Nationaal Lucht- en Ruimtevaartlaboratorium

National Aerospace Laboratory NLR

Executive summary

UAV in civil airspace - OUTCAST or friend

Problem area
It is foreseen that in the timeframe 2010-2012 UAV systems will be introduced in Dutch and European airspace. Safe operation is a major concern for peacetime operation outside segregated airspace. At all times the pilot is responsible for collision avoidance even if the pilot is located in a ground control station. This responsibility is referred to as “” Detect and Avoid (D&A)”. The first question to be answered is: “Where and when do I want to fly with my UAV and what do I need for that”. The second question is whether the other stakeholders will accept the UAV as a friend in civil airspace.

Description of work
The goal of the OUTCAST project was to investigate a technical concept for D&A based on available ACAS technology in combination with an EO/IR camera to provide “visual information”. Therefore the NLR Cessna Citation research aircraft was equipped to operate as pseudo UAV by addition of such a camera and an ‘on board’ control station for a UAV crew. These additions required a re-certification of the aircraft. In an extensive flight test program with both ‘collision scenarios’ with several intruder aircraft from the Royal Netherlands Airforce and ‘roaming flights’ outside segregated

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This report is based on a presentation held at the 18th SFTE (EC) Symposium, Madrid, Spain, 11-13 June 2007.

airspace above the Netherlands a large amount of data was collected. Initial results are available but data analysis is on-going.

Results and conclusions

The results of this project are the recorded data from 36 flight test hours, the operational experience from real flights tests with a UAV alike and the opinion of a number of stakeholders that witnessed the UAV operation in flight.
The initial conclusions show a moderate positive acceptance of the OUTCAST concept, but there may be limitations in weather conditions and dense traffic areas with multiple targets. The results also need to be used for the improvement of cooperative and non-cooperative detect and avoid technology and the HMI development for the Ground Control Station of the UAV crew. Further investigations should be directed towards active fusion of data from both sensors to create more accurate and continuous tracking of the intruders
Finally there seems to be options to operate UAVs as friends in civil airspace fur the Dull-, Dirty- and Dangerous-work.

Applicability

The experiences within this project will also contribute to the discussions in international bodies for rule-making for and certification of UAVs[1)]

[1)] A UAV is nowadays usually indicated as an Unmanned Aircraft System or UAS.

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Summary

One of the most prominent aspects of the changing world environment in aeronautics is the rapidly progressing introduction of UAVs. Various countries aim to introduce UAV systems in civil airspace in the timeframe 2010-2012. Therefore a demonstration of safe operation is required: maintaining separation and avoidance of collisions with other traffic during UAV operations. “Sense and avoid” or “detect and avoid” are hot topics for unmanned vehicles because this is the primary responsibility of any pilot according to the ICAO rules, and a key aspect that currently restricts UAV operations outside segregated airspace. For UAVs, where the ‘pilot’ is operating remotely and lacks visual clues, a solution needs to be found with at least an equivalent level of safety.

The challenge to find a feasible solution in the 2010 timeframe was addressed in the Netherlands with the National Technology Project OUTCAST[2)]. OUTCAST investigates a concept based on existing technology like ACAS in combination with the EO/IR camera that will be available on most types of UAV. The viability of the concept depends on the ICAO mandate for carriage of Mode S transponders on all IFR and VFR flights after 31 March 2008. The investigation had to be performed by flight testing a demonstration system, installed on a ‘manned’ aircraft, in a representative air traffic environment.

The project started in April 2004 and now progressed into the fourth phase: Data Analysis & Reporting. The NLR Citation II laboratory aircraft was equipped with all the required sensors, including the Toplite II EO/IR payload (EOP) from Rafael (Israel) installed in the nose of the aircraft. The functionality of a UAV crew “ground” control station was emulated in the aircraft by installing two working positions, one for the UAV pilot and a second one for the Payload Operator. This set up together with the facilities for the communication with the pilots in the cockpit and the servers for the different application programs formed the Demonstrator Hardware Architecture. Finally a data acquisition system for recording of all the test parameters and signals was added. Also aircraft from the RNLAF were equipped with a position reporting system because in most flight test scenarios ‘intruder’ aircraft need to be introduced.

The paper describes the hardware required for the flight tests, the path to certification of the installation of the EOP, an example of the one-to-one scenarios for the flight tests and the first results of the initial flights with the system.

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

Contents

Abbreviations

ACAS	Airborne Collision Avoidance System
ACU	Airborne Control Unit
ATC	Air Traffic Control
CAA	Civil Aviation Authority
CFD	Computational Fluid Dynamics
CR	Contract Report
D & A	Detect and Avoid
EO	Electro optical
EOP	EO Payload
FAR	Federal Aviation Rules
FMS	Flight Management System
FoV	Field of View
GPS	Global Positioning System
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IR	Infra Red
MALE	Medium Altitude Long Endurance
NLR	National Aerospace Laboratory
NTP	National Technology Program
OAT	Operation Air Traffic
OUTCAST	Operations of UAV – Transition to Civil Airspace and Traffic environments
PF	Pilot Flying
PO	Payload Operator
RNLAF	Royal Netherlands Air Force
STC	Supplemental Type Certificate
TC	Toplite Controller
TCAS	Traffic alert and Collision Avoidance System
TMFD	Toplite Multi Function Display
UAV	Unmanned Aerial Vehicle
UCS	UAV Control Station
UP	UAV Pilot
UTC	Universal Tome Coordinated
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WP	Work Package

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1 Introduction

The National Technology Project OUTCAST (Operations of UAVs – Transition to Civil Airspace and Traffic environments) was initiated to support the introduction of UAV systems in Dutch and European airspace in the timeframe 2010-2012. The safety, the separation with other traffic and the avoidance of collisions, is a major concern for peacetime operation outside segregated airspace. ATC provides safe separation in controlled airspace but according to ICAO rules [1] the pilot is – at all times – responsible for collision avoidance, even if the pilot is located in a ground control station. In uncontrolled airspace the pilot is responsible for both separation and collision avoidance. This responsibility is usually referred to as “sense and avoid” or in accordance with ICAO phraseology “detect and avoid (D&A)”. It is clear that the D&A requirements depends a.o. on the class of airspace and therefore the solution also. The right question to be answered is: “Where and when do I want to fly with my UAV and what do I need for that?”

