Technical Report RSC-08

# REMOTE SENSING IN AGRICULTURE: AGRONOMIC SCIENCES
# A SELECTED BIBLIOGRAPHY WITH ABSTRACTS

compiled by

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# REMOTE SENSING IN AGRICULTURE: AGRONOMIC SCIENCES. A SELECTED BIBLIOGRAPHY WITH ABSTRACTS

R.H. Griffin II

The objective of this bibliography is to bring together in one document abstracts of current reports on remote sensing in agriculture, with special emphasis placed on the area of soils and agronomic crops. Included are articles that range from suggested or possible agricultural uses of remote sensing to articles that deal primarily with the theory of measurement by a particular sensor.

This search covers primarily the literature from 1967 to the present as bibliographies by Hornea and Printice (1968), Llaverias (1968), and Walters (1968) cover most of the remote sensing literature, including agriculture, prior to 1968. Myers and Allen (1968) did an excellent job of discussing remote sensing in agriculture and included a good coverage of the literature prior to 1968. The Michigan University Symposium Proceedings are invaluable to anyone interested in remote sensing and serves as primary reference for state-of-the-art techniques. There are other key papers and reports that are to numerous to list here, but which are included in the references.

The primary sources of abstracts have been Scientific and Technical Aerospace Reports (STAR), International Aerospace Abstracts (IAA), U.S. Government Research and Development Reports (USGRDR), and Biological Abstracts (Biol. Abstr.). As most of the references are contract reports and not considered as published material, the code numbers of the source journals are included, in parenthesis, following the reference number assigned for this publication. The code is source journals is as follows:

Scientific and Technical Aerospace Reports (STAR) - N

International Aerosapce Abstracts (IAA)-- A

Biological Abstracts - Biol. Abstr.

Dissertation Abstracts - Diss. Abstr.

U.S. Government Research and Development Reports (USGRDR) - all other letters

Instructions can be found in the abstract journal for obtaining copies of the reports abstracted therein.

An attempt has been made to cross index each of the references under several different key works, to allow for maximum retrieval of articles dealing with a particular subject. The articles are indexed according to the number assigned within each alphabetical letter grouping and include the letter following by four (4) numerical digits (i.e. A0100).

A0100
Allen, W.A. and A.J. Richardson. 1968. Interaction of light with a plant canopy, p. 219-232. In Proc. 5th symp. remote sensing of environment. Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

The Kubelka-Munk (K-M) theory has been applied to light interaction with leaves stacked in a laboratory spectrophotometer. The theory can also be applied to an actual field plant canopy. The K-M theory is a two-parameter generalization of the one-parameter Bouguer-Lambert, or Beer's law, relation. The older theory accounts for transmittance of a medium but not for reflectance. The K-M theory, however, yields a theorectical value both for reflectance and transmittance. The K-M theory is applied in this paper to the reflectance and transmittance of stacked mature cotton leaves over the spectral range 0.5 - 2.5 . The standard deviation between theory and experiment, after known biases are calculated and removed from the data, is about one percent--a discrepancy well within experimental error. A procedure is developed to apply the K-M theory to an actual plant canopy. The method involves regression analysis to light flux measurements within a plant canopy. Differential coefficients are derived for use in both stacked leaf and canopy applications.
Authors

A0200 (A69-13722)
Altshuler, E.E. 1968. New applications at millimeter wavelengths. Microwave J. 11:38,40,42.

Discussion of uses of millimeter wavelengths in communications, navigation, and research. Such wavelengths may permit the establishment of secure communications channels for reentry vehicles, and provide an important means of overcoming communications black-outs in future "lifting-type" reentry craft. Other channels of communication that can be made more secure are ship-to-ship and shore-to-shore links. In addition, the effects of improved range resolution on precision radars for tracking, guidance, mapping, and target resolution are detailed. Remote sensing, in which the propagated

wave is used as a diagnostic tool for probing the earth, its atmosphere, the sun, moon, and planets can also be extended. The use of radar and radiometric sensors placed on satellites, ballons, or aircraft to obtain geological, hydrological, agricultural, and oceanographic information is discussed. Observations of the atmosphere, the sun, moon, planets, galactic and extragalactic sources are all areas in which new information can be obtained through radiometric measurements at millimeter wavelengths.
B.H.

A0300 (A69-10023)
Anson, A. 1968. Developments in aerial color photography for terrain analysis. Photogram. Eng. 34: 1048-1057.

Brief review of advances being made in the development of aerial camers, filters, high-speed sensitive color emulsions, and rapid-processing equipment for the employment of aerial color photography for the extraction of terrain information. Some recent aerial color photography tests employed color films and false color films with attendant results. Loss of color detail from small-scale aerial color photography is often balanced by the overview of the terrain's tectonic strucutre, where dominant terrain hues aid in information extraction. Needs are indicated for government aerial color photography testing programs in which all agencies participate. M.M.

-B-

B0010
Badgle, P.C. 1966. Current status of NASA's natural resources program. p. 547-570. In Proc. 4th symp. remote sensing of environment. Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

The National Aeronautics and Space Administration (NASA) is supporting research activities in those areas of remote sensing from Earth-orbiting spacecraft which are related to the study of natural and cultural resources. These sensors are believed to possess a number of unique advantages for the discovery, inventory, evaluation, development, and conservation of such resources. Many Government

agencies, universities, and research institutions are cooperating with NASA in this effort. The current status of this program is described in this paper. Author

B0020
Badgley, P.C. and W.L. Vest. 1966. Orbital remote sensing and natural resources. Photogram. Eng. 32 (5): 780-790.

A Natural Resources Program has been initiated in the National Aeronautics and Space Administration (NASA) for utilizing remote sensors in space for the discovery, inventory, evaluation, development, and conservation of natural and cultural resources. Resources which can be studied in this manner include mineral districts, soils, crops, timber, water housing, transportation networks, and human resources. These instruments in Earth-orbital spacecraft possess a number of unique advantages, some of which are; rapidity and continuity of observations, greater freedom from weather disturbances, synoptic views for regional syntheses, reduced data acquisition times, reduced costs, and better quality data of several types. Authors

B0100 (N67-11848)
Blarithwaite, J. 1966. Dispersive multispectral scanning: a feasibility study. U.S. Geol. Survey, Washington, D.C. Tech. Letter NASA-65. 61p.

Optical mechanical line scanners can be used from aircraft and satellites to obtain strip maps of the surface over which the vehicle passes. The feasibility of combining wavelength dispersing techniques with such scanning techniques has been studied. This combination makes it possible to obtain spectral and spatial information simultaneously. Appropriate data processing techniques will then permit us to interpret the spectral data to produce surface maps of various kinds, such as maps of crop type or of

surface geology. Parametric equations representing a generalized dispersive multispectral scanner are developed and discussed in the light of subsystem and component state of the art and from the point of view of prospective users usch as geologists and agriculturalists. Author

B0200
Barringer, A.R. 1963. The use of audio and radio frequency pulses for terrain sensing, p. 201-214. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-3-X.

Extensive investigations are being carried out on the transient response of the ground to pulses containing audio frequency and radio frequency components and varing in length from 1.5 milliseconds to fractions of a microsecond. One method has been developed into an operational airborne prospecting system. The receiving equipment is designed to measure the characterisitics of the transient decay of eddy currents in the underlying terrain, with regard to both amplitude and time constant. Adiitional work has been carried out using unipolar pulses of a duration ranging between 1 sec to 40 sec. The transient responses from these pulses are a function of both the dielectric constant of the ground and its conductivity. Further work is now in progress using VHF frequencies and a high resolution radar technique which shows promise of providing information on the moisture content of the top few feet of soil together with some information on its layering characteristics. Author

B0300 (N67-13492)
Barringer, A.R. 1966. The use of multi-parameter remote sensors as an important new tool for mineral and water resource evaluation. p. 313-325. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

The requirement for greatly improved methods of exploration for natural resources is discussed in relation to the expanding demands for raw material. A new approach is suggested involving the use of mul-

tiple remote senors in aircraft on a regional or national scale in order to assist in the production of high quality geologic maps. Examples are given of the joint use of electromagnetic, magnetic and radiometric airborne survey equipment. The application to water resource problems is demonstrated and the latest advances in airborne pulse electromagnetic equipment are descirbed. Progress is reported on the development of fully instrumented airborne systems with digital readout and computerized data reduction. Author

B0400 (66676)
Birth, G.S. and G.R. McVey. 1968. Measuring the color of growing turf (Windsor bluegrass) with a reflectance spectrophotometer. AGron. J. 60(6): 640-643.

A single-beam spectrophotometer was used to measure the spectral reflectance properties of growing turf. From the data a 2-wavelength reflectance ration R745/R675 was developed for an objective index of turf color. This ratio changed from 3.0 for light green turf color to 6.5 for dark green turf color. (visual rating of 4 to 10, respectively). A 2-filter instrumetn (Ratiospect) was used to measure this index on 8 samples of turf of 3 species. A correlation of 0.984 was obtained between the Radiospect readings and a visual score of turf color. Authors

B0490
Brannschweiler, D.H. 1957. Seasonal changes of the agricultural pattern: a study in comparative airphoto interpretation. Photogram. Eng. 23(1): 131-139.

This paper deals with the pictoral variations of the agricultural landscape as recorded on a series of aerial photographs taken at monthly intervals during a year. Tone, texture, and structure (stereoscopic appearance) of land use units are investigated. The effect of these image elements on the photo pattern is analysed. It is shown that no single flight data

will bring forth best results for recognition of all elements, but that each of the months represented can be ideal for specific interpretational purposes. Author

B0500 (N69-28454)
Brennan, Barbara. 1969. Bidirectional reflectance measurements from an aircraft over natural earth surfaces. Goddard Space Fight Center, Greenbelt, Md. NASA-TM-X-63534, 84 p.

As part of a program to determine the reflectance patterns of solar radiation from natural surfaces, measurements were made over a variety of surfaces with a scanning radiometer mounted on a CV-990 aircraft. Of particular interest was the relectance pattern dependence on surface type and solar zenith angle. Since many present meteorological satellites utilze narrow beam scanning radiometers and are not capable of measuring reflected energy in all directions, reflectance patterns for natural earth surfaces are needed to interpret these measurements in terms of the albedo of the earth. Author

B0600
Buettner, K.J.K., C.D. Kern, and J.F. Cronin. 1965. The consequences of terrestrial surface infrared emissivity. p. 549-561. In Proc. 3rd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. of Michigan, Ann Arbor. Rep. 4864-9-X.

Infrared signals received in the 8 to 12 micron water vapor window by weather sattellites and aircraft are dependent on surface temperature, surface emittance and atmospheric interference. Nowhere can variations of surface emissivity be neglected in order to evaluate the correct surface temperatures. Three methods of determining surface emissivity are presented: (1) Reflection data from polished samples run on a spectrophotometer, (2) a device constructed by Buetnner and Kern called an emissivity box, and (3) emissivity as inferred from the TIROS satellite data. Some geological interpretation of the TIROS data are presented along with values of emissivity determined by the above three methods. Authors

C0100 (N67-13462)
Cain, S.A. 1966. Current and future needs for remote sensor data in ecology, pp. 3-6. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech. Univ. Michigan, Ann Arbor, Rep. 4864-11-X.

Certain ecological problems of interest to the Bureau of Commercial Fisheries, the Bureau of Sport Fisheries and Wildlife, and the National Park Service are briefly outlined. Affecting the fisheries are problems of: non-random distributions, especially of schooling and commerical fishing fleets; limited covereage by research vessels in relation to vast areas of the oceanic ecosystems; and, evasive behavior toward sampling gear. To this end, the feasibility of underwater cameras and TV, passive acoustic sensors, surface sensors, and lasers from satellites is considered. For an inventory of wildlife populations and migratory movements, the use of sensors at a distance from inches to feet or hundreds of yards is mentioned. Aerial photography observations, implemented by high-resolution remote sensors, are cited as a means to enhance visitor enjoyment and appreciation of the national park system.
R.L.I.

C0110
Cantrell, J.L. 1964. Infrared geology. Photogram. Engr. 30:916-922,941.

In the not too distant future geologists and, in particular, photogeologists will have a new remote tool--infrared imagery--to aid in solving geologic reconnaissance problems. By comparing airborne infrared imagery with aerial photography, unique information can be obtained about the earth's surface features.
The military is continually developing infrared imaging systems for suveillance and target acquisition purposes; but only recently have geologists discovered the value of these systems for their purposes.
Interpreters of infrared imagery for geologic purposes must be fully aware of the physical phenomena in-

volved in generating infrared imagery. They must recognize the fact that infrared imagery is created primarily by emitted energy and not reflected energy as in conventional phtography.

Author

C0200

Carneggie, D.M. 1968a. Applying remote sensing technology for improving range resource inventories, p. 373-385. In Proc. 5th symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor, Rep. 4864-18-X.

Improved inventories of rangeland are required in order to increase productivity of forage and animal products. Much of the information needed to improve range inventories can be collected using various remote sensing devices. Aerial photography and other kinds of imagery obtained from single or multilens cameras, optical mechanical scanners, thermal infrared imagers and radar sensors have been examined and carefully field checked. The usefulness of each type is discussed in terms of the suitability for collecting relevant data about the range resource. Photographic systems which obtain high resolution images within selected regions of the visible and near infrared spectrum were judged most useful for improving range inventories. However, images from line scanners, thermal infrared imagers and radar sensors are more useful for certain kinds of special purpose inventories Author

C0300 (N69-25632)

Carneggie, D.M. 1968b. Remote sensing applications in forestry: analysis of remote sensing data for range resource management, annual progress report. Forestry Remote Sensing Lab., Univ. California, Berkley. NASA-CR-100894. 76 p.

Various remote sensing devices, including photographic systems, optical mechanical scanners, and thermal infrared scanners obtain remote sensing data at different seasons and scales. Portions of the electromagnetic spectrum in which remote sensing was accomplished ranged from the ultraviolet, through the visible and near infrared to the thermal infrared.

Analysis of the data for three range test sites showed that the season when imagery is obtained is critial in determining the amount of useful information obtainable from remote sensing imagery. This is due to the changing nature and characteristics of the forage resource. Range applications are discussed under two major categories: (1) obtaining range resource inventories and (2) assessing range management problems. For the most part high image resolution is desirable although broad vegetation and soil typing can be accomplished using lower resolution imagery. The level of detail required is partially determined by the intensity of management that is to be practiced. Author

C0400 (N67-19939)
Carneggie, D.M. and R.N. Colwell. 1966. The use of high altitude, color and spectrozonal imagery for the inventory of wildland resources. Volume III: The soil water, wildlife, and recreation resource. School of Forestry, Univ. California, Berkley. NASA-CR-82973. 97 p.

High altitude multispectral imagery of a large wildland area in the Sierra Nevada Mountains in California, was studied to determine the ease and accuracy of identifying and ampping important wildland resources. Keys for identifying terrain features, which are associated with each resource, based on their photo image characteristics were prepared for each image type. A feasibility table is presented which summarized the ease of using the image types tested for identifying wildland and terrain features. Ekta-Aero infrared film appears to be the most useful single film-filter combination for inventorying the greatest variety of terrain features found in a wildland area. Thermal infrared imagery appears to be useful for detecting distinct moisture conditions in meadow ranges and may prove to be a valuable tool for inventorying numbers of wildlife and cattle. K-band radar imagery appears to be useful for inventorying gross watershed characteristics.

Author

C0500 (N67-19905)
Carneggie, D.M., W.C. Draeger, and D.T. Lauer. 1966. The use of high altitude color and spectrozonal imagery for the inventory of wildland resources. Volume I; The timber resource. School of Forestry, Univ. California, Berkley. NASA-CR-82963. 78p.

