Swedish Evaluation of a MALE UAV-System in Civil and Military Airspace from a Civilian Airport

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This paper is a summary of the approved FMV Evaluation Test Report [1].

ABSTRACT

During may-june 2002 the Swedish Defence Material Administration and the Swedish Space Cooperation evaluated a MALE UAV-system operated from Kiruna Airport in the northern part of Sweden. The project was carried out in cooperation with the Swedish Defence forces, the Meteorological Institute of Stockholm University, the Swedish Civil Aviation Administration and with European Aeronautic Defence and Space Company and Israeli Aircraft Industry Ltd as contractors for the UAV-system (IAI/Malat EAGLE).

The test flights were performed in both civilian and military airspace, within the North European Airspace Test range (NEAT), with the UAV taking off and landing at Kiruna Airport. The evaluation was a pre-demonstration of a MALE UAV for the planned System Demonstration 2005, a demonstration of the new Swedish NBF, "Network Centric Warfare". The purpose of the evaluation was also to evaluate a MALE UAV-system for both civil and military use and, in cooperation with military and civilian airworthiness authorities, establish a feasible airworthiness process for Flight Test Permits. As Kiruna airport is the second airport in Sweden to receive the new VDL mode 4, GPS-based, transponder system, the UAV was equipped with this system.

The results from the evaluation performed show that it is possible, within the current rules and regulations, to perform flights with UAV's from a civil airport within civil and military airspace. The results also show that NEAT is a proper space to perform this type of flights, as the area is very vast. It also showed that MALE UAV-system would be of use in System Demonstration 2005 as well as for other civilian and military purposes.

1.0 INTRODUCTION

The Swedish Armed Forces (FM) view UAV's as potential platforms for different purposes in the new Swedish "Network Centric Warfare" (NBF) concept. In the NBF a great number of part systems will be

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interconnected, many times as receivers as well as distributors of information, to enhance the awareness for all involved.

In 2005/2006 FM will perform it's first test of the NBF concept, System Demonstration 2005 (SD05), where many different features of NBF will be demonstrated. As FM has no experience in handling MALE UAV-systems, FM asked the Swedish Defence Material Administration (FMV), in cooperation with the Swedish Space Cooperation (SSC), to perform an evaluation test of a MALE UAV-system during 2002 from Kiruna Airport in the northern part of Sweden.

The SSC foresee a civil use of MALE UAV's as complement to rockets and balloons for atmospheric research.

2.0 UAV-SYSTEM EAGLE

SSC performed an initial selection of suitable MALE UAV-systems available for the activities intended. Of the four contenders, European Aeronautic Defence and Space Company (EADS) with their sub-contractor Israeli Aircraft Industry Ltd was contracted with the EAGLE UAV-system.

Picture 1. The IAI/Malat EAGLE UAV-system

During the demonstration the EAGLE-system consisted of:

- One Unmanned Air Vehicle
- Two Ground Control Stations (GCS)
- Two Ground Data Terminals (GDT)
- Maintenance Equipment

2.1 UAV-system level 3

A working group within FM suggested then that Swedish Military UAV's should be classed at four different levels[1]. The classification rules were based on different system design parameters and qualification status requirements. For the actual evaluation test, the EAGLE was declared airworthy with respect of what's required for a UAV-system level 3. This means that the system fulfilled the following demands/was limited by the following restrictions:

- Operation was only allowed in restricted airspace.

[1] These suggestions have after the tests were performed been approved.

- The pilot was always to have full knowledge of the UAV's position.
- The UAV was to have system functionality that prevents the UAV to fly outside a restricted airspace.
- The UAV was to be able to immediately and in a non-hazardous way abort the flight.

2.2 VDL-mode 4 Transponder

Kiruna Airport was the second airport in Sweden to receive a ground station for the new GPS-based VDL mode 4 transponder system. An airborne transponder was, after request from the Swedish Civil Aviation Administration (LFV), installed in the UAV for LFV to perform some tests during flight. Due to the risk the UAV, in case of an emergency, could be flying "under the horizon" from Kiruna a ground station was installed also at Vidsel air base, in the southernmost part of NEAT.

