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Unmanned Air Vehicles for Environmental Disaster Evaluation and Management

MEMbrain - Work Package 4

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Preface

"Tragedy is a tool for the living to gain wisdom, not a guide by which to live".
Robert F. Kennedy.

In recent years, the world has witnessed devastating disasters; nature disasters like the eruption of volcanoes in Cameroon and Philippines, man-made disasters like the chemical leak in Bhopal, India, which poisoned thousands of innocent victims, and the Chernobyl accident, which demonstrated all to clearly how quickly a radioactive cloud can spread, and how fatal its fall-out can be.

When a nuclear or chemical accident occur, it is imperative to immediately ascertain the density, direction, speed and the fall-out of the plume. But sending in men on the ground or in the air with equipment to make radioactive readings, even with the most protecting clothing, may mean sending them to a lingering and painful death. This is unacceptable and unnecessary threats to human lives. Today available technology makes it possible to use remotely controlled unmanned systems to do the important, but dangerous work.

The world is more fragile to environmental disasters today than ever, and will probably be even more so in the future. Hopefully, responsible authorities will grasp the challenge and learn the lessons from previous tragedies, raise the necessary funds to establish a reliable organisation with "know-how" and capacity to handle possible hazardous disasters in the future.

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Summary

Norwegian Institute for Air Research (NILU) is participating in the EUREKA-project MEMbrain which is coordinated by QUASAR Consultants and OCEANOR. This report which is a part of the EIS module (Environmental Information System), describes the possibilities, advantages and different categories of unmanned air vehichles (UAV) to be used as a basis for further evaluation of the use of UAVs in the MEMbrain consept.

This report presents the possibility to use Unmanned Air Vehicles (UAVs) for environmental disaster evaluation and management. This introduction to the UAV technology gives an overview of technical and operational requirements, as well as the structure and operation of a UAV system.

UAVs can be any size and complexity, and they are capable of a wide range of performance. From small, hand-launched, low-altitude UAVs with operational range of 10 km or less, to large wing-span, high-altitude, long-endurance UAVs, that is able to traverse the globe.

UAVs can be an important support to the Emergency Response Manager and his staff, as well as to a ground based emergency response team. UAVs can even be a main part of such a team, and can in some instances replace vulnerable complex network of fixed location monitors.

There are several alternative UAV systems available in the market, some of these have been described in this report. The needs of UAV depends on the type of disaster/distance, chemicals and the documentation necessary to describe the accident.

The TASUMA CSV-20 X is a low cost Close Range UAV system that can be used as a technological demonstrator, and can be useful for small scale accidents as well as in research and development programs for testing of various monitors and sensors. The cost for this equipment is approximately 1.5 mill NOK.

The most flexible and cost-effective solution for MEMbrain is the EAS CROW UAV. This system can be up-graded from a simple low cost, limited Close Range system, to a more professional high capacity Short Range system for handling larger accidents. The cost for this solution is 3.5 mill NOK and upwards.

An organisation that can operate a UAV system can be established within one year, or by a block-upgrade approach over a desired period of time.

In disaster management, where there is danger for human health, the advantages of using the UAV technology are obvious and can be highly recommended.

Unmanned Air Vehicles for Environmental Disaster Evaluation and Management

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1. Introduction to Unmanned Air Vehicles (UAV)

Norwegian Institute for Air Research (NILU) is participating in the EUREKA-project MEMbrain which is coordinated by QUASAR Consultants and OCEANOR. This report is a part of the EIS module (Environmental Information System). This report describes the possibilities, advantages and different categories of unmanned air vehichles (UAV) to be used as a basis for further evaluation of the use of UAVs in the MEMbrain consept.

UAV can be developed, produced and operated at a fraction of the cost of a manned aircraft in airframe, engines, fuel consumption, pilot training, logistics and maintenance. They can be made smaller, more numerous, more available, and above all more survivable, all without putting a single human operator at risk. In the latest 10 years period, technological advances in composite materials, electro-optics, sensors, computers, microelectronics and modern satellite navigation systems have opened up a well of possibilities for development and production of UAVs. These developments provide new opportunities for their use in earth science and environmental studies.

1.1 Categories of unmanned air vehicles (UAV)

UAVs can take many forms: they can be fixed wing, rotary wing, glider or gyro plane. They can be heavier than air or lighter than air; single or multi-engine; propeller, ducted fan or jet; battery-powered electric, solar-powered electric, microwave-powered electric, gasoline and diesel powered.

UAVs can be of any size and complexity, and they are capable of a wide range of performance. From small, hand-launched, low-altitude UAVs with operational range of 10 km or less, to large wing-span, high-altitude, long-endurance UAVs, that is able to traverse the globe.

A UAV is an airborne part of an overall system which also includes a fixed or mobile ground control and mission planning station, with data transceivers and processing terminals. There are also launch and recovery equipment and a field maintenance capacity (Figure 1).

UAVs are normally classified by their operational capabilities, where maximum range of operation, payload capacity and flight endurance are the key factors as described in Figure 2.

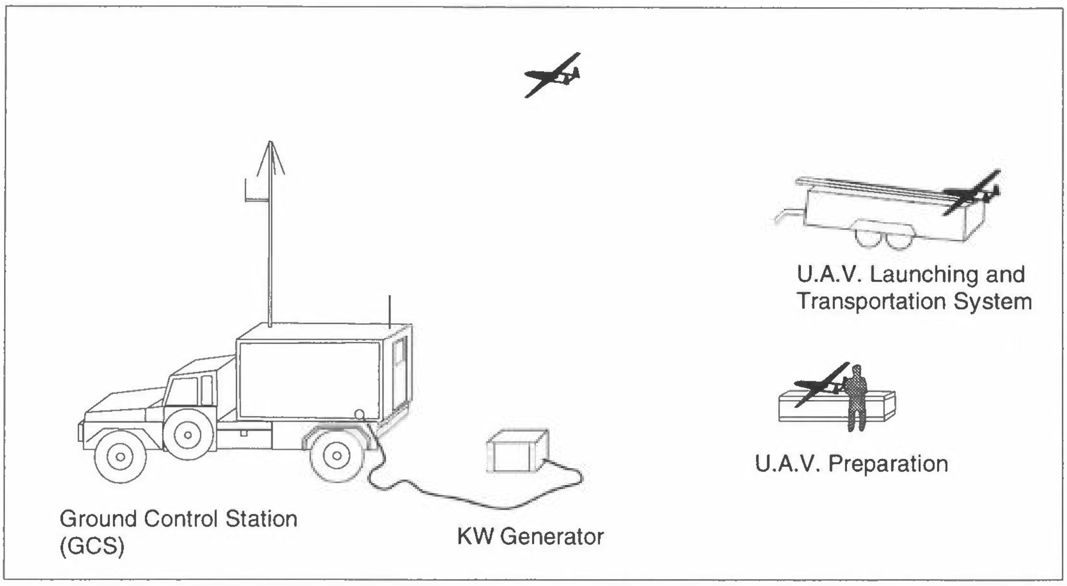

Figure 1: UAV system composition.