High altitude multispectral imagery of a large wildland area was studied to determine the ease and accuracy of identifying and mapping those terrain features which aid in the inventory or evaluation of timber production, planting sites, harvesting, and forest protections. Photo interpretation keys for identifying important terrain features associated with the timber resource were prepared for four principal image types. A feasibility table summarizes the ea of using the separate image types for identifying wildland terrain features. No single-film-filter combination or image type interpreted is best suited for identifying or mapping all terrain features. More information can be obtained from interpretation of two or more spectral bands in concert. Ekta-Aero infrared film is the most useful single film-filter combination for inventorying the greatest variety of terrain features when interpreting small scale photography. However, large scale Aerial Ektachrome photography was as accurate as the Ekta-Aero infrared for identifying individual tree species. Thermal infrared imagery can distinguish differences in timber density and K-band radar imagery can map gross vegetation boundaries and topographic features within watersheds. Author

C0600 (N68-17671)
Carneggie, D.M., C.E. Poulton, and E.H. Roberts. 1967. The evaluation of rangeland resources by means of multispectral imagery, annual progress report. School of forestry, Univ. California, Berkley. NASA-CR-93181. 180 p.

Various kinds of photography and other imagery for improving inventories of rangeland resources

were studied, including multi-spectral photography, 18-channel line-scan imagery, thermal infrared and K-band radar imagery, and Gemini color photography. The results of remote sensing research on an annual grassland range, a perennial bunchgrass range, and in mountain meadows are discussed in terms of both present applications using fixed wing aircraft and potential applications, employing earth orbitin satellites. Included is a progress report on rangeland resource interpretations made from Gemini color photography. The limitations, advantages, and potential applications of such photography are discussed and recommended image quality specifications are given for an optimum orbital system for the inventory of range resources. Examples of color composites made by image enhancement techniques are shown and their advantages for increasing the interpretability of imagery are discussed. Limited factors of satellite imagery and recommendations for further research are given. Author

C0700 (A69-24265
Carneggie, D.M. and J.N. Reppert. 1969. Large Scale 70-mm aerial color photography. Photogram. Eng. 35: 249-257.

Evaluation of large-scale 70-mm color-infrared aerial photographs of northeastern California grassland and shrublands, in order to determine their interpretability for improving range resource inventories. Detailed interpretation of these photographs indicates many potential applications in the inventory and management of range resources. M.G.

C0800 (N66-39698)
Carneggie, D.M., E.H. Roberts, and R.N. Colwell. 1966. The use of high altitude, color and spectrozonal imagery for the inventory of wildland resources, Volum II: The range resource, annual progress report. Pacific SW Forest and Range Exp. Sta., Berkley, California. NASA-CR-78879. 70p.

High altitude multispectral imagery of annual and perennial rangeland in the Sierra Nevada, Cascade Mountians, and foothills of the Coast Range of California was studied to determine the ease and accuracy of identifying and mapping important range characterisitcs. Further consideration was given to the time or season for otaining imagery that would yield the greatest quantity of useful information. Preliminary analysis indicated that no one film-filter combination or image type was best for identifying all significant features. However, considerably more information was obtained from interpretation of two or more spectral bands in concert. Ekta Aero infrared film appeared to be the most useful single film-filter combination. In addition, thermal infrared and K-band radar imagery were obtained and their usefulness in making forage inventories is discussed. The objective of this feasibility study was to provide for eventual use of imagery to be obtained from manned earth-orbiting vehicles.

S.P.

C0850

Carter, D.L. and V.I. Myers. 1963. Light reflectance and chlorophyll and carotene contents of Grapefruit leaves as affected by $Na_2SO_4$, NaCl and Ca $Cl_2$. Amer. Soc.Hort. Sci. 82: 217-221.

Young nucellar Red Blush grapefruit trees were grown on sour orange rootstock in Willacy fine sandy loam surface soils and irrigated with water containing $Na_2SO_4$, NaCl and $CaCl_2$ under greehouse conditions.
The percent of incident light reflected from upper leaf surfaces was increased by NaCl and $CaCl_2$ at wavelengths from 500 to 750 m . Some increases also resulted from $Na_2SO_4$ treatment. The effects of $Cl^-$ were manifested both through increased light reflectance and through visual toxicity symptoms. The possibility of detection of salt injury by photographic techniques is discussed.
All 3 salts caused about a 50% decrease in chlorophyll contents of leaves, and about a 33% decrease in

carotene content. All 3 salts had about the same effects, suggesting a similar mode of action in decreasing the concentrations of these pigments. The reduction in pigment content caused by the salts did not account for all differences in light reflectance, and indicates that salts may also cause leaf structural changes. Author

C0900 (A69-10532)
Castruccio, P.A. 1968. Use of remote sensors in earth-orbital space for the discovery, inventory, evaluation, development and conservation of earth's natural resources. U.N., Conf. Exploration and Peaceful Uses Outer Space, Vienna, Austria. Paper No. 68-10464. 148p.

Examination of the use of space technology for the administration of earth's natural resources. The concept of a resource is defined, and a resource classification in six areas is given. The different problems presented by each resource area are briefly defined, and the general actions required to improve the availability of each resource are discussed. The principal technical considerations and many factors which enter into the conception and design of earth-resource satellites are presented. A concrete example of how the methodology is applied to an agricultural-survey satellite is given. The design procedures for oceanography, geology, hydrology, geography, and atmospheric science resource-survey satellites are discussed. Particular emphasis is placed on derivation of the objectives of these satellites, which is the first and fundamental step of design. The types of benefits expected to accrue data are discussed, and an example is given of how such data are calculated. The problem of the reduction and dissemination of the data returned from earth-survey satellites is discussed, along with the international implications and political problems of disseminating such data. Suggestions as to how such dissemination can be practically implemented are presented.

Z.W.

C1000 (N67-13529)
Chalfin, G.T. and W.B. Ricketts. 1966. 3.2mm thermal imaging experiments, p. 859-871. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Millimeter-wave thermal-imaging experiments were obtained at a wavelength of 3.2 mm (94 GHz). The sensor was a super-heterodyne radiometer having a T of 10°K for the integration time used. A resolution cell of approximately 0.5° was used and images were obtained having about 50 scane line with about 90 resolution cells per scan line. The radiometer putput was recorded on magnetic tape. The tapes were processed by a computer to correct certain distortions and to obtain contrast enhancement. The images were displayed by a incremental plotter programmed to produce halftone images. Analysis of the images shows that the contrast between reflectors such as water or metal and absorbers such as vegetation is always very prominent at 3.2 mm. Also, the contract between rough and smooth soil surfaces is usually detectable. Reflections from smooth surfaces such as water and snow are prominent and, in the case of water, the cleanness of the reflection depends on the smoothness of the surface in a manner very similar to reflections in the optical range. In general, the gross features of the 3.2 mm images correspond very closely to visible-light photograms of the same area. However, in heavy fog, where visible and near-infrared photographs show practically nothing, a useable image can still be obtained at 3.2 mm. Author

C1100 (A69-16855)
Cole, Monica M. 1969. Observations of the earth's resources. Roy. Soc. (London), Proc., Series A, 308: 173-181.

Discussion of the kind of information about the earth's resources which may be obtained from spacecraft and space satellites. Topics discussed include mapping of the land from space; the type of geological information obtainable from

the Gemini space photographs; the use of information from remote sensing techniques in agriculture, forestry, and mineral exploration; the contribution of information from earth resources satellites to specific vegetational problems of importance in mineral exploration and in agricultural development; and the importance of earth resources satellites in solving fundamental earth resources problems. Hydrological and oceanographic information obtainable from spacecraft and earth resources satellites are discussed, as well as the implications involved in the collection of information from earth resources satellites.

Z.W.

C1180
Colwell, R.N. 1965. Spectrometric considerations involved in making rural land use studies with aerial photography. Photogrammetria 20(1): 15-33.

After presenting some of the basic spectrometric considerations involved in making rural land use studies with the aid of aerial photography, this paper considers several practical applications of these considerations. It concluded with a statement as to the present availability of spectrometric data and with the prediction that data of this kind, in which the rural land use analyst is currently evincing great interest, soon will be far more readily available to him.

Author

C1190
Colwell, R.N. 1966a. Aerial photography of the earth's surface; its procurement and use. Applied Optics 5(6): 883-892.

Some of the most important applications of the optical sciences are in the taking of aerial photographs of the earth's surface and in the extraction of data from them. This article is intended to serve both as an introduction for the articles following it in this issue and as a summary of the factors that must be considered in the taking and interpretation of aerial photo-

graphs. Special emphasis is placed on the means by which photographic images of high quality can be obtained and viewed in order to facilitate the data extraction process. A summary of the more important current applications of aerial photography in the earth sciences and life sciences also is provided. Author

C1200 (N67-13472)
Colwell, R.N. 1966b. Uses and limitations of multispectral remote sensing, p. 71-100. In Proc. 4th smyp. remote sensing of environment, Inst. Sci and Tech. Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Some enthusiastic proponents of multispectral remote sensing herald it as the means by which virtually all of man's data-gathering problems, both terrestrial and extraterrestrial, can best be solved. However, certain high-level decision makers feel that such optimism is not justified. They assert that little or no information of vital importance has been found to be better derivable through multispectral remote sensing than through any of several other less shophisticated means. Consequently they are of the opinion that the continuation of a vigorous research and development program in this area is unwarranted. Perhaps both groups need to examine more carefully, and in more specific terms, the used and limitations of multispectral remote sensing. This paper undertakes such an examination through the use of bothspecific examples and analytical discussions of the various factors governing remote sensing. It is hoped that the approach used here will help to place in better focus both the enthusiastic claims and the pessimistic criticisms, thereby assisting the reader in formulating his own opinion relative to the potential usefulness of multispectral remote sensing. Author

C1250
Colwell, R.N. 1967. Remote Sensing as a means of determining ecological conditions. Bio Science 17(7): 444-449.

Remote Sensing is a valuable aid to those wishing to derive ecological information. Such an aid provides the investigator with both the broad perspective view of a vast area and the highly detailed record for every portion of it. Some elements contributing to the cological analysis of an area are best obtained when remote sensing is accomplished in one spectral band while other elements are best obtained by remote sensing in other spectral bands; furthermore, the interpretability of remote sensing imagery can be greatly improved if it is supplemented with a limited amount of field checking in representative protions of the area being studied. Once this "ground truth" has been obtained, extrapolations usually can be made with confidence to nearby areas for which only the remote sensing imagery is available.
In view of these facts, it is important to avoid the mistake that some investigators have made in regarding remote sensing as a complete sustitute for direct on-the-ground observation. The relatively new techniques of extracting ecological information from an analysis of remote sensing imagery should be considered as complementary to, rather than competitive with, the time-honored techniques that involve direct on-the-ground observation of ecological factors.

Author

C1290
Colwell, R.N. 1968a Remote sensing of natural resources. Sci. Amer. 218(1); 54-69.

Discusses types of sensors used, photographic, optical-mechanical scanner, side-looking radar, and gamma ray spectrometer. Also, lists possible used and gives examples of data obtained with various sensors. Discusses the capabilities of various types of data gathering systems, such as orbiting satellites. R.H.G.

C1300

Colwell, R.N. 1968b. Determing the usefulness of space photography for natural resource inventory, p. 249-289. In Proc. 5th symp. remote sensing of environment Inst. Sci and Tech., Univ. Michigan, Ann Arbor, Rep. 4864-18-X.

The time is fast approaching when space photography will become available for the making of natural resource inventories of vast areas. It is then that we will be expected to make good on the highly optimistic claims that have been made good on the highly optimistic claims that have been made regarding the optential usefulness of space photography for such purposes. Unfortunately, only a limited amount of direct evidence is available as the the optential usefulness of space phtography for natural resource inventory. Even less is known regarding the best procedures for its use. Some authorities maintain that natural resource inventories of the future can better be made on photography taken from high-flying aircraft than on that taken from spacecraft. Other assert that a combination of both aerial and space photography, augmented as necessary with direct on-the-ground observations, will be required. The present situation would seem to call for the employment of more vigorous efforts and more rigorous procedures as we seek to determine the usefulness of space photography for natural resource inventory. This paper, while not attempting to resolve all of the pertinent issues which it raises, describes a procedure which the writer and his associates have employed when seeking to determine, for specific geographic areas, the usefulness of space photography for various kinds of natural resource inventory. Phtographic examples are given to illustrate the successive steps in that procedure, and suggestions for the improvement of it is solicited. Author

C1350

Colwell, R.N., W. Brewer, G. Landis, P. Langley, J. Morgan, J. Rinker, J.M. Robinson, and A.L. Sorem. 1963. Basic matter and energy relationships involved in remote reconnaissance, report of subcommitte I, photo interpretation comm., Amer. Soc. of Photogrammetry. Photogram. Eng. 29 (5): 761-799.

Earth scientists, space scientists and life scientists frequently have need to detect and identify various objects and conditions in the physical universe solely from information collected by sensors that are remotely situated with respect to the area being investigated. Enery that is either emitted or reflected from the objects of interest is recorded by the sensors, either in photographic form or in a form which can be readily reconstituted into a photo-like image. Empirically it has been found that some parts of the desired information are best obtained when sensing the energy returns in ONE BAND of the electromagnetic spectrum, while other parts are best obtained by sensing in a DIFFERENT BAND.

These considerations lead to a major area of concern to Subcommitte I, dealing as it does, with the basic characteristics of matter and energy in relation to image creation by remote reconnaissance. The time has come when real progress in the acquisition of inf rmation by remote reconnaissance must be sought through fundamental research solidly founded on the basic sciences.

This paper first considers certain basic characteristics of the electromagnetic spectrum that are of importance in the remote sensing process. It then considers various electromagnetic sources (including the sun) that can be used in remote reconnaissance, and what happens to the energy from these sources as it encounters various media during the remote sensing process. Specific examples serve to illustrate that absorption, emmission, scattering and reflection of electromagnetic energy by any particular kind of matter are selective with regard to wavelength, and are specific for each structure. Additional effects exerted by larger aggregations of matter such as

crystals, plant tissues and even by large masses of rock, soil or vegetation also are considered. The paper concludes with a consideration of the manner in which accurate but highly complex data which summarize basic matter and energy relationships can be profitably analyzed by an electronic computer, permitting remarkably accurate predictions to be made of the type of imagery obtainable with various remote sensing devices under various environmental conditions.

Author

C1400 (N66-39305)
Colwell, R.N., J.E. Estes, C.E. Tiedemann, and J.E. Fleming. 1966. The usefulness of thermal infrared and related imagery in the evaluation of agricultural resources. An exploratory study, Volume I, final report. Univ. California, Berkeley. NASA-CR-78740. 152p.

Multispectral imagery of the Sacramento Valley of California was studied to determine its usefulness in the inventory and analysis of the livestock, soils and water resources. Optimum specifications and recommendations are presented for a reliable inventory of livestock through the use of conventional aerial photography. In doing so, the season for obtaining useful imagery, the optimum scale of imagery and the usefulness of each film or image type is illustrated and discussed. Additionally a comprehensive series of selective aerial photo identification keys, accompanied by feasibility ratings, is included to facilitate the inventory of animal types and animal breeds. Also discussed are the applications of remote sensing technology for the inventory and anlysis of the soil and water resources. A discussion of the adaptiveness and usefulness of a multispectral approach to the evaluation of these resources is presented with selected illustrations. Author

C1600 (N68-18199)
Colwell, R.N. and J.D. Lent. 1967. A test of the concept and practical application of multiband and reconnaissance, final report, Univ. California, Berkeley. NASA-CR-93365. 89p

The potential advantages, limiations, and means of optimizing multiband reconnaissance techniques for earth-resource inventories are explained. Use is made of artivicial and natural arrays to illustrate the concepts of tone signature analysis and color additive image enhancement, and a means is given for determining from a number of film-filter combinations, which ones are the best for a two-band reconnaissance can give useful information about earth's natural resources, the basic matter and energy relationships are assessed along with photographic relationships in terms of energy levels, and target tone signature analysis. The problems of the multiband techniques discussed include natural terrain features that tend to be more complex than artificial target arrays, optimum wavelength bands for use in achieving various objectives. obtaining the required spatial resolution in multiband imagery, and problems occasioned by limitations of the image analyst. B.S.O.

