is found which proves that the postulated structures are inaccurate or non-existent.

(5) In areas of regional metamorphism, aerial photographs frequently provide the most reliable, as well as the quickest, way of ascertaining the strike of metasediments.

(6) In metasedimentary areas, the aerial photographs indicate the bedding, rather than the foliation, direction; and where only one direction of lineaments is observed, that direction represents the bedding.

(7) Because aerial photographs sometimes provide the most reliable evidence of the strike of metasediments, they also sometimes provide the most reliable evidence of faults and folds.

(8) Aerial photographs sometimes indicate the origin of certain rocks even when the field evidence obtained from individual outcrops is equivocal.

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Airborne Geoscience Research

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(*Abstract is on next page*)

DR. ABRAMS* has been very honest in his appraisal of the present status of aerial photography, its interpretation and applications. We heartily concur with his major thesis and find it quite difficult to conceive of other individuals unwilling or unable to accept the fact that we are indeed at the crossroads of a new era in photogrammetry.

As evidence of our concurrence, we are outlining here our own feelings on a subject which we feel has virtually unlimited application in many different fields of endeavor. "Airborne Geoscience," for convenience, may be defined as methods used for obtaining terrestrial information through airborne means.

BACKGROUND

Military specialists in electromagnetic radiation have seldom considered the problem of sensing the geophysical environment of the earth's surface. Instead, their interests have

* Abrams, Dr. Talbert, "Aerial Photographs are Obsolete," PHOTOGRAMMETRIC ENGINEERING, December, 1961, Vol. XXVII, no. 5, pp. 691–694.

been largely directed toward targeting problems which face the intelligence community, strategic, tactical, and defensive operating commands, or those involved in gathering reconnaisance and surveillance information.

Currently, within military and government organizations, considerable interest has been demonstrated in the airborne acquisition of terrestrial environmental information. Airborne Geoscience as it is called, has no stringent affiliation with typical military reconnaissance operations within this current sphere of interest; however, any kind of information gained from certain areas of the world would have obvious geopolitical implications. Instead, the objective is primarily scientific: to increase our meager overall understanding of the vast terrestrial environment through airborne means.

ABSTRACT: *The program and philosophy of airborne terrain sensing under study at the Air Force Cambridge Research Laboratories is presented. Initial emphasis is placed on the examination of sensing techniques which appear feasible in preliminary study. Eventual plans call for the instrumentation of a C-130 aircraft to include airborne gravity, magnetics, photography, radar, infrared, and other terrain sensing devices. This effort should ultimately help to supplement aerial photography, as well as provide other data. Plans for using information obtained are discussed; the airborne method of terrain data collection will help satisfy the ever-increasing need for information for scientists and engineers.*

Scientists in fields concerned with extending our understanding of various factors of environment have been very slow in adapting the new and powerful tools of airborne sensing to their research, and hence have often been woefully lacking in the amount of useful data which is required for their needs. Conventional field investigations in remote areas are costly and time-consuming, compared to the rapid coverage of wide geographic areas possible with appropriately instrumented aircraft.

The Terrestrial Sciences Laboratory of the Air Force Cambridge Research Laboratories has therefore initiated a program to study and develop advanced air borne sensing techniques to help bridge this gap in providing data relating to the physical character of the surface and subsurface of the earth.

WHY THIS INTEREST?

Virtually any scientific discipline that a person could mention is interested in the earth: its processes and morphology; its biologic, cultural, and physical manifestations; its history and future implications. The interest embraces its most remote and inhospitable areas, largely unknown to mankind. Unfortunately, our primitive cultures inhabiting remote areas have done little to advance our scientific knowledge. Primary assumptions from which we must start are:

a. That many facets of the earth's environment are not clearly understood and are vitally important to mankind.
b. That much of our globe has yet to be explored, and present means of exploration are inadequate to effectively and efficiently accomplish our objectives within the next few years.
c. That our earth and its processes are in a constant state of flux, however subtle it may be, and these changes need to be recorded and analyzed.
d. That knowledge and techniques gained from earth-based studies can logically be used in studying other moons and planets.

