft. Although the ACAS warnings were not used for evasive maneuvering in OUTCAST, they were recorded during the flight tests to evaluate their applicability to UAS and to assess compatibility between ACAS and the separation minima requirements.

ACAS surveillance of Mode S transponders provides minimally: an accurate range, accurate altitude information and a bearing which is inaccurate (up to 15 degrees error). In order to integrate the ACAS data in the demonstration system, a provision was realized in OUTCAST to read out the ARINC 735A data stream between the ACAS computer and the ACAS displays.

Key requirements for the selection of the EO/IR camera system were:

- the availability of an autotracker;
- a Narrow Field of View < 1 degree for accurate bearing measurement;
- a gyro-stabilized camera system;
- the possibility to exchange control and status data between camera and the demonstration system.

After a selection process with four candidates, a Rafael high-performance Toplite II EO/IR camera was acquired as secondary sensor. The ‘Toplite’ system comprises a turret with EO and IR cameras, a Toplite Multi-Function Display (TMFD) and a Toplite Controller stick (Fig. 1.)

In the OUTCAST demonstrator the Toplite camera field of view could be (roughly) directed to intruder aircraft by feeding the camera with azimuth and elevation angles that were derived from ACAS data. Via an RS422 interface camera control data and status information was exchanged with the computers in the OUTCAST demonstrator system. After the intruder was visible with the camera, usually after a manual controlled search around the

[3] ACAS refers to the concept, TCAS refers to equipment

ACAS position, the autotracker was engaged for continuous tracking.

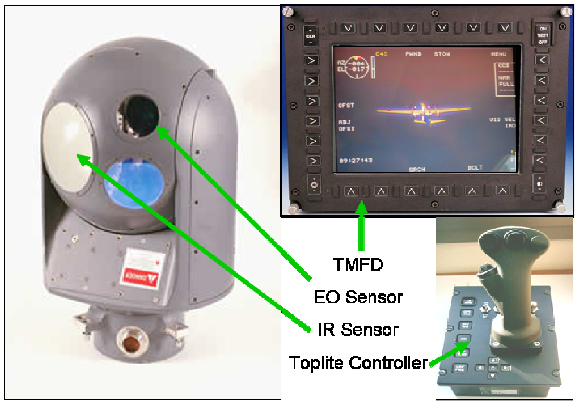

Fig. 1. RAFAEL Toplite II camera system

3.2 Human Machine Interface Design

OUTCAST assumed a typical UAS crew composition: a UAS pilot (UP), tasked with navigation, and a Payload Operator (PO), responsible for the operation of the mission sensor. For both the UP and the PO a working position was designed. The goal was not to develop a full UAS Control Station, but to focus on the prevention of traffic conflicts. The design of the working positions, including the Human Machine Interface (HMI), was not optimized. The OUTCAST project focused primarily on the 'detect and track' part, and aimed to get insight into real-life sensor data quality and availability. After the data / information quality is known and initial feedback from UAS crews is gathered, HMI optimization can be performed, in future projects, with much more focus and direction.

It was decided to place the UAS crew consoles in the cabin of the test aircraft and not to use a (radio) data link. This provided more flexibility in the flight tests as some flights took place over a large area and at low altitude where data link range limitations are quickly encountered. Also, no coupling to the autopilot was installed to reduce the development and certification effort. Instead, the UP transferred the flight commands to a display located in the cockpit in front of the Pilot Flying (PF), who implemented the commands in the actual autopilot. These simplifications had minor effect on the study's main objectives related to evaluating the 'detect and tracking' performance of the sensors.

The Citation crew also comprised a Test Leader (TL), a Flight Test Instrumentation Engineer (FTE), and a Safety Pilot (SP). The crew chair allocation is shown in Fig 2.