C1700
Colwell, R.N. and D.L. Olsen. 1965. Thermal infrared imagery and its use in vegetation analysis y remote sensing reconnaissance. p. 607-621. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci and Tech. Univ. Michigan, Ann Arbor. Rep. 4864-9X.

In recent years it has become acutely apparent that from both the military and civil standpoints, there is a need for some rapid, accurate and economical means of analyzing vegetation.
This paper will consider the various kinds of useful information which military and civil experts can obtain regarding vegetation from the use of a thermal infrared mapping system which operates in the 7-15 micron band. Special emphasis will be placed on the value of this imagery when used in conjunction with imagery obtained in the visible, near infrared, and near ultraviolet portions of the electromagnetic spectrum. Author

C1800 (N66-11760)
Colwell, R.N., G.A. Thorley, W.C. Draeger, and D.T. Lauer, 1965. A multi-spectral photographic experiment based on a statistical analysis of spectrometric data, final report., School of Forestry, Univ. of Claifornia, Berkeley. NASA-CR-68001.137p.

An experiment was conducted to determine spectral responses of terrain features in order to adequately interpret airborne and spaceborne photography. Spectral reflectance characteristics were defined for selected terrain features by on-the-ground measurements of spectral reflectance. From an anlysis of spectrometric data, optimum film-filter combinations were determined for multispectral photogra. Predictions of tone signatures for terrain features are given. The effect of seasonal changes on light reflectance from vegetation is briefly considered.
C.T.C.

C1890
Conaway, J. and C.H.M. van Bavel. 1967a. Radiometric surface temperature measurements and fluctions in sky radiant emittance in the 600 to 1300 $cm^{-1}$ waveband. Agron J. 59:389-390.

Observations of sky radiant emittance in the 600 to 1300 $cm^{-1}$ (7.5-16 ) waveband were made near Phoenix, Ariz., in the spring of 1966 in connections with radiometric measurement of soil surface temperatures. A marked diurnal fluctuation was found which appeared to be correlated with high ozone concentrations near the ground, in turn caused by local air pollution.
Author

C1900
Conaway, J. and C.H.M. van Bavel. 1967b. Evaporation from a wet soil surface calculated from radiometrically determined surface temperatues. J. Applied Metro. 6(4):650-655.

The temperature of a naturally exposed, bare wet soil surface was measured with a narrow bandpass infrared radiation thermometer. Corrections were made for actual sky radiance and for surface emittance, the latter also determined in the field. When used to calculate

evaporation rates with a Dalton-type equation containing a long-law wind function (drag coefficient X windspeed), excellent agreement was found with lysimeter values on both on hourly and daily basis. The results demonstrate the feasibility of surface temperature measurements and support the validity of the log law for describing transfer in the surface layer.

Author

C2000

Conway, W.H., R.R. Bacinski, F.C. Brugma, and C.U. Falco. 1963. A gradient microwave radiometer flight test program. p. 145-174. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-3X.

An experimental passi e microwave (Kuband) radiometer terrain mapping program is described. This discussion concerns itself primarily with the nature of the experiments, the equipment used, and the resulting thermal gradient maps. The primary objectives of the test program were: (1) to establish the feasibility of producing recognizable outline maps with an airborne gradient microwave radiometer, (2) to determine map reproducibility and variance, and (3) to establish the range of signal levels for different kinds of terrain. Raw video signals from the scanning radiometer were recorded on magnetic tape to allow optimum reduction and analysis in the laboratory. Included are samples of black and white maps which were produced as part of the data reduction and analysis program, e.g., alnd-water boundaries, cities, desert terrain, etc.

Author

C2100

Conway, W.H. and R. . Sakamoto. 1965. Microwave radiometer measurements program, p. 339-356. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci and Tech. Univ. Michigan, Ann Arbor Rep. 4864-9-X.

An experimental passive microwave radiometer measurements program is described. This discussion concerns itself primarily with the nature of the experiments,

the equipments used, and, above all, the resulting data. The primary objective of the program was to obtain accurate microwave measurements of the characteristics of a selected set of material surfaces, e.g., various soils, vegetation, etc., under rigorously controlled conditions. Measurements have been made at a variety of frequencies, e.g., various soils, vegetation, etc., under rigorously controlled conditions. Measurements have been made at a variety of frequencies, e.g., 13 kMc, 18 kMc, 35 kMc, and 70 kMc, and have also included effects of the depths of the surface material as well as the material itself. Multilayer effects with layers of different materials have also been included. Atmospheric measurements are also included.
A second prime objective of the program was to provide data to be used for analysis of the characterisitics of the various surfaces. Much of the data is presented compared to the predicted values.
Author

C2200 (N67-13501)
Conway, W.H., and L.A. Yarbrough. 1966. Characteristics and uses of an L-band radiometer, p. 467-473. In Proc. 4th symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

A tuneable airborne L-band radiometer was designed to rpovide reliable operation over a long period of time with a minimum of operator adjustment. To meet these design constraints, a unique system of automatic gain control (AGC) was applied, using a gas discharge noise tube as a reference source. In effect, this AGC system constantly adjusted the gain of the unit to maintain initial calibration. An additional advantage was obtained from the gas discharge noise source by using an automatic noise figure meter continuously monitored by front panel metering. This noise figure meter also provided the most important piece of maintenance equipment needed for the radiometer. The output of the radiometer was fed to an oscillography to provide an instantaneous and permanent record of data collected from a variety of targets. Selected frequencies of operation were chosen to

provide optimized operation while flying over specific areas of interest. Various materials and manmade signals produced characteristic target signature data which reveal the potential of an L-band radiometer operating at 700 MC as a reconnaissance instrument. Author

C2300
Cooper, C.F. 1965. Potential applications of remote sensing to ecological research, p. 601-606. In Proc. of the 3rd Symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-9-X.

Field investigations of the behavior of natural plant communities require knowledge of physical and biological characteristics integrated over areas of a few square feet to several square miles. Important properties potentially measurable by remote sensing techniques, singly or in combination, include leaf area, volume, wei t, and chlorophyll content of vegetation; heat budgets of vegetated surfaces; qualitative and quantitative local differences in water vapor and carbon dioxide fluxes; water content of soils and vegetation; and depth and density of snow. Some implications of these measurements for understanding of ecological processes are discussed. Close collaboration between instrumentation engineers and field biologists is essential if best results are to be obtained.

Author

D0100
Davis, B.R., E.B. Lipscomb, and S.J. Knight. 1965. Terrain analysis by electromagnetic means; laboratoy investigations in the 0.76- to 5.00 micron spectral region. U.S. Army Engr. Waterways Exp. Sta., Vicksburg, Mississippi. Tech. Rpt. No. 3-693, Rpt. 1. 165p.

This report presents the results of test conducted to determine the capabilities of active electromagnetic sensors operating in the 0.76- to 5.00- micron spectral region to measure terrain characteristics affecting trafficability of soils. Controlled tests were conducted under laboratory conditions in an attempt to

correlate the effects of soil composition, moisture content, and density with the quantity of infrared energy reflected from a soil sample. Results of the tests indicate that the composition and moisture content of homogeneous soil specimens can be characterized by active infrared sensors under controlled laboratory conditions. However, since infared energy is reflected by infinitesimally then surfaces of materials, information concerning density and subsurface parameters cannot be discerned. Techniques for prediction of soil parameter through the use of multiwavelength analysis are discussed. Author

D0200

Dellwig, L.F., MacDonald, H.C., and J.N. Kirk. 1968. The potential of radar in geological exploration, p. 747-763. In Proc. 5th symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

At the present time side-looking airborne radars (SLAR) are most useful to the geologist for regional studies of remote, previously-unmapped ducting regional investigations, but areas requiring detailed investigation can benefit from SLAR's unique ability to present certain types of data. Regardless of the nature of the study, dualpolarization imagery has proven the most effective in geologic investigation.
In regional studies, radar should be the primary, and in some instances may be the sole sensor. The value is best demonstrated in areas where photographic coverage is not possible (or feasible) and where ground investigations are difficult or impossible. Gross structural patter s are well-displayed on SLAR imagery because of the radar's capability to continuously image wide swaths of terrain. Such a use takes maximum advantage of the relatively low resolution, which suppresses distracting and redundant detail. SLAR is expecially valuable in the detection of regional-scale lineaments, and has demonstrated itself superior in most instances to aerial photography for such studies.

In detailed studies, the significant contribution of radar lies primarily in the detection of subtle changes of lithology. In some instances lithologic changes appear to be directly responsible for isolating anomalous areas. In other cases, the delineation of rock type may be achieved indirectly from radar imagery through examination of fracture textures, patterns of weathering, topography and vegetation. The full geologic significance of SLAR systems has not yet been demonstrated; however, it is anticipated that the value of radar to the geologist will be greatly enhanced when improved multi-band and dual-polarization systems can be utilized to obtain geologic data. The value of long-wavelength imagery will be realized only when it is produced simultaneously with X- or K-band imagery.

Author

D0290
Dill H.W., Jr. 1959. Use of the comparison method in agriculture airphoto interpretation. Photogram Eng. 25(1): 44-49.

Obtaining data on changes in the use of agricultural land is an expensive and time-comsuming process when field methods are used. The availability of successive airphoto coverage for many agricultural areas, made in the last few years, provides a means of comparing recent conditions with those prevailing before World War II. Two methods developed to provide data by airphoto comparison analysis are described. They overcome the difficulties posed by field survey methods.

Author

C0300 (N67-40161)
Dill, H.W., Jr., 1967. Worldwide use of airphotos in agriculture. Econ. Res. Serv., U.S. Dept. agr. handbook no. 344. 25p.

The increasing use of aerial phtography to provide data on agricultural production, inventory, planning, and development is reviewed. The major applications are identified as providing a base

for field surveys, supplying information by stereo interpretations of airphotos, and serving as a base for planning, administering, and recording agricultural programs. The scientific uses of airphotos are listed, and illustrative photographs are included. Worldwide airphoto coverage and uses are briefly described.

N.E.N.

D0350
Doverspike, G.E., F.M. Flynn, and R.C. Heller. 1968. Microdensitometer applied to land use classification. Photogram. Eng. 31(2):294-306.

The fundamental acquisition of land use data from aerial color photographs would be expedited if the process could be automated. However, color density alone does not seem to offer a solution to differentiate land use on the photographs. Although aperture size affected density readings, no improvement in land use discrimination could be ascribed to the aperture area. Moreover, the geometric shape of the microdensitometer aperture (circular, slit or square) was of little or no significiance. Density differences in the blue region of the spectrum offered more possibilities in separating ten land use classes than did the red or green.

Author

D0400 (N68-17406)
Draeger, W.C. 1967. The interpretability of high altitude multispectral imagery for the evaluation of wildland resources annual progress report. Forestry Remote Sensing Lab., Univ. California, Berkeley. NASA-CR-93187. 76p.

High altitude multispectral imagery of the Bucks Lake Test Site in the Sierra Nevada Mountains of California was studied, and field data collections were made in an attempt to ascertain the optimum specifications for remote sensing imagery on which to identify and evaluate wildland resources.

Examples of the information that can be extracted from various types of small scale imagery were prepared and discussed and a representative image interpretation guide for use in training interpreters was developed. Optimum image specifications were found to vary with both the resource involved and the type of management dicisions to be made. It was concluded, however, that the single image type for general purposes is that obtained using Ekta-Aero Infrared film in conjunction with a Wratten 12 filter. Of more flexibility, however, are several black-and-white photographic images in the visible and near infrared bands which can be studies individually, in concert, or converted into a color composit image by means of multicolor projection techniques. For specific applications such as soil moisture detection or study of geomorphology, sensors such as radar or thermal infrared detectors appear to be more advantageous.
Author

C0410 (N69-12159)
Draeger, W.C. 1968. The interpretability of high altitude multispectral imagery for the evaluation of wildland resources, annual progress report. Forestry Remote Sensing Lab., Univ. California, Berkeley. 75p.

This research has as its goal the determination of optimum image specifications for the procurement of useful inventory and survey data relevant to wildland resource managment. Particular emphasis is placed on very small-scale imagery as can be expected from very high-flying aircraft and/or earth-orbital vehicles. Included in this report are (1) an investigation of optimum spectral bands for the discrimination of various important wildland features, (2) a determination of optimum time of day for obtaining thermograms from which to quantify subsurface soil moisture, and (3) an investigation of the feasibility of determining gross timber volumes on intermediate scale (approx. 1/30,000 aerial photography.

In addition, preliminary studies pertaining to the detection of wildland water pollutants and the determination of the potential for converting non-forested areas to timber-producing types are discussed. Also included is a photo-interpretation key to the wildland terrain freatures of the NASA Bucks Lake Test Site.

Author

D0500 (N69-25296)
Du, Li-Jan. 1969. Rayleigh scattering from leaves. Electro Science Lab., Ohio State Univ., Columbus, SR-1. 32 p.

A Rayleigh region leaf model, consisting of a layer of uniformly distributed and randomly oriented leaves, is developed as a first approximation of a jungle environment. Such a model is appropriate for clutter calculations and for estimating the constitutive parameters of the medium. In this report, emphasis is focused on the latter application. Explicit expressions for the scattered field and the absorption and scattering cross sections of a single leaf are developed. From these results, the effective dielectric constant and conductivity of a layer of uniformly distributed and randomly oriented leaves are derived. Numerical calculations of these parameters for a frequency range from 30 to 300 MHz, leaf water contents from 10 to 50 per cent, and leaf volume concentrations from 0.03 to 0.1 percent are made.

Author (TAB)

E0100 (N68-30647)
Edgerton, A.T. 1968a. Passive microwave measurements of snow, soils and snow ice water systems, technical report, 1 Jan - 15 Nov. 1967. Space Divi., Aerojet-General Corp., El Monte, California. TR-4. 363 p.

The report summariezes field and laboratory investigations conducted to determine the microwave emission characteristics of a number of natural material. These experiments demonstrate a useful

relationship between the microwave brightness temperature and moisture content of soil and sediments. Small changes in soil moisture content can be measured by means of microwave radiometry. Other experiments have shown that multifrequency microwave measurements can provide an indication of the particle or fragment size distribution of exposed sediments. Laboratory measurements of ice-water systems demonstrate that definite relationships exist between the microwave temperatures and thickness of ice layers. Experiments were conducted with ice formed from both fresh and ocean water.

Author

E0200

Edgerton, A.T. 1968b. Engineering applications of microwave radiometry, p. 711-724. In Proc. 5th symp. remote sensing of environment. Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

These studies show that measured microwave temperatures are dependent on sensor frequency and polarization, and that sizable differences in radiometric response occur for the soils investigated. These variations are primarily attributed to differences in soil moisture content, particle size and surface roughness. Particle size and surface roughness variations influence the general shape and slope of the radiometric temperature versus antenna viewing angle plots, whereas moisture content variations cause the curves to shift along the temperature axis. The dielectric properties (both real and imaginary) of soils are strongly dependent on soil moisture content. Changes in the dielectric constant result in major changes in the emissivity and radiometric brightness temperature. Microwave temperature differences between saturated tidal mud and soils of low water content are on the order of 120°K. Experiments were also conducted on a playa surface wherein soil bearing strenghts were compared with microwave brightness temperatures.

