BALLOON FLIGHTS TO TEST REMOTE SENSORS

Alden P. Colvocoresses
U.S. Geological Survey
Washington, D.C.

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Alden P. Colvocoresses
Topographic Division
U.S. Geological Survey

Biography: The author obtained a BS in Mining Engineering from the University of Arizona in 1940, MS's in Civil Engineering and Geology from Ohio State University in 1959, and a Ph.D. in Geodetic Sciences from Ohio State University in 1966.5

He served as a topographic engineer in the U.S. Army for over 20 years and retired as a colonel on December 1968. He is now a research engineer for the Topographic Division of the U.S. Geological Survey. He is a member of the ASP, ACSM and SAME, and a registered engineer in Ohio.

Abstract: The use of balloon flights to gather remote-sensor data of the earth from altitudes not possible by aircraft has been largely ignored. Balloon flight technology has advanced significantly, and today balloons can be flown over a course and tracked with great precision or made to hover over a given area. Balloon flight environment to some extent simulates space flight environment (vibration free). Hence consideration should be given to the use of balloons to test more sophisticated remote sensors (I.R. radiometer, multispectral cameras, etc.) prior to NASA space experimentation. Photogrammetrists should take another look at balloons as a means of experimenting with advanced sensor systems and acquiring data of the earth so greatly needed for the development of our national resources.

INTRODUCTION

The U.S. Geological Survey recognizes aircraft as the conventional platform for testing and operating remote sensors, with the cartographic camera as the best-known sensor. The Survey's interest in remote sensing covers many disciplines in addition to cartography, and flights at altitudes beyond which aircraft normally fly are receiving a tremendous amount of interest. The Earth Resources Observation Satellite (EROS) proposal, involving a one-year orbital flight with video readout, exemplifies this interest. Obviously there is a need to fully test any new remote-sensor system before undertaking the actual space flight, and for such purposes balloons

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hold considerable promise. In anticipation of testing EROS, or other, sensor systems, the Survey has obtained two balloon gondolas and other auxiliary equipment. These are on indefinite loan from the U.S. Air Force, and one of the gondolas is currently on display at the Smithsonian Institution. Flying a balloon is beyond the Survey's current capability, and an agency or company with balloon experience should conduct the actual flights. Perhaps as a result of this meeting at least preliminary plans for such flights will evolve.

The Geological Survey's interest is principally in the experimental aspects, but if it can be shown that useful imagery can be reliably and economically obtained from balloons, then the Survey is, of course, interested in operational aspects. This paper, however, is restricted to the discussion of balloon flights for experimental purposes.

ADVANTAGE OF THE BALLOON PLATFORM

The Survey claims no expertise in the matter of balloons and hopes to learn a good deal from this symposium. However, there are certain advantages to the balloon platform that appear to be obvious.

Aircraft are just about competitive with balloons as to altitude, and they undoubtedly excel balloons as to reliability. The big appeal of the balloon mode is the hover or near-hover capability coupled with very high altitude. The ability to observe a scene and various phenomena for a protracted length of time provides some real advantages as compared with high-speed aircraft. Of course, the "high-lift" aircraft and helicopter can also accomplish this, but only at the lower altitudes. Another advantage is the relatively stable, vibration- and noise-free platform provided by the balloon.

A vibration-free platform that can hover at an altitude of around 100,000 feet is certainly appealing. The big problem of image motion disappears under such conditions, and for certain experiments this is highly desirable.

Another potential advantage of the balloon mode is cost. If the prototype of a space sensor can be flown in a balloon and not in a plane, then considerable developmental costs (and time) may be saved. These advantages certainly do indicate a proper testing mode for certain sensors before committing them to orbit.

POTENTIAL BALLOON EXPERIMENT

As taxpayers it is important for us to know that has been done so that we do not duplicate somebody else's experiment. In the case of balloons, it may be appropriate for someone to compile and publish a summary of all balloon flights related to remote-sensor experiments, with an analysis of the results. Available references

(1, 2, 3) lack such comprehensive treatment. Perhaps both classified and unclassified versions would be required. Without indicating which sensors may or may not have already flown in balloons, the following are considered possible candidates for balloon flights:

1. Mapping cameras of focal length varying from 1.5" to 18".

2. Panoramic cameras of focal length varying from 3" to 24".

3. Multiband frame or panoramic cameras of 3" to 6" focal length.

4. Tracking telescopes of up to 100" focal length (folded optics).

5. Video scanners, including the return-beam-vidicon.

6. Optical-mechanical imaging scanners.

7. Nonimaging detectors, both active and passive, which cover various portions of the spectrum and include such techniques as absorption spectroscopy.

