UAVS FOR ATMOSPHERIC RESEARCH IN THE NORTH OF SWEDEN

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ABSTRACT

During three weeks in 2002, a Medium Altitude Long Endurance Unmanned Aerial Vehicle was flown over the NEAT area in the north of Sweden. One of the objectives was to demonstrate the use of UAVs for scientific atmospheric research. The vehicle used was an EADS/ IAI Eagle UAV. A Condensation Particle Counter was installed in the fuselage cargo bay. The UAV was flown in a saw-tooth pattern to study the vertical variability between 4 and 8 km altitude. Two different layers of interest were discovered during this flight. At the end of the flight the UAV was flown horizontally in one of these layers to measure particles. The direct feed-back the scientist could give the UAV controller was extremely valuable. Using UAVs as scientific platforms from civilian airports is very feasible, in our opinion.

Fig. 1 Eagle UAV at take off

1. THE CAMPAIGN

During May-June 2002 the Swedish Space Corporation (SSC) and the Stockholm University, through its Department of Meteorology, was involved in a UAV demonstration of an "Eagle" Unmanned Aerial Vehicle that was flown from the civil airport of Kiruna. The vehicle flew for a total flight time of 26 hours with the objective of the demonstration to show the use of UAVs for military as well as civilian applications. Six flights were planned - one technical, four military and one scientific. All flights were executed, with one military flight incomplete due to thunderstorms in the target area. All tasks were then re-scheduled for a later flight and all objectives were met in the end.

2. AIR VEHICLE

The Eagle UAV, built by IAI and marketed in Europe by EADS, can be considered a mature UAV. It is approximately 17 m in wingspan, weighs 1100 kg and can fly up to 10 000 m altitude. The max speed is around 200 km/h and it has 24 hour endurance. The aircraft has a large cargo-bay in the middle of the fuselage around CG, which makes it easy to use payloads of different kinds as the different payload weight does not affect the CG. In other UAVs lighter payloads might have to be balanced with extra weights. The available volume is around 1 cubic metre and maximum payload weight around 250 kg. In the future, hardpoints will also be installed on the wings. These will be able to hold 50 kg each, making it possible to hang science pods on the vehicle.

Fig. 2 Eagle UAV

3. NEAT

The missions took place over NEAT, the North European Aerospace Test range, in the north of Sweden. NEAT consists of the Esrange Space Operations Facility and the Vidsel Missile Test Range.

The north part of Sweden has a very low population, at least compared to other parts of Europe. In some areas there are less than one person per square kilometre. In this region two independent ranges have developed in the 50's and 60's.

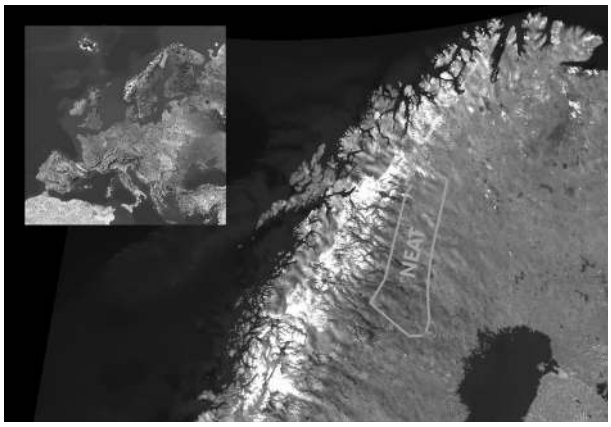

Fig. 3 NEAT area

At Esrange scientific rockets have been launched and at Vidsel tests of missiles and munitions have taken place. Thanks to their geographical position both ranges have developed over the years and the fact that safety has been high due to low population has also been beneficial.
The Esrange facility was established by ESRO, the European Space Research Organisation, in the mid-60's. At first the facility was only using sounding rockets and ground-based scientific equipment to conduct research mainly in the field of auroral research and atmospheric physics. The location north of the Arctic circle (68°N, 21°E) combined with a temperate climate made the site excellent for rocket-launchings into the aurora. One of the reasons for placing Esrange in the Kiruna region is the vast area that lies north of the base area. "Esrange impact area", as it is called, is diamond-shaped and some 120 km long and 70 km across. It is totally uninhabited and thus an excellent location to let spent rocket stages impact within. A 5000 square km large flight restriction zone is covering the area. This zone was used for the scientific mission of the UAV demonstration. Esrange is considered a technical facility and not a scientific one, as the research conducted there is done by personnel not normally present at the facility. Scientists from all over the world will come to Esrange over a period of time and perform research with the help of its personnel and equipment. These campaign periods can stretch from a couple of days up to several months. Over the years several methods to help researchers conduct their experiments have been adapted to the facility, at present sounding rockets, stratospheric balloons, satellites and ground-based instruments. Now, UAVs are considered a natural addition to the different platforms used for atmospheric research.

The Vidsel range has been a testing site for the Swedish military since the 50's. In 1958 it was established as a testing site for technical evolution of missile systems. Much like Esrange it is divided in a base area and a testing area. The base houses most technical facilities, as well as an airfield. The testing area is located 40 kilometres from the base. Due to the fact that live munitions are tested in the area, the whole test area is off-limits for non-authorised personnel, which makes it an excellent site for tests of new, untried vehicles. It is Western Europe's largest testing ground on land for practice firing and testing of airborne and land-based missile systems. The test range comprises a restricted, well-monitored hilly terrain site with a total area of 1650 square kilometres. Apart from the restricted ground area, there is also a 5000 square km restricted flight zone around and over the range, adding to the uniqueness of the range. This zone is called R02. The Vidsel range has been used over the years to test Swedish military aircraft ordnance, and is also the site where a number of European countries (apart from Sweden) have trained air to air and air to ground firings of live missiles and other munitions.