The VDL mode 4 system was used as a complement to the tracking radars, for monitoring the UAV position during flight, but wasn't allowed to be relied on as a single or a primary source of UAV position, as it wasn't certified for that then.

2.3 Condensation Particle Counter

A Condensation Particle Counter (CPC) was installed in the UAV instead of the SAR during the scientific flight.

3.0 TEST ORGANISATION

The test organisation incorporated all essential functions (UAV-operation, UAV-maintenance, radar surveillance, test range support, vendor support, Kiruna airport support etc) organised directly under the responsible Chief Test Leader. This made it possible to secure for short ways of communication.

Assistance to the Chief Test Leader was supported by three Test Leaders, one from IAI, one from FMV and one from SSC.

4.0 NORTH EUROPEAN AIRSPACE TEST RANGE – NEAT

For the flights, the North European Airspace Test range (NEAT) was used for the first time. NEAT consists of two originally prepared restricted flight zones and the airspace in between. The intermediate airspace was divided into four sections so the six zones/sections each could be made restricted during parts of the flights. Within the two originally restricted airspaces are the SSC rocket firing range Esrange and the FMV test range Vidsel respectively.

This arrangement made it possible, for the first time in Sweden, to allow a UAV to operate in civilian controlled airspace. No other a/c was allowed into the same zone/sections as the UAV, except for ambulance and/or forest fire reconnaissance flights, for which the minimum separation distance to the UAV was extended.

A number of No Flight Zones, around populated areas, as well as defined Emergency Landing Spots in vast areas were established.

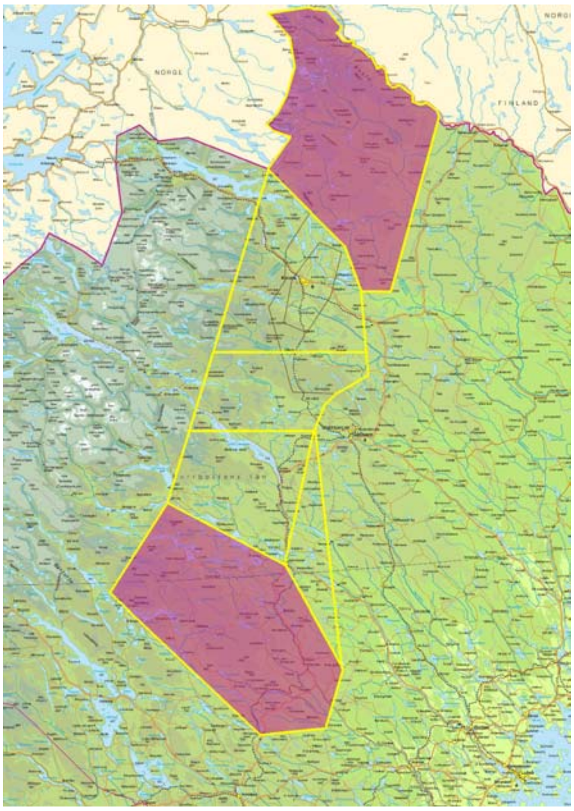

Figure 1. North European Airspace Test range (NEAT) with the six zones/sections.

The NEAT area is approximately 350*100 km (comparable with Denmark).

4.1 Kiruna Airport

Kiruna airport was used for take-off and landing. The airport is a civilian airport with about 10 regular airliner movements every day and lot of private a/c movements as well.

At Kiruna airport a forward and a rear test site was established. At the forward test site all UAV systems were located and at the rear, the Flight Operation Centre, briefing room etc. was located. For these testing purposes a new taxiway was built from the forward test site to the runway.

In the Flight Operation Centre the Chief Test Leader could monitor the UAV as the monitor information in the GCS as well as the RFN radar image together with the VDL mode 4 information was distributed to the centre. The activities in the GCS's were also monitored for the Flight Operation Centre by two video cameras.

4.2 Tracking Radars

Three different tracking radar systems were used to follow the UAV during flight (and supervise other a/c in the area):

- One close range air defence radar at Kiruna airport.
- One long range tracking radar from FMV in the southern part of NEAT.
- One long range tracking radar from FM in the northern part of NEAT.

The radar image from the RFN radar was transmitted to Kiruna so the Test Leaders could follow the UAV continuously during flight. Information from the other two radars was reported by phone or by radio.