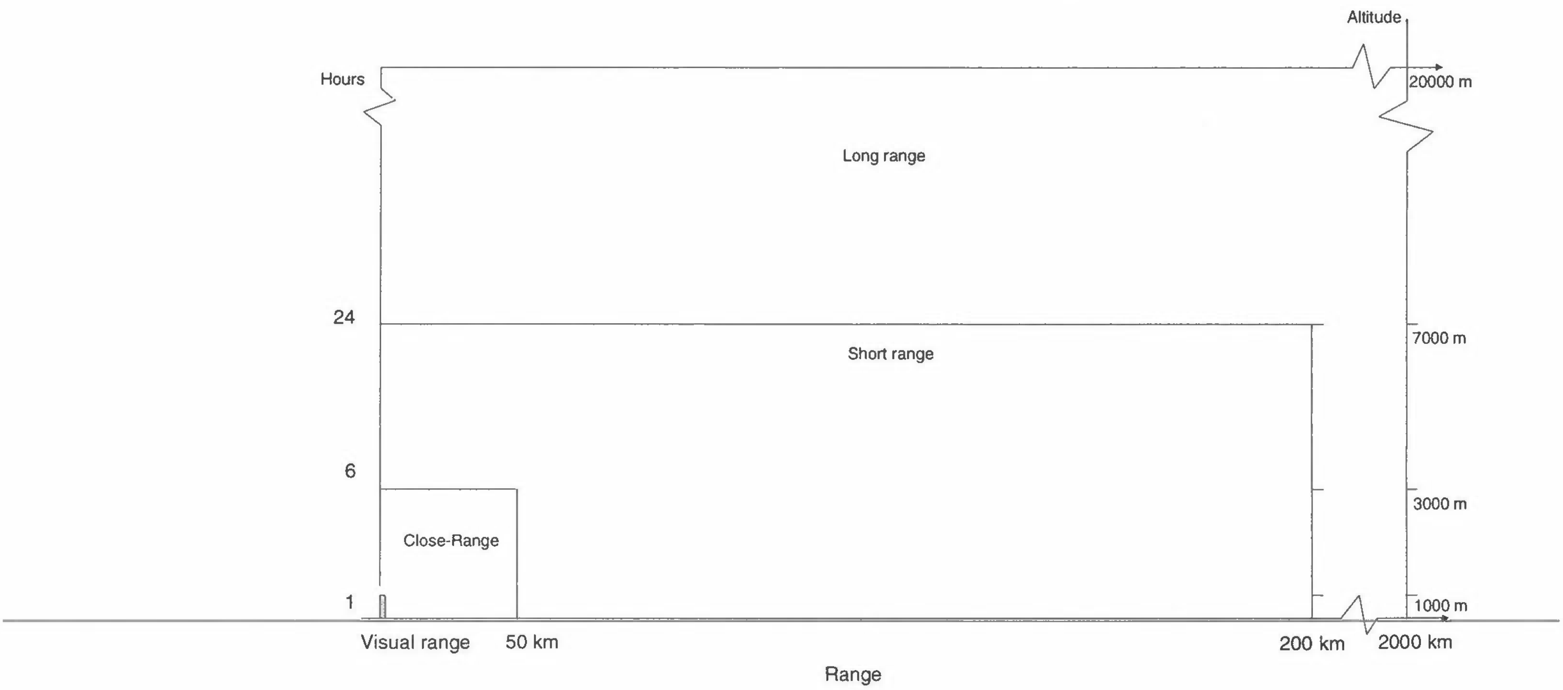

Figure 2: UAV category diagram.