8. Acoustical detectors at lower altitudes.

Combinations of several of the above sensors, depending on payload, should also be considered. Two specific instruments have been selected from the above list for detailed examination because of their particular suitability for balloon test flight.

RETURN-BEAM VIDICON (RBV) EXPERIMENT

The RBV is the most likely candidate instrument for the EROS program. Testing it in a balloon rather than in an aircraft offers certain distinct advantages provided by the hovering capability of the balloon. The rationale for flying the RBV in a balloon was spelled out by W. A. Fischer of the USGS in a letter to John Thole of NASA, Goddard, on May 29, 1968. In addition to the previously mentioned advantages of the balloon mode, this letter points out some other advantages with respect to the RBV. These advantages hinge on the need to test the RBV in the multispectral mode. From a balloon, one camera could sequentially image the same scene in different wavelengths, or two (or three) cameras, possibly of reduced size, could image the same scene simultaneously. In either case, the problem of registration and correlation of the separate multispectral images might be analyzed. Such analysis has been done in the laboratory, but these tests do not properly account for the effects of differential refraction of the atmosphere and variances in the geometry due to transmission anomalies. Moreover, existing concepts of optimum spectral zones for a three-camera system could be confirmed or modified by analyzing imagery taken through all but a small fraction of the atmosphere. In addition to the sensors, the data transmission link would get a good test, and some real imagery would result, which would at least indicate the form, if not the resolution, of EROS imagery.

At this time it is not known how many balloon flights would be required to fully test the RBV, but two to four flights are given as an estimate.

TRACKING-TELESCOPE EXPERIMENT

There are two basic modes for sensing the earth's surface for time-variant phenomena from space. The more common approach is to pass a sensor successively over the same area and record the changing scene. A second method involves an earth-synchronous satellite which literally sits over the same portion of the earth. This synchronous orbit is nearly 20,000 nautical miles above the earth, so it would certainly take a powerful instrument to see the earth in any great detail. To approach the "real time" concept, the system would have to include a data transmission link--perhaps using laser rather than an electronic signal.

This concept and the problems involved warrant a separate paper and one is in preparation. At this time it is enough to point out that viewing the earth from synchronous orbit, as demonstrated by NASA's Applications Technology Satellites (ATS), offers a new dimension for those who wish to survey the resources of the earth. In one of NASA's newest publications (4) it may be noted that future ATS synchronous satellites are being considered for observation of both cultural and natural earth-resource phenomena. Figure 1 is a transmitted photo of the earth taken from synchronous altitude with the small, 5-inch aperture; spin-scan (Suomi) camera on ATS. Note that the earth's surface is quite clear even when the viewing angle involves looking through the equivalent of two rather than a single atmosphere. Figure 2 is a rather crude photograph of the earth taken from space with a small Questar telescope of only 3.5-inch aperture. Optical energy collectors (telescopes) exist or are being designed that can overcome the obvious resolution problem, and it is well to remember that the noise level of the atmosphere under good seeing conditions is only on the order of two to three inches. The smallest object that can be resolved from space lies somewhere between the golf and tennis ball, regardless of how far out one may be.

How do balloons fit in?

By flying in a region of low wind velocities (possibly near the Equator) the balloon might hover for several hours over the same scene. By using a scaled-down tracking telescope with appropriate detector and data transmission, the various system components of a synchronous satellite could be thoroughly checked out in a [illegible]-space environment. In this case there are a large number of tests that should be made, as the space system involved would be one of very high cost. Some of the problem areas that might be investigated by balloon flights are as follows:

1. Scene acquisition and identification.

2. Tracking precision.

3. Spectral range and discrimination.

4. Effects of obliquity on resolution and detection.

5. Data transmission modes.

6. Data acquisition and transmission capacities.

At this stage the Survey is not prepared to recommend any specific balloon flights with respect to tracking telescopes because of the complexities involved. It is believed that the synchronous mode of earth sensing should be given a great deal of study by those disciplines that might benefit from such a system. It appears to hold promise as a long-duration, operational system of the future that might follow a series of the lower altitude EROS-type flights. As other agencies or groups may accept this concept, the Survey is willing to consider balloon flights, which appear to be the most effective mode for testing such a system and the problems involved.