These measurements clearly demonstrate that a useful qualitative relationship exists between the radiometric brightness temperature and bearing strengths of soils. This relationship has particular significance in the field of soil engineering.

Author

E0300 (N67-13513)
Egan, W.G. and H.B. Hallock. 1966. Polarimetry signature of terrestrial and planteary materials, p. 671-689. In Proc. 4th symp. on remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Terrestrial materials reveal polarization characteristics in reflected and emitted light which are functions of the phase (incident plus emergent) and the viewing (emergent) angles of the surface, as well as the spectral range. The polarization characteristics are exhibited by all surfaces, and are functions of the geometry and physical properties. Such geometrical properties as surface smoothness albedo, multiple scattering, particle size, shape, or spacing, and macrostructure can influence the polarization characteristics as well as physical properties such as dielectric constant, permeability and conductivity. Data will be presented to indicate the diversity of polarimetric signatures that are obtained on some materials. The data has been obtained, in part, on a large scale spectral polarimeter which permits observations to be made in the visible and infrared.

Author

E0400 (AD-683 584)
Ellermeir, R.D. Oct. 1968. Project Themis: A Center for Remote Sensing. Semiannual technical rept. no. 2, Apr. - Oct. 1968, Center for Research, Kansas Univ. Lawrence, Rept. No. CRES-Tr-133-6. 161 p.

This report summarizes the technical progress under the subject contract on a broad interdisciplinary effort for the improveemnt of user utility of remotely sensed data. This effort involves theoreti-

cal work, sensor development, processing and display, and data analysis for specific user application. A number of technical reports and memoranda describing work underway are attached.
Author

E0450
England, G. and J.O. Morgan. 1965. Quantitative airborne infrared mapping. p. 681-690. In Proc. 3rd symp remote sensing environment. Inst. Sci. and Tech. Univ. Michigan, Ann Arbor, Rep. 4864-9-X.

Gray scale variations or contrasts in aerial infrared imagery yield no quantitative information with regard to radiation or surface temperature. The difficulty of providing suitable calibration in the scanner and of evaluating atmospheric transmission are primarily responsible. A technique for calibration of the final imagery, employing quantitative radiometric measurements in combination with special electronic processing of magnetic tape recorded infrared scanner signals and densitometry, is under investigation. Direct use of tape recorded data permits evaluations of errors or nonlinearities due to cathode ray tube photography and variations in film processing.
Author

E0500 (N69-19076)
Eppler, W.G. and R.D. Merrill. 1968. Correlating remote sensor signals with ground-truth inforamtion. Electronic Sci. Lab. Lockheed Missiles and Space Co., Palo Alto, California. LMSC6-79-68-8. 69p.

Two compter-based methods are described for data handling and display which significatnly simplify the task of correlating remote sensor signals with ground truth information. These techniques were applied successfully to microwave radiometer and infrared spectrometer flight test data. Results indicate that the digital computer, with its associated storage and display capabilities, makes possible systematic and accurate analysis of remote sensor data at low cost.

In one approach, the computer is used to determine and display the exact path of the sensor boresight over the ground scene. Using this display, an investigator can boserve visually certain simple correlations between the sensor return and the ground scene. In the second approach, the analyst uses a special light pen console to put ground truth information (in graphical form) into the computer. Using techniques described here for storing, retrieving and processing graphical data, the computer automatically converts the ground truth information into a form where it can be correlated directly with the remote sensor signals.

Author

E0600 (N67-13479)
Estes, J.E. 1966a. Some geographic applications of aerial infrared imagery, p. 173-181. In Proc. 4th symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

This paper, by showing various applications of airborne infrared imagery, is intended to stimulate thinking among geographers toward the potentials of airborne infrared imaging systems as geographic research tools. Examples of the ability of airborne infrared imagery to aid investigations of rural and urban land use, climatology, physiography, resource development, and others are shown. By utilizing the capabilities of airborne infrared systems the researcher will gain valuable supplemental information which in many cases is unattainable from conventional aerial photography. The geographer, in turn, by making use of this tool may be able to aid in infrared systems development. There is still much research to be done on the capabilities and limitations of infrared and the trained geographer can make a significant contribution. At present academic and professional geographers may find it difficult to apply infrared

sensors to their research because of the relative expense of the system or the security classification of the imagery. However, as more imagery is declassified and more systems come into use geographers should be prepared to employ this new research tool. Author

E0601
Estes, J.E. 1966b. Some applications of aerial infrared imagery. Ann. Assoc. Amer. Geographers 56(4): 673-682.

This paper, by showing various applications of infrared imagery, is intended to stimulate thinking among geographers toward the potentiality of airborne infrared imaging systems as geographic research tools. By making use of the capabilities of airborne infrared systems the research will gain valuable supplemental information which in many cases is unattainable from conventional aerial photography. The geographer interested in earth science investigations will find infrared imaging systems quite valuable in the determination of certain geological formations and structural features. Hydrographic features, owing to the variation in land-water heat capacities, show quite well on most infrared imagery. Certain types of vegetation may be differentiated more readily in the infrared, than in the visible, portion of the electromagnetic spectrum. Other applications to archeological research, rural applications such as wildlife inventories, and urban investigations, such as computer studies are also suggested. High resolution infrared radiometers are already being used to great advantage in meteorolgoical studies from orbital altitudes. By applying infrared imaging devices in their research geographers, while gaining valuable supplemental information, may provide data useful in systems development. At present, the geographer may find it difficult to apply infrared sensor to his research because of the relative expense of the system or U.S. Department of Defense security classification of the imagery, but he should be prepared to employ this new tool as more infrared imagery is declassified and more systems come into use.

Author

F0100 (N67-13464)
Fischer, W.A. 1966. Geologic applications of remote sensors, p. 13-19. In Proc. 4th symp. remote sensing environment, Inst., Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

A generaliza ion of problems in geology, geochemistry and geophysics is briefly treated, and the feasibility of sensor application discussed. Guidelines for remote sensor utilization are provided under the trichotomy: the geologic problems to which the sensors can be applied, the basis used for sensor selection, and the manner of sensor application. Tabular data are presented for the characteristics and unique qualities of selected sensors, and for environmental variables and estimates of their potential effect on observations of color by various sensors. A graphic estimate (derived from aerial and ground photographs) indicates the ize-frequency distribution of macroscopic increments of terrain that vary in color from their surroundings. Also included is a comparison of the unique properties and applications of the camera, colorimeter, and the eye in a color observation system.

R.L.I.

F0200
Foote, R.S. 1968. Application of airborne gamma-radiation measurements to pedologic mapping, p. 855-875. In Proc. 5th symp remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

An airborne system for rapidly gathering large volumes of gamm-radiation spectral data is being used to examine the uranium: theorium; potassium distribution in surface soils. These data are accumulated using six NaI(Tℓ) detectors 11 1/2-in. ida by 4-in. thick. Spectral counting rates for an average surface elevation of 400 ft are sufficient to allow data accumulation periods as short as 2.0 seconds followed by a 0.5 second readout of the 400 channels on magnetic tape.

All results giving the magnitudes of the uranium, thorium and potassium-40-created radiation are first corrected for the spectral count contribution of the radioactive elements carried onboard the aircraft and contained in the atmosphere. These data are subsequently corrected to a constant surface elevation of 400 ft. Removal of the spectral contribution from cosmic radiation is performed during initial data reduction. Normal computer operation on the data gives isoradiation maps and radiation profile arrays for the near-surface $Bi^{214}$, $Tl^{208}$, $K^{40}$ and their ratios $Bi^{214}/Tl^{208}$, $Bi^{214}/K^{40}$ and $Tl^{208}/K^{40}$. Average soil types surveyed in the Atascosa County Area, Texas show a linear relationship between surface soil $Tl^{208}$ and $Bi^{214}$, which generally identifies the soil types. No correlations of $Tl^{208}$ and $Bi^{214}$ with $K^{40}$ are observed. The majority of the region is observed to have an approximately constant radiation balance between $Bi^{214}$ and $Tl^{208}$ with the exception of two regional anomalies.

Author

F0250

Fritz, N.L. 1967. Optimum methods for using infrared-sensitive color films. Photogram. Eng. 33(10):1128-1138.

Considerable interest has currently been expressed in the potential of Kodak Etachrome Infrared Aero Film, Type 8443, as a remote sensor for applications as diverse as aerial reconnaissance and the detection of diseases and pests in agricu tural crops. The results obtained with this film can be optimized through a knowledge of some of its special characteristics, and by using photographic techniques which take advantage of its unique properties. Consideration of the typical scene characteristics indicates tha the principal applications at the present time involve the photography of foliage. By observing appropriate methods for storing, exposing, and processing, one is assured of obtaining photographs having the highest information content.

Author

F0300
Fry, J.M. 1969. Methods of graphical and analytical mensuration of single terrestrial photographs. Dept. Civil Eng., Univ Illinois, Urbana. Photogrammetry Ser-23. 191 p.

In the field of photogrammetry considerable effort has been expended in the development of mensuration techniques .or both aerial and terrestrial photography. Mensuration on a single frame of photography falls outside the realm of stereophotogrammetry and requires a somewhatedifferent approach. Indeed, dimensional information may be needed of a particular subject imaged only on one photogra - a photograph in which the type of camera, format size, focal length, camera position and camera orientation area all unknown. Even under such adverse donditions it may be possible to provide reliable information if the geometry of the photograph can adequately be reconstructed. The fundamental concepts of photogrammetry and prespective geometry will serve as a basis for the graphical and analytical mensuration techniques applicable to a single photograph.

Author

F0400 (N69-25802)
Fu, K.S. and E.G. Henrichon, Jr. 1968. On nonparametric methods for pattern recognition. School of Elec. Eng., Purdue Univ., Lafayette, Indiania. TR-EE-68-19. 155p.

This study is concerned with the development of nonparametric classification techniques for application to pattern recognition. The methods proposed can be considered as special clustering procedures intended for off-line data analysis. The only assumption required is that observations from the same pattern class are independent and identically distributed according to some unknown continuous probability distribution. Examples involving real data in agricultural remote sensing are given to illustrate the application of these procedures.

Author
(USGRDR)

F0500 (A69-17396)
Fu, K.S., P.J. Min, and T.J. Li. 1968. On features selection in pattern recognition, p. 10-19. In Proc. 6th annu. allerton conf. on circuit and system theory, IEEE, New York.

Brief review of the problem of feature selection in pattern recognition. Feature selection techniques discussed include: (1) information-theoretic approach, (2) using direct estimation of error probability, (3) feature-space transformation, and (4) the approach of using the stochastic automata model. These techniques are applied to the selection of features in crop classification problems. Using minimax linear discriminant functions, a separability measure is derived for the problem of feature selection in parametric multiclass pattern recognition when features from each class are distributed according to a Gaussian probability density function with unequalcovariance matrices. Computer simulation results are presented and compared.

M.G.

G0100
Gates, D.M. 1965. Characteristics of soil and vegetated surfaces to reflected and emitted radiation, p. 573-600. In Proc. of the 3rd symp. remote sensing environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor; Rep. 4864-9-X.

A surface may be viewed by reflected sunlight or by emitted thermal radiation. The reflected radiation will be determined by the spectral reflectance of the vegetation, the spectral quality of the incident sunlight, and the geometry of the plant canopy. These factors are each described for specific examples.
The energy emitted by a plant canopy depends upon the plant temperature, which in turn is determined by the energy exchanged between the plant and its environment. Energy is exchanged by radiation, convection, and transpiration. The energy exchange process is described by means of examples.

Finally the radiation exchange is described as a function of the crop canopy geometry. This is done in generalized form so that the reflected and absorbed radiation is estimated as a function of the canopy density. The work described here is fundamental for the interpretation of aerial reconnaissance pictures of vegetated surfaces.

Author

G0110
Gates, D.M. 1967. Remote Sensing for the biologist. Bioscience 17(5): 303-307.

Briefly reviews the electromagnetic radiation spectrum and the means of detection for various segments. Discusses emitted and reflected radiation and some of the features affecting the spectral distribution and intensity. Give examples of how the spectral quality of reflected radiation and the intensity of emitted radiation can be used to identify surface features. Discusses some possible applications and potential benefits of remote sensing.

R.H.G.

G0120
Gates, D.M., H.J. Keegan, J.C. Schleter, and V.R. Weidner. 1965. Spectral proerties of plants. Applied Optics 4(1):11-20.

The spectral properties of plant leaves and stems have been obtained for ultraviolet, visible, and infrared frequencies. The spectral reflectance transmittance, and absorptance for certain plants is given. The mechanism by which radiant energy interacts with a leaf is discussed, including the presence of plant pigments. Examples are given concerning the amount of absorbed solar radiation for clear sky and overcast conditions. The spectral properties of desert plants are compared

with those of more mesic plants. The evolution of the spectral properties of plant leaves during the early growing season is given as well as the colorimetric behavior during the autumn.
Author

G0200 (A69-30456)
Gausman, H.W., W.A. Allen, and R. Cardenas. 1969. Reflectance of cotton leaves and their structure. Remote Sensing of Environment 1:19-22.

Cotton plants were grown hydroponically with low-, medium,- and high-salinity substrate levels formulated with sodium chloride, Leaves were sampled from third and fourth nodes down from apexes of cotton plants, simulating what an overhead remot sensor would see. A spectrophotometer was used to measure reflectance and transmittance of light impining on upper surfaces of individual leaves. Total reflectance of light in the 750- to 1300 -m spectral range was greater from leaves of cotton platns grown in medium- and high-salinity substrates than from those grown in low-salinty substrates. This increase in reflectance and a lessening in absorptance were consistent with the observed thicker leaves of the saline substrate grown plants which had larger palisade cells and loosely arranged spongy mesophll. These structural changes resulted in more intercellular spaces, this supporting the premise that internal scattering of light is increased by cell wall-air cavity interfaces.
Author

G0300
Gausman, H.W. and R. Cardenas. 1968a. Effect of pubescence on reflectance of light, p. 291-297. In Proc. 5th symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

Hairs were removed from ventral surfaces of young leaves of Gynura aurantiaca (velvet plant) with an electric razor. Pubsescence significatly increased total and diffuse reflectance in the 750 to 1,000 mu region, but it decreased total and diffuse reflectance in the 1,000 to 2,500 mu region.

Hairiness had little effect on the reflectance of visible light within 500 to 750 mu. Theoretically, hairs increased scattering of incident radiation and thereby increased total reflectance in the near-infrared region between 750 to 1,000 mu. This mechanism does not explain the reduced reflectance due to hairiness in the 1,000 to 2,500 mu region. Further research is needed to explain this phenomenon.

Author

G0310
Gausman, H.W. and R. Cardenas. 1968b. Effect of soil salinity on external morphology of cotton leaves. Agron. J. 60:566-567.

Fourth leaves from the apex of cotton plants were samplied in a field containing areas of low and high levels of soil salinity. Microscopic examination revealed that high salinity ca sed fewer epidermal cells and stomata per unit area, increased surface size of epidermal cells, and increased leaf thickness.

Author

G0400 (N69-16106)
Gawarecki, S.J. 1969. Infrared survey of the pisgah crater area, San Bernardino County, California: A Geologic interpretation. Geological Survey. Tech. Letter NASA-99. 71 p.

Infrared imagery in the 8-14 band to the Pisah Crater area has provided useful geologic information to complement data obtained from ground studies and from aerial photography. Thermal contrasts representative of those found through the diurnal cycle were acquired during three of six flight periods: at about 2000 (post-sunset), 0400 (Pre-sunrise), and 1200 (midday). The largest amount of information on geologic thermal parameters from a single imaging period was obtained from the imagery flown shortly after sunset. Among the geologic features shown on imagery of one or more flight periods were basalt flow contacts where the adjacent flows differed in surface character, distribution of pyroclastics and

and their alluvial derivatives on the flows, collapsed lava tubes, fissured areas, detail of the Pisgah fault, zonation within Lavic dry lake, active drainage on an alluvial fan, and moist areas suggestive of ground water conditions.