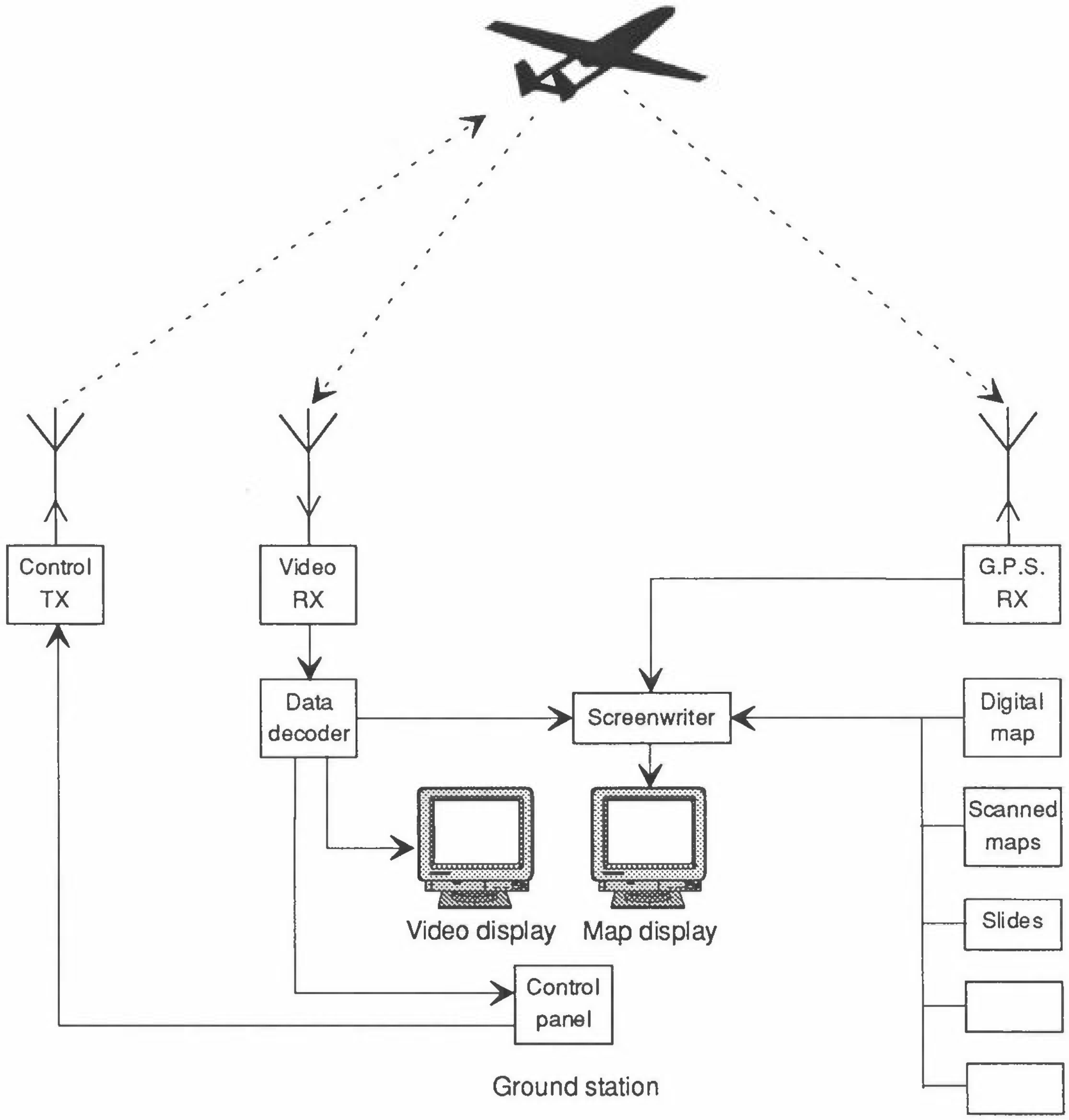

Figure 3: UAV system block diagram.

UAVs are primarily remotely piloted by manual control with reference to navigational aids and with the assistance of a sophisticated flight control system on board (Figure 3). There are some systems, however, which by means of Differential Global Positioning System (DGPS) can be pre-programmed for fully automatic flights.

UAV systems can, depending on the equipment, perform operations day and night and under almost all kinds of weather conditions. UAVs are ideal platforms for reconnaissance, survey and measurements, over small as well as large areas. They can reach areas where it may be too difficult or hazardous to send in personnel, such as disaster sites where radioactive or chemical waste preclude the use of piloted vehicles.

The systems can vary from simple low cost alternatives to expensive sophisticated and redundant systems.

A UAV system can be designed between these extremes to meet the user's need and requirements.

A UAV capacity can be built up in modules over a period of time (block upgrade approach) from a minimum technology demonstration level, to a desired operational capacity (Figure 4). By this approach the user can adapt the systems gradually to various requirements for both the UAV platform, the sensor-package and the ground control station. There is though, a certain minimum requirement to the equipment for safe handling of the flight operations, and to perform adequate survey missions.

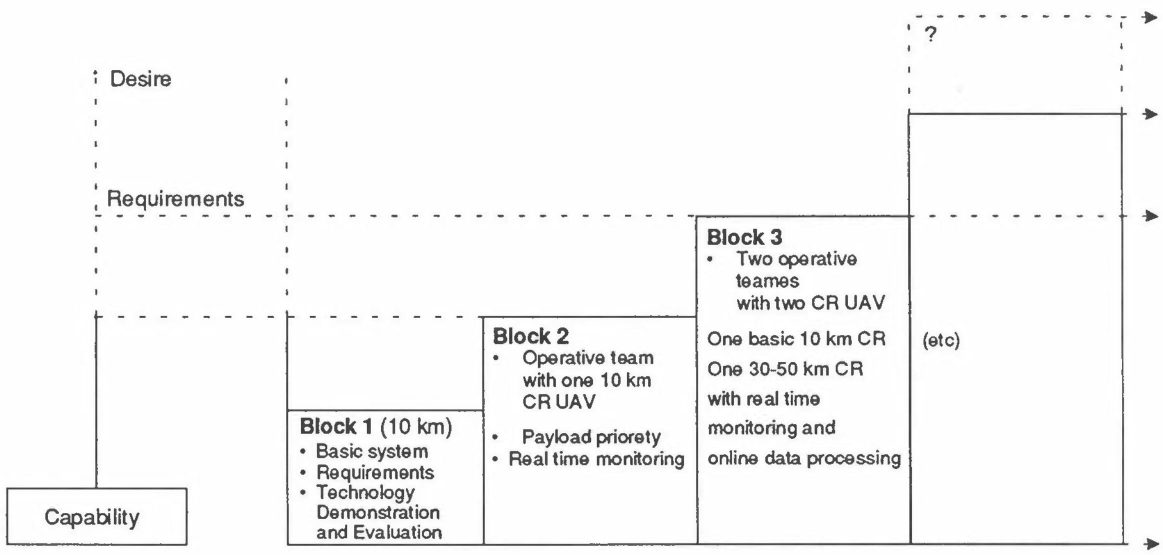

Figure 4: Block upgrade approach.

1.2 How to operate the UAV

A minimum UAV system which is required as a technological demonstrator, contains one or two suitable air vehicle(s) equipped with a proper engine, a generator to produce necessary electric power for the on board systems, a simple auto pilot for the air vehicle stability, a GPS receiver for navigation as well as a altimeter and air-speed sensors, all connected to the data link system.

A forward looking video camera will probably be required for air traffic and flight safety reasons.

An emergency fail safe system will also be necessary in case of loss of communication with the UAV. This system can have two options:

a) A pre-programmed return home mode which automatically takes over and returns the UAV towards the ground station, assuming that once in close range of the Ground Control Station (GCS), the communication will be re-established, and/or:

b) If the communication cannot be re-established, the engine will be cut-off, and a parachute will be deployed to perform a safe landing.

Further a portable GCS will be necessary. The GCS can be installed in a car (large station wagon,) or in a small trailer to form a easy mobile ground control station. The GCS consists of two consoles with keyboards installed in small light weight rugged cases. One console is for presenting sensors and video pictures, and for controlling the payload. The second console present the air vehicle control data, and the GPS-data on a coloured map.

The UAV is controlled by commands transmitted from the pilot in the GCS, and by the flight control system on board the UAV. Other equipment that is necessary is a first line maintenance facility and equipment. This equipment is needed for preparations for flight, and for field maintenance between the flights.

A professional UAV unit with full mission management control is a large mobile system. Such ground control station consists of one or two air-conditioned shelter(s) equipped with highly sophisticated, programmable control and communication electronics. This unit provides total management of all aspects of the system, from mission planning and video image analysis to flight of the air vehicle, and control of its various payload sensors. There are data link transceivers, video down-link, various antennas and encode/decode facilities. There is a work station for the pilot, the payload engineer, and the scientist that is responsible for the data processing and modelling.

The UAV pilot and the payload engineer can fly the UAV from the shelter, monitor and control the payload, as well as record and analyse the data in near real time during the flight.

The UAV can also be flown autonomously by entering navigation, flight control and payload control instructions into the UAVs central flight control computer through the module's mission planning console. The pilot in the GCS can over-ride the pre programmed flight instructions, or change the program at any time during the flight if necessary or desirable.