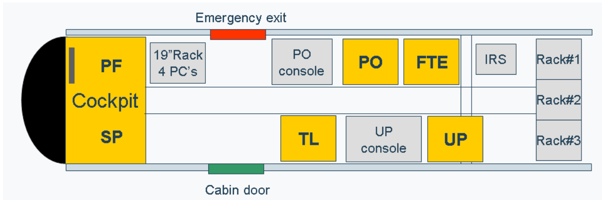

Fig. 2 OUTCAST crew positions in the NLR Cessna Citation.

An HMI needed to be designed for the UP, the PO and the PF. As a first step in the HMI design process, the tasks in the OUTCAST sense and avoid process were identified for each of the crew roles, see Fig. 3. The red-dashed line outlines the tasks for the UAS crew.

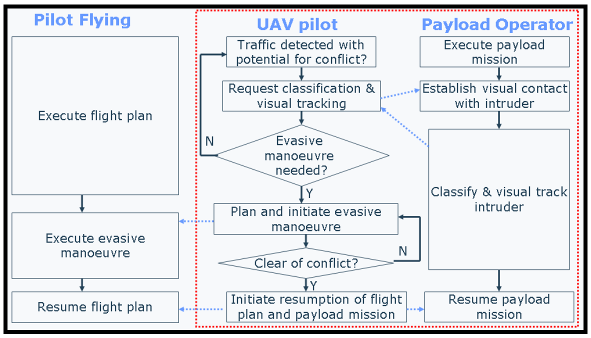

Fig. 3: OUTCAST UAS Crew tasks

The UAS Pilot and PO consoles are displayed in Fig 4. The UP working position has a video monitor on top, and a touch screen that presents traffic and UAS flight information. Below the touch screen a rotary control panel is mounted.

The touch screen (Fig. 5) contains a Navigation Display (ND) with planned route, air traffic and feedback on camera pan angle and horizontal Field of View (FoV). A vertical display provides feedback of the camera elevation angle and vertical FoV relative to the target aircraft selected for camera monitoring. A Primary Flight Display (PFD) presents an artificial horizon, speed tape, altitude tape and heading compass. Finally, a tabbed panel is available with a 'UAV CTRL' page for commanding evasive maneuvers. TCAS targets to be monitored with the camera can be selected with the left rotary dial. The request is transmitted to the PO or cancelled by respectively pulling or pushing the dial. The three rotary dials on the right side are used to command heading, speed or altitude to the PF for evasive maneuvering in case of a traffic conflict.

Fig. 4. UP (left) and PO (right) working position

Fig. 5. The UP touch screen

The PO working position (Fig 4., right) consists also of two screens. The screen on top is the TMFD, which shows the camera EO/IR image and is used for some payload control functions. Below the TMFD a touch screen and rotary control panel is located similar to the UP working position. On the right the Toplite Controller is available to manually slew the payload and engage the autotracker.

A 'pre-selected' TCAS target by the UP is displayed on the PO display. The PO can acknowledge the request, after which he can choose several types of slaving on the 'PAYLOAD' page of the tabbed panel (Fig. 6.) A 'SHOOT' mode directs the sensor to the latest available TCAS sample, a 'TRACK' mode continuously slaves the camera to TCAS, and two scan modes ('SCAN' and 'L SCAN') to initiate an area or (horizontal) line scan around the latest available TCAS sample. The 'STICK' mode enables manual payload control with the Toplite Controller.

Fig. 6. The PO touch screen.

The PF has a similar touch screen interface as the UP. He flies as accurately as possible the planned route on the ND. Upon request of the UP, the PF will execute an evasive maneuver presented on the 'UAV CTRL' page of the tabbed panel. After Clear-of-Conflict, the PF uses the ND to resume the original flight plan.

3.3 Integration and Certification

The demonstration system was functionally integrated and tested in a laboratory environment. Due to good interface definitions functional integration was almost first-time-right.

