Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

Executive summary

Small Unmanned Aircraft Systems (UAS) for Law Enforcement

The use of UAS within the Dutch Police forces

Problem area
The Netherlands Police Agency (KLPD) recognised the potential of small Unmanned Aircraft Systems (UAS) for police tasks and asked NLR to support the introduction of UAS within Dutch Police forces.

Description of work
NLR defined scenarios to support the Agency with the Operational Test and Evaluation (OT&E) of a number of UAS. The aim was to determine - by executing test flights - to what extent a specific small UAS type meets a requirement, and which small UAS performs better. It is essential that information generated from air surveillance with UAS is integrated in information systems already in use. This subject was dealt with in the Fire-Fly project. The goal was to integrate acquired images into the command chain, instead of just presenting them to the Remote Pilot.

The KLPD wished to give attention to all possible safety and training aspects to enable the safe operation and application of small UAS. NLR was asked to develop and provide a small UAS Remote Pilot Training. Evaluation of the use of small UAS, revealed the need for technical and operational improvements, among which are: airworthiness qualification, robustness, user interface and operation in stronger wind conditions.

Results and conclusions
This work confirmed the usefulness of small UAS for police force activities in addition to the already available manned aeroplanes and helicopters.

Applicability
The support activities performed by NLR contribute to the introduction and useful application of small UAS within different Police forces.

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Small Unmanned Aircraft Systems (UAS) for Law Enforcement

The use of UAS within the Dutch Police forces

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Abstract[1]

The Netherlands Police Agency (KLPD) first started experimenting with small Unmanned Aircraft Systems (sUAS) in 2007. After some first experiments, the Agency started to investigate the application of these aircraft for a diversity of police force specific scenarios. A more thorough approach was chosen by involving the National Aerospace Laboratory NLR. Scenarios were defined to support the Agency with the Operational Test and Evaluation (OT&E) of a number of UAS. The aim was to determine - by executing test flights - to what extent a specific sUAS type meets a requirement, and which sUAS performs better. This evaluation confirmed the usefulness of sUAS for police force activities in addition to the already available manned aeroplanes and helicopters. The manned and unmanned aircraft (systems) operated by the Dutch national police address different information needs. It is essential that information generated from air surveillance seamlessly integrates in the information systems already in use. This subject was dealt with in the Fire-Fly project, for which NLR developed the imaging system. The goal of this project was to integrate the acquired images into the command chain, instead of just presenting them to the Unmanned Aircraft's Remote Pilot.
Another area of interest is the upcoming regulation for professional use of sUAS. It is the concern of the Dutch police force that new rules and regulations enhance safety, without unnecessary limiting sUAS operations. Meanwhile attention is given to all possible safety and training aspects to enable the safe operation and application of sUAS. NLR was asked to develop and provide a sUAS Remote Pilot Training.
With respect to the systems themselves, technical and operational improvements are needed on several areas. Especially airworthiness qualification is considered important to enable practically unlimited operations within populated areas. Secondly, robustness, user interface and operation in stronger wind conditions are high on the police forces list of requirements.
Next to the KLPD the article encompasses other Dutch police forces and the Civil Military Cooperation (CIMIC).

1. INTRODUCTION

Air-to-ground surveillance systems provide a unique contribution to gain situational awareness. The overview picture that they generate, combined with their perspective from above, provides users with a context and type of information unmatched by other sources. Soon after military UAS operations started, these systems attracted the attention of the Dutch police forces. The Netherlands Police Agency (KLPD) started experimenting with Unmanned Aircraft Systems in 2007 and since then investigated the application of these aircraft for a diversity of police force specific scenarios. The activities started by simply acquiring an unmanned helicopter, but rapidly evolved into a more thorough approach including the involvement of the National Aerospace Laboratory NLR. Also the

[1] Paper presented at the UAS 2011 conference,
organised by UVS International, in Paris, France, 14–16 June 2011.

Universities of Delft and Wageningen were contacted for cooperation. Trials were set up to obtain more insight in the possibilities and applicability of the different systems. Scenarios were defined and tested. This confirmed the usefulness of Unmanned Aircraft Systems for police force activities in addition to the already available manned aircraft. With respect to the systems themselves, technical and operational improvements are needed on several areas, of which the airworthiness qualification is the most important from a safety point of view. The Remote Pilot Station is probably one of the most urgent from a user's perspective. Another important area of interest is the upcoming regulation for professional use of UAS. It is the concern of the Dutch police force that the rules and regulations might limit their UAS operations. Meanwhile attention is given to all possible safety and training aspects to enable the safe operation and application of small UAS (0 < Maximum Take-off Mass < 150 kg).
Next to the KLPD activities, this paper includes activities performed by the regional police force of Amsterdam-Amstelland and the Program Against Organized Crime And Cannabis Cultivation.