The ground station also include a first line maintenance equipment, and at least one alternate air vehicle to support the field operations.

The airborne vehicle contains a central flight control computer and an auto pilot which controls the air vehicle stabilisation, engine operation, and the automatic takeoff and landing system. There is data-link transceivers which is connected to the flight control computer and the various payloads for on-line communication with the GCS.

The UAV can also fly autonomously to perform missions over the horizon and beyond range of the main GCS. This is attainable by using data provided by the onboard GPS receiver, and navigation way point information programmed into the UAVs central flight control computer.

Another possibility is to use a second UAV or a satellite as a data and communication relay-platform. By this option, can the payload information data be transmitted to any desired receivers anywhere in the world.

The third possibility is to "hand over" the control of the air vehicle from the main GCS to another portable and remote positioning GCS. In case of serious interference of the guiding frequencies, or loss of the data link communication, will the pre-programmed auto pilot automatically return the UAV home, or to a pre-programmed position for a safe landing.

The human element must not be forgotten in all the technical discussions of a UAV system. In spite of that the air vehicle is unmanned, there is of course an important human element within the GCS. A safe operation is thus not only a technical matter. It also calls for a professional organisation with qualified and responsible leadership. It is necessary that the UAV team operate its system with precision and accuracy, follow the manuals, procedures and checklists in all aspects of its activities.

2. Disaster Management

The Emergency Response Manager (ERM) and his staff have to consider and prepare for several types of accidents and scenarios. In a small scale scenario with minor chemical accidents, the operation work field may be limited to a distance within 10 km from the base, depending on the character of the accident. In case of a large scale disaster like the fatal nuclear accident in Chernobyl, the operational theatre will have a radius of about 50 km or more. This means that the requirement for a UAV system will vary from a “Close Range” category, to a “Short Range” category. To cover the most probable scenarios, a 50 km “Close Range” UAV system will be necessary and desirable for adequate missions.

A UAV system is a unique cost-effective solution which provides considerable advantages over conventional systems, and can play a very important part of a system designed especially to handle an emergency situation. The UAV team can be quickly deployed to the area of interest and perform reconnaissance and measurements missions within an hour after arrival. The UAV team can by this provide damage assessment, as well as chemical and/or nuclear readings information in near real time - at least several orders of magnitude faster than any other alternatives. But far more importantly, it saves human lives from unnecessary exposure to a hazardous environment.

UAVs can perform preparedness flights. This means collecting background information from selected areas where there are potential risks of leaks from nuclear or chemical sources or activities. Such missions could also mean monitoring of dangerous goods transports

In case of a disaster the ERM and his staff have to respond to:

- Type and the magnitude of the accident
- Dose estimates and identification of the area affected by the release of toxic material to the atmosphere
- Evaluate the exposure dose to the public of the toxic material, from the initiation of the accident up to a given time
- Forecast the exposure in advance
- Limit the effects on the public health and to the environment

The decisions taken by ERM are vital. His decisions may be based on prepared model calculations for various scenarios and special trained crews operating mobile and/or stationary measuring platforms.

The UAV team can operate separately, or as a part of a larger emergency response team. A UAV system can even be a main part of a response team, and can in some instances replace vulnerable complex network of fixed located monitors.

The principal features of this approach are:

- Involve the user (ERM) from the beginning,
- get the capability in the user's hands as quickly as possible so important decisions can be made and necessary actions can be put forward.

The advantages of a UAV system are:

- The mobile ground control site can be outside the disaster area, although close to it. A UAV operation can thereby be performed in endangered environment; preventing unnecessary and unacceptable injury to personnel; while providing both real-time data acquisition and on-line processing.

Emergency response missions can be as follows:

- After deployment to the area of interest, the UAV team can immediately perform reconnaissance, and survey sorties in order to verify and recommend the best representative, but still safe location for the main ground station/container that follows.

- The UAV can also maintain reconnaissance and survey missions in front of the container, towards the disaster area and perform early warning missions for the safety of the personnel involved in the emergency operation. A typical flight pattern is described (Figure 5).

Perform remote observing and monitoring of the emergency source. Measure and map the meteorological parameters of interest such as wind speed and direction by using the on board GPS and measure the temperatures at and around the disaster site with an IR camera. Measurements of nuclear radiation levels while distinguishing between the various radioactive isotopes and between sources on the ground and those in the atmosphere can also be performed by the UAV. The

UAV can loiter continuously above the disaster site, as well as track the moving chemical or radioactive plume, it can follow the cloud of radioactive gases and particles and map the nature and distribution of the radioactive or chemical fallout of the exposure.

UAVs can perform reconnaissance and survey missions to locate "hot-spots" radioactive fragments after a possible explosion etc.