SUMMARY

The U.S. Geological Survey is planning in terms of applying space towards the inventory and management of the earth's resources. Cartography is also involved and of paramount interest. The number of candidate sensor systems is large, but at least two of these are uniquely suited for experimentation on balloon flights. These are the return-beam vidicon and a tracking telescope with a data transmission system.

There undoubtedly are other sensors which warrant balloon testing and if they offer a meaningful contribution to the Survey's evaluation of resources, then they will also receive appropriate consideration. With respect to the RBV, the Survey would like to see specific balloon flights scheduled by NASA and executed as soon as the required components can be made available. The two gondolas available to the USGS are likewise available to NASA, as well as such other assistance as the Survey might appropriately offer. At this stage we suggest that concerned agencies, all of whom are well represented at this meeting, get together and either lay out a tentative schedule and plan for flying the RBV in a balloon or, if the obstacles appear too great, drop the entire matter. Perhaps in the near future serious consideration may be given to the tracking telescope and other sensor systems for which balloon flights offer the prime mode for testing.

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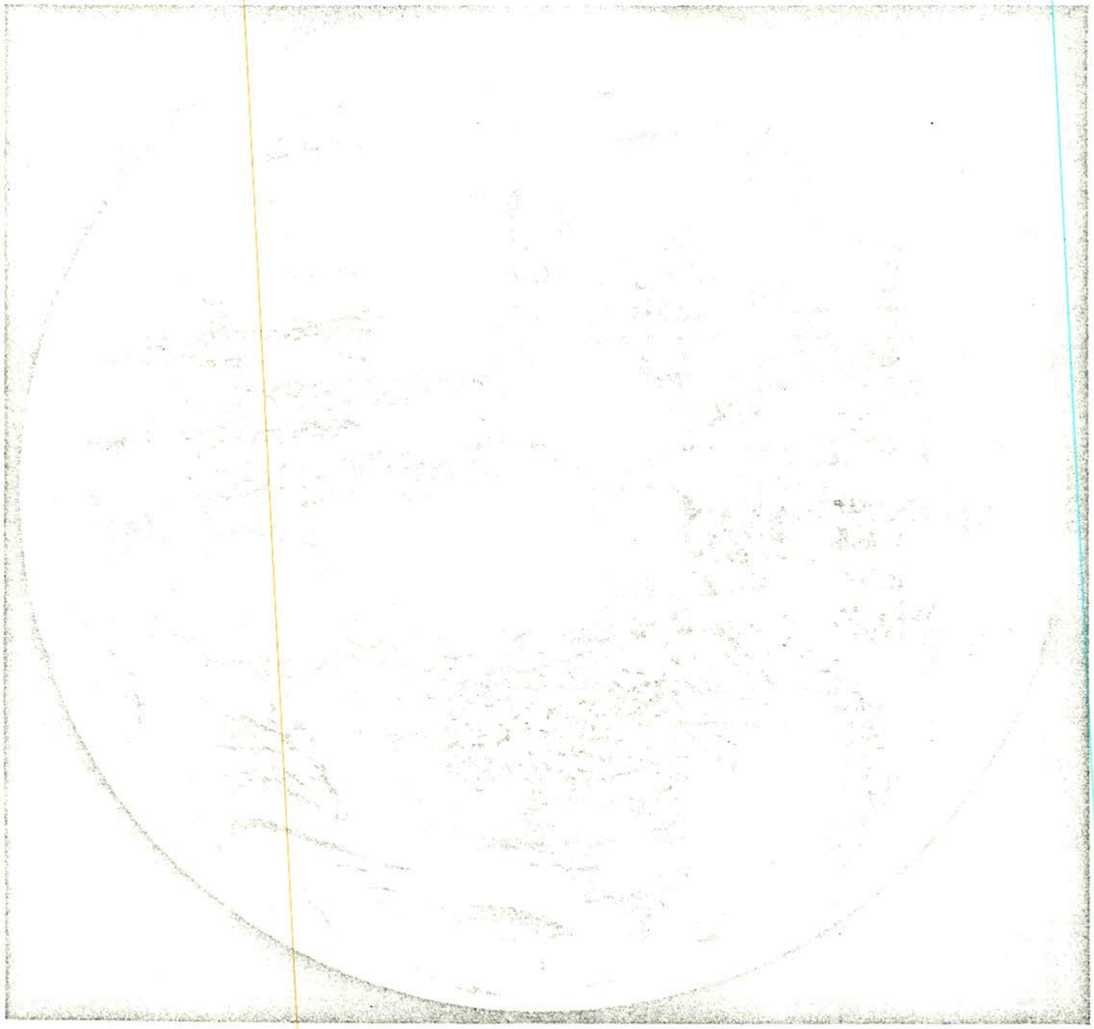

Figure 1. The earth from synchronous altitude (ATS).