1.1 Project goal

The goal of OUTCAST was to investigate a technical concept based on available ACAS technology in combination with an EO/IR camera to provide “visual information”. ACAS, although designed for a manned interface, is a proven technology that may provide a mature technical basis for UAVs as well. Moreover, Eurocontrol guidelines under development [2] stipulate that a UAV D&A solution should be compatible with ACAS systems in manned aircraft. This, and the ICAO mandate to carry Mode S transponders for all IFR and VFR flights after 31 March 2008[3)], supported the investigation of ACAS as part of a technical solution. The nature of the OUTCAST project was very practical: flight testing a demonstration system with appropriate functionality, installed in a ‘manned’ aircraft with standard TCAS, in a representative air traffic environment in the Netherlands.

The result of the project should give an indication how UAVs can be operated with an equivalent level of safety as manned aircraft. This was the minimum requirement for acceptance of UAV airspace integration by all stakeholders. And there are many stakeholders like military and civil authorities, ATC, UAV operators, other airspace users, industry and not at least the general public. The second goal of OUTCAST was to introduce this technical solution and show the stakeholders that the safety of air transport is not reduced by UAVs. Therefore main items for our research were: what is “Equivalent Level of Safety”, how do we achieve it and how do we *prove* it, i.e. acceptable means of compliance?

[3)] In transponder mandatory airspace

1.2 Project plan

The OUTCAST project started in April 2004 and had four phases that would run till the end of March 2007. Due to the unforeseen possibility to introduce a second flight test period in 2007 the overall project timeline is extended till the autumn of 2007, as shown in Figure 1-1.

Figure 1-1 OUTCAST Project Phases

The regulatory and operational environment was mapped in Phase 1 “Requirements Capture and Concept Definition” [3], and TCAS and EO/IR equipment issues were identified.

From April 2005 until July 2006 Phase 2 was executed [4]. In Figure 1-2 the work package break down for this phase is given in more detail. In WP5 the demonstrator system was developed by integrating existing systems and developing new software and displays for the interface between the systems with each other and with the operators. In WP6 a tool was developed to visualize scenarios and geometries for the evaluation of the planned flight tests. In WP7 the actual planning for the flight tests programme and detailed flight test scenarios were defined.

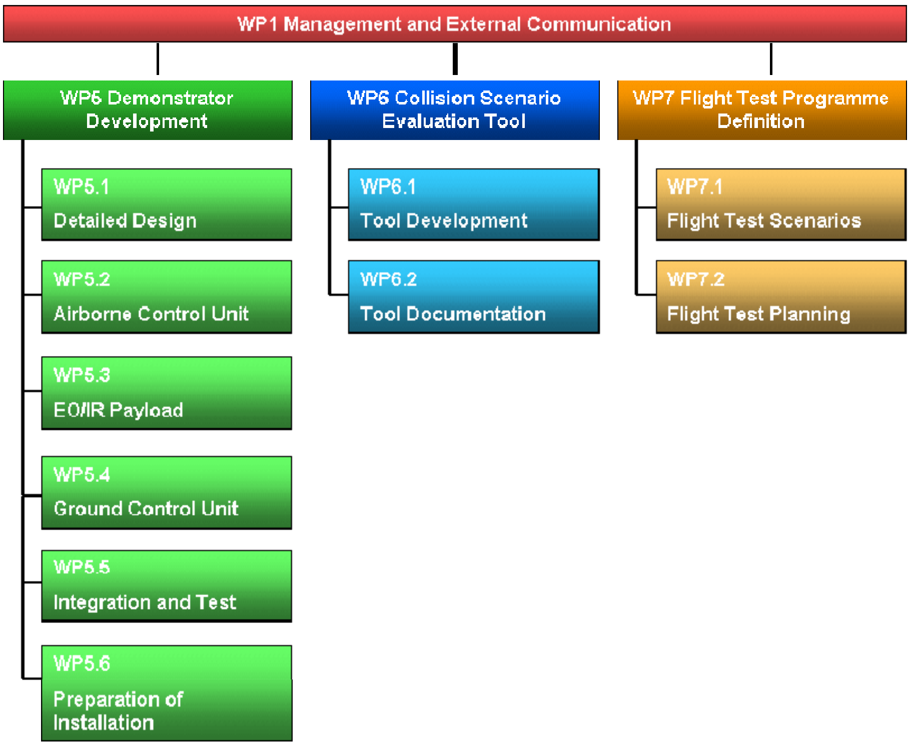

Figure 1-2 Work Package break down for Phase 2

In the period from September till November 2006 the NLR Citation II research aircraft was reserved for the installation of the OUTCAST instrumentation together with the EO/IR sensor, the certification flights for the Dutch CAA and the flight test program. Several delays in the selection of the EO/IR sensor, the selection of the location of this sensor, the design and development of the integration with the aircraft and the certification plan led to a very limited time for actual flight tests. Therefore a second period for executing the flight test program was scheduled in the period March-April 2007. All planned tests were flown in that very short period due to the good weather, no malfunctions in the demonstration system and aircraft, and the smooth organization with the assistance of the RNLAF and NLR staff.

In June 2007 Phase 4 has started with the creation of a catalog of all recorded data and fine tuning the tools for data analysis and data presentation.

2 Demonstrator and instrumentation

At the start of the development of the demonstrator system two main decisions on data link and autopilot were taken to simplify the system without compromising the project goals.