CONVENTIONAL SENSING TECHNIQUES

Airborne photography has been the principal tool of airborne information acquisition for a long time, and will most assuredly retain its high status through future years, because of its unequalled economy and reliability. While standard photographic equipment and films are continually improving, several inherent limitations are evident.
These are:

a. Lack of specific finite detail. Much information is gained through experience, inference, and by indirect analogy; however, it cannot always yield direct indications of soil, rock, subsurface, and other properties.
b. Atmospheric and light limitations. Although usually these are not severe, restrictions are evident.
c. Photographic and equipment limitations. The resolution and spectral response capability of lenses and films, although now developed to a high degree of efficiency, has restrictions.

Items of Study at AFCRL

Terrestrial Properties of Current Interest

The Terrestrial Sciences Laboratory is primarily concerned with response and resolution capabilities of various sensors to the following parameters:

a. Moisture content, ground water
b. Composition (mineralogical and chemical)
c. Texture (soil grain-size and distribution)
d. Topography and micro-relief
e. Temperature and albedo
f. Vegetation, zoologic effects
g. Geologic structure, surface hardness

1. *Project SATAN (Sensors for Airborne Terrain Analysis)*

A thorough evaluation of anticipated useful sensor systems to measure specific terrestrial parameters is being conducted by Laboratory scientists in conjunction with Texas Instruments Inc. specialists. It is anticipated that many sensor systems originally designed for other purposes will be found which can be usefully applied to determination of ground parameters. Upon evaluation, means of modification or improvement of existing sensor systems will likely become apparent. Recommendations for the instrumentation of an optimum airborne geoscience vehicle will be the eventual end product of this study.

2. *Remote Sensing of Environment*

Through mutual cooperation with the Office of Naval Research, the Army Research Office, and the National Academy of Sciences, the Air Force Cambridge Research Laboratories is contributing to a study being performed to assess the needs, the state-of-the-art, and the solutions to short and long-range problems encountered in remote sensing of environment. In addition to military agencies, scientific and university groups are being surveyed for contributions. The University of Michigan is conducting this study.

3. *Project WESTAR (Waterways Experiment Station Terrain Analysis Radar)*

The Air Force Cambridge Research Laboratories through mutual cooperation with the Army Engineer's Waterways Experiment Station and Texas Instruments Inc., is contributing to a study being performed to quantify terrain properties through measurement of response on various radar configurations. Infrared and radar measurements are being taken concurrently on controlled soil samples to determine the feasibility of establishing a catalogue of ground parameters having distinct recognition capabilities. Studies are being conducted in the laboratory; results may be extrapolated for future airborne use and interpretation.

4. *Photogrammetric Research*

A study and analysis of basic stereo-photogrammetric techniques and methods of interpretation for achieving accurate identification of surface properties from flight attitudes, are being conducted by ITEK Laboratories. This includes investigation of the application of airborne spectrograph or band spectral camera, color film and filter combinations and color transfer techniques to provide determinations of properties such as micro-relief, vegetation, and moisture content. Study will determine and recommend specialized equipment and techniques for an experimental program of airborne reconnaissance flights to achieve ground property measurements.

5. *Photo-Interpretation Research Facility*

The objective is to conduct in-house research toward improvement of terrain quantification from the aerial photographic record. Studies are concerned with spectral reflectance measurements of critical surface parameters, an understanding of specialized spectral response characteristics of different films, studies of improved pattern recognition and image enhancement of terrestrial surface parameters, and analysis of methods used in quantitizing terrain geometry.

6. *Analogous and Direct Geographic Area Investigations*

The objective is to delineate specific type areas of the world for correlation with little known or otherwise inaccessible areas. Studies will make use of all information described above to extrapolate aerial information for customer usage. Through understanding type areas, systems requirements for global utilization in remote areas are made more readily understandable and accessible. Engineering specifications are included in evaluations as well as means of treating specific problem solutions through modification of the ground environment.

