A SMALL LIGHT-WEIGHT ROTOR PLATFORM FOR GROUND OBSERVATION AND POLLUTION CONTROL

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Abstract

Environmental control and pollution measurement play a more and more important role in the protection of the delicate equilibrium between healthy life, social and economic growth, comfort and profit, and the desire to guarantee all the former for the future. In case of accessibility, it is already routine to use stationary measurement systems for long term investigations or portable equipment for special checks in emergency cases. However, accessibility is not provided in all situations. This paper discusses the applicability of a versatile, flying rotor platform for measurement or observation purposes in inaccessible locations. Different applications and their boundary conditions will be demonstrated and results of test measurements using a prototype of the platform will be presented. Finally, an outline of an optimized rotor platform will be developed. For that layout, different boundaries like weather conditions, training standard of the pilot, duration of the measuring task, and aviation regulations have to be accounted for. The design will also be influenced by requirements of architectural applications like airborne observation and measurement tasks in building control without the need of scaffoldings.

Introduction

It is obvious that we have to activate more and more effort to protect our endangered environment. Our life, social and economic growth, health, and future depends strongly on the vitality of the environment. To be able to develop "environment-friendly" techniques or even to be able to discuss possible actions or regulations, it is necessary to know a lot about pollution of air or water and its distribution, about damage in forestry and its exact reasons, about radiation of dangerous matter at power plants or at chemical and other industry. Exact measurements are necessary to be able to make forecasts or to start activities.

There are many examples of stationary measurement systems at power plants, in cities, at highways, or on airports - all these are very well accessible places. In many cases, however, a special measurement platform is desirable, which should be easy to use in inaccessible regions, in low altitudes in the air or over water, and which should be able to carry different measurement equipment. These requirements could be fulfilled by a flying rotor platform.

This paper discusses several of these applications and presents test results achieved by using a simple prototype of such a rotor platform. Using the experiences gathered by testing the prototype platform, an outline of an optimized rotor platform will be developed which meets all the measurement and observation requirements mentioned above and in the following paragraphs, is easy to fly and maintain, meets the aircraft regulations and can be folded to fit in very small compartments.

Typical applications for a small rotor platform

There are many applications for a flying rotor platform in environmental control and ground observation. Most of these applications, however, can be covered by simpler and more cost-effective methods like small aircraft, large car cranes, tethered balloons, or other techniques to take samples of air or water at inaccessible places or perform measurements.

Naturally a rotor platform has to be equipped with some kind of a complex auto pilot system and special light-weight measuring and photographic equipment to be a valuable tool. The operation of such a platform can be very expensive.

Therefore it is necessary to find and discuss all applications where the rotor platform could provide the only means to get the desired measurements done. In the following enumeration several applications will be presented which should - at least under special circumstances - prove the advantages of a flying rotor platform.

A. Photographic applications:

1. Water pollution control:
   Waste fluids, injected into rivers or lakes, normally differ at least slightly in temperature from the surrounding water. Using an infrared video camera system, it is possible to check water pollution very quickly and measure its dimensions.
2. Forestry:
   It can be necessary to examine directly the condition of single trees or tree-tops, which is not possible by normal airborne or satellite photography. The rotor platform can perform hover flights directly over the tree top and take photographs in different spectral ranges (visible, infrared).
3. Damage control of buildings:
   Without any expensive scaffolding it is possible to take sets of stereometric photographs of buildings and measure depths of cracks, using

photogrammetric procedures. This is an important step in renovation projects.

4. Expert evidences at traffic accidents:
At traffic accidents it is often desired to take photographs of a height level of several meters to get views of the location of vehicle debris or "brake traces". This may be very important for the reconstruction of the circumstances of the accident. Normally, little scaffoldings are used which are limited mechanically to a height of 5 to 7 meters.