Author

G0500

Geleynse, M. and A.R. Barringer. 1965. Recent progress in remote sensing with audio and radio frequency pulses, p. 469-494. In proc. of the 3rd symp remote sensing of environment, Inst., Sci. and Tech., Univ Michigan Ann Arbor. Rep. 4864-9-X.

Further developement of the input or induced pulse transient electromagnetic system has resulted in higher powered miniaturized equipment of improved sensitivity. Airborne programmes in Australia and the southwestern United States have proven the capabilities of the system for detecting and resolving geologic features beneath highly conductive saline soils. Ore deposits of the porphyry copper type have for the first time been detected from the air in a comprehensive test programme. Continuing development of very short pulse VHF radar mounted in a vehicle has yielded new information on the VHF reflective properties of soil under varying conditions of layering, moisture content and soil type. The feasibility has been established and the parameters outlined for an airbonre low level terrain sensing system utilizing VHF pulses.

Author

G0600 (N66-21664)

Gerharz, R. and W.A. Fischer. 1966. Reflectance measurements in the 0.6 to 2.5 micron part of the spectrum. Geol. Survey. U.S. Dept. Interior. Tech. Letter NAS-8. 17 p.

Preliminary observations indicate that some rocks and minerals selectively absorb electromagnetic energy in the 0.6 to 2.5 micron part of the spectrum, and many of these observations correspond closely to positions in known atmospheric absorption bands. The observed bands are believed to relate to the

absorption characteristics of the rock specimens rather than that of the intervening atmosphere. Measurements were made with a DK-1 Beckman infrared spectrophotometer, which is not considered ideal for such reflectance investigations. Spectral resolution varies with wavelength for this spectrometer, which was used with an integrating sphere.

M.W.R.

G0610
Gerlach, A.C. 1968. Advances in geographic and thematic mapping applications of remote sensor data. p. 191-196. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

The development of a variety of remote sensing instruments for use in aircraft and spacecraft has removed significant barriers to geographic and cartographic research, expanded tremendously the horizons for participation in the analysis and applications of new forms and great volumes of data, and stimulated a review of traditional objectives and methodologies. The hardware and instrumentation requirements for obtaining useful data from orbital heights are described in terms of current objectives, and results of research contracts financed by NASA through the Geological Survey are summarized in terms of data selection, signature identification, sensor calibration, and the development of information systems and printout techniques. The potentials and economics of international cooperation in Earth study from orbital platforms are mentioned.

Author

G0610
Gerlach, A.C. 1968. Advances in geographic and thematic mapping applications of remote sensor data. p. 191-196. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

The development of a variety of remote sensing instruments for use in aircraft and spacecraft has removed significant barriers to geographic and

cartographic research, expanded tremendously the horizons for participation in the analysis and applications of new forms and great volumes of data, and stimulated a review of traditional objectives and methodologies. The hardware and instrumentation requirements for obtaining useful data from orbital heights are described in terms of current objectives, and results of research contracts financed by NASA through the Geological Survey are summarized in terms of data selections, signature identification, sensor calibration, and the development of information systems and print-out techniques. The potentials and economics of international cooperation in Earth study from orbital platforms are recognized, and some of the current possibilities are mentioned.
Author

G0650
Goodman, Majorie S. 1959. A Technique for the identification of farm crops on aerial photographs. Photogram. Eng. 25(1):131-137.

This paper includes a description of a technique developed for the purpose of setting down aerial-photo identification criteria for various farm crops at several stages of growth in Northern Illinois. The general aspects of the photo appearance of these crops are also described.
Author

G0660
Goodman, Majorie S. 1964. Criteria for the identification of types of farming on aerial photographs. Photogram Eng. 30:984-990.

Geographers, economists, planners, and others who do research in agricultural regions commonly face the task of identifying types of farming for the purpose of delimiting type-of-farming regions. The usual method employed for the task requires field research that is costly in terms of both time and labor. Recent research in the

application of aerial photographs to the identification of types of farming indicates that one can expedite the task with aerial photographs and do most of the work in the laboratory. Three sets of criteria that can be read or inferred from aerial photographs serve as indicators of types of farming: (1) farmstead features such as barns, granaries, and silos; (2) crop associations on individual farms; (3) the uses that are made of corn and hay.
Farmstead features are recognized readily on aerial photographs but are frequently unreliable as indicators of types of farming. Farm crops and crop associations are less readily identified on aerial photographs but are more reliable as indicators of types of farming. Still more reliable is the crop association considered in conjunction with the inferred uses that are made of corn and hay. Finally, application of all three sets of criteria is most reliable; and, therby, aerial photographs can facilitate the task of identifying types of farming.

Author

G0700 (N69-22204)
Grant, K. 1968. A terrain evaluation system for engineering. Div. Soil Mech., CSIRO, Melbourne, Australia. TP-2. 28p.

The principles and concepts evolved for a scheme of terrain classification are discussed in detail in this paper. A scheme operating at four levels of generalization, known as province, terrain pattern, terrain unit, and terrain component, is suggested. The terrain covered by each level of generalization is defined and a numerical system of labelling for each level of geralization is proposed and explained. The methodology of operating the suggested terrain classification system is discussed and the role of aerial photographs is examined. The classification is based first on aerial photograph interpretation, but the classification so obtained is not regarded as valid until it has been checked in the field. The implementation of the terrain classification scheme and its engineering interpretation as considered.

Author
(USGRDR)

G0800 (A69-14653)
Griggs, M- 1968. Emissivities of natural surfaces in the 8- to 14- micron spectral region. J. Geophy. Res. 73:7545-7551.

The emissivities of the ocean, stratus clouds, desert, and snow are determined from airborne radiometric (8 to 14μ) temperature measurements. Corrections for the intervening atmosphere and for sunlight, skylight, and aircraft rediance reflected from the surface are discussed. The emissivities in thie 8- to 14-μ region are found to be 0.99 for the ocean, 0.98 for stratus clouds, 0.90 for the desert, and 0.99 for melting snow.
Author

G0900 (N69-21230)
Gwynn, A.P. 1968. Aerial photographic interpretation and land use classification , Regional Planning Council, Baltimore, Maryland. 60p.

Aerial photographs provide a rapid and relatively accurate means of developing and maintaining a regional land use inventory. Advantages of the system are speed and accurate size, density, and general coverage measurement. D sadvantages are the need for proper photography and trained personnel, and inability to identify all types of land uses to the same level of accuracy. A preliminary land use classification was developed and compared to the 'Standard Land Use Coding Manual' developed by the Urban Renewal Administration and the Bureau of Public Roads.
(USGRDR)

H0050
Haefner, H. 1967. Airphoto interpretation of rural land use in western Europe. Photogrammetria 22(4); 143-152.

A review is given of differnt aspects of the employment of aerial photography for rural land-use studies in western Europe. Progressess and results obtained are indicated as well as current projects and trends. References are made to institutions and persons engaged in research and the relevant literature cites. Research studies on basic interpretation problems and the development of interpretation methods are particularly considered.
Author

H0100

Haralick, R.M. 1968. Adaptive pattern recognition of agriculture in western Kansas by using a prdictive model in construction of similarity sets, p. 343-356. In Proc. 5th symp. remote sensing of environment, Inst. Sci and Tech. Univ. Michigan, Ann Arbor. Rep 4864-18-X.

Automatic classification of remote sensed data is a necessity since satellite remote sensors currently on the design board are expected to gather more data each hour than could be analyzed by traditional methods in a year. A machine which could determine the structure of the sensed environment by grouping together similar data signals and relabeling these signals with the same label would reduce both storage requirements and transmission times for the remote sensor in addition to doing pattern recognition in space or on the ground. The paper is introduced by a discussion concerning the adaptive process of how predictive models of an environment can be generated. This discussion leads into a mathematical description of such a model for pattern recognition. The model was programmed for the GE 625 and four possible combinations of transmitted and received like and complementary polarized K-band radar images of agricultrue in western Kansas were used as data.

Results confirm that various categories of vegetation such as alfalfa, grain sorghum, wheat stubble and corn cannot be distinguished from one another on the basis of their structure within the radar data. This suggests that for pattern recognition purposes, certain categories may be expanded with little or no information loss and increase in efficiency of the pattern recognition process. Further it also suggests that if the investigator wants to distinguish between the confused categories such as alfalfa, grain sorghum, wheat stubble and corn, an additional sensor must be used which can make the distinction. Author

H0200 (A69-29533)
Haralick, R.M. and G.L. Kelly. 1969. Pattern recognition with measurement space and spatial clustering for multiple images. IEEE Proc. 57"654-665.

Remote sensor imaging technology makes it possible to obtain multiple images of extensive land areas simultaneoulsy from the radar, IR, a visible portions of the electromagnetic spectrum. It would be useful to automatically obtain from such data land-use maps indicating those areas of similar types of land - i.e., similar as seen through the sensor's eyes. This classification problem is approached from the perspective of the structure inherent in the data. The classification categories or clusters so constructed are the natural homogeneous groupings within the data. There is high similarity within each cluster and high dissimlarity between clusters. Two clustering procedures are presented. The first partitions the image sequence, and the second partitions the measurement space. In both, the partition is constructed by finding appropriate center sets and then chaining to them all points similar enough The resulting clusters are simple connected and not necessarily convex. An example of the measurement space clustering procedure is presented for a set of three multispectral images taken over Pheonix, Ariz. Author

H0300
Harris, D.E. and C.L. Woodbridge. 1964. Terrain mapping by use of infrared radiation. Phtogram. Engr. 30:134-139.

In the last decade much progress has been made in the development of techniques for obtaining thermal maps of terrain using airborne scanning devices. To date the spectral region from visible light to about 14 microns has been exploited. Present state-of-the-art restricts the system designer to the use of single element infrared detectors or to very simple arrays of a few elements.

This paper describes a line-scanning technique that has been successfully applied in obtaining thermal terrain maps from the air. Pertinent design parameters are discussed and various factors that limit performance are analyzed. Thermal maps of various types of terrain illustrate the usefulness of the mapping technique.

Author

H0400 (N68-17408)

Heller, R.C. and R.C. Aldrich, W.F. McCambridge, and F.P. Weber, 1967. The use of multispectral sensing techniques to direct ponderosa pine trees under stress from insect and pathogenic organisms. Pacific SW Forest and Range Exp. Sta., Berkeley, California. NASA-CR-93173. 73 p.

Both grand and airborne operations were conducted to identify the likeliest sensors available to foresters to detect early tree stress. Aerial photography (color and false color) was taken at five periods (October 1966, May, June, July, and August 1967) over six infestation centers to capture the changes in foliage coloration. Optical-mechanical scanning imagery was obtained in three wavelengths (2.0-, 2.6, 4.5-5.5, and 8.0-14.0 microns) over a three-day period in June 1967. Better ground instrumentation was developed this season for measuring sap flow, emitted foliage temperatue, and meteorological conditions. A promising new device (Scholander bomb) measured highly significant differences in needle moisture tension between healthy and stressed foliage. Foliage discoloration rates of all 204 infested trees were established by comparison with Munsel cards. Ground Munsell notations of infested foliage were very similar to Munsel notations of the tree images in color aerial transparencies; however, Munsel notations on 35 mm. ground photography showed less agreement with either of the above.

Author

H0410

Heller, R.C., R.C. Aldrich, W.F. McCambridge, F.P. Weber, and S.L. Wert. 1968. The use multispectral sensing Techniques to detect ponderosa pine trees under stress from insect or pathogenic organisms, annual prop. rep. Pacific SW Forest and Range Exp. Sta., Forest Serv., U.S.D.A., Berkeley, California. 45p.

The objectives of this study are twofold: one, to determine what airborne sensors may be used to detect and map the presence of dying conifers before visual symptoms occur, and, two, to establish what the smallest scale of aerial photography may be to detect insect epidemics from space altitudes.

The first phase of this study was reported on in detail in the two privious progress reports. AGain, during the 1967-68 season, biological and meteorological measurements were made to relate the "ground truth" to aerial imagery. Not only were large-scale color photographs taken but also imagery was produced by the 17-channel optical-mechanical scanner from the Willos Run Laboratories, University of Michigan.

A pilot test was conducted on a three-square mile area to simulate conditions expected from space photography. Color and infrared color transparencies were produced at the following scales; 1:116,000, 1:63,360, 1:31,680, 1:15,840, and 1:7, 920.

Dying pine trees were again measured to be up to 6°C. warmer than healthy trees during the same month in 1966 in 1967. Imagery from the Michigan flights is not available yet for ana ysis and reporting purposes. Because 1968 was a drier year than 1967, dying foliage was more yellow-red than for the samemonth the previous year. Photo interpretation of large-scale transparencies (1:1,584) showed best results when foliage was most discolored in August. As in 1966 and 1967, color transparencies were as effective in detecting dying trees as color infrared transparencies. Again, neither film was an effective previsual sensor.

On the pilot study area, as the images became smaller (smaller scale) and as the size of the infestation became smaller, photo interpreation accuracies decreased.

For the greates accuracy, we found that entomologists need a scale of at least 1:7,920 to detect the

presence of a new epidemic which usually manifests itself in small infestations of 1 to 3 trees (5 to 20 feet).
Dectection on 1:15,840 scale photography is only slightly less successful than on the 1:7,920 scale. With the exception of small infestations, 1 to 3 trees in size, a 1:31,680 scale will result in detection almost as good as on larger scales, at much less cost. Infrared color film is better than color for detecting small infestations on these three larger scales.

Author

H0500 (N66-39304)
Heller, R.C., W.F. McCambridge, R.C. Aldrich, and F.P. Weber, 1966. The use of multispectral sensing techniques to detect ponderosa pine trees under stress from insect or pathogenic organisms, annual progress report. Pacific SW Forest and Range Sta., Berkeley, California. NASA-CR-78741. 70p.

Investigations are underway to determine the groun instrumentation, aerial sensing equipment, and techniques required to detect vigor loss and pre-visual signs of tree mortality caused by bark beetles in coniferous timber stands. Ground and aerial studies have been started and data were collected on spectral reflectance, emissivity, and transpiration of ponderosa pine trees and foliage. Aerial photograph (color and infared color) was exposed over 11 infested test sites at four time intervals. Optical-mechanical scanning imagery was taken diurnally on 3 days in May and June 1966. Almost 75 percent of the dying trees were not detected until 10 months had elapsed. No difference in interpretation accuracy was found between color and infared color films but commission errors were slightly more numerous on the infrared color film. Resolution of the thermal imagery was too poor to determine whether thermal differences of stressed trees could be detected from the air.

H0600
Hodgin, D.M. 1963. The characteristics of microwave radiometry in remote sensing of environment. p. 127-137. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-3-X.

The use of passive microwave detection of terrain emission promises to serve scientists in remote sensing of earth characteristics similar to the service now being rendered by infrared. In fact, microwave sensing augments infrared sensing in many important areas as in earth, snow, cloud penetration measurements, and in measurements applications where atmospheric constituents must not interfere. Conversely, microwave sensing can provide excellent information about the water vapor absorption spectrum in the 1.25-cm wavelength region and in the 5-mm wavelength region where molecular oxygen absorption occurs.