The OUTCAST demonstration system would not have a data link in terms of actual hardware. The UAV Control Station (UCS) was placed in the cabin of the Citation aircraft. This provided more operational flexibility during the flight test, as maintaining a line-of-sight data link connection between a ground station and the aircraft was not required. The UCS and the "airborne" part were still separated, i.e. they were operated on different computers, connected by a network. In interpreting the flight test results to general conclusions, interrupted data link availability and data link latency still could be taken into account.

No coupling of the demonstrator system to the autopilot was realized. Although it has been achieved previously, the main reason was that the analogue Citation autopilot is difficult to control in the pitch axis and therefore the interface development was very expensive. Instead, the Pilot Flying would enter the desired heading, speed and altitude into the Citation autopilot on request of the UAV pilot. The project goals are not compromised because there is no hard requirement for an automated collision avoidance function, except for the emergency condition that the control data link is not available. It also does not degrade the performance of the collision avoidance function as TCAS is designed to have a human in the loop.

Figure 2-1presents an overview of the hardware architecture of the design. The dashed line through the centre of the picture depicts the 'data link' separation.

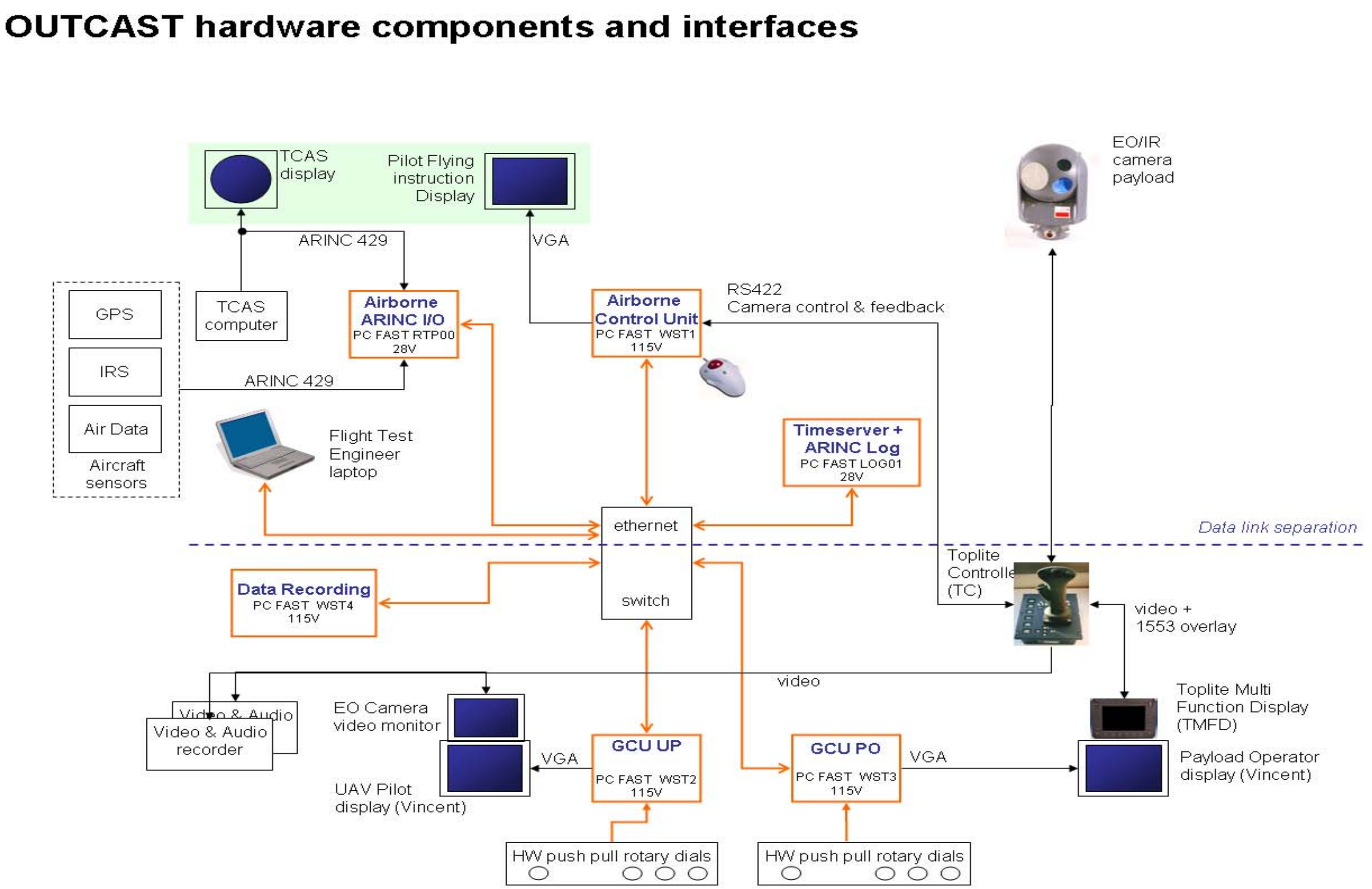

Figure 2-1 Overview of demonstrator hardware

2.1 Primary sensors

In the OUTCAST demonstrator system, the primary sensor for traffic detection is the standard TCAS II system, depicted by the TCAS computer (see Figure 2-2) and the standard TCAS cockpit display. Note that a TCAS system also comprises two antennas (top and bottom) and is connected to the Mode S transponder, but since these are part of the standard Cessna TCAS installation, they are not presented here. A facility to read out the ARINC 429 data bus between the Honeywell CAS67A computer and the display was realized. From the TCAS intruder file the key parameters of maximal 30 intruders were tapped in order to realize the option to slew the camera automatically to the expected relative position of the intruder. The key parameters are the range, bearing (with accuracy < 15 deg) and the relative altitude.