B. Probe and measurement applications:

1. Air analyses:
Using chemical analysis tubes or, in the near future, small on-chip gaschromatographic equipment, it is possible to take air pollution measurements at inaccessible locations or in different heights. Examples are the smoke wake measurements at large catastrophic fires and the measurement of the distribution of pollution at different wind and weather conditions.

2. Measurement of radio-activity:
Using little Geiger counters, connected to telemetric transmitters, inaccessible radio-active contaminated terrains can be scanned.

C. Mixed applications:

A very important application could be the fast and complete examination in case of suspicion of water pollution. As mentioned above, the rotor platform can visualize the spreading or distribution of waste fluids in real time, using an infrared video camera system including a video transmitter and a control monitor on the ground. In case of confirmation the platform can directly fly down to water level and take samples of the contaminated water for analysis.

The prototype of the platform and initial tests

The proposed rotor platform will be a complex tool which has to be designed for the various applications. It is hardly possible to optimize the construction without knowing anything about the specific tasks. In order to test the feasibility of the application of such a rotor platform, a simple test platform was used to perform test measurements. This platform is a regular radio-controlled model helicopter (Fig. 1). Rotor diameter is 1.4 meters, overall takeoff weight is 8 kg, including about 2 kg payload. The model is driven by a 2 hp piston engine, the flight time is about 20 minutes with 0.5 liter fuel. Some modifications allow the use of different measurement equipment. The investigations performed with that test platform will be presented here. The fundamental usage of regular model helicopters or at least of some of their mechanical parts will be discussed in the next chapter.

The principal interest in these initial test was to get information about operation and performance of regular photographic cameras and video cameras and the use of electric pumps for the use with chemical air analysis tubes. For these purposes a photographic motor-camera was installed into a crash-safe compartment in front of the model (Fig. 2). An electric gas pump device was placed on the landing gear of another helicopter model (Fig. 3). Both the motor-camera and the pump could be triggered by radio-control. The films used are high speed (400 ASA) color slide films and KODAK EKTACHROME infrared films. The electric pump is designed to drag 0.1 to 1.0 liters of air per minute over a special chemical substance in a glass tube. These tubes are available by the Dräger company for various organic and anorganic analyses (Ref. 1,2). Different Dräger-tubes have been tested like active-coal-tubes for testing of organic substances which have to be analysed in a laboratory using a gas-chromatograph or other tubes for anorganic or organic tests which give the information directly by a color change of their chemical substances.