This paper will discuss the relationship of material emissivity, thermal temperature, and the relected temperature contributions to the measured radiometric temperature in order to provide a fundamental basis for the discussion to follow.
The results of several experimental radiometric measurements will be shown and compared to measured emissivities of materials by other investigators. The basic limitations of the state of the art in instrumentation will be discussed in terms of thermal resolution, angular resolution and time for integration at the detector. Author

H0700 (N67-13475)
Hoffer, R.M., R.A. Holmes, and J.R. Shay. 1966. Vegetative soils, and photographic factors effecting tone in agricultural remote multispectral sensing. p. 115-134. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Current research has as its purpose the identification of crop species and conditions of health and maturity for several economically important crop types in the corn-belt region, using multispectral imagery ranging from 0.3- to 14 wavelength and radar imagery. This study has revealed a large number of vegetative variables which often cause marked tonal variations in portions of the electromagnetic spectrum. Those variables of primary importance are: crop species and variety; relative size and maturity at the time of flight missions; soil type, moisture content, and relative amounts of soil and vegetation observed; and geometric configuration of the crop. Spectrophotometric curves on individual leaves do not always indicate accurately the relative reflectance observed on multispectral imagery. Crop or leaf geometry has a marked influence on reflectance of vegetative canopies, particularly in relation

to certain photographic instrumentation variables. It is the purpose of this paper to present certain photographic factors and biophysical reasons that cause remote view spectral tonal variations, together with experimental evidence in support of these reasons. With accurate knowledge of the instrument limitations and biophysical causes of tonal variations over the electro-magnetic spectrum, more precise analysis of multispectral reponse signatures will be possible, assuring detailed remote sensing a role in agricultural information collection and utilization.

Author

H0750

Hoffer, R.M., C.J. Johnson, and M.F. Baumgardner. 1967. Agricultural applications of remote multispectral sensing. Proc. Indiana Acad. Sci. 76: 386-395.

Discusses the concept of multispectral sensing and illustrates the differences in response that could occur for a given object at different wavelengths. By the multispectral response signature for a crop and comparison with the signatures from known crops, the unknown can be identified by the use of a pattern recognition technique. The potential uses are discussed.

R.H.G.

H0800 (A69-13195)

Holmes, R.A. 1968. An agricultural remote sensing information system, p. 142-149. In Eascon '68; Inst. electrical and electronics eng., electronics and aerospace sys. convention, Washington, D.C., Sept. 9-11, 1968, record. IEEE, New York.

Description of an information system capable of delivering timely knowledge of the state and trends of earth resouces. The system is composed of data acquistions, data processings, and information extraction and interpretation phases. The data contain spatial information in radiance variations over the scene raster, spectral information in each recorded band, and temporal information in the time of year of the flight. Flight tape processing yields computer prints of the scene with better gray scale and worse spatial resolution than an aerial photo. Spectral information extraction is shown through crop and soil identification on a

thresholded maximum likelihood basis in a 12-dimensional radiance space. Anonalies due to a variety of agricultural and instrument factors are illustrated. The interplay of physical phenomena, instrumentation choices, data format choices, and information extraction success is discussed F.R.L.

H0950
Holter, M.R. and R.R. Legault. 1965. The motivation for multispectral sensing. p. 71-77. In Proc. 3rd symp. remote sensing of environment, Inst. Sci. and Tech. Univ. Michigan, Ann Arbor, Rep. 4864-9-X.

The motivation for the University of Michigan programs in simultaneous multispectral reconnaissance is described. It is shown that present methods of presenting imagery are deficient in that they cannot display in a useful form all the infromation that is obtainable. This is particularly true of the common attempts to use a "best" film-filter combination to obtain and present imagery. A practical method of presenting the results of multispectral sensing is described. Related succedings papers are introduced.

Author

H1000 (N68-36402)
Honea, R.B. and Virginia L. Prentice. 1968. Selected Bibliography of Remote Sensing. Geological Survey, U.S. Dept. Interior, NASA-129. Sept. 35 pp.

Publications pertaining to the geographic applications of remote sensing techniques are presented in a four-part bibliography. The first part included publications that provide an overview of the field and its geographic applications, while more technical publications are listed in the second part. Publishers and prices of the latter list are

included. Part III contains documents relating to land use classification and analysis, and Part IV is a selected bibliography of data handling and automatic data processing techniques used in remote sensing. References in each part are listed alphabetically according to author. M.W.R.

H1100 (N69-18104)
Hovis, W.A. 1968. Spectral Studies of Reflected Solar Energy Fields, Red Tide, Kelp. 0.68 to 2.4 Microns C-47 Aircraft. Goddard Space Flight Center, NASA, Greenbelt, Maryland. NASA-TM-X-63404.

As part of a program to determine the spectral distribtuion of reflected solar energy from natural surfaces measurements were made, over a variety of surfaces, with a down-looking spectrometer mounted on a C-47 aircraft. Of particular interest was the magnitude of energy reflected from vegetation, both marine and terrestrial, in the spectral interval, and since the Nimbus B-2 High Resolution Infrared Radiometer has a channel responding to radiation in the interval from 0.7 to 1.3 microns the question arose as to what degree fields of green vegetation might be confused with clouds, also a strong reflector from 0.7 to 1.3 microns. A previous flight, on the NASA Convair 990 jet aircraft, over the Yucatan Jungle of Mexico showed that jungles were rather poor reflectors, but the question of cultivated fields and marine vegetation remained unanswered. The data presented here do not, of course, present a complete answer, but they are at least allow the magnitude of the problem to be estimated. Author

H1200
Howe, R.H.L. 1958. Procedures of applying air photo interpretation in the location of ground water. Photogramm. Eng. 24(1): 35-49.

This paper discusses a new phase of air photo application. The technique of air photo inter-

pretation has been used and tested in the location of ground water bearing formations. A procedure for the application of this technqiue has been developed and improved. It includes the following steps in terms of order: (1) air photo mosaic assembling, (2) study and identification of ground materials, (3) study of surface drainage pattern and systems, (4) study of land forms, land uses, and other ground features, (5) interpretation of ground water conditions with the aid of literature and (6) preparation of a ground water map for the ara investigated.

Author

H1250

Howe, R.H.L. 1960. The application of aerial photographic interpreation to the investigation of hydrologic problems. Photogramm. Eng. 26 (1): 85:95.

This paper discusses the application of aerial photographic interpreation to various hydrologic problems. Aerial photographic interpretation has been found to be useful in the investigation of surface water problems, including: (1) the preparation of drainage maps, (2) the study of surface drainage patterns, (3) the evaluation of a watershed, (4) the study of a stream channel condition in relation to geology, and (5) the preparation of a hydrologic model. Aerial photographic interpretation also have been (1) the identification and location of water-bearing formations,(2) the aerial photographic patterns of water-bearing formations, (3) the evaluation of ground water potentials, (4) the evaluation of ground water inventories and the preparation of a regional ground water map, and (5) the prediction of ground water quality of an area.

Author

J0100 (PB-183414)
Janza, F.J. 1969. Electromagnetic sensor correlation study, final report. Ryan Electronic and Space Systems, San Diego, California. 150 p.

Correlation studies between electromagnetic remote sensor outputs and hydrological signatures of the terrain such as soil moisture, snow cover and depth, and water areas show positive correspondences. Multisensor direct and cross correlations as compared to single sensor correlations are shown to strongely increase the confidence level of the hydrological information.
Author

J0200 (N67-13518)
Johnson, P.L. 1966. A consideration of methodology in photo interpretation, p. 719-725. In Proce. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Instruction in remote sensing and photo interpretation for biological purposes is just developed beyond the forestry curriculum. The need is immediate and crucial to develop this new technology for application to broad ecological problems involving food supply, waste disposal and pollution, resource inventory and management, and environmental manipulation. Methods of teaching interpreation and deriving inferences are discussed in terms of mechanical techniques, reasonable processes, and technical examples. An entropy model for information extraction is offered. It is concluded that a theorectical foundation is needed as well as specific soluation to biological problems if remote sensing technology is to enter the arsenal of the ecologist.
Author

J0300 (N68-19870)
Jones, Natalie E. and R.A. Leestma. 1966. Bibliography of Remote Sensing of Resources. Corps. of Eng., U.S. Army, Fort Belvoir, Virginia, NASA-CR-93738. 40 p.

References on remote sensing of resources that appeared in the open literature between January 1960 and June 1966 are presented alphabetically according to author. A subject index lists article under vaious space-related projects, scientific disciplines, spectral fields, radar uses, and photographic techniques.

M.W.R.

K0050
Kennedy, J.M. and A.T. Edgerton. 1967. Microwave radiometric sensing of soils and sediments. Presented at the 48th ann. meeting, Amer. Geophysical Union, April 17-20 (Abst.) Amer. Geophysical Union, Trans., 48(1):154-

A field and laboratory measurements program sponsored by the Office of Naval Research, Air Force Cambridee Research Laboratories, Army Cold Regions Research and Engineering Laboratorie and Space-General Corporation has been conducted to determine the response of microwave radiometers to various soils and sediments. Field portions of the program were conducted in the western United States. The materials investigated include beach sand, river channel sand and gravel, unconsolidated tideland mud, playa sediments, and two varieties of loam. Dual polarization measurements were taken at frequencies of 13.5 Ghz and 37 Ghz, with aspect angles ranging from nadir to the local horizon. The results of these studies show that measured and that sizeable differences in radiometric response occur for the materials investigated. These differences are primarily attributed to differences in moisture content, particle size, and emissivity of the various materials studied. Particle size, variations influence the general shape and slope of radiometric temperature versus aspect angle plots, whereas moisture content variations cause the curves to shift along the temperature axis.

Author

K0100 (N68-2310)
Keefer, W.R. 1968. Evaluation of radar and infrared imagery of sedimentary rock terrain, south-central Yellowstone National Park, Wyoming. Geological Survey, U.S. Dept. Inter, Denver, Colorado. NASA-106. 14p.

Side-looking radar imagery (K-band) and nighttime infrared imagery (3-5 band) were compared over the same sedimentary terrain of south-central Yellowstone National Park to determine if either type of imagery could be used in differentiating rock types and delineating structural features. Although sedimentary rock types of greatly contrasting composition occur in the area, none had detectable tonal characteristics on either types of imagery. This is believed to be due, in part, to masking by vegetation. Flay lying volcanic rocks having smooth topographic profile were readily detectable on both radar and IR imagery. Quaternary surficial deposits were easily detected in IR imagery. Numerous faults of large displacement were not detected by either form of imagery except where the faults were expressed by topography.
Author

K0200
Kinsman, F.E. 1965. Some fundamentals on non-contact electromagnetic sensing for geoscience purposed, p. 495-515 In Proc. of the 3rd symp remote sensing of environment, Inst. Sci and Tech., Univ. Michigan Ann Arbor. Rep. 4854-9-X.

This paper presents some conventional and non-conventional airborne sensing techniques used for geophysical data collection. State-of-the-art and developmental types of sensors which may become standard tools of the future are described. The value of data collected in various portions of the spectrum is demonstrated and some critical problems awaiting solution are identified. Pertinent gephysical data collected by some of the newer types of sensors are also presented.
Author

K0300 (N69-24634)
Kondratev, K. Ya., E.P. Novoseltsev, and N.E. Ter-Markaryants. 1968. Determining surface temperature and cloud temperature from meteorological earth satellites. (Transl. from Russian) p. 3-23. Foreigh Tech. Div., Air Force Sys. Command, Wright-Patterson AFB, Ohio FTD-MT-24-88-68.

The factors which are responsible for errors in surface temperature and cloud temperature measurements from artificial earth satellites are considered for various spectral intervals (3.5-4.0; 8.0-12.0 microns). The radiation temperature is computed for 25 locations in the USSR during different seasons and this information is used to propose the most probable corrections to the temperature of the surface measured from meteorological satellites.

Author (TAB)

K0400 (A69-16633)
Kondrat'ev, K. Ia. and O.I. Smoktyi. 1969. Geophysical investigations on manned spacecrafts. Pure and Applied Geophysics 72(1):227-246.

Review of the first results and perspectives of investigations in geophysics and bordering sciences by means of manned orbital space laboratories A detailed treatment is given of the problems of interpreting terrain pictures from space. Photometric processing techniques and results are considered for atmospheric photography near the horizon, with the purpose of studying atmospheric optical nonhomogeneties (in particular, aerosol layers). The possible investigations based on the use of data regarding the spectra of outgoing radiation are mentioned.

Z.W.

K0500 (N67-13493)
Konecny, G. and EE Derenyi. 1966. Geometrical considerations for mapping from scan imagery. p. 327-338. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Scan photography and the geometrical related scan imagery introduce a variety of geometrical problems which made their use for mapping a

difficult task. Ways of achieving a complete geometrical evaluation are outlined. Formulations for frame photography, strip photography, panoramic scan photography and line scan imagery are compared. An example for the theoretical fidelity of line scan imagery is presented; other passive and active imagery systems are discussed.

Author

L0010

Langley, P.G. and D.A. Sharpnack. 1968. The development of an earth resources information system using aerial photography and digital computers, ann. prog. report. Pacific SW Foresty and Range Exp. Sta., Forest Ser., USDA, Berkeley, California 26p.

Work has begun toward fulfilling the three main objectives of this research effort as they pertain to forestry applications. These are (1) to develop the framework of an earth resource information system, (2) to provide techniques for scanning and interpreting aerial photographs automatically and (3) to develop survey procedures which optimally utilize the information system at several levels to provide timely data for resource analysis and decision making.
A systems analysis is under way to specify the software packages needed to build a preliminary information system with the equipment complement available. Programming will begin in the near future. Two models have been tried to discriminate between forest stands, comprising various combinations of conifer and hardwood species, by means of automatic photo scanning of panchromatic prints. A linear discriminate model using first power terms was tried with satisfactory results. However the inclusion of second power teams resulted in substantial improvements; 97 out of 100 data cells were classified correctly as to forest type by means of automatic photo scanning. Additionaly the probability of occurrence of all possible ordered pairs of tone density values in a multinomial model is being tried with encouraging results. This classification procedure assigns an area of land to the most likely forest type.

Likelihood is measured in a probabilistic sense. In the first trial using the model, 46% of the observed forest areas were automatically classified correctly as to type while only 25% of the areas would be expected to be correctly classified with a purely random assignment. While 46% correct classification is sueful in some applications, further effort is under way to improve the performance of the model.
The statistical theory of a multi-stage sample design, capable of taking optimal advantage of information obtainable from several levels in space from satellites to the ground, has been developed. Preliminary trails indicate that this desing may be superior to any other known sampling method for general application in the field of remote sensing. A larger scale field trial is now under way on the 100,000 acre Consumnes test area.

Author

L0050
Latham, J.P. and R.E. Witmer. 1967. Comparative waveform analysis of miltisensor imagery. Photogramm. Eng. 33(7):779-786.

Video conversion of imagery to sampling scane lines which generate waveforms measuring gray tones (or thermal variation) in the distribution pattern demonstrates a basis for instrumented comparative analysis. Distribution pattern are sampled by parallel scan lines for analogue wave form interpretation. Orientation controls and gray tone differentiation are referred to the relation between signal rise time and boundary determinations as illustrated by land and water surface thermal contrasts. Illustrations drawn principally from the central image area gain greater resolution and biaxial fidelity. Graphical and statistical comparative analysis of waveforms generated by infrared imagery demonstrates both information content and trade-offs associated with level of generalization resulting from variations in either resolution

of imagery or resolution of scanning systems. The possibility of directly analyzing an image from the signals which transmit it is noted. Experimental results demonstrate the value of waveform analysis for revealing geographic patterns.

Author

L0100
Lattman, L.H. 1963. Geologic interpretation of airborne infrared imagery, p. 289-293. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-3-X.

Modern airborne infrared (IR) imagery allows the photogeologist to view the earth's surface in a vast new range of the spectrum. This imagery is a function of the energy emitted from, not reflected by, the terrain object. As this energy is a function primarily of the object's emissivity and temperature, the photogeologist must retrain himself to interpret terrain features in a new aspect.
A photogeologic interpretation of an IR image of Mt. Nittany, Pennsylvania, reveals that shale may be distinguished earily from sandstone and that valleyside springs are more clearly shown than on conventional aerial photography. As more IR imagery becomes available, more geologic information will undoubtedly be obtained from this medium.