NEAT is also excellent for low-temperature testing in winter, as the temperature normally drops to -30°C or below. Several European car manufacturers perform tests in the region around Vidsel and are also, when safety permits, allowed to use the roads in the range for tests.

Fig. 4 Eagle UAV in front of Kiruna airport terminal

The main advantage in using NEAT for UAV flight-testing is the large area that can be used for flights. 350 km one way and a total area of more than 10 000 square kilometres gives long flight times and also a possibility to use hand-over between different ground-stations that are outside field-of-view from each other. The low density of air-traffic in the vicinity, and the fact that the airspace above the Esrange and Vidsel ranges are restricted gives very good opportunities to test UAVs in the area. At the Vidsel range, the testing of lethal UAVs can be conducted, as a large part of the ground area also is restricted. The possibility to use the range for long-

term tests with low, if any, change of the site where the observation is intended to be performed can also be advantageous for certain applications.
The region has a well developed infrastructure, both in communications and in regards to staying in the area. It also includes a rich environment for recreational activities.

4. SCIENCE FLIGHT

Fig. 5 Payload bay in UAV with CPC (white box)

The Meteorological Institute of the University of Stockholm flew a TSI Model 3010 Condensation Particle Counter on the last mission. The CPC counts sub micrometer particles continuously, up to 10000 particles/ cm^3. The scientist responsible for the test was sitting in the GCS alongside with the controller and could give instant feedback to him regarding the flight and changes to the flight plan.
The goal of the mission was four-fold:

- to demonstrate whether an UAV could be used as a platform for atmospheric research
- gain experience in developing, installing and using instruments aboard a specific UAV
- measure the vertical and horizontal variability of particle concentrations in an area outside the town of Kiruna at 67 degrees North.
- gain experience in using a UAV platform for aerial measurements related to the Calipso satellite.

The flight took place on the 10th of June 2002 over the restricted zone R01 north of Kiruna. Starting from Kiruna airport, the UAV flew in a saw-tooth manner varying altitude from 4000 to 7500 metres. Four tracks north-south were flown and two different aerosol layers were detected, one at 4300 m and one at 6100 m altitude. During the last part of the flight the UAV was to be flown in the lower layer to measure the horizontal variation of that layer. The UAV managed to follow the layer for some 40 km before losing track of it. As the scientist sat by the controller, he could guide the controller back to the layer and subsequent scientific data was collected. This direct feed-back was considered extremely effective and valuable. From a scientific point of view, the flight was a total success. The instrument worked flawlessly during the mission, as did the data relay.

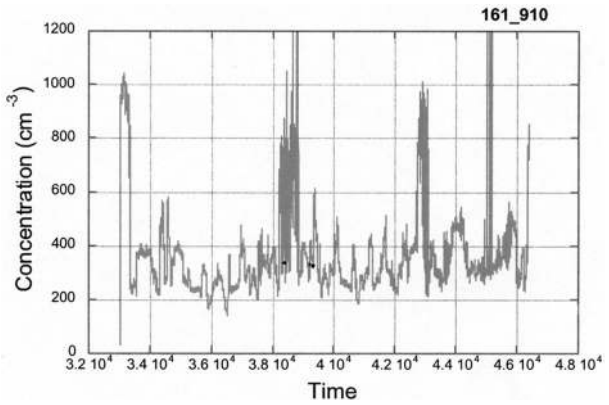

Fig. 6 CPC data from UAV flight

5. USING UAVS FOR CIVILIAN SCIENCE MISSIONS

UAVs are supposed to be used in D^3 missions - those that are Dull, Dirty or/and Dangerous.

Scientific research can sometimes fall under these. Sitting in an ER-2 aircraft for 8-10 hours, flying at 20 km altitude in something that resembles a spacesuit, without the possibility to rest can probably fall in the categories “Dull” and “Dangerous”. Flying into a volcano plume to sample its content is definitely considered both “Dangerous” and “Dirty”, but probably not “Dull”.

For atmospheric research, the main advantage of using UAVs is probably the possibility to fly extended missions at high altitudes. Several projects aim at placing High Altitude Long Endurance UAVs in the atmosphere. NASA has flown up to almost 30 km with its HELIOS UAV. Most of these HALE UAVs are also supposed to fly on solar energy, making it possible to stay aloft for weeks.

The possibility to fly into dangerous areas, such as turbulent winds or into where severe icing occur, without risking any crew also shows the advantage of UAVs. We believe that UAVs will become an important complement to manned aircraft, rockets and balloons for scientific research.

6. UAVS IN CIVILIAN AIRSPACE

As for now, UAVs cannot be used to their full extent, due

to heavy restriction on where they can fly.
The biggest hurdle to overcome is to be able to “file-and-fly” a UAV just as a regular aircraft. The process is very cumbersome right now, as UAVs cannot fly together with other aircraft and therefore have to fly in restricted airspace. This means that research is hard to do in several areas where interesting results might be found, such as over populated areas.

The Swedish Space Corporation is currently involved in two EU-funded projects that aim towards using UAVs for civil use in civilian airspace.

7. CONCLUSION

After six flights and more than 25 hours in the air, of which one flight and 5 hours were for a civilian scientific mission, our opinion is that UAVs are feasible as a platform for atmospheric research. The direct contact between controller and scientist sitting in the GCS together gives great flexibility during flight. One thing that was not demonstrated during this mission was the possibility to fly long-duration flights where a UAV can easily be operated as crews and scientists can work in shifts “on the ground”, without having to sit in an aircraft for long times.