Fig. 1 Model helicopter for test measurements

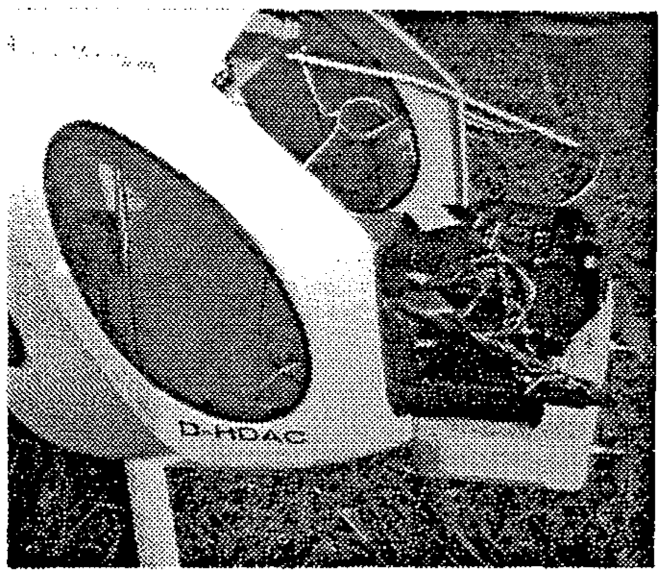

Fig. 2 Set-up of motor camera for airborne photography

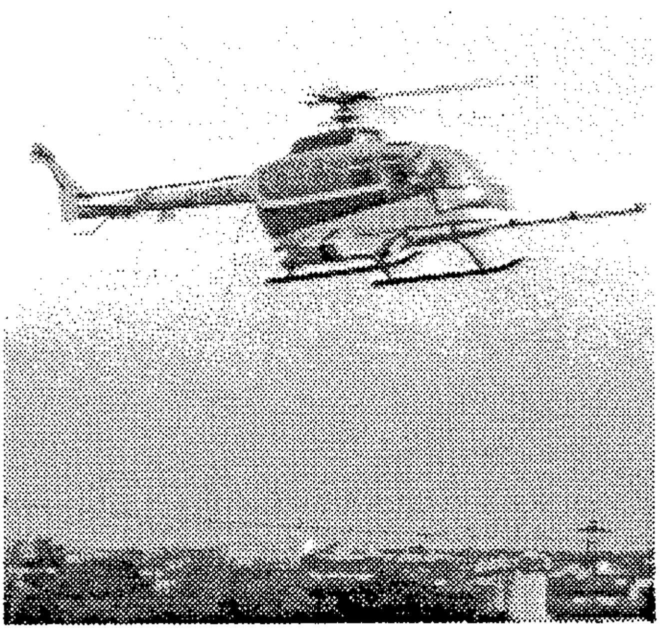

Fig. 3 Helicopter with gas pump device

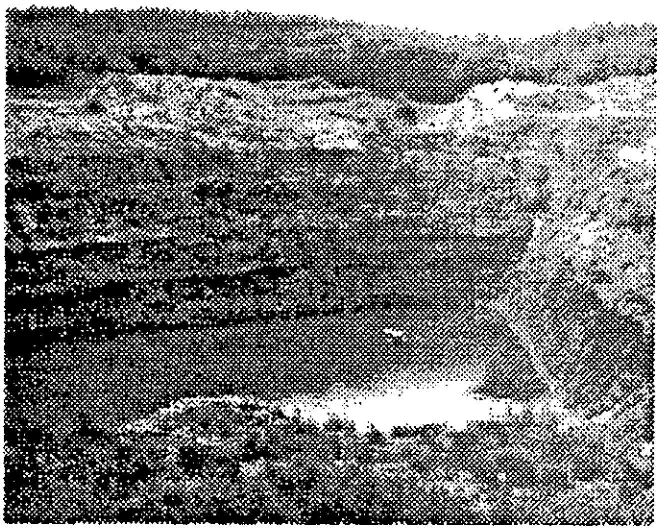

Fig. 4 Side view of a dredged lake

Due to the lack of an auto-pilot or a real-time video transmission from the model to a ground station, which will be a must for the establishment of the operational platform, large deviations from the optimal flight paths for the relevant measuring tasks have to be taken into account. Furthermore, flight distance and flight height was limited to ranges where the model was visible and controllable. These requirements limited the maximum distance from the pilot to the model to about 100 meters, the flight height to about 50 meters. These restraints, however, are not a problem in the testing phase of the platform and do not hinder the process of gaining information about the requirements of the measuring system.

The first example is a stereometric measurement task at a small dredged area, filled partially with water. The diameter of that area measures about 100 meters. Photographs of this area have been taken from the edge of the dredged part and, using the rotor platform, from a height of about 50 meters over the area (Figs. 4,5). Corresponding photographs serve as an input for a stereometric reconstruction procedure. For this procedure, the photographs have to be digitized into an image processing computer. They have to be scaled and geometrically stretched or de-distorted and rotated. Using these corrected images, the computer can reconstruct the area, using corresponding recognizable points in both images. The result, a 3-dimensional data set of the surface, can be used to produce surface plots, contour line plots, or volume calculations (Fig. 6).