2. SMALL UAS USED

The Dutch police forces use several small UAS, either owned by the KLPD and the regional police force Amsterdam-Amstelland, or under support from the Ministry of Defence. Within the Program Against Organized Crime And Cannabis Cultivation experiments were performed with a rented small unmanned rotorcraft for the fight against narcotics. The UAS used and some examples of their application are described below. The main specifications are presented in table 1.

Table 1. UAS used by the Dutch Police Forces

UAS used by the Dutch Police Forces	Delft Dynamics RH2a	AscTec Falcon 8	AirRobot AR-100	CannaChopper Suave 7	AeroVironment Raven B
Dimensions:					
- Rotor	Ø 180 cm	8 rotors	4 rotors	Ø 182 cm	
- Overall span		77 cm	100 cm		137 cm
All-up Mass	17.0 kg	1.8 kg	1.0 kg	15 kg	1.9 kg
Payload	2.5 kg	0.5 kg	0.2 kg	6 kg	0.2 kg
Engine	combustion	electrical	electrical	combustion	electrical
Endurance	60 minutes	15 minutes	15 minutes	120 minutes	90 minutes
Max. windspeed	10 m/s (5 bft)	8 m/s (4 bft)	4 m/s (3 bft)	10 m/s (5 bft)	10 m/s (5 bft)
Payload sensor	EO/IR	EO/IR	EO	EO/IR/sniffer	EO/IR

2.1 Netherlands Police Agency (KLPD)

The KLPD uses one Delft Dynamics RH2a robot helicopter, three Ascending Technologies Falcon 8 UAS, operated by themselves and the AeroVironment Raven B, operated by the Netherlands Defence Forces and made available under a support agreement to the Dutch Police Forces. The main applications for these UAS are obtaining a better situational awareness by getting a bird's eye view and mapping of the crime scene. The RH2a is used more often in harsh environments like the higher wind speeds and whenever a longer endurance is required. The Falcon 8 is used more often in close range, quick response, waypoint navigation and short endurance circumstances. The Falcon 8 can be deployed faster than the RH2a. The Raven B is used for special circumstances in which the small unmanned rotorcraft capabilities do not satisfy the required operation. The Raven B is operated by the Ministry of Defence in separated airspace (e.g. special rules area or parts of a control zone, CTR).

- ***Delft Dynamics RH2a***
  The RH2a system consists of a helicopter with camera or other sensor(s) and a Remote Pilot Station from which the Remote Pilot controls and monitors the helicopter. The helicopter is equipped with sensors and a computer system that provide flight stabilisation and control.

- ***AscTec Falcon 8***

The Falcon 8 is equipped with 8 rotors and able to maintain high levels of flight stability in wind speeds up to 10 m/s. If one of the rotor/motor combinations fails in flight, it is still able to continue flying with maximum payload and strong winds. As soon as a GPS signal is established the Falcon 8 is able to hold its position. By using the way-point planning software a mission can be planed, before and during the flight. The system can also be controlled by the Remote Pilot using the life video feed. The V-layout of the Falcon 8 enables the camera to be faced completely down, horizontal and completely up without any of the rotors blocking the image.

- ***AeroVironment Raven B***

The Raven B is a lightweight fixed wing unmanned aircraft suitable for rapid deployment and low-altitude surveillance and reconnaissance. The system can be piloted manually or programmed for automatic operation, utilizing the system's advanced avionics and precise GPS navigation. The hand-launched Raven B provides aerial observation, day or night, at line-of-sight ranges up to 10 kilometres.

2.2 Amsterdam-Amstelland Police Force

Amsterdam-Amstelland police force uses one AirRobot AR-100 UAS. Similar to the UAS used by the KLPD, the main objectives for operating this UAS are better situational awareness and crime scene mapping. The AR-100 has been used successfully during clearance of squatter's actions and multiple mappings of accident and crime scenes.

