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Fig. 1. Filling a tethered balloon to carry an aerial camera.

Tethered Balloon for Archaeological Photos

Various cameras were suspended over sites in Greece and Turkey for photogrammetric compilation.

(*Abstract on next page*)

Numerous archaeological studies were completed over the past three years using balloon photography for various expeditions in Turkey, Greece, Italy and Cyprus.

Three years ago, in Sardis, Turkey, at the site of King Croesus capital in ancient Lydia, we filled our 600-cubic-foot balloon with hydrogen under 200 atmospheres pressure from divers' back tanks (Figure 1). The balloon was made by Ballonfabrik of Augsburg, Germany, and cost approximately $350. The three-meter sphere, made of impregnated cotton, coated with aluminum and free of static, weighed approximately 15 pounds.

We hung the camera, a Linhof 6×9-centimeter format with Schneider Kreutsnach wide-angle lens, in a gimbal preparatory to lift (Figure 2). It had a pneumatic release from a hand bulb on the ground. The camera was 150 feet above the ground and the balloon 30 feet above the camera.

True vertical photos (Figure 3) were taken over a 7th Century B.C. Lydian site being excavated by the archaeologists from the Harvard-Cornell expedition in Turkey. The balloon and camera on its platform were then walked to another nearby site (Figure 4), the

Fig. 2. Hanging the camera preparatory to a balloon flight.

* Presented at the symposium, Earth Observations from Balloons, sponsored by the American Society of Photogrammetry in Washington, D. C., February 1969, under the title "Photogrammetry from Tethered Balloon Supported Camera Platform."

ABSTRACT: *A tethered balloon was used successfully to support aerial cameras for recording and mapping archaeological sites in Turkey, Greece, Italy and Cyprus. Camera altitudes ranged from 30 to 2000 feet, and included the Linhof, Graflex and Hasselblad. Some of the sites were submerged in shallow sea water. Aerodynamic kite balloons were also utilized (especially in the presence of wind), as well as the author's* BIPOD *camera support. Various schemes were used to obtain stereo coverage including an electrically advanced, radio-controlled camera.*

balloon being held at 50 feet above ground and the camera about 30 feet below it. Photos (Figure 5) were next taken over the remains of an ancient 2nd Century B.C. synagogue. Note the mosaic floors clearly seen from 150 feet above.

The next view was taken in Greece. The balloon was brought inflated to a water site tied down to the roof of an auto during a short trip from its overnight mooring. A Graflex XL $2\frac{1}{4}\times3\frac{1}{4}$-inch format camera with Schneider Kreutsnach wide-angle lens and radio release were hung in the gimbal preparatory to flights up to 2000 feet over land and water.

A photo over shallow water (Figure 6) from 1500 feet shows the remains of a Roman bath, now under water. A submerged bomb crater from World War II may be observed as well as evidence of Greek city walls. An-

FIG. 3. A vertical photograph taken at 150 feet above an archaeological site in Turkey.

FIG. 4. "Walking" the balloon and aerial camera to the target area (Turkey).

other similar photo (Figure 7) from 1000 feet clearly shows remains of submerged ancient walls near the shoreline.

Plans of archaeological remains were mapped. The film was developed and printed each day for interpretation and mapping under a Zeiss Stereoscope in the mapping tent. Stone by stone details are plotted from low elevation coverage showing submerged city walls and the foundations of round defense towers (Figure 8). A swimmer is shown floating over the round defense tower directly below him while he held the balloon tether. The camera was released by shore radio and the swimmer proceeded to another nearby location to be similarly recorded through the water surface. The balloon remained aloft over the water while the swimmer pulled the camera down to advance the film and then sent it back aloft to the desired height for the next photo. A faster procedure was developed in the next season with an electrically advanced camera, also radio operated. Orientation of the picture formats for stereo pairs is governed by a separate very light nylon line held on the ground, well off to one side.

Photogrammetric coverage of deep-water sites, down to about 150 feet, was obtained from a horizontal traverse bar stationed over the sea bottom site. The cameraman led a Rollei Marine 6×9-centimeter format camera along the 30-foot traverse, taking a succession of vertical photos at known separation and height above the ground control plane. The system was designed by the author, built in

FIG. 5. Archaeological ruins in Turkey.

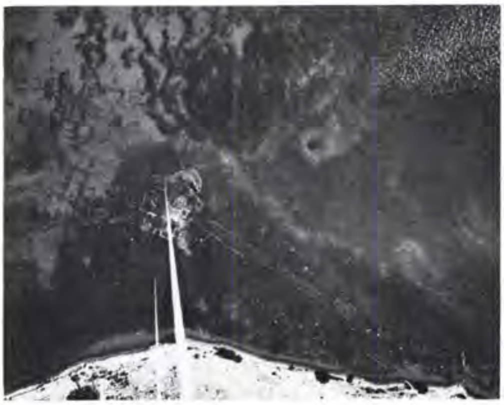

FIG. 6. Photograph from 1,500 feet over shallow water showing a submerged archaeological site in Greece. Note the Roman ruins as well as a bomb crater.