The next example presents a very important application in environmental water protection: using an infrared sensitive film the introduction or injection of poisonous chemical fluid into a lake or a river can easily be observed and analysed by its temperature difference to the surrounding water. Figure 7 shows a small scale experiment of the measuring task: The shore of a lake can be seen with a measuring rod of a length of 2 meters. For Figure 8 a barrel of hot

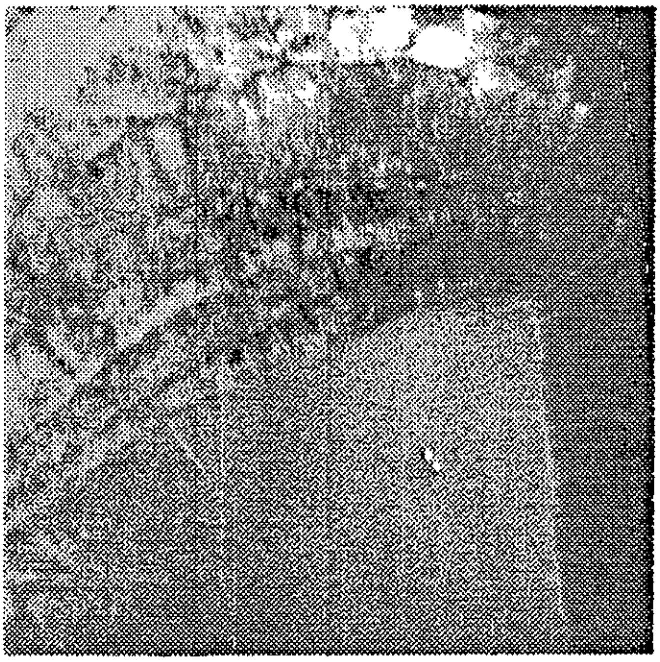

Fig. 5 Aerial view of the lake

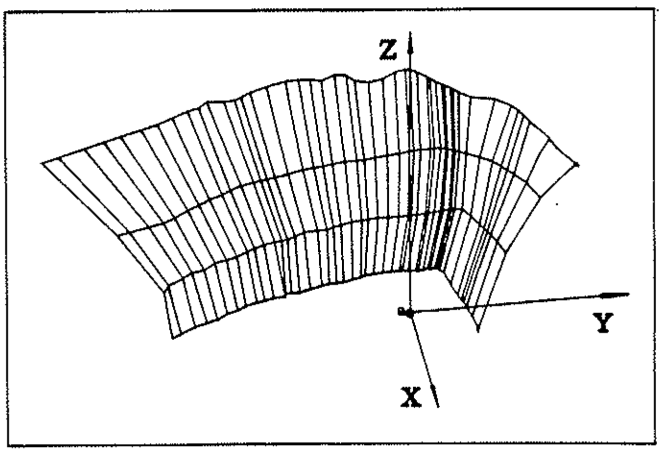

Fig. 6 Surface plot of part of the lake

Fig. 7 Lake shore in aerial view

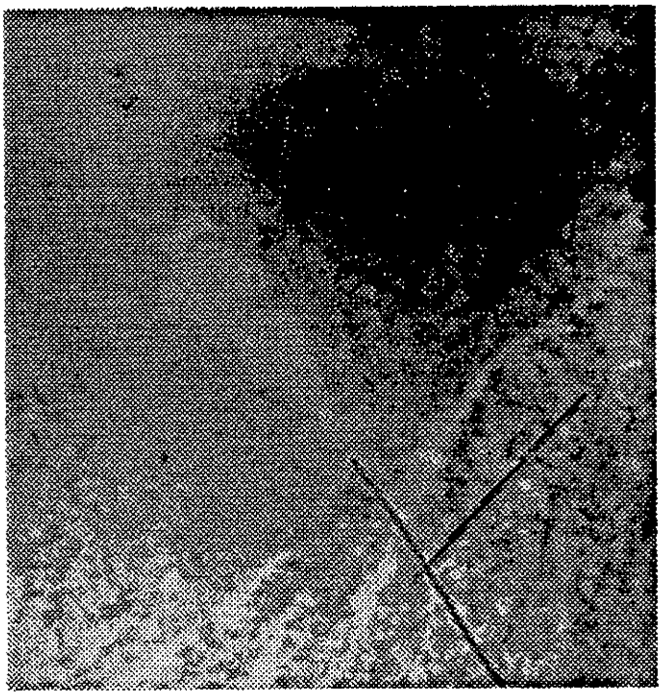

Fig. 8 Lake shore with waste water contamination (infrared photograph)