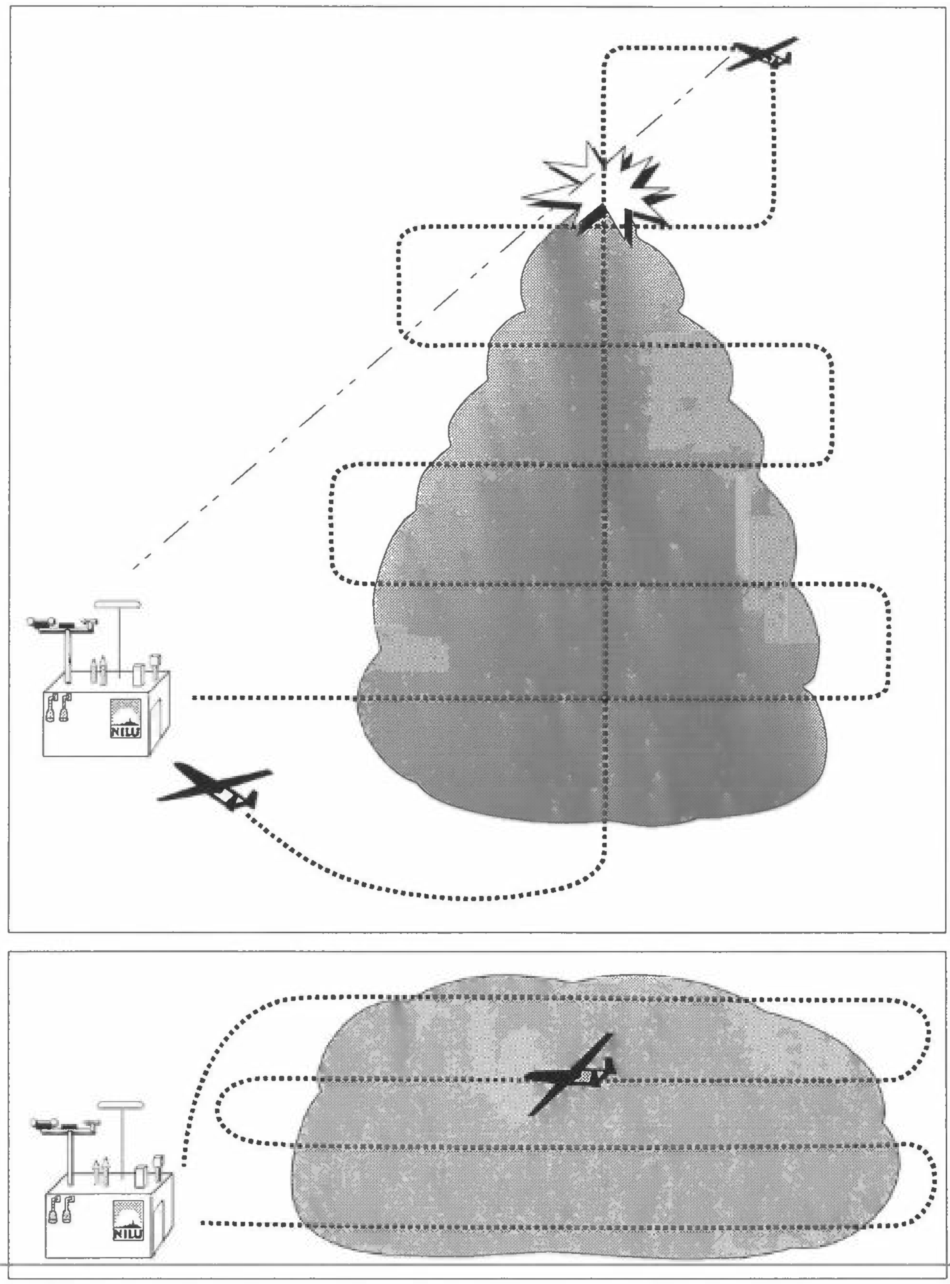

Figure 5: Alternative UAV survey mission.

Such continuous monitoring enables determination of the areas affected by the dose exposure, and can provide guidance for desirable counter measures and deployment of emergency response teams on the ground.

The following phase will be devoted to the total assessment of the impact of the toxic materials on the public and to the environment, and will invoke any additional measures needed to protect the public. Even in this phase will the UAV system equipped with an appropriate payload be very useful. The UAV can perform the data collection, and the Mobile Ground Control Station (MGCS) can processes and presents the data in near real time.

3. Cost estimates

Several alternative UAV systems are available on the market, from small and simple low-cost alternatives, to more expensive, professional and redundant systems. This report will concentrate on a few alternatives that reflect the relationship between the technology level, operational capacity and the price level. All the alternatives can be called "low-cost" for their category, compare to any other alternative to attain the same information in real time without putting human lives at a high risk level. The alternatives are based on a minimum of equipment needed in the ground station to make a safe operation possible. One air vehicle without payloads, but with a minimum of spare parts which is necessary for a serious field operation, is taken in account.

3.1 UAV alternatives

1) **Close Range, Low Cost system**
The smallest system that can be recommended is the “Close Range” TASUMA-“CSV-20 X” This system has a limited capacity concerning data down link, payload weight capacity of 10-12 kg, flight endurance of 2 hours and operational radius range of 10-20 km.

This system can be a technology demonstrator, and can be used in case of small scale accidents, as well as to perform early warning missions for ground based personnel in larger accidents. NOK 1 200 000

2) **Close Range system that can be build out to a Short Range system.**
This alternative is based on a flexible and cost-effective system from Electronic and Aviation System EAS “CROW”. This system can be build out in a block up-grade approach, from a simple low-cost “Close-Range” systems, to a more advanced professional “Short Range” systems if or when that comes necessary or desirable.

The "CROW" UAV can take payload weight of 25 kg and can perform 9 hours endurance flights. The operational range is depending on the desired electronic, computer and data-link capacity, from 10 km to 150 km. NOK 3 500 000-6 000 000

3) **Short Range**
This alternative is based on the French "Short Range" from CAC Systems "FOX AT1 or AT2". This system is a professional mobile unit. The FOX AT2 can take up to 25 kg payload to a range of 250 km with an endurance of 4 hours. NOK 8 000 000-10 000 000

4) **Long Range, Long Endurance system.**
This is the most professional and desirable system of these alternatives, and is based on the General Atomics Aeronautical Systems Inc, "GNAT-750". This highly sophisticated UAV system can cover any types of disasters, due to its operational capacity.

The UAV can take up to 200 kg of various payloads, and the system can operate up to a maximum range of 2000 km. The flight endurance can be in excess of 40 hours. Flight levels above 25000 feet is possible. The GNAT-750 UAV can even operate at a range of 800 km. and be there for up to 24 hours before it has to return home, or to an other airfield within the distance of 800 km. NOK 70 000 000

3.2 Payload alternatives

Several interesting UAV payload alternatives are available off-the shelf today. These can be interfaced to an on line data link system (prices are indicative as of December 1994:

♦ Pilot-camera and video-link	NOK	150 000
♦ Meteorological (met) sensor package for temperature, humidity, and air pressure. Some of these met. data can be read from the UAVs flight system. The GPS navigator may be able to provide wind profiles	"	15 000
♦ Miniature Sodium Iodide Detector, (Ruggedised) for the detection of gamma radiation. This detector can be integrated in the UAV. As an option, several units can be equipped with GPS and a transmitter and be dropped in parachutes from the UAV in selected positions to form a real-time monitoring grid	"	150 000
♦ Chemical Agent Monitor (CAM) to detect several gases, Nerve and Blister agent vapours, Cl_2, NO_2, H_2S, SF_6	"	50 000
♦ Environmental Vapour Monitor (EVM) Portable GC-IMS	"	50 000
♦ Micro Tip, "sniffer", sum of gases is detected	"	75 000
♦ Snapshot GC with 2 modules, separates gas components before detection	"	160 000
♦ Chrompack miniature GC with TCD	"	180 000
♦ Low light non stabilised IR camera	"	300 000-825 000
♦ LITE, Thermal Imaging System	"	300 000
♦ Forward Looking Infrared camera (FLIR)	"	650 000-3 075 000

Other types of payload may also be used, like various filter-samplers and absorption tubes, etc. These samplers will not yield real time measurements, but will be analysed immediately after landing by use of portable GCs or other analysers.