- ***AirRobot AR-100***

The AirRobot is equipped with 4 rotors and allows for autonomous stable 'hands-off', hover operation using GPS. The unit is further stabilized with a combination of gyroscopic, barometric and magnetic sensors. The AR 100 can maintain its position, direction and flight altitude without operator interference. It can be controlled by the Remote Pilot using a life video feed. The unit does not have to be in sight, this way the unit is flown like the operator is sitting in it. All moving parts are protected by a ring, which avoids damage to the rotors in case of an unintended collision.

2.3 Program Against Organized Crime And Cannabis Cultivation

Within this program a rented Suave 7 unmanned helicopter was deployed successfully in April 2009 in the battle against the illegal growth of cannabis. This program against organized crime and cannabis cultivation was already successful on the first day the helicopter was deployed, detecting several cultivation locations. The unmanned helicopter became well known under the name 'CannaChopper' due to abundant media attention.

- ***CannaChopper Suave 7***

The Suave 7 can hover or fly pre-planned routes for several hours. The Remote Pilot can fly it by remote control or use the automatic way-point navigation system. The onboard equipment consists of a high quality digital camera and a heat sensing camera. Additionally, this aerial observation tool is equipped with the 'cannabis sniffer', a sensor used for the intake of air samples, to instantly recognise particles indicating the presence of cannabis.

3. EVALUATION AND IDENTIFIED SCENARIOS

In 2009 the KLPD initiated a project to determine the operational usefulness of different types of aerial surveillance systems, for example helicopters, fixed wing aircraft and a balloon. The National Aerospace Laboratory NLR, due to its experience with testing of small UAS for the Netherlands Defence, was asked to support the KLPD with the Operational Test and Evaluation (OT&E) of a number of UAS. Several police units drafted scenarios based on their tasks to describe the possible employment of UAS systems. These 'scenarios' were used to capture the operational requirements for UAS. From these requirements, scenario independent test flights were developed. The aim was that by executing these test flights it could be determined to what extent a specific UAS type meets a requirement and if possible which UAS performs better or worse. The scenarios and defined tests are presented in table 2. The tests can be executed independent from each other and can also be used for training the UAS Remote Pilots to gain operational experience.

Table 2. Scenarios related to test descriptions

		Test code and test description											
		a1	a2	a3	b1	b2	B3	c1	c2	d1	d2	e1	e2
	Scenario title	Point observation	Line observation	Area observation	Recognition of group of people	Shape recognition in thermal imagery	Detail recognition with day light camera	Position fix	Continuous observation	Noise detection of UAS aircraft	Visual detection of UAS aircraft	Use of UAS in building	Land/Start at distance and deployment of equipment
1	Security measures international venue			x	x		x	x	x				
2	Indoor observation			x	x		x	x	x			x	
3	Recognize weed containers		x		x	x		x					
4	Event			x	x		x	x					
5	Record crime scene		x				x	x					
6	Hostage situation	x				x	x	x		x	x		x
7	Observation during arrest	x				x	x	x		x	x		
8	Disaster		x			x	x	x					
9	Reconnaissance in urban area			x		x	x	x		x	x		
10	Burning ship in port			x		x	x	x	x				
11	Search missing person		x			x	x	x					

4. AIR SURVEILLANCE MEANS

The KLPD operates both manned as well as Unmanned Aircraft Systems with surveillance capabilities. These aircraft address different information needs through their differences in flight endurance, visibility, payload capacity etc. UAS play a complementary role with respect to manned aircraft and can not be just seen as competitors. Each means for air surveillance has its own specific advantages and disadvantages. Table 3 presents an overview as identified by the KLPD.

Table 3. Air surveillance means overview

	Advantages	Disadvantages	Remarks
Manned Helicopters	Many/large sensors Long endurance	Noise Visibility No local control	No regulation development issues
Manned Aeroplanes	Many/large sensors Long endurance	Noise Visibility No local control	No regulation development issues
Satellites	Overview large areas	Old information Weather dependent Low resolution	High cost or low reliability No regulation issues
Aerostats	Silent Long endurance	Visibility Wind sensitive Difficult repositioning	
Unmanned Rotorcraft (combustion)	Flexible applicable Local control Low visibility	Small sensor payload Noise (limited) Low maturity	Regulations under development
Unmanned Rotorcraft (electrical)	Flexible applicable Local control Low noise Low visibility Ease of use	Limited sensor payload Limited endurance Low maturity	Regulations under development
Unmanned Aeroplane (electrical)	Flexible applicable Local control Low visibility	Limited sensor payload No vertical take-off Limited urban suitable	Raven B UAS operated by the Ministry of Defence Flown in separated airspace

Evaluation of the advantages and disadvantages by assigning values to the specific characteristics resulted in Figure 1, clearly showing the supplementary value of UAS to manned surveillance aircraft.