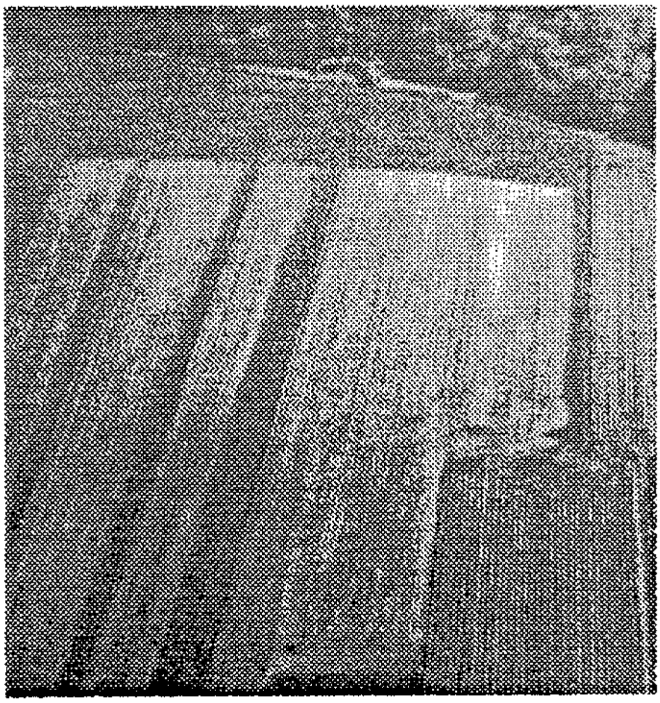

Fig. 9 Agricultural area

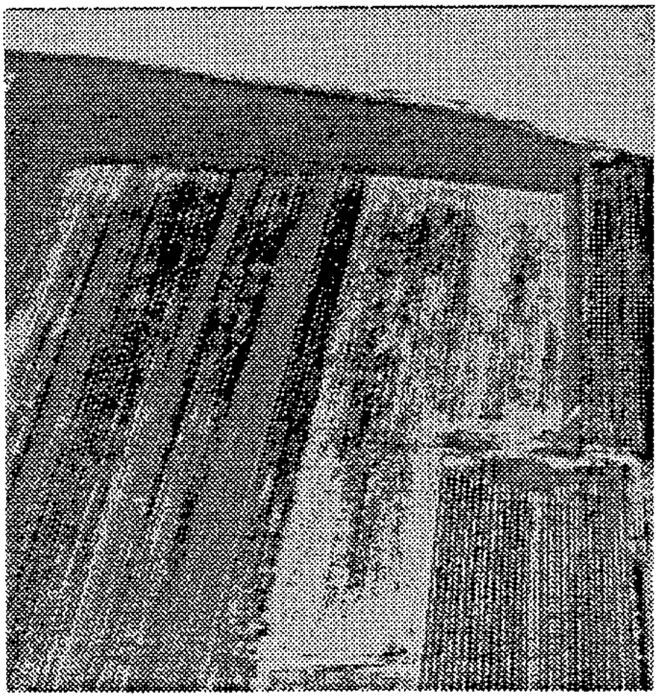

Fig. 10 Plant growth differences made visible by infrared photograph

water was emptied into the lake by a thin tube. In this infrared photograph, which is contrast-enhanced and weighted by a special grey scale (corresponding to the well-known false colors), the spreading of the hot water can be observed clearly. In a real life application, it would be an easy task to observe the fluid injection and then fly down to water level and take a water sample for later analysis. High sensitive infrared cameras with a temperature resolution of 0.1 °C are available for smaller temperature differences.