4. Training and organisation of a UAV team

Operations with UAVs calls for strict adherence to safety rules and procedures, which means that the operating crew has to be qualified and adequately trained. The number of crew members needed depends on the size and the complexity of the system, and the requirement for continuous operations. Generally will a basic "Close Range" system need minimum two crew members. A "Short Range" and a "Long Range" system will normally need three crew members for handling and safe operations. This is though a basic figure. For a continuos flight operation in the field, several crew's will be necessary.

The pilot in the ground control station is responsible for the pre-flight planning and the safety of the mission during flight. He must have the full understanding of, and be able to handle and follow the air phraseology, rules and regulations. Consequently, the operator must hold a specific UAV pilot's licence including a radio operator's licence. A periodic flight training program (PFT) is necessary to maintain the pilot's proficiency.

The payload engineer has to be qualified and trained for handling the total complexity of the UAV payload configurations, and data-link as well as support the pilot during flight operations.

The scientist responsible for data processing and modelling has to participate in some of the flight training program. This is important because he or she has to be an integral part of the UAV team during flight operations in an emergency situation.

The extension of the training program is depending on the complexity of the system, and the possibility to use the system in other activities and projects throughout the year. Though this may be limited by the desired readiness of the UAV system.

The minimum amount of working hours to keep the UAV team reliable for an alert situation is proximately 2400 man hours per year. At least 50 hours of these are minimum flight time.

The UAV team can perform its training activities separately, but need to be an integrated part of the emergency (field operations) response team. The lines of commando and procedures must be definite, and accepted by the personnel involved.

The personnel must be given clear priorities and be trained to meet a real challenge. A full scale exercise should be arranged at least once a year, with deployment of the entire monitoring equipment and personnel in the field for a realistic test, concluding with a thorough evaluation.

The ERM and his staff have to discuss, decide and establish the desired system of readiness. The system must reflect the need for the availability of personnel and necessary equipment within specific time and will also need to be tested and evaluated within the full scale exercise.

5. Precautions

Before significant use of UAVs can be realised, there are some challenges which must be overcome. Operational and technical issues concerning flight safety within national and international air space and over populated areas must be solved. The International Civil Aviation Organisation (ICAO) must agree upon safety requirements and standards for UAV operations, the systems and pilots proficiency etc. This work is going on, and international regulations will be a reality within few years. Meanwhile UAV operations have to be co-ordinated with the air traffic authorities on an ad hoc basis. Allocated air-space "tunnels in the sky" for UAV operation is one possibility. In an emergency situation UAV operations will need highest priority of the air space in question.

Frequency allocation is another issue that has to be solved. UAV operations need reliable frequencies for guiding and control of the air vehicle as well as for transmission of data and video pictures etc. back to the ground station. This issue is not trivial but, with proper care, a solution is achievable.

Insurance is an other issue that have to be negotiated. There are reasons to believe that the insurance-rates will be compatible to insurance-rates for manned aircrafts, when the understanding of the proficiency requirements involved in UAV systems are absorbed, and when acceptable rules and regulations for safe operation is established.

Contamination of personnel, the monitoring equipment and the UAV platform, is another important detail which must be prepared for and solved. This may be done in co-operation with military expertise in this field. They have experience and equipment to handle Nuclear Biological Chemical (NBC) contamination as well as protecting techniques against electromagnetic interference caused by high radiation. Co-operation with the military authorities will be necessary and natural anyway. An environmental disaster scenario may include an accident caused by military activities, as in the Gulf war in 1990-91. An emergency response team can very easily end up in a large grey zone between civilian and military authority.

Civilian emergency response teams should be covered in a detailed and comprehensive contract. The contract defines time, risks involved, protection equipment and the safety of the personnel. This agreement must also define the economical details and insurance coverage. The teams could also be based on voluntary personnel.

Deployment of the emergency response team with their equipment into other countries may mean running into bureaucratical obstacles which must be overcome. This will need careful planning and organising. Agreements have to be established concerning costume handling and clearings, support from the local police to guarantee free travelling and safety of the personnel and for the operations. Co-operation with air traffic authorities and the local air traffic controller, for air space priority, allocation and clearings for use of necessary radio frequencies, data-links, satellite-telephone and other necessary communication systems. The emergency response team cannot spend valuable time to deal with these issues at the arrival in a foreign country. Such problems should be taken care of by authorities in the countries concerned in advance of the deployment, or before the arrival of the team.

6. Other countries' use of UAVs

The development of UAV technology opens new possibilities for airborne reconnaissance and survey for many important applications. About 65 countries has taken up UAV projects and programs (military as well as civilian.)

Applications taken up by most of the countries are mainly related to damage assessment and exerting control in natural disasters such as earthquakes, floods, storms, hurricanes, volcanic-eruptions, forest-fire prevention, communication-relay, and environmental pollution detection and control, in addition to the military applications. Over the next two decades the use of UAVs is forecast to multiply fivefold. International forecasts predict a $10-$15 billion growth market for UAVs over the next 10 years with the civilian market anticipated to grow four to five times faster than its military counterpart.

These developments make it essential that the UAV industry and operators have an accessible reference source for manufacturers and users alike, where operational requirements and applications can be readily assessed. At the Shephard Conferences, UAV 93 and UAV 94 in Paris, were 26 countries participating, most of them with their own programmes. At the conferences and at the following Paris air-show in 93 and at EURO SATORY 94, several of these programmes were presented.

6.1 France

The CAC SYSTEMES S.A. has developed a “FOX” AT1 and AT2 UAV for military and civilian applications. The “FOX” is a “Short Range” UAV system, and can perform 4 hours flights with up to 25 kg payload for real-time reconnaissance. and survey missions. In May 1993, following demands from Canadian officers in Bosnia, the United Nations Protection Force (UNPROFOR) put out a request for quotation for a lightweight UAV system. The initial requirements were for three systems with crews, to be available within eight days and least for three months. The system had to be low cost, with minimum operators and support vehicles, all-weather, simple and highly mobile, equipped with daylight payloads, and data links with a maximum range of 40 km. After a successful demonstration in June 93 of FOX AT1, CAC Systems of France was awarded a contract in October. The system was to be deployed in January 1994 at Velika, near Bihac.

Operational tasking of the unit was carried out by UNPROFOR in association with NATO, which controls Bosnian airspace. The system was mainly used to support humanitarian operations, particularly in route planning for aid convoys, but it was also a need to survey isolated areas for humanitarian and military purposes. (Corizzi, 1994 and Harbison, 1994.)

AEROSPATIAL-CR2A and the CGI company has developed a Seri of small, and low cost UAV for visual and Close Range survey missions. “Etablissement D' Etudes et de Recherches Meteorologiques” (EERM) has been using UAVs from this company since 1976. (“Sonde Aerologique Motorise'e”) SAM-B, SAM-C, and SAM-D as unmanned atmospheric sounding vehicles. These systems have been used to sample gas and particles over the volcano Etna in Italy. The system was also used for meteorological and chemical measurements in an expedition in Antarctica late in 1993. (Dolivet, 1994.)