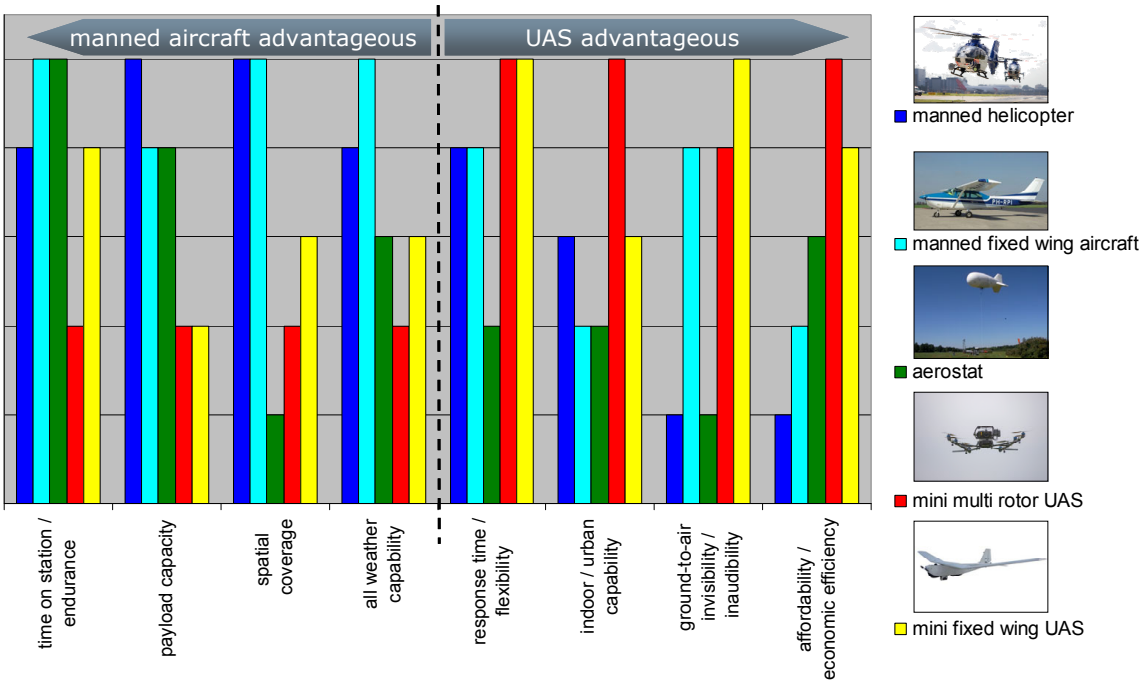
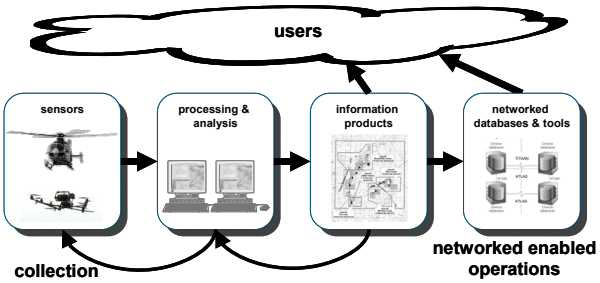


Figure 1. Graphical presentation of the available surveillance means characteristics.

5 INFORMATION INTEGRATION



Although the availability of air-to-ground surveillance means already provides a unique contribution to building up situational awareness, the presentation to the right police officers combined with the required meta data completes the overview picture and provides users with a context and type of information unmatched by other sources. Therefore, it is essential that information generated from air surveillance should seamlessly integrate in the information systems already in use. This integration aspect is often undervalued.

As mentioned, the manned and unmanned aircraft (systems) operated by the Dutch national police address different information needs. However, the integration issue with information is largely comparable. Technical and operational challenges remain and new challenges arise in efforts to maximise the operational and economical benefit of air-to-ground surveillance systems.

Figure 2. National helicopter aerial video network.

A ground station network – national (Netherlands) coverage – is being installed for wireless data transmission between the (manned) helicopters and the users on the ground, see figure 2. The smaller UAS require a different integration, as these act in tactical operations and require local control. In this respect, a project should be mentioned that focused on the issue of information integration, and which was closely followed by the Netherlands Police Agency, the so called Fire-Fly project.