Figure 2-2TCAS computer

The EO/IR sensor is a Toplite II system from Rafael (see Figure 2-3). The Toplite Controller (TC) is used for manual control of the EO/IR camera (pan, tilt, zoom etc). More functions as autotracking and selection of Field of View are available on the TC. Further the Toplite can be used in slaving mode after which the camera is controlled by inputs from the OUTCAST Airborne Control Unit (ACU). The ACU software contains the control algorithms to slave the EO/IR camera to a TCAS intruder or to a pre-defined scanning pattern.

The Toplite Multi Function Display (TMFD) is used to present the Toplite System information as an overlay in the selected camera view and to control the system via a menu and the push buttons. The main features of the camera for this purpose are the three Fields of View including a narrow FoV of less than 1 degree.

Figure 2-3 Toplite II Controller, Multi Function Display and EO/IR Payload

2.2 The UAV on-board Control Station

It was not the objective to replicate a complete UAV Control Station, only the functionality related to the detection and avoidance of other traffic was supported. The focus in developing the Human Machine Interface (HMI) was to perform realistic flight test and data gathering, and not on optimizing the functionality from an HMI point of view.

The OUTCAST UAV Control Station comprises two consoles: the UAV Pilot console and the Payload Operator console (see Figure 2-4).

Figure 2-4 UAV Pilot (left) and Payload Operator (right) Consoles

The UAV Pilot (UP) console is designed for performing the monitoring of air traffic by the UAV Pilot and for providing navigation commands from the UP to the Pilot Flying to divert from the flight plan. It comprises:

- a touch screen computer monitor,
- a video monitor screen
- a push/pull rotary button panel.
- console housing

On the ruggedized computer display, the Human Machine Interface (HMI) display software was designed for the UP, using the NLR rapid prototyping tool *Vincent* [5]. It displays only the information relevant for navigating the UAV and keeping situational awareness with respect to surrounding traffic, see Figure 2-5.

It consists of:

- a traffic situational overview display – containing information on traffic and the planned route
- a primary flight display – containing the basic flight parameters

The symbols of the traffic display were based on traditional TCAS symbols [3]. A vertical display has been added to provide feedback on the actual Toplite elevation angle relative to the required elevation angle towards the selected intruder aircraft. A key extension of the TCAS HMI for OUTCAST is the additional information about the camera, to correlate the video image with the air traffic situation. The sensor type (IR = red, Optical = orange), the view direction and Field of View (beam width) are displayed, as depicted by the red dashed area in an example, see Figure 2-5.

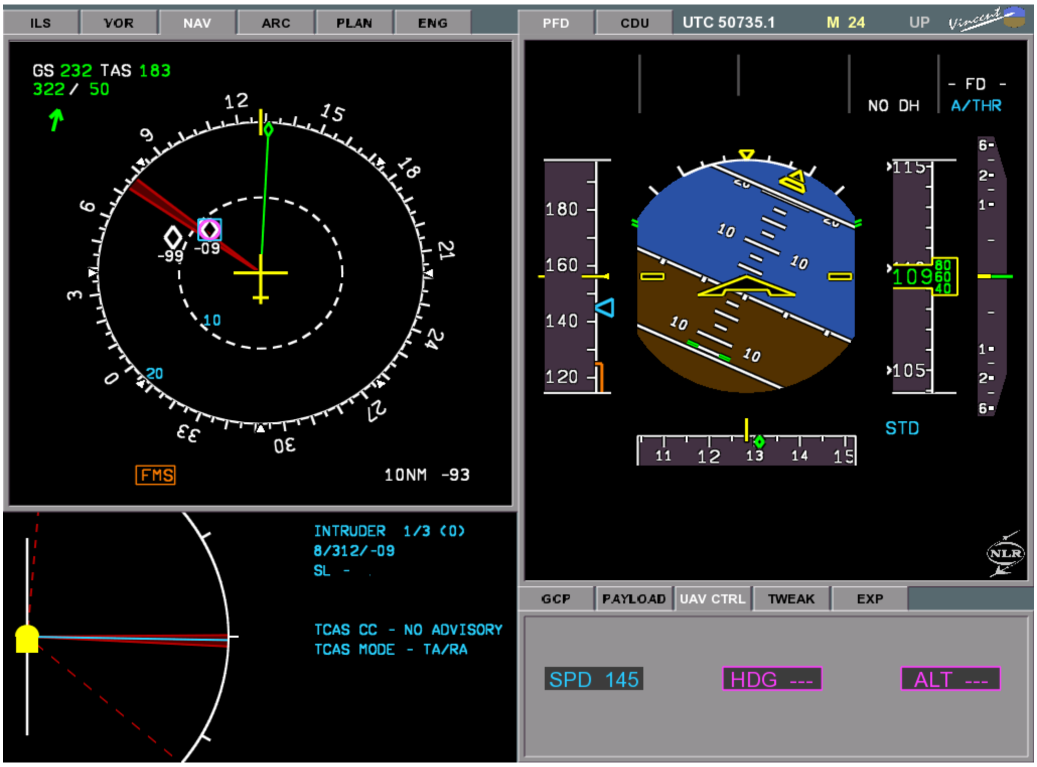

Figure 2-5 UAV Pilot HMI Displays – IR camera selected; Medium FoV

The UP can select an aircraft for monitoring by the payload operator (PO) by using one of the rotary buttons. The selected aircraft is highlighted. Confirmation with the push function of the rotary button will send the request to the PO. In order to deviate from the flight plan, the UP can provide navigation commands (speed, heading, altitude) to the PF, see Figure 2-5 on the bottom-right. Again confirmation with the push/pull buttons will send the request. The UP can also transmit a “resume flight plan” command by clearing all navigation commands.

The PO console was similar to the UP console. The main differences were the TMFD instead of the video monitor above the display, and the Toplite TC mounted next to the computer monitor. The HMI of the operator (Figure 2-6) was similar in lay-out, specific touch screen buttons were added to control the camera. The PO will see on his traffic display which aircraft has been selected by the UP for monitoring. He can confirm the request with a pull action and, after this, he uses touch screen buttons to engage the TCAS and Scan slaving modes. Intruder classification and other information on the conflicted traffic can be reported by voice to the UP.