5.0 AIRWORTHINESS PROCESS

The test flights were to be the first flights with a UAV in civil Swedish airspace. This made the Airworthiness Process the most essential pre-flight activity.

5.1 Military Air Regulations – RML

In Sweden, the Military Air Regulations (RML) regulates military flight related activities. At this time RML was not adapted for UAV activities, why FMV had to apply certain interpretations for some of the regulations that were not directly applicable for that.

5.2 Air Worthiness Reviews

Two airworthiness reviews were planned to be held in Israel prior to the evaluation flights. The first was held as planned during which the documentation of the system was presented and reviewed.

The second review had to be postponed and was therefore held at Kiruna airport immediately after the system had arrived there. During this review the system was examined physically with respect to electrical and mechanical installations etc.

5.3 Airworthiness Documents

A number of documents had to be prepared (if they didn't exist already) before the request for a military Test Flight Permit could be sent to the military Flight Safety Inspector (FSI). The main objectives with the Airworthiness documents are to:

- Define the configuration and the design/qualification status of the system.
- Secure that the system is safe (System Safety Analysis)
- Secure that the risks for personnel and third persons are tolerable.
- Declare what personnel are allowed to operate and to work with which part of the system.

All the Airworthiness Documents were then listed in a Test and Airworthiness Declaration, together with other relevant documents (for example the Flight test programme and approval from LFV to use Kiruna Airport and NEAT), which were sent to FSI. FSI reviewed the declaration and issued the Flight Test Permit, which is the final document required before the evaluation flights could be started. In the Flight Test Permit the FSI may add further restrictions and/or requirements for the flights, which was also done in this case.

6.0 TEST PROCEDURES

6.1 Ground Tests

Before the flight tests started, three ground tests had to be performed with acceptable results:

A Map Control Test, to verify that the translation of the Swedish maps in the system didn't generate any positioning errors.

A Radar Illumination Test, to verify that the air defence radar at Kiruna airport didn't interfere with the UAV from the EMI point of view.

A Taxi Test, to verify the basic functionality of the system as well as to familiarize the External Pilot with the runway (wider than normal for UAV operations).

6.2 Flight Tests

The evaluation of the MALE UAV-system was carried out during six flights (approximately 30 h flight in all). Of the six flights

- one (the first) was a Technical Check Flight.
- four were Military Test Flights.
- one (the last) was a Scientific Test Flight.

During the Technical Check Out Flight the UAV was flown in the vicinity of Kiruna airport.

The Military Test Flights were performed over the Vidsel Test range. The purpose with those flights was to perform sensor tests as well as to get handling experience of the UAV. During one of those flights the sensor images were distributed in real time to FM Headquarter in Stockholm.

The Scientific Test Flight was performed over the Esrange firing range. The purpose of the flight was to evaluate the UAV as a tool for metrological tests and to perform one such test with the CPC.

During all flights (not the first) it was planned that Swedish personnel should be handling the system themselves under supervision of IAI.

7.0 RESULTS

7.1 Ground Tests

All three ground tests were performed with acceptable results. Therefore the Test Flights were cleared to start.

7.2 Military Test Flights

The four military test flights were performed as planned except for some changes of the flight routes, which had to be made due to the weather situation over Vidsel. One flight had to be aborted, as a flight safety warning was set. After landing and replacement of a faulty rudder servo the flight could be performed without remarks.

The following was achieved:

- Swedish personnel manned all positions in the GCS during flight.
- Both SAR and EO/IR sensors were tested.
- Hand-over control of the UAV between the two GCS was done at least twice every flight.
- Some problems with the UAV was experienced, as it wasn't completely adapted for Nordic climate.
- The Israeli Extended Pilot raised a flight safety remark – mosquitoes might be a severe problem when controlling an UAV during take-off and landing.

- The general view of the EAGLE was very positive.
- The sensors were evaluated separately [2].

Notable is that during one of the flights two out of three tracking radars went down due to technical problems.

7.3 Scientific Test Flight

During the flight, two atmospheric layers of particles were identified. Of those the lower was further explored. There were some resolution problems with the CPC due too low temperature in the UAV.