The next photographs show an agricultural surface. In the normal photograph (Fig. 9) almost no difference in the plant growth can be observed. In the infrared photograph (Fig. 10), however, large differences are made visible which can develop due to different soil type and water distribution or due to different fertilizer type and distribution.

All these photographs show that regular photographic cameras perform very well. Video equipment could not be tested.

Air analysis tests have been performed using active-coal tubes. These tests prove that it is possible to take air samples without any significant exhaust gas admixture of the platform engine by using a one meter long tube extension on the nose of the platform and by holding the platform in the local wind direction.

Design of an operational rotor platform

The design of a versatile rotor platform for observation and pollution control purposes is a very delicate task. The platform has to be easy to use and maintain. It has to be ready to use at any time to provide the possibility of measurements at catastrophic incidents or urgent observation requests. It must be operational at difficult weather conditions like strong wind, rain, or night time. It should not occupy too much storing space and should be very robust. Furthermore, it has to provide a large payload compartment, which can be equipped with different tools like photographic and video cameras, collectors for air and water probes, and telemetric systems for transmission of video signals or measurement samples. It should have a long flight duration and should not produce too much noise.

Even though these modern high-tech models are very well developed, this long list of requirements cannot be covered by a regular radio-controlled model helicopter. However, several of the mechanical subsystems could be used. In the following paragraphs, the mechanical systems of a model helicopter will be described together with possible improvements.

The models are equipped with a Hiller-type rotor system with very good flight characteristics. Additional electric gyroscopes help to stabilize the flight path. Normally, the gyroscopes are attached to the tail rotor function, but they can be used for all axes. With all this effort, however, the model still needs a very well trained pilot. The installation of an automatic pilot in a regular helicopter model could raise problems: due to the asymmetric design with one main rotor and a tail rotor, all control functions influence each other. A completely decoupled system like a two-rotor side-by-side system would make the flight control system much simpler (Fig. 11). This side-by-side concept would have even more advantages which will be discussed below. Height and azimuth control systems are available at low cost, laser gyroscopes will be used more and more for non military tasks and will get affordable in the near future.

The mechanical systems are well designed, leightweighted and robust, but maintenance is a complex task. The models are powered by small piston engines, which are connected to the gear box by free wheels, providing the possibility of autorotation in case of engine failure or mechanical problems. A bad disadvantage is that all space at the center of gravity is occupied by the engine. Due to their weight differences, the interchangable measurement tools have to be placed near to the center of gravity.

Another problem is the piston engine itself. It runs on methanol and synthetic oil and releases a large amount of waste gases, which can influence the air analysis. Additionally it produces high frequency noise at sound pressure levels of 85 dB(A) and more at a distance of 7 meters. An electrically driven rotor platform only could help over these handicaps. Both the latter problems can be overcome by the side-by-side concept: using two separate electric engines within the wing-tips could result in very simple gear boxes, would free the complete space in and near to the center of gravity, and the system would have a good hover efficiency due to the absence of a power consuming tail rotor.

After this presentation of advantages and disadvantages of the regular model helicopter mechanics and discussion of improvements, two possible concepts crystalize for an operational platform:

If a very short-time solution is asked for and if only some very specific tasks have to be flown, and if additionally a skilled model helicopter pilot is available, then the modification of an existing helicopter model should be considered. The payload of 2 to 4 kg is enough for the normal camera or measurement equipment and the model is inexpensive.