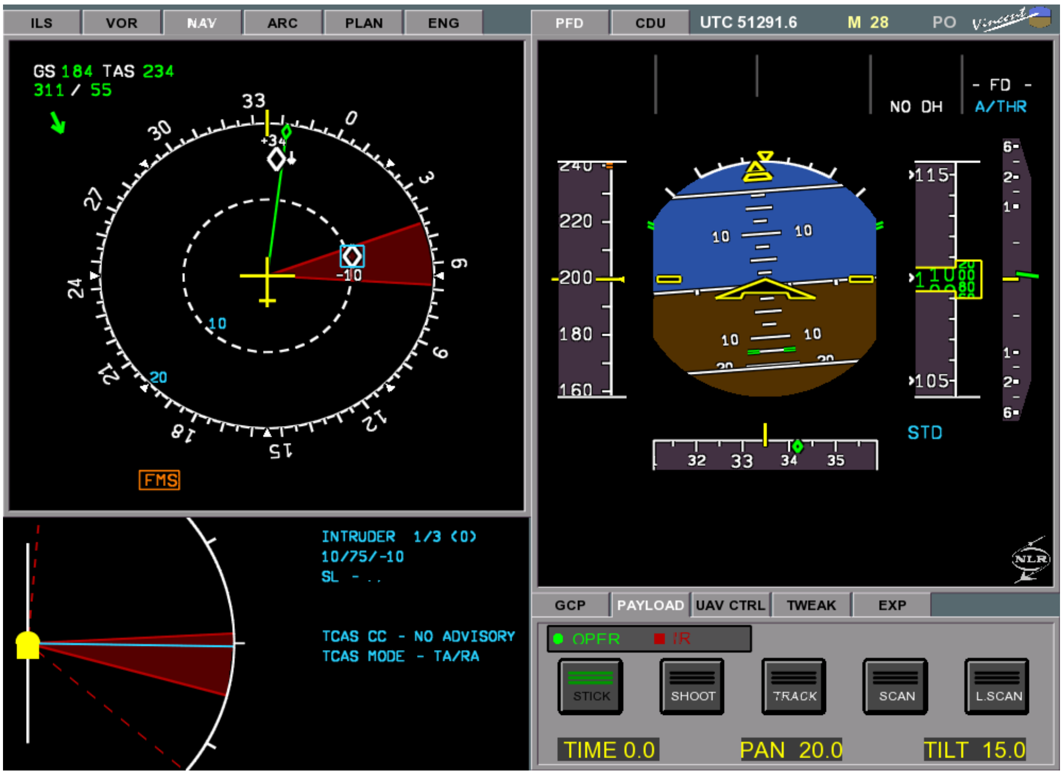

Figure 2-6 Payload Operator HMI Displays – IR camera selected; Wide FoV

Navigation information was available for the UP from a flight plan (as would normally be programmed into an FMS before the flight) and deviations from that flight plan should be communicated by the UP via a Pilot Flying Instruction Display in the Citation's cockpit. The PF manually sets heading, speed and altitude commands from the UP into the autopilot of the Cessna Citation.

The Pilot Flying (PF) display is very similar to the UP display, only the camera view angles are not displayed because no picture is included. The PF can acknowledge the UP's navigation requests via the touch screen buttons on the display.

2.3 Instrumentation

All communication between the different computers is based on the internet protocol and relayed via an Ethernet switch. All Ethernet data streams are recorded and time stamped with UTC from a GPS-receiver for data analysis and replay of the flight. Digital video recorders are present to record all voice communication in the cabin and the cockpit on one audio channel and on three video channels: the selected camera with the video overlay from the TMFD, the selected camera sensor with raw payload data and the non-selected camera sensor with raw payload data. Also the video data is time-stamped with UTC for correlation with the other recorded data.

3 Certification

As mentioned earlier the selection of the EO/IR camera was delayed because the weight and size of this sensor would effect the location of the payload. And the location would have a big impact on the certification plan for the Citation II research aircraft. Although the NLR is certified for maintenance and small modifications on this aircraft it became clear very soon that is this case a Supplemental Type Certificate from the Dutch CAA [6] was required. After some initial calculations on the structural strength of the nose at the location of the weather radar is was decided that the selected EO/IR payload could be placed in the nose of the aircraft in an upstanding position. To prevent the generation of vortices two fairing had to be designed and manufactured: a big one after the turret and a small one in front of the lenses. The second one was needed to prevent the vortex generation at the sharp edges of the turret. From a long series of items on the FAR 25 list that were affected by this modification, the main concerns were related to structure and aerodynamics.

3.1 Structural aspects

The design of the supporting structure can be seen in Figure 3-1. In combination with a report on strength and stiffness of the installation this aspect of the aircraft modification was accepted by the Authority.