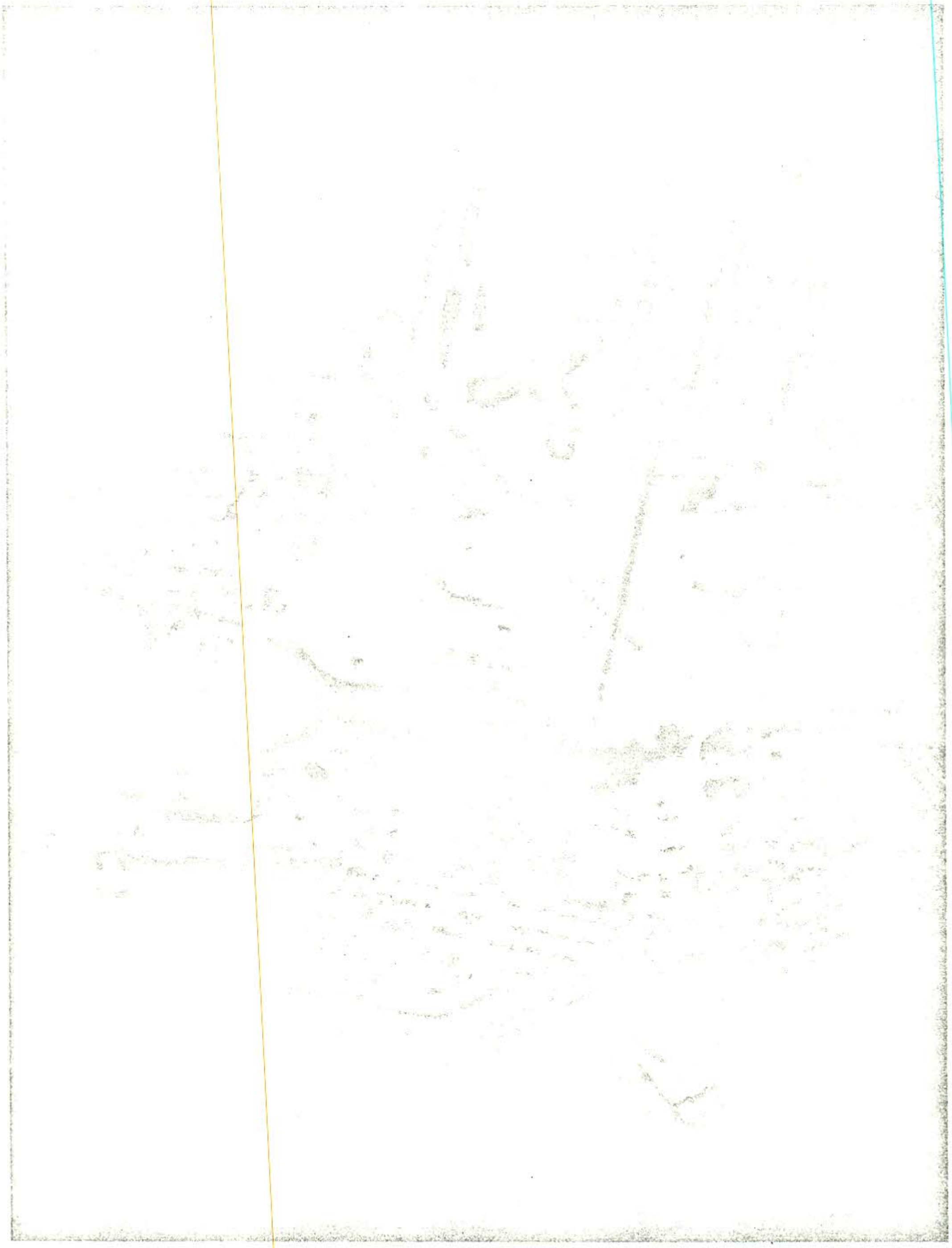

Figure 2. Love Field, Texas, photographed from space through a small Questar telescope.