Installation in the Citation was a major modification for which a Supplemental Type Certificate (STC) was required. The 60 kg Toplite II system was installed in the nose on the location of the 6 kg weather radar. The consoles were installed in the cabin. All design and integration work such as structures design, manufacture and installation, was performed by NLR and are described in [4]. NLR gathered

evidence for the STC via analysis and flight tests, after which the STC was issued by the Netherlands Civil Aviation Authorities.
As can be seen in Fig. 7, the camera is located in the nose in an upward position, which is unusual for a UAS. This position was chosen to reduce the integration and certification effort, while it was ensured that the camera view angles did comply with the coverage angle requirements defined in Phase-1 of the project.

Fig. 7. Toplite II installation in NLR Citation

4 Flight Tests

In Phase-3 of OUTCAST, 33 test flights were performed, with three types of scenarios:

1. One-on-one ‘passive’ scenarios
2. One-on-one ‘active’ scenarios
3. Roaming flights in Netherlands airspace

In total approximately 170 Gb of data was collected. Crew comments were captured in de-briefings.

4.1 One-on-One Passive Scenarios

The objective of the one-on-one passive scenarios was to evaluate the performance of the sensors in detection and tracking of other air traffic. Pre-defined collision scenarios were flown against three types of intruder aircraft from the Royal Netherlands Air Force (RNLAF): a Pilatus PC-7 trainer, the Fokker 50 and a Lockheed-Martin F-16 (see Fig. 8). The intruder aircraft represented general aviation aircraft, transport aircraft and fighters respectively, in size and speed. No avoidance was initiated in these scenarios in order to test tracking performance up to the ‘collision point’

The collision scenarios consisted of straight three-minute legs towards a collision point (a small altitude split was used to avoid a collision). Various approach angles of the intruder aircraft were used between 0 degrees (head-on) and 180 degrees bearing (UAS being overtaken). In combination with the different flight speeds and climb rates for each intruder this resulted in a test matrix of 15 scenarios; each of which was repeated minimally 5 times.

Both the UAS crew and the Citation pilots were requested to announce the moment of visual acquisition of the intruder, so that a comparison could be made under the same conditions. Both the UAS crew and the Citation pilots were informed of the scenario (and in that respect had the same advantage).

Fig. 8. F-16 in head-on collision course

4.2 One-on-One Active Scenarios

The active scenarios consisted of pre-defined tracks flown against the Pilatus PC-7. The objective was to evaluate the conflict assessment and conflict resolution by the UAS crew. In some runs the PC-7 initiated a conflict, and in some runs the PC-7, although nearby, did not initiate a conflict. In these scenarios the UAS crew was not briefed on any details of the scenario, and needed to distinguish between conflicts and non-conflicts. Fig. 9 shows an example. The Citation and PC-7 start at C1 and I1 on a North-bound course. At M1, the PC-7 either keeps flying North, or turns to North-West to initiate a ‘collision’ near C2.

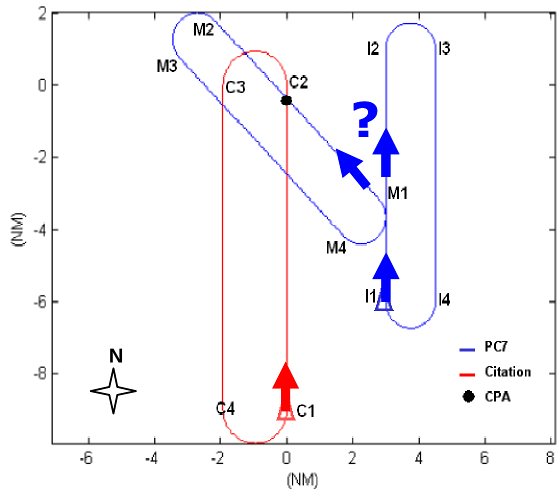

Fig. 9. One-on-one active scenario with PC-7

4.3 Roaming Flights

The objective of the nine roaming flights was to fly in real traffic conditions against unplanned, and potentially multiple intruders. The UAS crew needed to avoid conflicts (if any) with all other air traffic. The flights were performed largely in traffic areas with VFR traffic, taking off and landing from the national airport Schiphol. A variety of intruders was encountered such as airliners, general aviation aircraft, gliders and helicopters.