Author

L0200 (N66-39386
Lauer, D.T. 1966. The feasibility of identifying forest species and delineating major timber types in California by means of high altitude small scale aerial Photography, annual prog. report. Pacific SW Forest and Range Exp. Sta., Berkeley, California. NASA-CR-78757. 172 p.

Identification of forest species in California on high altitude small scale aerial photography

is possible when optimum photographic specifications are utilized. Recognizing tonal and morphological differences occurring between species is directly related to the following factors: film-filter combination, photographic scale, season of year, photo interpretation equipment, film exposure and film processing. Each of these factors has been analyzed and conclusions have been drawn as to the optimum specifications for identification of each of the species studied. A photo interpretation key for the identification of representative stands of several California species has been prepared utilizing aerial photography flown to optimum specifications.

Author

L0300 (N68-11494)
Lauer, D.T. 1967. The feasibility of identifying forest species and delineating major timber types by means of high altitude multispectral imagery, annual progress report. Pacific SW Forest and Range Exp. Sta., Berkeley, California. NASA-CR-93185. 113p.

A systematic analysis was made of the factors affecting image tone or color, image detail, and stereoscopic parallax in order to improve the quality of remote sensing imagery. The optimum combination of factors was determined for identifying the major tree species and timber types in selected parts of the world, using imagery taken from earth orbit. The value of such advanced techniques as sequential imagery, spectronzonal imagery, and false color image enhancement for identifying forest species was investigated. A Gemini VII photo was used for test interpretations of tree species, timber type boundaries, and cultural patterns.

Author

L0310 (N69-16113)
Lauer, D.T. 1968. Forest species identification and timber type delineation on multispectral photography. School of Forestry and Conservation, California Univ., Berkeley. NASA-CR-99184. 90 p.

Research performed at the various NASA Forestry Test Sites is described, and the results obtained are reported. Within the various test sites, it was found that a skilled photointerpreter can determine major vegetation type boundaries and identify the predominant forest species on high altitude-small scale aerial photography. However, the photography must be flown to optimum specifications in terms of film filter combination, season of year, and time of day. Analysis of photography taken over homogeneous pure stand cover types occurring within an extended study area, Flicker Ridge, indicates that (1) accurate vegatation surveys can be made without implementing expensive and time-consuming on-the-ground inventory techniques, (2) color infrared photography provides the interpreter with significantly more information on vegetative cover than panchromatic photography, and (3) color infrared photography requires approximately 25% fewer man hours of interpretation time than black-and-white photography.
Author

L0400 (N67-13474)
Leestma, R.A. 1966. Applications of air and spaceborne sensor imagery for the study of natural resources, p. 111-113. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech. Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

The use of multisensor imagery can revolutionize the portrayal of geographic information. Man can now measure total surfaces of the earth. This concept of totality is being examined and developed and will cover all the fields of geoscience. New methods of photointerpretation combined with comparative studies of imagery from the various remote sensors will advance scientific capabilities and result in more comprehensive knowledge of the earth.
Author

L0500
Legault, R.R. and F.C. Polcyn. 1965. Investigations of multi-spectral image interpretation. p. 813-821. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci. and Tech. Univ. Michigan, Ann Arbor. Rep. 4864-9-X.

The problem can be stated simply. Given N images of a scene in N different spectral bands how do we use this information to identify objects in the scene? The use of spectrophotometric data is straight-forward. The images contain spatial information. They do not allow one to compare radiant intensities between bands for a given object. In fact no absolute radiometric information is available. The available spectral information is the order of radiant intensities within a band and partial information about the radiance difference between objects within a band. Two preliminary approaches are being investigated. The first identifies spatially at least one object in the scene and using the spectrum of the identified object estimates the absolute spectra of the remaining objects. An example of this procedure is presented. The second approach uses the radiance order and radiance difference changes between bands to identify objects. A test case separating botanical from non-botanical objects is presented.
Author

L0600
Leighty, R.D. 1968. Remote sensing for engineering investigation of terrain-radar systems, p. 669-685. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

This paper discusses the present and future potential of radar for engineering investigation of terrain. The purpose is to acquaint the engineer with the applicable radar literature pertaining to radar uses, radar systems, radar theory and emperical measurements, qualitative analysis of radar imagery and miscellaneous radar techniques.
Author

L0700 (N66-39303)
Lent, J.D. 1966. Cloud cover interference with remote sensing of forested areas from earth-orbital and lower altitudes, annual progress report. School of Forestry, California Univ. Berkeley. NASA-CR-78742. 57 p.

Most remote sensing devices do not adequately image the Earth's surface when separated from it by cloud cover. Since few weather stations are located in forested areas, little has been known about the potential limitations of cloud cover for the remoted sensing of forested areas. This study analyzes the cloud cover problem for selecged forested areas in California, including the area in which the NASA Forestry Test Site (the Bucks Lake Test Site) is located. Cloud cover information from several selected meteorological stations in California was interpreted in order to determine its influence on remote sensing applications over forested areas. The question of predicting percent cloud cover at various altitudes was examined by relating recorded ground station observations with representative Earth-orbital cloud imagery. A comprehensive bibliography of recent research on cloud cover conditions, including satellite applications, is included.
Author

L0710 (N69-16461)
Lent, J.D. 1968. The feasibility of identifying wild land resources through the analysis of digitally recorded remote sensing data, ann. prog. rept. Forestry Remote Sensing Lab., Univ. California, Berkeley. 130 p.

This report describes the research performed during the first funding year of this study which seeks to determine the feasibility of identifying and classifying wildland terrain features through the use of digitally recorded remote sensing data. Primary emphasis during this phase has been the discussion of the rationale for using automated interpretation techniques. The pattern recognition program developed by

personnel at the Laboratory for Agricultural Remote Sensing, Purdue University, is examined for its applicability to wildland terrain data. These data consist of eighteen-channel optical-mechanical line scan imagery obtained in 1966 in cooperation with the University of Michigan Willow Run Labs.
Preliminary greyscale printouts received from L.A.R.S. reveal that, with accurate ground truth information, certain features show promise of being automatically identified and classified. The statistical aspects of wildland feature identification by automatic means is currently being studied with members of the L.A.R.S. staff. Results from these investigations will be reported upon in forthcoming progress reports and the 1969 annual progress report.

Author

L0800 (A69-30458)
Lent, J.D. and G.A. Thorley. 1969. Some observations on the use of multiband spectral reconnaissance for the inventory of wildland resources. Remote Sensing of Environment 1:31-45.

Examination of three types of multiband sensors: (1) multilens photographic systems, (2) optical-mechanical scanners, and (3) radar devices. The current capability of these devices to provide multiband data is reviewed. A summary of characteristics governing the feasibility of remote sensing in various parts of the electro-magnetic spectrum is tabulated.

B.H.

L0900
Leonardo, E.S. 1964. Capabilities and limitations of remote sensors. Photogramm. Engr. 30:1005-1010.

Modern remote sensor imagery has greatly improved in recent years. Until recently, airborne imagery, whether for mapping or intelligence purposes, was collected on sunny, cloud-free days within

predetermined time periods. Now passive and active remote sensors can collect data twenty-four hours a day in the visible, infrared and microwave regions of the electromagnetic spectrum. No individual sensor has reached such a state of development that its store of information cannot be increased by supplemental use of other systems. Radar, for example, collects its data through clouds or at night. Infrared systems detect thermal variations between adjacent features. Neither system, however, approaches modern cameras in resolution, dynamic range and detail.

Author

L1000 (N69-28151)
Lewis, A.J. 1968. Evaluation of multiple polarized radar imagery for the detection of selected cultural features. Geol. Survey, U.S. Dept. Interior, Washington, D.C. Tech. Letter NASA-130. 56 p.

Four types of polarization are investigated: (1) horizontal transmit, horizontal receive (HH); (2) horizontal transmit, vertical receive (HV); (3) vertical transmit, vertical receive (VV); and (4) vertical transmit, horizontal receive (VH). The like-polarized (HH and VV) and orthogonally depolarized (HV and VH) components of K-band radar imagery are evaluated empirically and statistically for detection of cultural features. A summary of the results comparing two polarizations received simultaneously on one pass is presented. The HH polarization in general proved better for delineation of vegetated areas within an urban complex, detection of transportation and communication arteries that traverse water bodies, and detection of communication lines oriented parallel to the flight path. The HV polarization was better for detection of buildings in a rural setting, as well as shopping centers, industrial and manufacturing plants, and other cultural conglomerations that produce a high orthogonally depolarized signal, and detection of communication lines oriented at an angle other than parallel. Variations between VV and VH imagery were only tested in the detection of buildings, where it was found VH imagery was better than VV.

Author

L1100
Limperis, T. 1965. Target and background signature study. p. 423-433. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep 4864-9-X.

A U.S. Air Force sponsored data collection program concerned with measurements of target and background characteristics is described. The utility of this collection to interested members of the scientific community is discussed and plans for the analysis program which will use these data are described briefly.

Author

L1200 (N69-28505)
Llaverias, Rita K. 1968. Bibliography of remote sensing of earth resources for hydrological applications. Geol. Survey, U.S. Dept. Interior, Washington, D.C. Tech. Letter NASA-134. 75 p.

This preliminary bibliography was prepared to acquaint hydrologists with the basic literature involved in this field. Some of the references concern specific hydrologic topics or specific remote sensing methods. Other references on vegetation mapping and geology were included so that the reader can find information on the selection, processing, and use of remote sensing data in these cognate fields. A number of meteorological references were included because in many remote sensing applications, especially from earth orbital satellites, atmospheric effects must be taken into account in interpreting the views of the earth.

Author

L1300
Loor, G.P. de. 1969. Possibilities and uses of radar and thermal infrared systems. Photogrametria 24:43-58.

Apart from being a useful additional tool, radar is a "tool in itself" for rapid small scale

mapping of large areas for surveying and inventory, even under adverse weather conditions. Infrared systems are primarily an extra and very useful aid in combination with conventional aerial photography.
The very specific imagery obtained, the typical distortions, together with a lower absolute resolution than in conventional photography require a flexible and adaptive attitude of the interpreter to make full use of the many new possibilities offered to him.

Author

L1310
Lowe, D.S. 1968. Line scan devices and why use them, p. 77-101. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

In summary, scanner imagery has a unique and useful role in remote sensing. Scanners can generate imagery in both the photographic and non-photographic region. The scanner signal is in electrical form which permits electronic processing prior to producing an image. With relatively little effort, video data can be generated in several wavelength regions simultaneously, and the data can be calibrated to yield quantitative radiometric information.
On the other hand, scanner imagery has generally poorer resolution and more spatial distortions than camera systems. Consideration of these factors are necessary when selecting the instruments for an aerial survey for a given application. As the type of camera is selected on the basis of the survey application, so should the scanner be selected on the basis of the user need and application. All scanners are not alike! Factors to be considered are ground resolution, temperature sensitivity, angular coverage, and aircraft velocity. Further, the system can be modified to produce quantitative radiometric data necessary for many of the earth resource applications involving thermal mapping and observation of temperature changes with time.

Author

L1350
Lowe, D.S. and J.G.N. Braithwaite. 1966. A spectrum matching technique for enhancing image contrast. Applied Optics 5(6):893-898.

Interpretation of imagery requires contrast between the object being sought and its background. A technique is described for increasing the contrast of selected objects based on their spectral reflectance or emittance characteristics, and two applications are discussed. Means for implementing this technique with an optical-mechanical scanner, multielement dispersing spectrometer, and electronic signal processing equipment are discussed.

Author

L1400
Lowe, D.S., F.C. Polcyn, and R. Shay. 1965. Multispectral data collection program. p. 667-680. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-9-X.

The University of Michigan has two programs for generating multispectral reconnaissance imagery in the spectral region between 0.32-14 microns. In one program, around-the-clock simultaneous multispectral imagery of selected sites was obtained at two week intervals over a period of one year. In addition to conventional photography, imagery was obtained in the following four bands: 0.32 to 0.38μ, 2.0 to 2.6μ, 4.5 to 5.5μ, and 8.2 to 14μ. In the second program, around-the-clock imagery was generated in twenty overlapping spectral regions during five periods which were selected to observe various phases of the growing vegetation cycle. The sites were selected and monitored by the Department of Botany and Plant Pathology of Purdue University. This paper discusses the measurement programs, the airborne instrumentation, the ground measurements, and data handling and reduction.

Author

L1500 (N68-11714)
Lowman, P.D., Jr. 1967. Geological applications of orbital photography. NASA, Goddard Space Flight Center, Greenbelt, Maryland. NASA-TN-D-4155. 42 p.

The potential geologic applications of orbital photography (photography of the surface of the earth or similar bodies from orbiting spacecraft) with illustrations from various Gemini flights are summarized. Advantages of orbital over conventional aerial photography include: large area per photograph, rapid coverage, rapid repetition of coverage, world-wide coverage (subject to orbital parameters), absence of restrictions on dissemination of American photographs, availability of color at small added cost, and a wide range of scales. The major limitations of orbital photography include: restriction by orbital characteristics (inclination to equator, apogee, and perigee), the generally high global cloud cover, daylight restrictions, atmospheric scattering, resolution limit inherent in extremely small scales, loss of resolution and color fidelity in oblique photos, site acquisition, and degradation of film by radiation and other space environmental conditions. Three major geologic uses of orbital photography can be predicted: regional geologic mapping, monitoring of variable properties and geological education.

Author

L1600
Lundien, J.R. 1966. Terrain analysis by electromagnetic means; radar responses to laboratory prepared soil samples. U.S. Army Engr. Waterways Exp. Sta., Vicksburg, Miss. Tech. Rpt. No. 3-693, Rpt. 2, 99 p.

Laboratory tests were conducted with radar sensors to detect the presence of and measure the depth to subsurface interfaces when the surface was bare, and to determine the influence of vegetation at various stages of growth on radar responses. A secondary purpose was to continue earlier studies to relate radar returns and the electrical constants

that they provided to moisture content and density of samples. Large laboratory samples were prepared at various moisture contents and densities and with various depths to a subsurface metal plate. Standard pulsed radar sensors operating with frequencies of 297, 5870, 9375, and 34,543 megacycles/sec and directed at various angles of incidence to the surface were employed. The results of this laboratory study indicate that the standard pulsed radar sensors can provide information that will permit an estimate of the moisture content of deep, homogeneous soil samples and the detection of surface vegetation of various heights. Radar signatures of vegetation-covered soil were more significantly altered at Ka-, X-, and C-band frequencies than at P-band frequencies. However, standard pulsed radar sensors used monochromatically cannot provide information for predicting depth to subsurface interfaces or for directly indicating the presence of a subsurface interfaces. The systematic manner in which soil depths were varied in this study permitted an analytical solution to the problem of measuring depths of layers and led to the conclusion that properly designed radar systems could measure depths to subsurface interfaces. Three such systems are proposed.

Author

L1700

Lundien, J.R. 1967. Terrain analysis by electromagnetic means; Laboratory investigations in the 0- to 2.82 mev gama-ray spectral region. U.S. Army Engr. Waterways Exp. Sta., Vicksburg, Mississippi, Tech. Rpt. No. 3-693, Rpt. 3, 128 p.

Gamma-ray spectra over the energy range 0 to 2.82 mev were obtained from samples of sand, silt, and clay. All tests were conducted in the laboratory in a specially designed low-background enclosure. Data were analyzed by considering both photopeak energy level and radioactive source content in relation to soil parameters. The results indicate that the thorium, uranium, and potassium photopeak counts are proportional to moisture content expressed as

a percentage of dry soil weight. When expressed as ratios to one another, the photopeaks lose nearly all moisture content information but appear to be related to each of the three selected specific soil types. Appendixes A and B present a listing of the FORTRAN computer program and a discussion of the data reduction techniques that it uses in the analysis of gamma-ray spectral data.

