

# CAMERAPLATFORMS FOR LOW ALTITUDE AERIAL PHOTOGRAMMETRY AT THE DEUTSCHES BERGBAU-MUSEUM

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## Introduction

Looking for suitable cameraplatforms since 1980 the Deutsches Bergbau-Museum was concerned with different manned and unmanned vehicles like helicopters, aeroplanes, microlight aircrafts, airships and kites.

Aerostatic airborne systems (Fig. 1) and remotely piloted vehicles (Fig. 2 and 3) stood some good test series and can be recommended as tools in low altitude aerial photogrammetry.

## AEROSTATIC AIRBORNE SYSTEMS

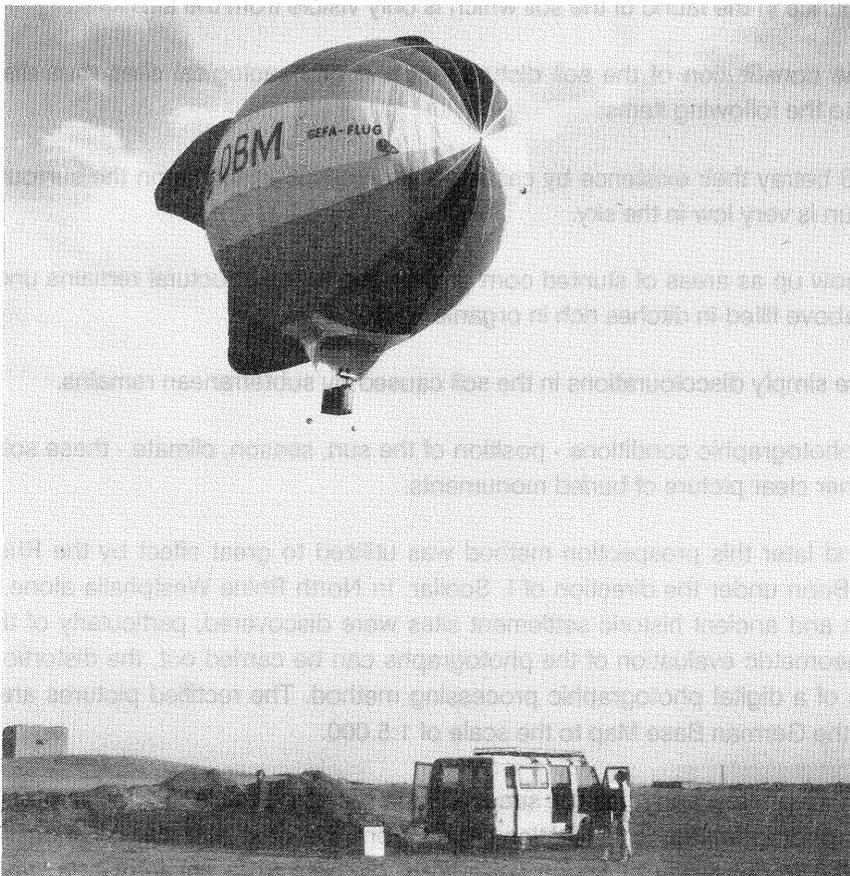


Fig.1 Hotair-airship GF 200 of the Fa. GEFA-Flug/Aachen and the German Mining Museum/Bochum from the year 1985 over the excavation area at Tell Shech Hamad/Dur Katlimmu (Syria)

The range of applications and the usage of unmanned, remote-controlled balloons and airships as camera carriers has been put to the test in various archaeological research projects. The advantages of the aerodynamically shaped airship have also been proved; for use in the Third World a hot-air system has also been fitted because there is little guarantee that inert gases such as hydrogen or helium are obtainable. Apart from this the hot-air system has proved itself to be robust in its construction and simple in its operation and maintenance.

### **The contribution of aerial photography to archaeology**

The development handier and less weighty cameras in the late 19th century led to the first attempts being made to photograph archaeological excavations from manned balloons or model kites.

It was not until the investigation of the aeroplane, however, and its being equipped with a camera for military reconnaissance that the systematic documentation of objects best visible from the air became possible. Thus in 1916 German pilots were able to make a photographic record of the state of ancient urban sites in Palestine and Syria on behalf of the German-Turkish Office for Architectural Preservation. Similar developments were also taking place on the English and French fronts.