5.1 The Fire-Fly project

In the Fire-Fly project, NLR was asked by the fire brigade of the North and East Gelderland safety domain to research the possibility of deploying a small, unmanned flying observation system to supplement existing fire-fighting equipment. The goal of the project was to offer chief fire fighting

officers a real-time overview of the fire area by sending the obtained aerial images to a crisis centre as well as the police, other fire brigades and fire fighters in the field, allowing them to tackle the fire more effectively. NLR was in charge of the technological development of the imaging system, including system design, the processing of video images, and the storage of data and visual images.

Tests were conducted with the Delft Dynamics unmanned helicopter in 2010, transmitting the first metadata images to the fire brigade's crisis management system, where all data are gathered. In collaboration with the Amsterdam-Amstelland fire brigade, video images were acquired by the UAS for use during an exercise. During the end demonstration on 11 may 2011, live images were sent directly to the fire brigade's crisis management system, without intermediate steps. The images were gathered by two Unmanned Aircraft, the Delft Dynamics Robot helicopter, and the AeroVironment Puma AE and successfully fed into the crisis management system.

NLR conducted the Fire-Fly project in cooperation with the fire brigade of the North and East Gelderland safety domain as well as the industrial partners Nieuwland Automation, Geodan Systems & Research and Delft Dynamics. The project was part of the Safety chapter of the Dutch government's Social Innovation Agenda, which in turn is part of a broader government programme stimulating entrepreneurship in innovation in the Netherlands.

NLR research activities are ongoing, linking the NLR's Quadcopter via a Remote Pilot Station interface provided by NLR's Multi-UAS Supervision Testbed (MUST). The video images and data traffic will subsequently be processed and modified to offer the required overview to the end users.

6. OPERATIONAL ASPECTS

Currently small UAS air regulations in The Netherlands are under development and therefore all Police Force small UAS operations are currently being performed under the Model Flying Regulations. This limits the use of UAS to those aircraft with a maximum take-off mass below 25 kg (including fuel and payload). Additionally, the main requirement is that the operation of the aircraft may not endanger any person or property on the ground nor other airspace users. To meet the first part of this requirement, the area of operation can be closed to the public. The regulations limit operations to a maximum operating height above ground level of 300 meters in class G airspace. Operations in class C airspace have been arranged with local ATC in a covenant. To ensure public safety, the Minister of Transport can close or restrict parts of the airspace temporarily upon request of the local authorities. In practice, small unmanned rotorcraft are typically operated between 15 and 70 meter above ground level and the fixed wing aircraft (Raven B) is operated between 120 and 180 meter above mean sea level in separated airspace (day and night). All civil operations must be performed within Visual Line Of Sight (VLOS) of the Remote Pilot.
The main limiting factors experienced for Police force operations are the prohibited (civil) operations beyond VLOS and at night. Another limiting factor is the maximum wind speed in which the UAS can be operated. The average wind speed in The Netherlands is more than 4 bft for over 45% of the time throughout the year.

7. UAS REMOTE PILOTS TRAINING

To enhance safe operations, a need for a more thorough technical and theoretical background was recognised and NLR was asked by the KLPD to develop a UAS Remote Pilots Training. Since the legislative framework for UAS operations was lacking in the Netherlands, there were also no legal requirements for crew training and licensing. NLR already wrote a training plan for the training of it's own Facility for Unmanned Rotorcraft Research (FURORE) UAS Remote Pilots, which was approved

by the Netherlands Civil Aviation Authorities (CAA) until legislation is introduced. This training plan, derived from Private Pilot Licence learning objectives, was further adjusted on the basis of available information on regulations under development in this area. Objective of the Remote Pilots Training is the proper, safe and with understanding operation of a Small Unmanned Rotorcraft System in the Netherlands for police tasks.