7. *Airborne Geoscience Research Vehicle*

Plans are being made to modify and instrument AFCRL's ski-equipped C-130 aircraft to include airborne gravity, magnetics, radiometry, photography; and to serve as a test vehicle for sensor research. This vehicle is the ultimate goal in which the feasibility of research findings may be evaluated, and

techniques and equipment refined. Installation of radar, infra-red, and other devices is planned subsequent to results of the efforts described in the previous paragraphs.

Analysis of in-flight acceleration problems has shown that gravity observations can be made at high aircraft velocities with proper flight programming and navigation systems. Results of airborne gravity measurements will assist us: to determine the geoid and true size and shape of the earth; to unify the geodetic and gravimetric datums of the world; to determine the variations of the earth and planetary gravimetric fields; and to program accurate flight trajectories of ballistic and inertial guided missiles and earth satellites.

A simultaneous airborne magnetic and gravity survey not only would provide valuable and useful data, but it would be unique in that it has never been done. New relationships of these apparently unrelated phenomena may become evident. Data obtained from the VAM-2 magnetometer will yield the total magnetic component of an area in which no magnetic data have been recorded. It will thus enable an approximation to be made of the total intensity value through spherical harmonic analysis. A survey of this type will also permit extrapolation of values into space in a zone of maximum magnetic activity, that is, the magnetic pole and the auroral zones.

The state-of-the-art of the heat energy balance of the earth-atmosphere system indicates that this field suffers from the lack of good usable data. What is generally known concerning this subject is largely through theory rather than by adequate measurement and is inadequate as a usable tool. Arrangements have been made with the U.S. Weather Bureau and the Air Weather Service to obtain and install up-and-down sensing pyranometers to determine surface albedo.

As a result of the operating altitude of the C-130, it will also be possible to obtain cloud albedo measurements in the Arctic for the first time. Aerial photographs will be used concurrently to determine the amount and type of the clouds. Flights at various altitudes are planned in order to provide a measure of the change of albedo with height. This will give a measure of the absorption of solar radiation in the clear-polar atmosphere, and a means of determining surface albedo from the airborne measurements.

High resolution vertical and oblique cameras will be installed. This is rather flexible as it is felt that whatever cameras are necessary can be obtained.

To assist in the precise navigation required for such measurements the following equipment will be installed:

a. An astro tracker or star tracker
b. An ASN 24 computer
c. A Radan 500 Doppler
d. An LS-19 Vertical Reference Indicator
e. A photorecorder system
f. A B-6 driftmeter or TV viewfinder
g. Airborne Profile Recorder

After instrumentation, the ski C-130 will become the first remote area research vehicle of its type that is available anywhere, and will be able to acquire a wide range of field data never before obtained. The results of this research effort in the Terrestrial Sciences Laboratory will enable evaluation of the capabilities and limitations of present and future terrain sensing systems, selection of most efficient instrumentation, data collection by airborne surveys of remote areas, and data evaluation and application for intelligence, strategic, and tactical operations. This information will help to fill the void that has existed so long in areas heretofore almost inacessible and of ever increasing importance.

The airborne geoscience research vehicle is not a panacea. Time-proven field examination methods will always be needed in conjunction with airborne measurements; ground control will be an integral part of the program, where possible.

Conclusions

The airborne method of environmental data collection has demonstrated a multitude of distinct advantages not realized by other methods. The airborne geoscience research vehicle will provide the opportunity to test and evaluate new knowledge and techniques —knowledge and techniques now considered more and more vital by scientists and engineers.

The study of environment, through the medium of remote sensing, will undoubtedly involve the cooperation of many scientists of many different disciplines, each contributing to the overall problem. Similarly, no single "black box" is going to yield all the answers. Many sensors, working harmoniously together, will be necessary to give answers to the larger problem.

What we have said here covers a lot of ground, and yet at the same time, very little. We would like to share this problem of environmental sensing with all scientists. We feel strongly that we are only in the infancy of this subject, and, appeal to you to contribute to the problem. Comments and suggestions from interested readers will be welcomed.