Working in Wessex in the 1920's, the Englishman O.G.S. Crawford opened up a completely new field of application for the new technology - the prospection of archaeological remains buried under the surface. He made the experience that every architectural fragment hidden just under the earth's surface causes a disturbance in the fabric of the soil which is only visible from the air.

According to the constitution of the soil disturbance the archaeological sites thus discovered have been classed into the following items:

**SHADOW SITES** betray their existence by casting characteristic shadows on the surrounding countryside when the sun is very low in the sky.

**CROP SITES** show up as areas of stunted corn growth due to the structural remains underneath, or of denser growth above filled-in ditches rich in organic waste.

**SOIL MARKS** are simply discolourations in the soil caused by subterranean remains.

Under suitable photographic conditions - position of the sun, season, climate - these soil disturbances can reveal a rather clear picture of buried monuments.

In the 1960's and later this prospection method was utilized to great effect by the Rheinisches Landesmuseum in Bonn under the direction of I. Scollar. In North Rhine Westphalia alone, several thousand prehistoric and ancient historic settlement sites were discovered, particularly of the Roman period. Before a geometric evaluation of the photographs can be carried out, the distortion rectified pictures by means of a digital photographic processing method. The rectified pictures are then entered accordingly on the German Base Map to the scale of 1:5.000.

So far, however, air photography has not succeeded in replacing the land surveying of archaeological excavations by photogrammetric evaluation. Apart from the cost and organisation involved, this is mainly due to the impossibility of taking large-scale pictures from an aeroplane, restricted as this method is by minimum flight altitudes and speeds.

## Differences in the system

Normal balloons always have a right to a place alongside the aerodynamically shaped airships, even though their suitability for the production of pictures which can be used for measuring purposes is limited because of their much greater tendency to sway in high winds. The advantage of the "Normal" balloon shape over the airship is its simple manufacture. If only survey photos of an excavation area are desired, and these pictures are not to be analysed for measuring purposes, then such balloons show definite advantages. Because the shape of the balloon has a much smaller surface area than that of an equivalent, in relation to its volume, airship then the amount of material and hours required for its construction are greatly reduced, a ratio of approx. 2:3. A normal balloon envelope (hot-air) with an empty payload of 10 kg and a volume of about 100 m<sup>3</sup> would cost about 3000 German Marks. Approximately the same amount must be paid for the burner, remote-control unit and camera mounting. For an airship with the same payload one would pay about 15.000 Marks.

Through experience with these types of balloons and airships we estimate 300 hours to be the approximate service life of the balloon envelope; 400 hours have been achieved by manned balloons, but under easier conditions. A new envelope is required in all cases after this amount of time; the rest of the equipment should at least receive a general overhaul (remote-control unit, burner, camera mounting etc.).

This list gives a simplified estimate of the depreciation of a balloon or airship. Further 10 Marks for each operational hour must be included for fuel. Up to 6 - 8 pictures suitable for measuring purposes can be produced in each hour: simple survey photos without positioning or alignment of the camera took only half the time.

## Limitations

Through experience with different systems certain different limitations can be noted.

**SIZE OF THE AREA TO BE DOCUMENTED:** An "aerostatic" airborne system is suitable for relatively small areas because it can record even the smallest of details. Thus there is no competition from conventional surface aircraft, because they can only offer cheap "documentation costs per hectare" for larger areas, and cannot pick out exact details. In many cases such a balloon or airship system is the only possibility for aerial photograph documentation, so that a higher interpretation expenditure per hectare, because of the large amount of pictures, seems justifiable. Any solution to reduce the amount of pictures to be analysed through the use of large format cameras must be viewed critically by the balloon/airship constructor.

**CLIMATE, WIND AND WEATHER:** When it is decided to use a balloon or airship for aerial photography in the documentation of an excavation site, then the climatic conditions of the area must be comprehensively studied, especially wind speed. The airship we used proved to be operational for measuring work in winds of 8 - 10 knots. For survey photos (requiring less exact positioning) the airship could be used in wind speeds of up to 10 - 12 knots. The appropriate information about temperature, airpressure and wind speed can be obtained from airports or meteorological stations in the respective country. When the field work is to be carried out over a period of weeks or months, then one can usually rely upon enough possibilities for the airship's operation.