The following general aviation theory subjects, adjusted for Small UAS operations, are included in the training:

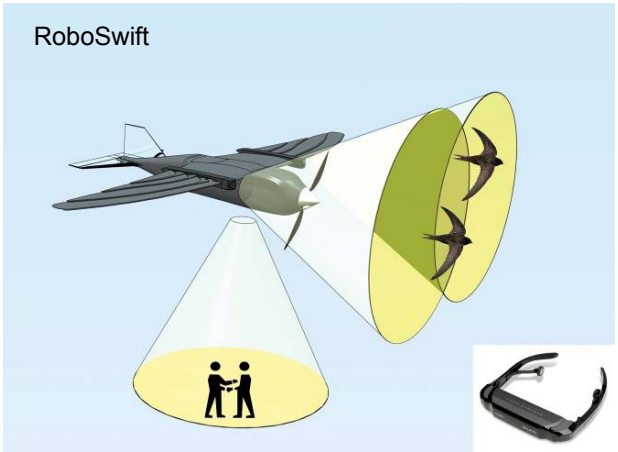
- UAS General knowledge
- Principles of flight
- Flight performance and planning
- Air law
- Meteorology
- Human performance and limitations
- Navigation
- Operational procedures.

NLR prepared a training programme of two days in which practical simulation training is included upon request of the National Police Agency. The students are provided with a syllabus and tested on the knowledge gained.
This multidisciplinary training is the result of close cooperation between several NLR departments with knowledge on (rotorcraft) UAS, Human Performance, and UAS operations.

The training was first given March 2010 at NLR and attended by UAS Remote Pilots from multiple Police forces.

8. COOPERATION

In carrying out a large number of police tasks an increasing need for air surveillance is identified. Some (regional) police forces have already purchased some smaller UAS and gained experience with the technology and operational use. The KLPD has set a goal to support various police forces by the implementation of UAS. Co-operation with military forces has been established and the cooperation with emergency services like fire brigades is expected to follow soon. The support of police tasks by the Ministry of Defence has been agreed between the Ministries of Interior and Defence. The agreement defines when and where the Ministry of Defence supports civil authorities. Such a commitment is always at the request of and under the leadership of the civil authorities.



The KLPD supports the development of the RoboSwift, a micro airplane fitted with movable wings, inspired by the common Swift, under development at the University of Wageningen and the Technical University of Delft.
Together with the Technical University of Delft the EMAV 2009 conference was organised and sponsored with equipment and personnel. Currently the IMAV 2011 conference is being organised, which will also be sponsored as well as provided with a price for the best 'user deployable UAS'.

9. UAS IMPROVEMENTS NEEDED

Main focus within the Dutch police is the tactical deployment of UAS. The goal is to obtain information through (remote) sensing at difficult and/or dangerous locations. The operational experience and use of UAS learned that the currently available UAS still have limitations, but can become a powerful tool.
Improvements of the current systems are necessary on:

- Airworthiness qualification;
- Robustness;
- Operation in stronger wind conditions;
- User interface (control logic);
- Data transfer to command station in a secure network;
- Mobility (by one person);
- Sensor quality;

Especially airworthiness qualification is considered important to enable practically unlimited operations, also within populated areas. Secondly robustness, user interface and operation in stronger wind conditions are high on the police forces list of requirements.

10. CONCLUSIONS

The Netherlands Police Agency (KLPD) recognised the added value of Unmanned Aircraft Systems for a diversity of police force specific scenarios.

The police forces in the Netherlands operate with several unmanned rotorcraft systems in the Maximum Take-Off Mass range below 25 kg, among which are: the Delft Dynamics RH2a, the AscTec Falcon 8, and the AirRobot AR-100. A fixed wing system (AeroVironment Raven B) operated by the Ministry of Defence is available for support of police tasks through an agreement between the Ministries of Interior and Defence.

An overview is given of the available air surveillance means available to the police force. The use of UAS clearly has an additional value next to, thus not replacing, manned aviation for police tasks.

The (initial) activities lead to the involvement of the National Aerospace Laboratory NLR for technical and operational support. Among these activities are:

- Trials to obtain more insight in the possibilities and applicability of different systems;
- Definition and testing of police task scenarios, confirming the usefulness of UAS for police tasks;
- Information integration of the acquired images into the command chain (Fire-Fly project);
- Development and providing a UAS Remote Pilot Training.

For Police force operations some limiting factors are experienced. These are the:

- Prohibited (civil) operations beyond VLOS and at night;
- Maximum wind speed in which the UAS can be operated.

With respect to the unmanned systems, the following technical improvements are high on the police forces whish list:

- Airworthiness qualification;
- Robustness;
- User interface;
- Less sensitive to (cross-)wind.

The airworthiness qualification is important both from a viewpoint of safety and to enable unlimited operations within populated areas.

The police forces are continually looking for cooperation with other technologically advanced parties for further improvement of their systems and keeping a forefront position with up-to-date technical equipment.