5 Analysis and Results

In Phase-4, a detailed analysis was performed and results were captured in a Contract Report, which is not publically available. Some key observations are provided in this chapter.

5.1 Intruder Detection and Acquisition

The TCAS detection range proved to be adequate; usually well before the required 90 seconds before CPA. In some cases the transponder antenna signal was partly masked, particularly in head-on encounters with smaller intruder aircraft (PC-7 and F-16) where the transponder antennas are located on the back of the aircraft. This hampers TCAS detection and tracking and reduces time available for separation provision. Usually sufficient time is still available for collision avoidance.

The EO/IR acquisition range after detection by, and slaving to, TCAS was recorded. The Citation pilots were also asked to report visual acquisition of the intruder, for comparison. The camera system, cued by TCAS, proved to provide acquisition at larger range than a pilot’s eye.

The IR camera proved to be best for acquisition. Especially in hazy conditions the IR camera outperforms the daylight camera and definitely outperforms the human eye. The IR camera also makes aircraft visible beyond TCAS range (> 30 Nm), which can sometimes lead to acquisition of the wrong intruder. In some cases, the intruder was not found because of a cluttered background or large bearing inaccuracies of TCAS. Table 2 presents the acquisition statistics in absolute numbers and as a percentage of the amount of acquisitions that were possible. In some scenarios EO/IR acquisition and pilot visual acquisition were not possible, since the intruder was overtaking the Citation ‘UAS’.

The daylight camera is, in general, better for obtaining information on intruder type and intruder intent information (level flight / turning flight).

Intruder acquisition with EO/IR camera	#	% of possible
Correct	166	91.7
Not found	7	3.9
Wrong aircraft	8	4.4
Total possible acquisitions	181	100
Not possible	16	-

Table 2. Intruder acquisition statistics

5.2 Tracking Accuracy

TCAS does provide sufficiently accurate range and altitude information. As expected, TCAS bearing accuracy was poor with average errors up to 10 to 15 degrees and peak errors up to 40 degrees. An example of TCAS inaccuracy and the resulting position errors is given in Fig. 10, which presents a God’s eye view of a head-on scenario with a PC-7. The time after the start of the run is marked in minutes: 0’, 1’, 2’, etc. TCAS derived position of the PC-7 is plotted in green versus GPS derived position in blue.