## **Greater payloads - large format cameras**

In principle it is conceivable to produce balloons or airships with greater payloads for the transport of cameras with a larger format than the previously used Rolleiflex 6 x 6.

The wish to reduce photo and analysis time is understandable, but from the point of view of the constructors the following factors contradict:

A simple increase in the volume does not lead to a very great increase in the construction and fuel costs of such a system, in any case proportionally lower than the volumal increase and the greater payload. However, an enlargement does inevitably lead to an increase in operational personnel. While our airship could be safely controlled by about 3 - 4 people, an increase in volume and empty payload, with the thus increased airresistance of the whole machine, leads to a steady increase in the amount of personnel required.

Each member of the ground team can hold no more than 30 kg traction for any length of time, especially when the adhesion and stability are lowered in areas of rubble and debris. One solution could be improvements in the balloon or airship construction, with the aim of improving positional exactness and reducing the amount of time needed for photographic work. Possible improvements have already been considered, such as the automatical alignment of the camera by gyroscope or electronic compass. The construction of movable steering elevators on the airship would most probably reduce the amount of time required per aerial photograph, but on the other hand it certainly leads to complications in the system as a whole. A consequence thereof is that the machinery would require more maintenance, and in some cases repairs could not be carried out on site with the equipment available, which never caused any problems with our more simple system in Pakistan. The constructor has to watch that each improvement in detail does not lead to more complications, and that the airship can only be manned by a highly qualified team after the improvements.

## **Summary and future prospects**

There are two different approaches to aerial photography work:

1. A simple, relatively small system with a payload of only a few kilograms and corresponding low construction and operation costs, which can be easily operated and maintained by trained assistants and one "qualified" pilot. This system would be equipped solely with a miniature of 35 mm camera for survey photos only, and in exceptional cases even photos for measuring purposes. The operation should be carried out fully by a Research Project Team.
2. A comparably complicated system with automatic positioning and corresponding greater expenses, to be used solely for measuring photos, which can later be analysed. The operational costs would certainly be about several hundred Marks per day, as a result of the high production costs and allowing for the fact that at least one qualified person, with the theoretical and practical knowledge of a hot-air balloon would be needed to control the machine (and would have to be paid for this). Only exceptional archaeological research projects would include such qualified personnel.

It is hard to put payload limitations as described into concrete figures, the limits of which are clearly rather vague. Given the present state of balloon and airship technology, a payload limit of 30 kg must be estimated. Greater payloads and the associated costs would most probably exceed the budget of a "standard research project", these costs being close to those of a conventional manned aerial photography system.

## REMOTELY PILOTED VEHICLES

For several tasks, e.g. flying over small areas at low altitude and operations in Third World countries, conventional photographic flight systems are only suited with certain reservations or are even unsuitable. So, the topographical maps - if available at all - often dispose of too small scales or they are too inaccurate. Many users are missing an auxiliary gearbox for aerial photos - not only for cartographic tasks, but in general. Due to the new drone family, it is now possible to offer an individually adjusted solution with a low expenditure of costs and personnel. The system, a radio-remotely controlled mini aircraft, has a modular design. This allows an optimal adaptation to the tasks. Irrespective of the terrain, launching is executed from a transportable catapult, whereas landing - according to the terrain conditions - is effected on the chassis or by a parachute. With the aid of an electronic control unit, the mission is largely carried out autonomously so that only one person is needed for the service. This "portable flying robot" ("a flying robot out of the case") shall serve as an instrument being able to carry out independent measurements in a shortest period of time. In different flights - even under harder conditions - the construction has proved its operational capability impressively.

The aerial photo, taken by reliable camera carriers, is a prerequisite for cartographic work, geo-scientific studies, supervision, environmental protection tasks, etc. The carrier systems - whether special measuring aircraft or satellite - have been tested and they work. As it often applies to procedures with a flair of "dinosaurians" (monstrous, expensive and "missing the point of evolution") there is a number of tasks which cannot - or only insufficiently - be managed by the conventional method. By a lot of reasons their operation is impeded, resp. it becomes impossible (too high costs, inefficiency, too high altitudes, inflexibility, danger of casualties during operations within danger zones, lack of suitable launching- and landing- fields).