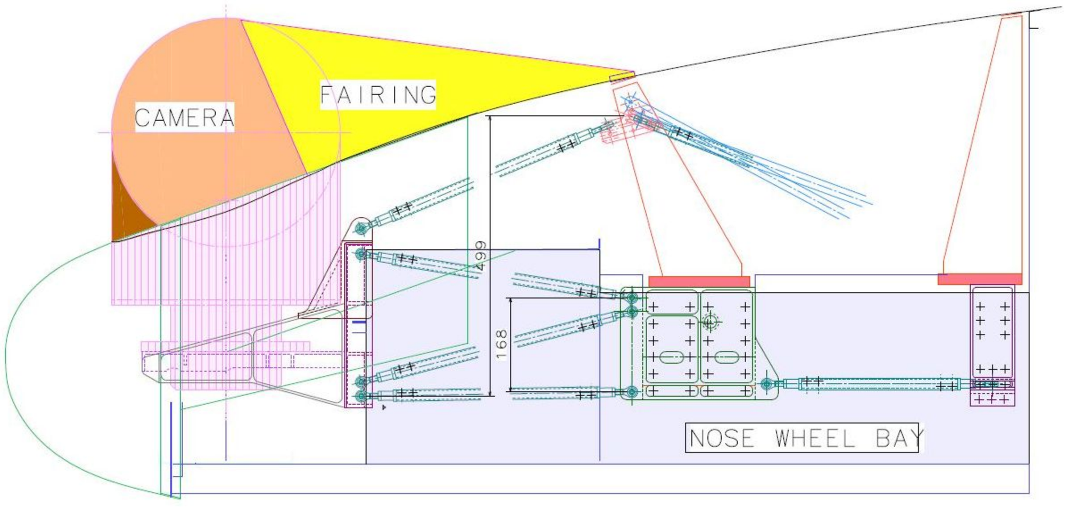

Figure 3-1 Structural design for installation of Toplite in nose of Citation

The actual modifications, needed to replace a 6 kg weather radar by a rotating 60 kg EO/IR payload, can be seen in Figure 3-2. Of course the original nose of the aircraft was saved and for this configuration with a hole on top a second nose was purchased. Replacing the weather radar by a camera limited the operational envelop to almost VMC and a maximum speed of 235 knots.

Figure 3-2 Citation PH-LAB with weather radar or EO/IR payload

3.2 Aerodynamic aspects

Certification requirements on aerodynamics were covered in two ways. First the results of a theoretical analysis based on computer simulations were reported. The aero dynamical consequences of the proposed modification to the external shape were investigated with Computational Fluid Dynamics (CFD) tools. Figure 3-3 shows an example of the computer model that was used for the payload installation on the left and the flow analysis with respect to the effect of the payload and fairing on Altitude and Speed indication on the right. In this way all possible aerodynamic effects were analyzed.

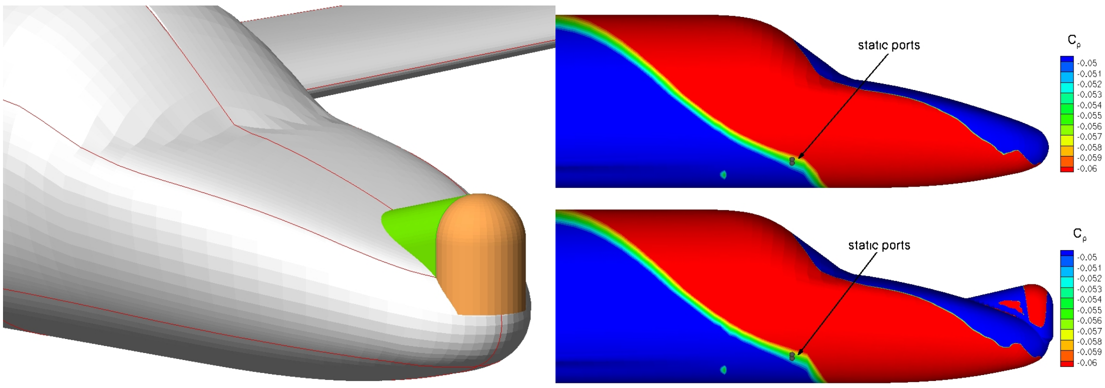

Figure 3-3 Payload installation model and influence on static port

3.3 Certification flights

Afterwards a small flight test certification program was executed in accordance with the certification plan to judge the effects of the payload in flight. Video cameras were installed on the left and right side of the glare shield and a number of woolen threads were attached to the nose and fairing to visualize the airflow. On the left side of Figure 3-4 the configuration for these test flights is shown. After some ground and taxi tests the certification process could be finalized with three certification flights. Rotating the payload still caused small vortices that hit the windscreen, but this was acceptable because during critical phases of the flight the payload will be stowed in a backwards, down looking position.

Figure 3-4 Payload installation before and after certification

Nevertheless it was decided to adjust the fairings and diminish all spaces between the turret and the fairings as much as possible without hampering the free rotation of the turret up to the maximum rate of 60 degrees per second. The final result is shown on the right hand side of Figure 3-4. Note that the maximum down looking angle, that was already limited by the installation in upstanding position, was further limited by the front fairing. For the OUTCAST tests this was no real limitation. Also due to the location of the payload with respect to the location of the engines the operation in known ice conditions was forbidden.

4 Flight tests

4.1 Objectives

Currently the development of “Detect and Avoid” systems is a chicken and egg situation where activities on system specifications and actual system developments are conducted in parallel. Many studies are paper studies, which may be based on statistical or empirical data from the past, but are not tested in reality in first hand. The OUTCAST flights tests could play a role in shedding light on the equipment performance of the concept under consideration in OUTCAST, but also on the requirements and specification side.

The technical objectives of the project are:

Specifications and requirements

- Determine the required (equivalent) level of safety
- Evaluate, as far as possible, the completeness and correctness of functional and performance specifications of detect and avoid systems that are currently under development.

“Detect and Avoid” system performance

- Determine actual performance of a typical TCAS system, with respect to detection of, tracking of, and alerting for intruders equipped with Mode S radar transponders.
- Determine the actual performance of a typical UAV EO/IR camera (stand-alone, slaved to TCAS, in terms of detection, tracking, and classification)
- Determine what is needed in the UAV Ground Control Station to provide sufficient situational awareness.

The communicative objective of the project is:

- Familiarize the civil and military stakeholders with the OUTCAST results, and with routine (military) UAV operations in non-segregated airspace under “peacetime conditions[4)]”.

4.2 Flight Test scenarios

Three types of scenarios have been defined for the flight tests to evaluate the Detect and Avoid capability of the OUTCAST concept. The scenarios provide an incremental build up of the test programme, slowly increasing the realism.