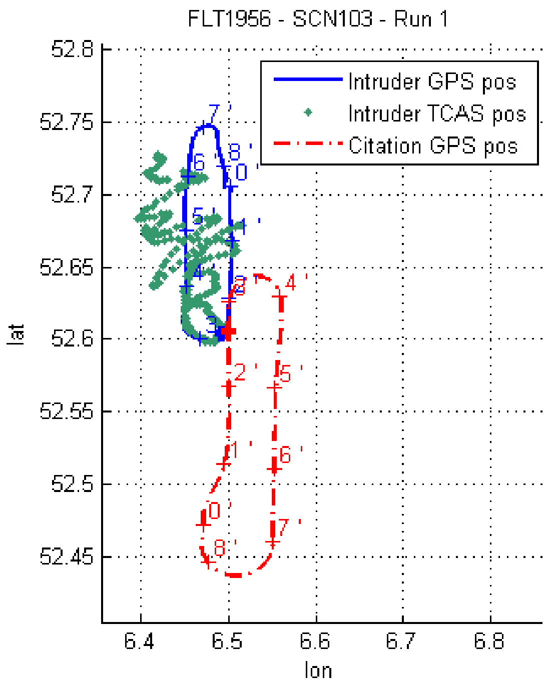

Fig. 10. GPS position track versus TCAS

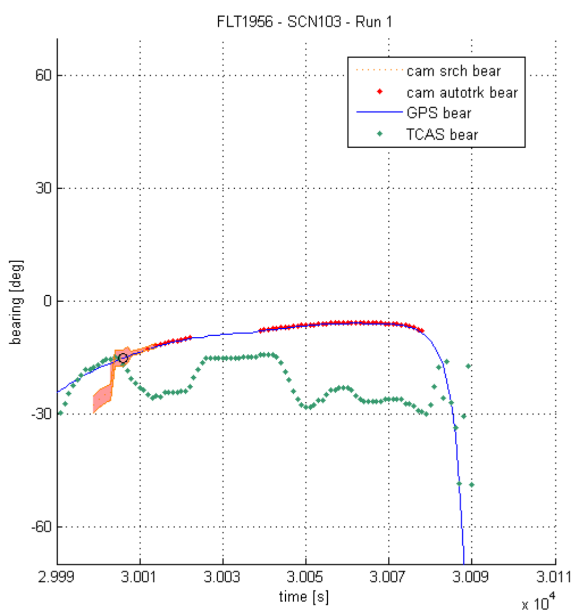

Fig. 11. Camera bearing accuracy

The bearing accuracy obtained from camera tracking is much better, around 0.5 degrees average error. This is shown in Fig. 11 where bearing angle (red dots) is plotted against time for the same scenario and run as in Fig. 10. TCAS bearing angle is plotted again in greed, and the GPS derived ('true') bearing is plotted in blue.

5.3 Conflict Assessment

As expected, conflict assessment proved to be a challenging and time consuming task with the HMI provided to the UAS crew. Inaccurate TCAS position information, lack of reliable trend information (e.g. flight direction and flight speed of the intruder) make it difficult for the UAS crew to correctly and reliably execute the separation provision function.

The video image proved to be helpful in identifying the type of traffic, and to assess whether the other traffic is turning or flying level. On the other hand, the video image also had adverse effects on occasion. It distracted the attention of the UP from the other displays. The autotracker keeps the intruder 'steady' in the centre of the screen, even if ownship or the intruder move, which can work confusing as it is different from the experience in a cockpit. In some occasions the intruder appeared to fly backwards in the video image in reference to the clouds in the background. Also, the video image is not corrected for bank maneuvers of the ownship, what can suggest that the intruder is climbing or descending while this is not true.

With the motto 'better safe than sorry', the UAS crews often initiated maneuvers when they were not necessary, see Table 3. Not many collision courses were missed, but a few were spotted late.

	Horizontal Manoeuvre	Vertical Manoeuvre	Combined Manoeuvre
False alert – no conflict	12	5	0
Conflict avoided	17	3	1
Separation violation	5	0	1
Near miss	0	0	0
Total 44	34	8	2

Table 3. Maneuver Effectiveness

5.4 Conflict Resolution

In conflict resolution, the lack of (horizontal) situational awareness was apparent in several instances where the selected maneuver direction was incorrect and in some cases actually worsened the conflict. The UP tended to resolve conflicts based upon TCAS traffic information only, due to the difficult mental integration with the information provided by the camera. TCAS bearing and range information alone however is not suitable for separation provision, confirming the official viewpoints [5]. In case of late conflict detection, horizontal maneuvers usually did not timely avoid loss of separation. The horizontal maneuvers used (heading rates of 1 to 2 degrees per second) were representative for long endurance UAS.

Due to the accurate altitude information from TCAS, vertical maneuvers are more straightforward to select. All vertical maneuvers in OUTCAST were successful, but the climb rates used (1000 to 1500 ft/min) are beyond the capabilities of most (long endurance) UAS.

5.5 Potential HMI Improvements

All the required information is present, but it is divided over multiple displays[4] and needs to be observed over a time period to get an impression of the trend. Therefore, building a mental picture of the traffic situation is not straightforward.

Available sensor data should be merged to improve the accuracy of traffic position information and estimate traffic trend information. In the analysis phase it was shown that by using the accurate camera azimuth angle (when an aircraft is being tracked) and the range and altitude of TCAS, it is possible to estimate the intruder track angle (flight direction). Estimating the intruder speed with the available range data (from the ARINC 735A interface) proved difficult, as the resolution of this range data is only 1/16th of a Nm, solely meant for displaying purposes. Using the more accurate range data in the TCAS computer should yield more accurate speed information, especially after filtering.