Looking for a system which is able to solve the a.m. problems, which fits in the requirement-niche and is flexible at the same time, the following solution was found:

The camera carrier is a flying, unmanned robot the RPV (Remotely Piloted Vehicle). It is guided from a ground station by means of a radio control- and navigation- system which is connected with the on-board autopilot. At the same time, this ground station receives all important data from the mini aircraft. The transmitter, the platform necessary for launching, and of course the aircraft itself can easily be put into a station wagon and form a mobile unit.

All the a.m. negative points of conventional systems are not relevant for this remotely piloted, unmanned picture-taking system:

Procurement and operational costs can easily be controlled, large scales can be taken, due to low altitude and speed, due to the mobile system, the operation can be planned and executed promptly. It is directly available to the user. The loss of the flying vehicle is financially negligible, there is no danger of casualties. Launching and landing are possible even on pathless terrain.

Another important advantage of the new system:

The one who is charged with the execution of an investigation becomes independent by the new "portable" flying technique out of the case. That means that he is able to carry out his investigations autonomously. As a consequence, a manipulation of the measuring results by third persons -whether deliberate or not-is impossible.

Thus a new drone family, exactly tailored for the new task, was designed and built. The development comprised aerodynamics, mechanics and electronics. It was executed in two steps. In the first step, a

conventional, well-proved aerodynamical concept gives the base. This first RPV served as a testunit for the newly developed electronic components. At the same time, the first "hot" missions could be flown with this system. On the basis of the experience gained during these flights, a new drone concept was developed, which, among others, was distinguished by its high aerodynamical qualities.

### The technical concept

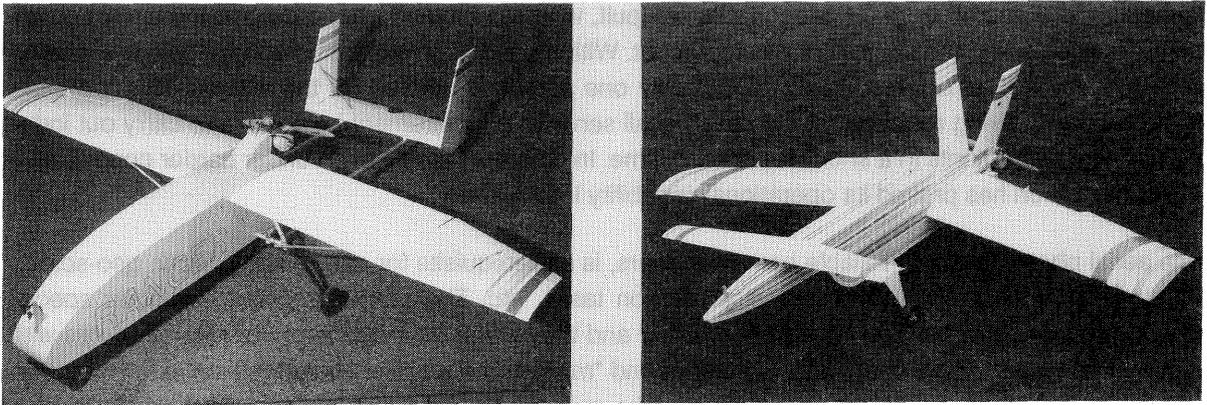


Fig. 2 and 3 Remotely piloted vehicles I (MK 103) and II (MK 104) of the Fa. Kügelgen/Köln and the German Mining Museum/Bochum

#### RPV I

The basic data result from the premisis to provide a secure transportation of a 3-kg-payload and not to surpass an entire wing loading of  $100 \text{ g per cm}^2$ . The mini aircraft has a wing span of 3 m at a take-off weight of 14 kg. As the camera lens must be free of exhaust fumes, only a rear drive can be taken into consideration. Here, a 4 h.p. two-stroke single-cylinder engine powers a specifically calculated and constructed wooden propeller. Due to this driving system, the tail unit is connected with the wing assembly via a double fuselage. The vehicle is piloted by all controls/rudders (i.e. elevator, aileron and rudder) with the elevator being splitted and serving at the same time as an additional aileron. A landing flap, which is integrated in the wing, reduces the launching- and landing distance as well as the minimum speed (see Fig. 2).