[4)] The term “Peacetime conditions” is used to describe that (part of) the flight is conducted in airspace where separation provision and collision avoidance are executed according to ICAO regulations.

1. One-on-one passive scenarios ("Detect")

Collision scenarios (with a safety altitude split) are staged in restricted airspace between the Citation and the three RNLAF intruder types: PC-7, Fokker 50 and F-16. The focus of these scenarios is to evaluate the "detect" part of the process, gathering TCAS data versus GPS position and evaluating the EO/IR acquisition of air traffic cued by TCAS. No avoidance maneuvers will be undertaken (hence 'passive scenarios').
The scenarios vary in collision geometry and closure speed, in such a way that range (0 – 20 Nm) and bearing (full 360 degrees) are sufficiently covered. To give an impression of a one-on-one scenario, an example has been given in Figure 4-1.

The vertical separation during these tests needs to be sufficiently small to obtain TCAS alerts, but sufficiently large to maintain adequate safety. At least the vertical separation should be brought down to 500 ft, in line with the minimum vertical separation distance and equal to the minimum miss distance for collision avoidance as defined by the authorities.

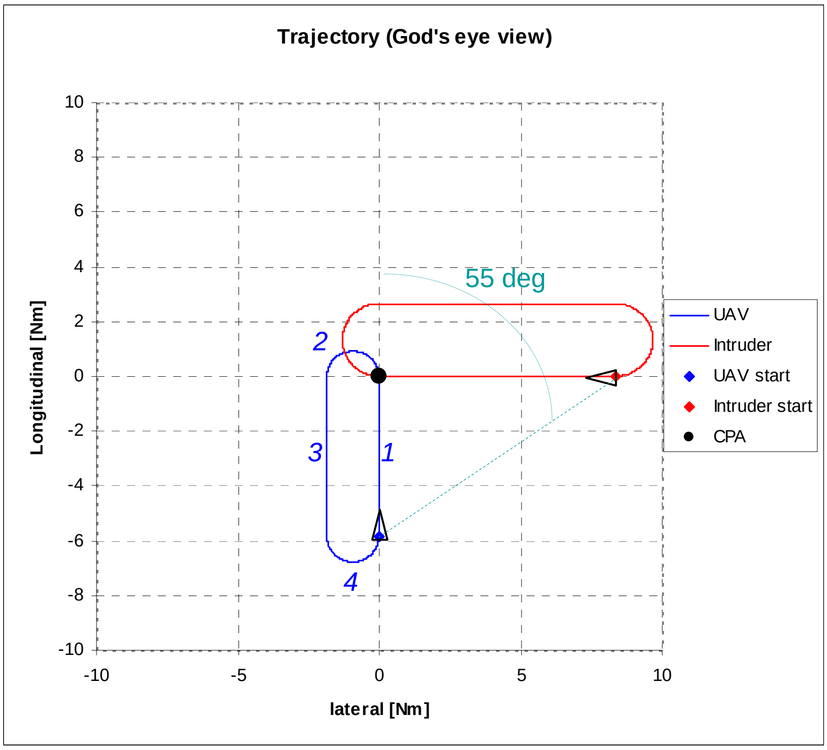

Figure 4-1 Example of one-to-one passive scenario: conflict with Fokker 50 at bearing 55 deg

2. One-on-one active scenarios ("Detect and Avoid")

Collision scenarios similar to the passive scenarios are staged in restricted airspace between the Citation and the RNLAF PC-7, but now the focus is on "situational awareness" and the "avoid" part of the process (hence the name 'active scenarios'). Both self-separation and collision avoidance are addressed, by varying the distance at which the conflicts are initiated, and the relative closure speed.

3. Roaming scenarios (“Detect and Avoid” in non-segregated airspace)

UAV flights will be simulated as realistically as possible outside segregated airspace above the Netherlands, with other airspace users as “targets of opportunity”. Part of the flight focuses mainly on traffic detection (UAV crew ‘passive’) and in part of the flights the UAV crew will perform self-separation to avoid any collision hazards and triggering of TCAS alerts (UAV crew ‘active’). An example of this scenario is presented in Figure 4-2.

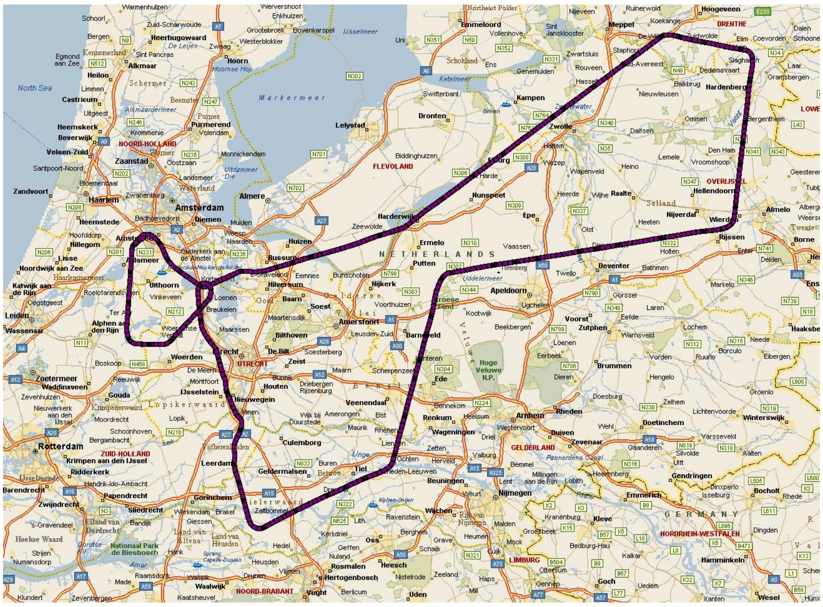

Figure 4-2 Example of a roaming scenario over the Netherlands

Figure 4-3 shows on the left the RNLAF Pilatus PC-7 intruder aircraft during the altimeter check run. For every new combination of aircraft this run was required in order to be able to use a vertical separation of 500 ft safely during the tests even in a climbing situation. On the right hand you see the PO display with a nice view from the EO camera during the first one-to-one scenario in November 2006. Almost all the one-to-one scenarios were executed in a restricted area in the North-East of the Netherlands. For two flights with the Fokker 50 a restricted area north of the Netherlands above the North Sea was used.