6.2 Germany

International Aerospace Technologies has developed a "Close Range" MK-105 "FLASH" UAV for surveillance and other roles. The UAV made its public debut at the 1988 Hanover Air Show, and has been demonstrated in Germany, Italy and Portugal. The "FLASH" UAV has a grate potential for environmental survey missions. (Harbison, 1993.)

6.3 Great Britain

ML AVIATION COMPANY LTD (Flight System Division) and Graseby Ionics have been developed a UAV helicopter "SPRITE" for NBC detection. The system is in service in England, Canada and the United States. (Munson, 1988).

TASUMA LTD has developed several types of "low-cost" UAVs for reconnaissance and survey missions. TASUMA delivers UAV systems for military and civilian applications. National Power, former Central Electricity Research Laboratories (CERL) has been using "Wasp" UAVs from TASUMA since 1977 for atmospheric sampling, temperature, humidity and various pollution in the vicinity of power stations. (Ellis and Varey, 1978; Munson, 1988.)

6.4 Israel

Israel Aircraft Industries (IAI) MALAT together with the Soreq Nuclear Research Centre and the Geological Survey of Israel are developing a comprehensive UAV system for environmental monitoring and geophysical surveys. The system includes: measuring of nuclear radiation levels while distinguishing between the various radioactive isotopes and between sources on the ground and in the atmosphere; tracking the cloud of radioactive gases and particles; mapping, with a high sensitivity, the nature and distribution of the radioactive fallout; measuring wind speed and direction in the vicinity of the air vehicle; observing the accident source in the visual spectrum from a height of several hundred meters up to 5 km, with a high resolution and with zoom capability; remotely measuring and mapping the temperature in and around the source with IR camera. (Zafrir et al., 1990.)

The Electronic and Aviation System (EAS) has developed several "low-cost" UAV alternatives for similar purposes as IAI. The UAVs are called: "Snooper", "Fire Fly", "Crow", and "Vanguard". These systems are based on the theory that the customer want to (or need to) build up their UAV systems in module (a block upgrade approach). (Gross, June 1993).

The Silver Arrow UAV DESIGN AND PRODUCTION, was established in 1985 to develop high technology projects and to produce UAVs for several applications like: Real and non real time reconnaissance and survey missions, damage assessment, meteorological measurements, Counter drugs, Nuclear disaster assessment, Environmental inspection, border patrol, government facilities monitoring, as well as wild life and forest management. The most successful UAV is the "MICRO-VEE" which is a very professional "Close Range" system. (Beit-or, June 1993).

6.5 Italy

The AERCOSMOS Aerospace Engineering is developing a "VISTA" UAV The "VISTA" is conceived to perform a wide variety of both civilian and military operations, such as: country survey, mapping and aerophotogrammetry, hydrography, archaeology, agriculture, patrol operation such as environment and industrial control, highway traffic patrol, civil protection and police application, photographic, commercial and journalistic purposes specially in inaccessible areas. The VISTA has been designed so that the collected images and data can be either transmitted to Ground Control Station in continue or random mode, or recorded and later analysed on the ground. (Arienta, June 1993 and September 1993).

6.6 Mexico

The Mexican national oil company is building up a UAV system in co-operation with Electronics and Aviation Systems LTD.(EAS) for pollution survey and control around oil pipelines and installations on-shore and off-shore. The UAV system that will be used is the "VANGUARD" from EAS. (Gross, June 1993).

6.7 Russia

General views of UAV development and use in Russia. In spite of today's leading position of piloted vehicles, UAVs more and more begin to achieve their own place in the military and civilian fields. The Russian UAV program began in the early 60s, mainly as a military program. The Yakolev OKB has been working on UAV programmes since 1982. The first UAV to be revealed publicly is Yak-061 "SHMEL-1". In the latest years, the UAV program is taking up civilian applications as well, and a civilian variant of the "SHMEL" has been developed. The latest information describe a new UAV, from Yakolev and ELAS, the "COLIBRI" which is a special platform for atmospheric and environmental monitoring, and to promote this UAV for a diverse range of national civil and ecological tasks. It can be used as a sensor-carrying vehicle only (RPV-0), or in conjunction with a second (RPV-R) acting as relay to extend range to 700 km. In case of a disaster similar to Chernobyl, measurement of radiation is to be done only by UAVs. People deserve to be protected. Natural catastrophes (earthquakes, fires, floods etc.) environmental and ecological control, terrain survey, ice patrol etc. .is other important applications for UAVs. This will be important parts of the Russian UAV program in the years to come. (Barkovski, June 93).

6.8 Saudi Arabia

Mid-Continent Scientific Company has developed and used a MSC PL-60 UAV. since 1979. Applications described for the PL-60 include surveillance and other military duties, border patrol, forest fire surveillance, aerial photography, traffic patrol, air pollution and weather monitoring. (Munson, 1988).

6.9 South Africa

The interest in UAVs in the Republic of South Africa can be traced back to the late sixties, early seventies because of the numerous application possibilities of UAVs. This interest lead to a national UAV master plan, not only for military operations, but also for civilian applications. The plan resulted in a number of advantages:

1) A co-ordinated approach without wasting energy on schemes for which there is no need,
2) Optimal utilisation of scare financial resources,
3) Use of common modules and subsystems for the different projects, and,
4) Ensure a balanced marketing and product portfolio, structured towards the practical realisation of the needs of the user.

The Kentron company, a Division of Denel Ltd, has been heavily involved in the UAV development. Their newest UAV called "SEEKER" has been into service since 1986. This UAV is design also for various civil applications, including forest-fire prevention and surveillance, pollution detection, mapping, coastline, harbour and highway traffic control. etc.

The highlight of the current use of the "Seeker System" is beyond doubt the day and night monitoring service it rendered during the general elections which recently took place in South Africa (Jan van Eeden, 1994).

6.10 Spain

"Instituto Nacionale De Tecnica Aeroespacial" is co-operating with the German company Dornier, to establish a UAV system "SIVA" for forest-fire prevention, fire control and management. Forest-fire detection and surveillance missions during forest-fire-fighting operations. The system will also be used in search and rescue operations and to support the police management in case of a disaster situations etc. (INTA, June 1993).