#### RPV II

In order to obtain a higher payload capacity and a larger speed range, a new, more compact airframe was designed. Concerning the construction of the new RPV's, the "canard"-configuration was chosen (Fig. 3), that means that the elevator unit is placed in front of the main wing. The advantage of this design: In oppositite to the conventional wing-tail structure, there are only lifting wings/surfaces; the overall lift is greater, the minimum speed is lower. Due to the front- resp. canard-wings, the aircraft is extremely safe against stalling and agreeable even in low-speed flight.

The main wing/surface is swept forward. This involves a minimal, induced resistance, and thus better flying qualities, due to reduced marginal vortices of the wing. This RPV is also powered by pressure drive and it is completely decomposable. The vehicle is constructed in sandwich style and consists of foam plastic and glass fibre-reinforced plastic. For highly-stressed zones, as for example the wing root,

carbon fibre is used; the fuselage is reinforced by Kevlar. In order to allow an operation in pathless terrain, as well, launching is effected by a catapult, landing by a parachute.

### **Aerodynamics and structure**

**Electronics:** More important than the aerodynamic layout of the aircraft was the development of an electronic control unit which largely relieves the pilot on the ground. Only an intelligent RPV which is easily operating can work as a real complement to conventional aero-photographic systems.

**Flight stabilization, winglever:** In order to meet, for example, even highest photogrammetrical requirements, the RPV must be able to keep an exact course in spite of cross-wind influences. By a gravitational field surveyor, the bank is permanently compensated. The sensor "sees" an imaginary horizon and controls aileron and rudder by a process computer. Without mechanical parts, like for example at a gyro-system, it exactly pilots the aircraft on a line.

**Altitude stabilization:** In order to assure the plotting capability of stereoscopic pictures the vertical difference within one photo series may not exceed 5 %. An electronic statorope guides the aircraft - exaggerating a bit, one can say in dolphin style - on a pre-programmed altitude. Besides, it provides for the optimal angle of climb during the climb phase.

**Constant speed device:** An acceleration-free trajectory is necessary among others, if, in case of serial photographs, a definite longitudinal overlap of the photos is required. A current-carrying heat wire is cooled off in line with the passing air and thus, it changes its resistance. This information is processed electronically and, as a control impulse, conducted to motor throttle and air brake.

**Navigation system:** In the field of aerial photogrammetry, two kinds of navigation tasks have to be carried out. The course navigation with particular importance being attached to safety and optimal execution of the flight. Determination and recording of the spatial flight position for a particularly economic evaluation of the pictures and for a chronological coordination of the measuring points. Therefore, in order to be able to work on large areas, as well (radius of action < 5 km), an autonomously navigating RPV is necessary. Imaginable - and also feasible - is the integration into an existing radio control system. Better is the employment of an inertial navigation system which makes a permanent three-dimensional control of the flight position possible without external influence.

**Telemetry:** For surveying tasks it is not enough to store information photographically and to evaluate them later on. A real time transmission of the photo is necessary. Taken up by a CCD-vidio camera, the picture is transmitted to the ground station together with the most important air data.

**Evaluation:** All electronic components have proved to be good. Navigation systems are at present being investigated. The optimal technology will be employed for each task.

**Operational spectrum:** Equipped with a photogrammetric camera (analyzer, e.g. Rolleimetric 6006 Réseau) and/or an infrared camera (e.g. Aga-Thermovision) and/or a video-camera with real time transmission, large operational areas open for an RPV-unit (ground station, launching platform, vehicle).

## Present state of being (application)

In order to prove the operation of the system, a lot of flights have already been executed. The most demanding project took place in August 1986 in Portugal. For archaeological researches, the whole area of a Roman goldmine with a size of several km<sup>2</sup> was taken up by aerial photos. With the aid of these aerial photos, surface and state of exhaustion of the mining region should be reconstructed.

Encouraged by the successful termination of tasks up to now, new projects are being prepared at present. They concentrate on development support measures and applications for environmental protection.

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