Figure 4-3 The RNLAF PC-7 intruder during the altimeter check

Table 4-1 presents an overview of all OUTCAST flights with the NLR Citation II research aircraft for the OUTCAST project. In the period from the first certification flight on 25th of October 2006 till the last flight with a stakeholder on the 24th of April 2007 a total of more than 36 test hours with dedicated data for analysis were recorded.

Table 4-1 Overview of OUTCAST flights

OUTCAST	**Flights**				
Flight No	Scenario	date	UTC	Meas. period [min]	Remarks
1866		25-10-2006			cert.
1867		26-10-2006			cert.
1868		26-10-2006			cert.
1871	301	8-11-2006	1045-1250	115	roaming
1872	101	9-11-2006	0837-1032	65	PC-7
1873	102	9-11-2006	1302-1452	60	PC-7
1948	302	16-3-2007	1247-1405	70	roaming
1949	107	20-3-2007	0850-1115	95	Fo-50
1950	108	20-3-2007	1247-1441	64	Fo-50
1951	110	21-3-2007	0820-1035	85	Fo-50
1952	111	21-3-2007	1306-1417	0	Fo-50
1953	111/109	22-3-2007	0836-1042	76	F0-50
1954	112/107	22-3-2007	1300-1500	70	Fo-50
1955	303	23-3-2007	1136-1318	90	roaming
1956	103	27-3-2007	0735-0930	65	PC-7
1957	104	27-3-2007	1125-1307	52	PC-7
1958	105	28-3-2007	0810-0932	32	PC-7
1959	106	28-3-2007	1124-1312	58	PC-7
1960	114/ 115	30-3-2007	0858-1110	92	F-16
1961	113	30-3-2007	1245-1430	65	F-16

OUTCAST	**Flights**				
Flight No	Scenario	date	UTC	Meas. period [min]	Remarks
1962	201	2-4-2007	0741-0945	74	PC-7
1963	202	2-4-2007	1116-1324	78	PC-7
1964	206	3-4-2007	0736-0936	70	PC-7
1965	207	3-4-2007	1123-1327	74	PC-7
1966	209	4-4-2007	0744-0930	56	PC-7
1967	215	4-4-2007	1127-1329	72	PC-7
1968	218	5-4-2007	0747-0938	61	PC-7
1969	210	5-4-2007	1146-1337	61	PC-7
1970	304	6-4-2007	0830-1100	142	roaming
1971	305	12-4-2007	0828-0948	72	roaming
1972	102	13-4-2007	0812-1006	64	PC-7
1973	208	16-4-2007	1230-1400	40	PC-7
1974	306	18-4-2007	0849-0936	40	stakeh
1975	307	20-4-2007	1037-1136	52	stakeh
1976	308	23-4-2007	0806-0900	45	stakeh
1977	309	24-4-2007	1219-1300	35	stakeh
			Total	2190	
				36 hour 30 min	

4.3 Initial results

From the flight tests with the demonstration system a number of preliminary results can be derived. Final results will be available after a period of extensive data analysis which was started in June 2007.

With respect to Detection the following observations were made:

- In most weather conditions encountered during the trials the IR camera is able to detect the other aircraft over larger distances and with less visibility than the human eye;
- Usually the UAV crew ‘sees’ the other traffic earlier than the pilots in the cockpit;
- In some cases the pilots located the intruder earlier than the camera;
- In case of multiple targets, the camera acquisition time is too long for successive detection and tracking of more targets;
- Range and height information from TCAS is important to detect and track the right target.

The data analysis should indicate under what conditions the pilots detected the intruder earlier than the UAV crew and it should be investigated what this means for ‘equivalence of safety’.

With respect to Identification the following observations were made:

- Sometimes the identification of the class of aircraft can be done in infrared;
- The identification of the type of aircraft needs to be done optical.

The data analysis should indicate whether an accurate Identification of traffic is required for collision avoidance. Maintaining separation with small evasive vertical and lateral maneuvers was preferred by UAV crews even without identification of the target.

With respect to the Situational Awareness of the UAV crew the following observations were made:

- TCAS information seems to be the main input for the UAV crew for separation;
- Interpretation of the visual clues from the camera picture requires different training than for pilots;
- Combination of information from different displays together with the maneuvers of the 'UAV' was very difficult.

The data analysis should indicate how the situational awareness can be improved by displaying the right information in the right place and by dedicated UAV crew training.

5 Conclusions

The initial conclusions on the OUTCAST project are:

- Moderately positive about the OUTCAST concept, but there may be limitations in weather conditions and dense traffic areas with multiple targets
- The project generated a lot of results regarding
  - Operational experience from real flight tests
  - New input for rule makers (international importance)
  - Improvements for the cooperative and non-cooperative sense and avoid technology and HMI development
- Recorded data should be used to replay the flight for other UAV crew's to get more opinions
- Final conclusions can only be derived after the analysis of a wealth of recorded data
- Further investigations should be directed towards active fusion of data from both sensors to create more accurate and continuous tracking of the intruders

The operation of UAVs in segregated areas as an outcast is not necessary. There seems to be options to operate UAVs as friends in civil airspace to do the 3D-work for us: dull, dirty and dangerous.

References

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[6] Civil Aviation Authority-Netherlands (S. Oudakker, L.Brussaard), OUTCAST Installatie Cessna Citation PH-LAB", Supplemental Type Certificate, number SA0601NL, issue date November 7, 2006.