This improved intruder information can be used by computer algorithms to support conflict assessment and conflict resolution. This will reduce the duration of the SAA process considerably. Displaying the improved information will increase situational awareness. Furthermore, improvement can be obtained by optimizing the visual intruder (auto)tracking with the camera. Intruder relative movement which is compensated for by the autotracker should be integrated more intuitively into the HMI to maintain sufficient situational awareness (e.g. improved symbology, use of a Helmet Mounted Display).

Another improvement is to compensate the presented video image for the roll movements of the ownship. However, presenting or not presenting the video image to the UP should be reconsidered in the first place, when the required traffic information can be derived with sensor fusion and displayed on a single traffic display. Secondary visual information, such as class of aircraft, can always be requested aurally by the UP from the PO.

It is recommended to study the optimal task sharing, information sharing and HMI in a follow-on activity. Feedback from the UAS crews provides good direction for future improvements. NLR also has valuable experiences from similar research into Airborne Separation Assistance Systems (ASAS), which are based on the broadcast of flight information to other aircraft, see e.g. [6] and [7].

5.6 SAA Requirements

The coverage angles, separation minima and detection range were evaluated in the flight tests. It was recommended to increase the elevation angle to +/- 20 degrees. Also, a recommendation (not a requirement) was made for full hemisphere coverage for situational awareness. Even though aircraft overtaking a UAS have the responsibility to maneuver, from a situational awareness point of view it is helpful to know their presence, just like TCAS scans backwards for manned aircraft.

The separation minima of 0.5 Nm horizontal and 500 ft vertical did not match with ACAS as compliance with these minima can result in Traffic Advisories and Resolution Advisories. The vertical separation minimum was acceptable for the pilots in OUTCAST, but they felt a value of 0.5 Nm was not appropriate. They commented that a comfortable separation distance depends on many factors like the size and speed of the intruder, how early the intruder is visually detected and how predictable it

[4] video image, horizontal and vertical navigation display and primary flight display

behaves. Based on the test results a new minimum value was proposed for the horizontal separation (1 Nm). As VFR flight levels are stacked with 500 ft, this value was accepted as a minimum with the remark that it may trigger alerts in other ACAS aircraft.

It was assessed that the only possible requirements on detection range is that the system shall provide timely detection against all traffic in the same airspace in order to maintain the separation minima. The actual distance will vary for each system as it depends on the duration of the SAA process, including the maneuvering performance.

6 Conclusions and Recommendations

Flight testing proved to be indispensable to evaluate SAA system requirements and potential concept solutions. Many lessons were learned from real-life measurements and crew observations.

It was concluded that the OUTCAST concept is feasible in terms of sensor performance, to enable operations on a limited scale with military UAS outside segregated airspace. System improvements are required however, with the three key issues being:

- Data fusion to facilitate correlation of intruders between both sensors, and to derive information on intruder flight direction and flight speed;
- More intuitive integration of camera video image in the UAS crew HMI to decrease the cognitive effort for maintaining situational awareness;
- Providing automation support for conflict assessment and conflict resolution.

The OUTCAST concept should be accompanied by pragmatic flight procedures and ATC procedures, and UAS pilots should be trained to understand the HMI and the limitations of their SAA system. Also the regulatory framework should be put in place. Efforts should also be taken to mature the system concept and facilitate airworthiness certification.

NLR will discuss follow-on activities with the Netherlands MoD. As mentioned the OUTCAST concept should provide a workable solution on the short-term, a first step in a stepwise introduction of UAS. However, in finding a short-term solution, the longer term should not be overlooked. A long-term view will be developed by NLR based upon foreseen ATM developments as well as developments on SAA-related technology and UAS customer needs.

Acknowledgements

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