Greece, and used in Turkey by the University of Pennsylvania Expedition, directed by Dr. George F. Bass.

Similar deep coverage was taken in Turkish waters from the two man dry submarine, *Ashera*, built by General Dynamics Corporation of Groton, Connecticut, for the University of Pennsylvania. Two German aerial reconnaissance cameras, encased for underwater, were sequenced by an intervalometer, and carried over a submerged wreck, making simultaneous exposures for a stereo pair sequence. The submarine carried strobe lights on each side.

An electrically advanced, radio-controlled camera currently in use, was hung in a magnesium gimbal designed by the author and built by P. W. Winter, Inc. of New York. Four lines upward from the gimbal were joined for attachment to the balloon line from above. Four lines downward from the

FIG. 7. Photograph over a shoreline in Greece showing ancient submerged walls.

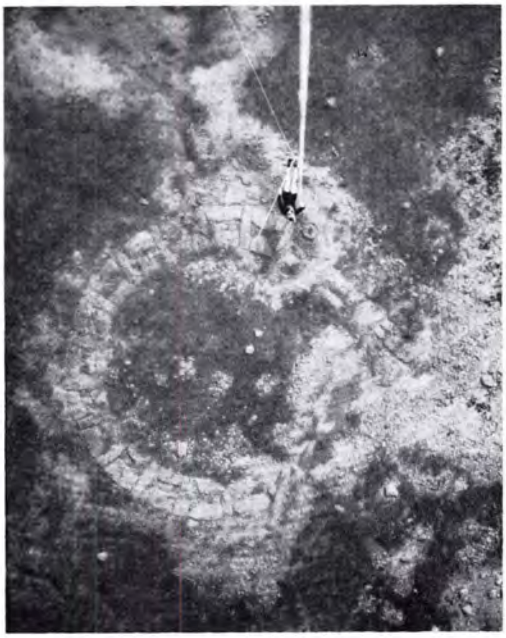

FIG. 8. A swimmer holds the tethered balloon and camera over the submerged foundations of an ancient defense tower in Greece.

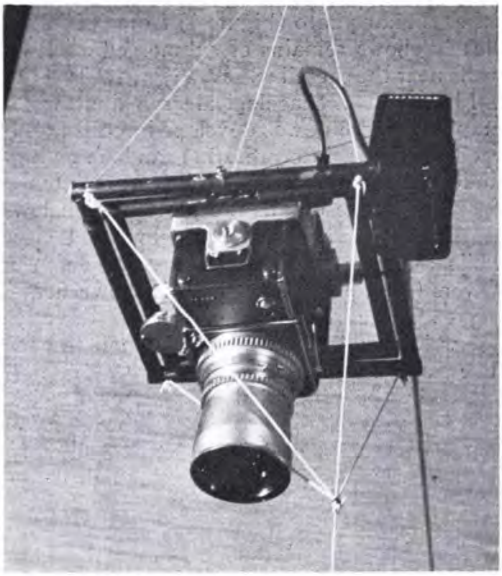

FIG. 10. The radio-controlled Hasselblad El 500 camera hung in its gimbal as seen from below.

gimbal were joined for attachment to the tether from the ground. The join point for the tether is outside the camera angle (Figures 9 and 10). The gimbal and rig are shown with the camera removed in Figure 11.

The camera is a Hasselblad 400 EL with Zeiss Distagon 50-mm wide-angle lens as used in the Apollo 8 flight. The radio-transmitter and receiver were built by Grundig and specially adapted for Hasselblad. The entire payload of the camera, lens, motor and power pack, radio receiver, antennae and magnesium ball-bearinged gimbal is six pounds. The camera frame is provided with fiducial marks installed by P. W. Winter, Inc. The cost of the above, complete with adaptions, is approximately $2,000.