The scientific test flight is to be reported by the scientist from MISU, but the preliminary results of the flight must be considered as a "complete success".

7.4 VDL mode 4 Transponder

The results from the VDL mode 4 tests have been reported by LFV [3]. In their report the most notable conclusion is that, with a VDL mode 4 transponder installed in a UAV, it might be possible to perform tests, like those performed in this program, without restricting the airspace around the UAV. Initially the separation between the UAV and other air vehicles might however need to be extended.

If a VDL mode 4 transponder is installed in a MALE UAV, the information about the "air traffic" in the UAV's immediate surroundings should be collected by the UAV itself and not by a ground station near the GCS.

7.5 NEAT

The NEAT area proved to be excellent for this type of tests. Some things however have to be considered when planning for tests:

- How to avoid interference with other users of the airport?
- How to minimize the interference with other aircraft, commercial and private?
- Proceedings for admitting urgent flights (ambulances etc) to use the restricted airspace?
- How to minimize (eliminate) the risks for inhabitants in the area of operation, in case of an incident?

8.0 CONCLUSIONS

The performed evaluation flights with the EAGLE MALE UAV-system were fortunate and most objectives were met. The experiences from the flights show that it is feasible to operate a UAV from a geographically remote smaller airport where regular airliners and private aircraft also operate.

Other conclusions are that

- a MALE UAV-system may be useful for both the FM and civilian users.
- the competence level for the first "generation" UAV-pilots should be what corresponds to an A-certificate for manned aircraft. Those pilots might then give recommendations for the training of the next "generation" of pilots of the system.
- VDL mode 4 has functioned well. It might be the "light-in-the-darkness" for UAV's and should be evaluated further for possible general implementation into military aircraft as "peacetime system".

- UAV's should be made playing a vital role in SD05. For that it is important to maintain the "know-how" gained. Further flight activities are thus recommended in advance of SD05.

The cooperation between the Israeli and the Swedish personnel was very good and the Israeli personnel shared their great experience in operating UAV's, with FM, SSC and FMV in a very open-minded manner. The cooperation with Kiruna Airport personnel was also good.

9.0 REFERENCES

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[3] Odin O "UAV demonstration Kiruna 2002 med ADS-B/VDL mode 4" (in Swedish)

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Picture 3. The team of UAV-demonstrator Kiruna 2002.

11.0 BIOGRAPHIES

Rolf Andersson was born on 22nd July 1960 in Kiruna, Sweden. He received an Aeronautical Engineer degree in 1988. Rolf was employed by SSC Aerospace Services Department in 2001 as a Project Manager. Before that he had worked as Aircraft engineer and technical and administrative manager of technical department and (JAR 145) CAA approval. He has also long experience in aircraft maintenance and a good knowledge in procedures, routines and repair schemes. Analyse and troubleshooting of technical systems. Experience as Licensed Engineering with the following AC/engine types; AS 350, BO 105, MD 500 series, DHC 2, SAAB 340 and FOKKER 50.

Claes Danielsson was born on the 26th June 1967 in Göteborg, Sweden. He received an engineering degree in polymers in 1987. Claes was employed by FMV in 1988 as a test engineer of Life support equipment. One of the main projects was the development of the Tactical Flight Combat Suit for SwAF JAS 39 Gripen pilots, were he was responsible for all the tests as Chief Test Leader. In 1999 he started working with UAV's as Chief Test Leader for FM first UAV system, UGGLAN.

Claes is also a lieutenant in the Swedish Army Reserve with the FM UAV unit.

Thomas Hylander was born on 26th of February 1974 in Ängelholm, Sweden. He received a Bachelors' degree in aeronautics in 2001. Before that he had worked as a furniture carpenter. Thomas was employed by FMV in 2002 as a test engineer of UAV's.

Thomas is also a dedicated hang-glider pilot and an excellent R/C model aviator.

Bengt Olsson was born on 6th Aug 1945 in Hudiksvall, Sweden. He received a M.Sc in electronics in 1970. Bengt was employed by Saab in 1970 as system engineer, avionic systems. In 1997 Bengt was employed by FMV as Chief Test Engineer (CPI), at the FMV Flight Testing Directorate in Malmslätt (Linköping).