For more sophisticated tasks, however, a new design and construction of a versatile rotor platform

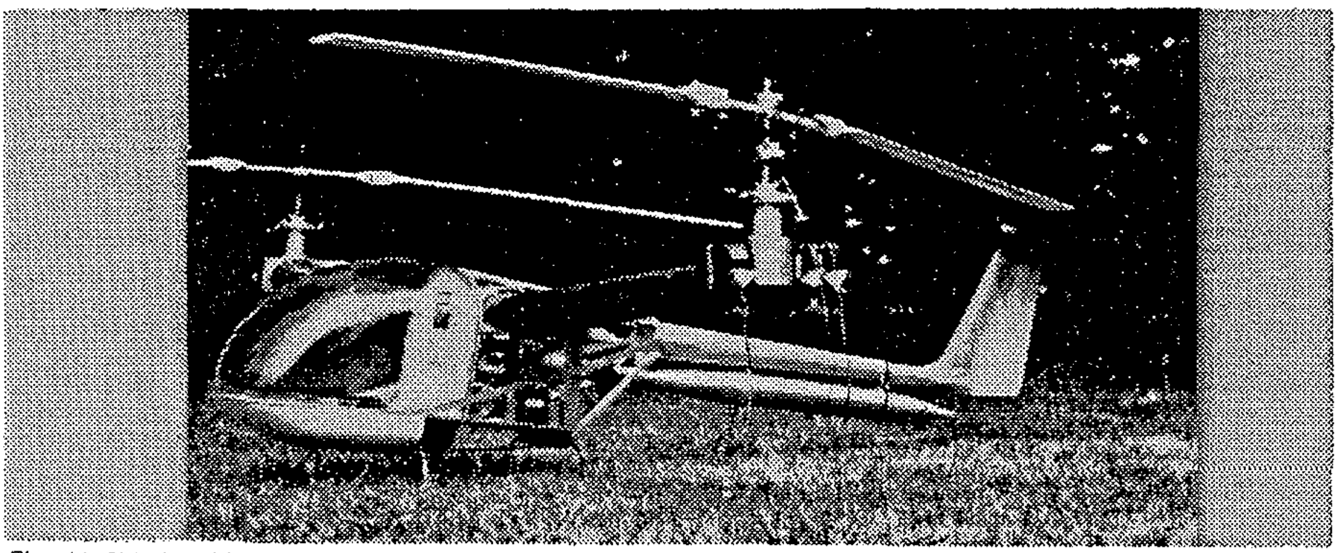

Fig. 11 Side-by-side concept

with electric power is recommended, which could be, depending on the boundary conditions, a regular main-rotor-tail-rotor system or a side-by-side concept. The overall take-off weight would be the same of the regular model helicopter, giving it a payload of 2 to 4 kg. If necessary, the payload could be increased up to about 6 kg with an overall take-off weight of 20 kg, which is the present weight limit for model aircraft in Germany without a special certificate. This will change to 25 kg in the near future. The use of electric power will simplify the construction but will also reduce the payload. Special types of accumulators or batteries like the Lithium-MnO_2-Battery or the new Aluminum-Air-Battery with the highest known power/weight ratio will enable the design of an efficient electrically driven platform and allow flight times of 10 or 20 minutes, which is enough for almost all applications. Change of the battery-pack is only one grasp - faster than refueling. The main payload compartment could be designed to meet all requirements of measuring or observation equipment.

This measurement and observation equipment will be offered in interchangable modules for the different applications. A very important observation tool will be a photographic camera with a video camera attached to its view-finder, combined with a video transmitter to a monitor or TV-set at the ground station. This would enable the collection of high resolution photographs from a selected point of view. The actual flight level of the platform and the simultaneous taken video signal would then be recorded at the ground station for later investigation. The photographic camera can be used with different film material in the visible and infrared spectral range.

Another module would be the infrared video camera with a light-weight fluid nitrogen cooling system and signal transmission to the ground station.

The probe module will consist of different calibrated pump devices for dragging air over analysis tubes or taking water samples. To be able to collect water samples from a larger flight distance of 50 or 100 meters, a simple height sensoring system will be installed. New dosimeters are under development which would make analysis even more simple. In the future even a small on-chip gas-chromatograph can be used for real-time analyses.

For special investigations a long probe extension can be attached to the nose of the platform to avoid the rotor downwash.

A rotor platform according to this description is under construction and the first flight tests will be performed in spring of 1992.

Acknowledgement

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