Close-up terrestrial photogrammetric coverage was taken from the BIPOD Camera Support, designed, built and patented by the

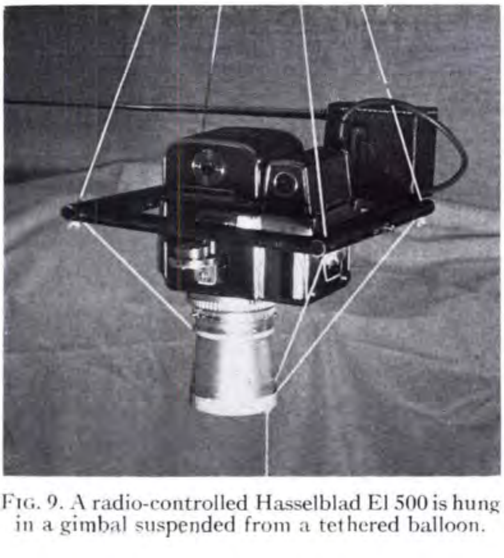

FIG. 9. A radio-controlled Hasselblad El 500 is hung in a gimbal suspended from a tethered balloon.

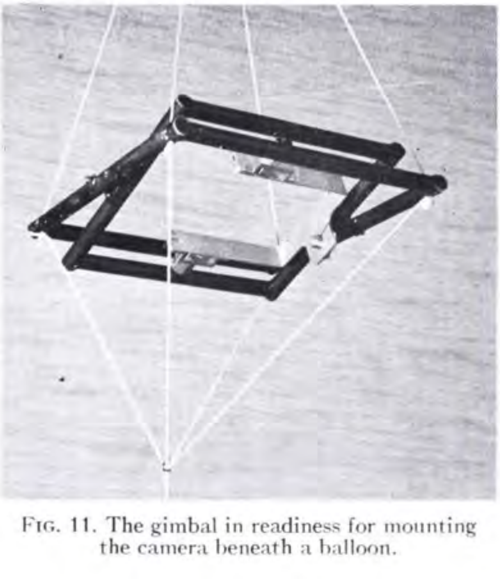

FIG. 11. The gimbal in readiness for mounting the camera beneath a balloon.

FIG. 12. A photograph from the balloon supported camera 2000 feet above an archaeological site in Greece.

author.* It was used in Corinth, Greece over the remains of an ancient Roman bath in 1967. A duplicate BIPOD, built for the U. S. Army Cold Regions Research and Engineering Laboratory, was used in the Arctic to measure plant growth and soil deformation under frost and loading conditions.

Figure 12 shows the photogrammetric coverage from the balloon at 2000 feet over an archaeological area in Greece in 1968.

A 700-cubic-foot ovoid balloon (Figure 13) recently made by Jalbert Aerology Laboratory for the author was moored in a 20-mph wind in Connecticut. Note the mooring line extended windward from the nose, the leg lines abeam to each side, and the shroud lines and back line to leeward.

* *Photogrammetric Engineering*, Vol. 32, No. 6, pp. 1005–1010, Nov. 1966.

The foregoing operations with spherical balloons have been practical only in relatively calm weather with the wind not over about five knots. Through-the-water surface coverage requires unrippled water. Aerodynamic kite balloons are otherwise required except as the JALBERT PARAFOIL has been found practical to support a camera platform. We have had some success in managing this after a number of field trials. However, in these instances, with a parafoil of but 42 square feet in area, we have flown a very light, single-shot, remote-controlled, balanced Graflex XL camera, weighing altogether 3 pounds.

The parafoil is flown up into a steady wind current of 15 to 20 knots where it will hold well. It stays there like a *sky-hook* at perhaps 1000 feet. The tether line is approximately 60 degrees from the ground. The pull may be very strong, requiring secure anchorage. The

FIG. 13. A hydrogen-filled balloon of 700 cubic feet moored in a wind of 20 miles per hour prior to a test flight in Connecticut.

camera is then hoisted up to a mid-point on the tether line, a small pulley having been installed in advance with a line looped over it. The camera is lifted vertically from the ground, its lifting line being taken-in up-wind from the anchorage point of the parafoil so as to minimize the downward component on the tether line.

Having brought the camera up to the pulley on the tether line, the camera-lifting line may then be taken to one side some distance from the anchorage point so that the camera is at the apex of a twin tether. This restrains the camera movement although it allows the parafoil to move about within the angle of the twin tether. The camera may be further restrained by a third tether down to windward; thus, a three-point tether is established.

We have used the same principle of a three-point tether for holding a balloon-supported camera platform perfectly still while the balloon was free to move about. Such tethering is well illustrated by Jalbert's diagram for holding kite balloons.

Articles for Next Month

Francis B. Reeves, Color versus B&W photos.
Hans Waelti, Forest road planning.
A. Viksne, et al, SLR reconnaissance of Panama.
Donald L. Light, Extraterrestrial work at Topocom.
Dr. Edward M. Mikhail, Relative control for extraterrestrial work.
Arnold H. Lanckton, Hydrid stereoplotter.
Ronald P. Noonan, The "Canadian" cross for relative orientation (a brief).
David L. Rife, A variation for stereo viewing (a brief).