6.11 Switzerland

Oerlicon-Contraves have been co-operating with Israel Aircraft Industries (IAI) and developed the "RANGER" UAV specially designed for European environments. The "RANGER" is designed to perform military as well as civilian applications. The civilian applications are: Traffic control, border and coast guard patrol, surveillance and monitoring of floods, forest fires, earthquakes and volcanic eruptions, detection and monitoring of nuclear radiation, low enforcement, earth and environmental surveys. (Schmierer, Mars 1993).

6.12 USA

In the United States about 100 research centres and companies are involved in UAV development projects and programmes, and the interest is growing rapidly. All this programs can not be reflected in this report, but here is some few interesting examples of this activities.

Aero Vironment Inc. has been involved in development of special aircraft's, (manned and unmanned) for many years. One of their smallest UAVs, called "POINTER" is a man-portable miniature sail plane that can be dismantled and carried, with its ground operators' radio control and imagery receiving equipment, in two backpacks with a combined weight of only 34 kg.

The National Science Foundation (NSF) has approached the Pointer hand-launched UAV to fly into steam escaping through a vent in the crater of Kileuea Volcano on the Island of Hawaii. The NSF would add a small, tin-can sized collector to the fuselage of the Pointer and collect samples of the volcanic ash or other material.

There has also been an inquiry through the National Parks Service concerning the use the Pointer UAV to over-fly and survey several sites thought to contain ruins of original inhabitants of areas in Canada that can be covered by water from a hydroelectric power dam. (Morgan, 1994.)

The National Aeronautics and Space Administration (NASA) has developed several low-cost "Mini-Sniffer" UAV platforms, designed for high-altitude atmospheric research in remote areas, to measure air turbulence and atmospheric trace gas and to determine the constituents of particles in the atmosphere (Munson, 1988.)

General Atomics Aeronautical Systems Inc., has design and developed a UAV system called "GNAT-750" This system represents the newest advanced technology. The "GNAT-750" has flight demonstrated endurance in excess of 40 hours. Operation can be carried out above 8000 m. The system have also large payload flexibility and capacity of up to 200 kg. The "GNAT-750" can operate at very long range, out to a max. radius/distance of 2800 km, or operate at a range of 800 km and stay there for 24 hours "on station" while report real time information back to the ground station, and/or to desired positions any where in the world by using satellite-communication.

The system makes it possible to perform full mission capability for round-the-clock operations with minimum manning. The "GNAT-750s" are routinely operated on missions manned by four people. The vehicle's combination of long endurance, large payload capacity, ease of use, and low maintenance requirements make it well-suited for most UAV missions at very low cost per flight hour. This UAV has been used by the U.S. Energy Department to fly over Oklahoma in a measure program for climatic changes studies (Rutherford, 1994; Ernst, 1994).

The Counter-Drug Technology Assessment Centre (CTAC) is leading the U.S. research and development efforts against the drug traffic. They are co-operating with federal law enforcement agencies and the defence department to establish an advanced technologies by using UAVs for nuclear weapons inspection, explosive detection, chemical weapons detection, counter-terrorism, and special operation activities. Detect drug crop plants and their processing laboratories as well as laboratories manufacturing synthetic illicit drugs, tracing drug smugglers in co-operation with U.S. Coast Guard and direct police unites on the ground to the best position for their actions. (Bradenstein, June 1993).

Aurora Flight Sciences Corporation in Virginia USA has developed a UAV (PERSEUS) specifically to support atmospheric science research. It will be capable of reaching extremely high altitudes, long range, and flight-endurance of up to 48 hours. Typical missions for Perseus B, will include measuring the earth's radiation or water vapour budgets and tracking severe storms. The high-flyer Perseus A, has a 30 km. altitude capability. It can carry a 70 kg payload to peak altitude, powered by a unique closed loop engine. It will support stratospheric ozone research and conduct environmental impact studies for high-speed commercial transport aircraft. (Langford, July 1993).

University of Texas at El Paso (UTEP) has developed and used a UAV: Manoeuvrable Atmospheric Probe Unmanned vehicle (APL MAP/UV 8001) since 1981. The main programme objective was to measure atmospheric processes and characteristics that might affect the performance of electro-optical devices and sensors. (McDonald, et al. 1984).

7. Conclusions and recommendations

The UAV technology is available for civilian applications, and is a cost-effective solution for real-time environmental disaster evaluation and management.

UAVs can be an important support to the Emergency Response Manager and his staff, as well as to a ground based emergency response team. UAVs can even be a main part of a such team, and can in some instance replace vulnerable complex network of fixed location monitors.

There are several alternative UAV systems available in the market, some of these have been described in the cost estimate chapter in this report. The question is: what is the user's (MEMbrain) needs and requirements, and what kind of UAV system can meet these needs. The best solution is a system that can perform the required missions efficiently at reasonable cost and risk.

The most flexible and cost-effective solution for MEMbrain is the EAS CROW UAV. This system can be up-graded from a simple low cost, limited Close Range system, to a more professional high capacity Short Range system if or when that become desirable or necessary to handle larger accidents.

The TASUMA CSV-20 X is a low cost Close Range UAV system that can be used as a technological demonstrator, and can be useful for small scale accidents as well as in research and development programs for testing of various monitors and sensors.

An organisation that can operate a UAV system can be established within one year, or by a block-upgrade approach over a desired period of time.

In disaster management, where there is danger for human health, the advantages to use the UAV technology are obvious and can be highly recommended.

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ABSTRACT
This report presents the possibility to use Unmanned Air Vehicles (UAVs) for environmental disaster evaluation and management. A response team may be faced with personal risk and health hazards when dealing with environmental disasters. The report points out how useful a UAV system can be to keep these risks at a minimum. An introduction to the UAV technology gives an overview of technical and operational requirements. Different categories of UAVs and available payloads options are described. A cost estimate for investments as well as for organising, training, maintenance is described. Finally some examples of UAV applications are given. These include applications of high interest and priority in other countries.

NORWEGIAN TITLE

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ABSTRACT (in Norwegian)
Denne rapporten beskriver muligheten for å anvende UAVer for evaluering og kontroll i tilfelle av miljøkatastrofer. Personell som vil bli satt inn ved en alvorlig miljøkatastrofe kan bli stående ovenfor store risikoer av helsemessig art. Denne rapporten peker på nytten av å bruke et UAV system for å begrense denne risikoen til et minimum. En introduksjon til UAV teknologien gir en oversikt over tekniske alternativer, operative forhold og forutsetninger, forskjellige kategorier av UAV systemer og mulige nyttelast alternativer. Et kostnadsoverslag beskriver behovet for eventuelle investeringer, samt sannsynlige kostnader til trening og vedlikehold for å holde et UAV system operativt. Interessen for å anvende UAVer til en rekke formål er stor i mange land. Noen eksempler på dette er også beskrevet

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