Author

L1800 (N69-20189)
Lyon, R.J.P. 1968. Field analysis of terrain, final report, 1 Nov. 1967-31 Oct. 1968. Remote Sensing Lab, Stanford Univ., Pala Alto, California. NASA-CR-100368. 128 p.

The feasibility of using infrared spectrometry outside the laboratory to identify and determine rocks and soils of geological significance is tested. Rock type materials of varying degrees of roughness, particle size, and porosity were observed with the spectrometer and diagnostic data identified. The analog data system was replaced by a fully digital system. A new spectrometer was developed and includes many advances in digital formatting to aid data reduction. The effect of the atmospheric path between the terrain and the experiment was identified, but it has not been possible to use these data in a corrective sense.

Author

L1900 (N67-13483)
Lyon, R.J.P. and J.W. Patterson. 1966. Infrared spectral signatures - a field geological tool, p. 215-230. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 864-11-X.

A continuing evaluation of infrared remote sensing shows that field geology can be performed by using spectral signatures from rocks and soils in the 8 to 13 micron wavelength region. By matching the incoming spectrum with standard curves in the memory of a computer, the bulk composition of the rock

surfaces can be established. Real-time evaluation of spectral rates up to 7 per second appear feasible, permitting mapping from mobile vehicles, aircraft and spacecraft. The present equipment consists of a portable grating spectrometer, using a copper-doped liquid-helium cooled germanium detector. over 1,000 spectral signatures have been obtained in a recently completed program involving operation in rough mountainous and desert field conditions. advanced rapid-scan equipment being constructed will utilize a spinning filter wheel to secure the spectral rates of 7 per second needed for aircraft and spacecraft operation. Spaceflight applications to terrestrial and lunar problems are discussed.

Author

L2000 (N67-30735)
Lyon, R.J.P. et. al 1967. Field infrared analysis of terrain, semiannual report, 1 Nov. 1966 - 30 Apr. 1967. Dept. Geophysics, Stanford Univ., Palo Alto, California. NASA-CR-85558. 113 p.

Research efforts conducted for accelerated ground support for the P3A aircraft program are reported. Patterns of work allocation are described, publications are mentioned, and field efforts at Reno, Mesquite, and Pisgah are summarized. Laboratory and data reduction studies covered include: analysis of the field IR spectra from David Agricultural Test Site, computer analysis of ground truth data, mineral analysis program, and IR emittance spectra from rock samples. Summary details are also given on the following academic research projects: experiments in IR scanning of water surfaces, analysis of Nimbus high resolution IR imagery, photoelectric analysis of stained rocks, multivariate analysis of multiband photography, and analysis of visible and near IR field spectra from Mono Craters, Calif. Articles on statistical analysis of spectral matching, remote sensing, and IR sensing from spacecraft are also appended.

L.E.W.

M0100 (N68-28636)
MacKallor, J.A. 1968. A Gemini mosaic along the thirty second degree of latitude from Baja, California to central Texas. U.S. Geol. Survey, Washington, D.C. NASA-CR-95478. 15 p.

A series of 39 overlapping photographs of the southwestern United States and adjacent areas of Mexico was obtained as part of an experiment of the Gemini 4 mission. Twenty-four of these pictures plus one from the Gemini 3 and four from the Gemini 5 mission were used to construct a 1:1,000,000-scale, black and white, semi-controlled mosaic. This mosaic covers about 150,000 square miles and extends along the 32d parallel of north latitude from the Pacific Ocean to the 100th meridian in west-central Texas, and averages about 150 miles in width. Many of the individual rectified photographs can be enlarged to a scale of 1:250,000 with little or no loss of resolution; such enlargements will be of great value to earth resources studies. If the angle of tilt is more than 35 degrees, some detail in the background of the photograph is lost. The U.S. Geological Survey is currently conducting several small research projects in which this 1:1,000,000-scale mosaic and the individual photographs are the prime research tools.

Author

M0150
Mayhew, G.H. 1964. Geophysical data as an aid to interpretation. Photogramm. Engr. 30:58-63.

The preliminary results of a recent research project of the Engineering Experiment Station, the Ohio State University, has shown that the use of geophysical methods in combination with an aerial photo interpretation, with a limited amount of drilling, will provide an accurate soils profile for preliminary highway design purposes. The project was sponsored by the U.S. Bureau of Public Roads and the Ohio Department of Highways. The electrical resistivity apparatus and the refraction seismograph were used to confirm soils boundaries visible on the aerial photographs. The geophysical work also provided layering information which contributed to the soils knowledge of the area. In several test areas, which included a peat deposit, an alluvium

filled valley and a lacustrine deposit, the data from the geophysical work permitted a more complete and accurate interpretation of the aerial photographs. The combination of photo interpretation and geophysical information permits the elimination of many needless drill holes. It is believed that this combination with a limited amount of drilling will cost less than a program of only photo interpretation and drilling.

Author

M0200 (N67-13520)
McAnerney, J.M. 1966. Terrain interpretation from radar imagery, p. 731-750. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

The interpretation of physiographic and cultural terrain features from imagery obtained with high resolution, side-looking radar alone is demonstrated. Two areas in the central United States are used as examples. Through a deductive process similar to that used in interpretation of visual aerial photography, it is shown that a trained interpreter can describe the physiography, geology and soil of a land surface and provide a reasonable assessment of the geography of a populated region. The discussion includes an example of measuring terrain relief from radar shadows.

Author

M0300
McClellan, W.D., J.P. Meiners, and D.G. Orr. 1963. Spectral reflectance studies on plants, p. 403-413. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-3-X.

The Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the U.S. Army Engineer Research and Development Laboratories (USAERDL), conducted spectrophotometric studies at Beltsville, Maryland, to provide basic information on the feasibility of using remote sensing methods such as film-filter combinations

for the measurement of crop yields and losses. The research was stimulated by the Committee on Aerial Photographic Surveys of Agriculture, of the Agricultural Board, National Academy of Sciences - National Research Council. USAERDL supplied a reflectance spectrophotometer which operates throughout the range of 350 to 2,000 millimicrons. Nearly 250 reflectance curves were obtained from readings made on fifteen crop plants and two weed species growing in the field, greenhouse, and controlled-environmental chambers. In the field, triplicate readings were taken from both weedy and weed-free crop plants and thin and normal stands. Seedling, vegetative, and mature soybean and wheat plants grown under controlled conditions with high and low levels of fertility and moisture, thin and normal stands, and with dark and light soil backgrounds were measured. In addition, reflectance measurements were made on disease-free wheat plants and those infected with black stem rust as well as on healthy and mildewed barley plants. The moisture content of the plants and of the soil, as well as the nitrogen content of the plants, was determined for each reflectance curve obtained. This information was compiled and is now being correlated to determine the future direction of the research.

Author

M0350

Meyer, M.P. and E.J. Woolfolk. 1967. Anthill infestations. Photogramm. Engr. 33(11):1247-1249.

Although grazing land forage losses due to ant infestations are seldom calculated due to high cost and problems of technique, they are estimated to be extremely high. The actual forage growth area loss due to anthill occupancy of a study area in Argentina was determined through the use of measurements of infestation area, anthill density and anthill diameter on 1:30,000 scale aerial photographs. A total of 121 hectares (299 acres), or 8.9 percent of a total area of 1,360 hectares (3,360 acres), was found to be physically occupied by anthills.

Author

M0400
Michigan, Univ. 1962. Proceedings of the first symp. remote sensing of environment. 13, 14, 15 February 1962. Inst. Sci. and Tech., Ann Arbor. Rept. No. 4864-1-X. 124 p.

These Proceedings resulted from the first symposium on remote sensing of environment, held at the University of Michigan on 13, 14, and 15 February 1962. The purpose of the symposium was to review the current state of the art of remote sensing technology and to explore possible applications of this technology to the various earth science fields. These Proceedings contain both the discussions of the remote sensing techniques and the working papers written in response to these discussions by each of three working groups composed of the participating earth scientists.

Author

M0500
Michigan, Univ. 1963. Proceedings of the second symposium on remote sensing of environment. 15, 16, 17 October 1962. Inst. Sci. and Tech., Ann Arbor. Rept. No. 4864-3-X. 459 p.

These Proceedings contain papers delivered during the second symposium on remote sensing of environment, held at The University of Michigan on 15, 16, and 17 October 1962. The purpose of the symposium was to explore possible applications of remote sensing techniques to scientific research programs and to assess the capabilities and limitations of remote sensing devices. The papers discuss gravimetric, seismic, and other force-sensing techniques, as well as those involving electromagnetic propagation.

Author

M0600
Michigan, Univ. 1965. Proceedings of the third symposium on remote sensing of environment. 14, 15, 16 October 1964. Inst. Sci. and Tech., Ann Arbor. Rept. No. 4864-9-X. 821 p.

These Proceedings contain papers delivered during the third symposium on remote sensing of environment, held at The University of Michigan on 14, 15, 16 October 1964. These symposia are part of a continuing

program to investigate the field of remote sensing, its potential in scientific research and engineering practices, and some of the factors important to the growth of the field. The purpose of this symposium was to stimulate an exchange of information among participants from diverse fields on all aspects of remote sensing conducted from airborne and satellite vehicles. Papers included in the Proceedings discuss the applications for remote sensing in space programs, atmospheric research, geology and geography, vegetation studies, and oceanography. Methods of handling and interpreting the data from the electromagnetic, acoustical, and force field sensors employed are also treated.

Author

M0700 (N67-13461)
Michigan Univ. 1966. Proceedings of the fourth symposium on remote sensing of environment. 12, 13, 14 April 1966. Inst. Sci. and Tech., Ann Arbor, Rept. No. 4864-11-X. 940 p.

These Proceedings contain papers presented at the Fourth Symposium on Remote Sensing of Environment, held 12 through 14 April 1966 on the campus of The University of Michigan. The symposium was conducted as part of a continuing program investigating the field of remote sensing, its potential in scientific research and engineering practices, and some of the factors important in the growth of the field. This work is being conducted by the Infrared Physics Laboratory of the Willow Run Laboratories, a unit of The University of Michigan's Institute of Science and Technology, and is sponsored by the Office of Naval Research (ONR) with funds made available by the ONR Geography Branch and the Air Force Cambridge Research Laboratories. The purpose of this symposium was to stimulate an exchange of information on all aspects of remote sensing, with special emphasis on such topics as needs for remotely sensed data, data management, and the special educational needs of people working in this field. In addition to special sessions and panels treating these subjects,

50 papers, dealing with many current remote sensing programs, data acquisition, data analysis and application, and equipment design, were presented.

Author

M0800
Michigan, Univ. 1968. Proceedings of the fifth symposium on remote sensing of environment. 16, 17, 18 April 1968. Inst. Sci. and Tech., Ann Arbor. Rept. No. 4863-18-X. 946p.

These Proceedings contain papers presented at the Fifth Symposium on Remote Sensing of Environment held 16 through 18 April 1968 on the campus of the University of Michigan. This sympoisum was sponsored by the Office of Naval Research with funds made available by the ONR Geography Branch, the Air Force Cambridge Research Laboratories, the Army Research Office, the Army Engineering Topographic Laboratories, the U.S. Geological Survey, and the Agricultural Research Service of the U.S. Department of Agriculture. It was conducted by Willow Run Laboratories of the University of Michigan's Institute of Science and Technology as part of a continuing program investigating the field of remote sensing, its potential in scientific research and engineering practices, and factors important in the growth of the field.
The purpose of the fifth symposium was to stimulate an exchange of information concerning the numerous aspects of remote sensing with emphasis on accomplishments during the past five years. Topical matter included reviews citing notable advances made in remote sensing during the past five years, advances in technology, and applications for these technologies. Also treated were such subjects as economics and practicality; and political, legal, and international implications. There were 700 registered participants at the symposium representing, in addition to the United States, Australia, Brazil, Canada, France, Iceland, Mexico, the Netherlands, Sweden, and the United Kingdom.

Author

M0900 (N67-13521)
Miller, L.D. 1966. Location of anomalously hot earth with infrared imagery in Yellowstone National Park, p. 751-769. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Pre. 4864-11-X.

Infrared imagery of Yellowstone National Park was used on the ground in the Park to locate several anomalously hot earth areas. The areas sought out were manifested at the surface only as hot earth, and not as hot water or steam. Only one of the approximately dozen such areas encountered had been previously specifically noted by individuals frequenting these areas. Interactions between the anomalously hot earth and the surrounding vegetation including tree cover will also be noted.

Author

M0950
Miller, V.C. 1968. Current trends in photogeology and in the use of other remote sensing methods in geological interpretation. Earth-Science Reviews 4(2): 135-152.

In its early years photogeology primarily entailed the mapping of dips, strikes, fold axes, faults, and stratigraphic contacts on stereoscopically-viewed black-and-white photos. The role played by the science of geomorphology has increased appreciably since that time. Fracture analysis, the mapping and analysis of photo-detected linear fractures, has received considerable attention. And color photography, so long awaited, has arrived, though its use is still limited by its higher cost.
Remote Sensing, in the non-visual as well as the visual parts of the spectrum, has in recent years been the object of a virtual avalanche of research activity. Particularly promising has been the demonstrations of the uses of radar and infrared in remote sensing of geologic features and relations.
The future in photogeology is certain to be far more varied and productive than the past, but it is essential that one not assume that the future is already arrived.

Into the near future the great bulk of the work to be done will still have to be done by time-tested techniques and time-tested instruments.

Author

M1000

Mintzer, O.W. 1968. Remote Sensing for engineering investigation of terrain-photographic systems, p. 687-699. IN Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor, Rep. 4864-18-X.

Since about 1942 the engineer has applied photo interpretation to soils studies primarily utilizing conventional aerial photography. He has refined the techniques by using aerial color and color infrared photography and geophysical survey techniques since about 1960. Now in 1968, he is fascinated with the potential of multispectral, radar and infrared thermal imagery. With the pattern element (conventional photography) systematic approach to engineering soils studies proving successful for many years, the engineer expects that the imagery mean of remote sensing will further refine the pattern element analysis method.

Author

M1100

Molineux, C.E. 1965. Aerial reconnaissance of surface features with the multiband spectral system. p. 399-421. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-9-X.

A unique airborne spectral camera and data reduction system has been developed for reconnaissance of terrain surfaces and especially for detecting manifestations of underground nuclear test activity. The system operates in the 0.35 to 5.0 micron region of the visible and inear-infrared spectrum. The airborne system consists of a 9-lens multiband camera, associated color reference cameras, a dual spectrometer system, cartographic camera, and skylight recording

camera, flown in C-130 aircraft. Details of equipment, system operation, and processing of the resulting imagery are discussed. Specialized color enhancement and printing techniques emphasize the spectral reflectivity differences on the film to enable analysis of surface effects. Ground spectral data are collected to assist the interpretation of aerial imagery significance. Photointerpretation of vegetation and geologic conditions by simultaneous photography in narrow spectral regions will be advanced by this system. author

M1110 (N69-16108)
Moore, E.G. 1969. Side-looking radar in urban research: A case study. Dept. Geog. Northwestern Univ. Evanston Illinois. NASA Tech. Letter NASA-138 27p.

The main part of the paper examines the capabilities of AN-APQ-97 radar imagery of Chicago in both HH and HV polarization modes with regard to the compilation of a land use inventory. The main conclusions are (1) the linear elements of the transportation network are clearly defined; the HV proves to be more useful than the HH as high returns from adjacent buildings on the latter prevent accurate interpretation; (2) the gross patterns of industrial, residential and open space land use are identified although it is not possible to map local boundaries of different land use types in detail; and (3) attempts to identify commercial land proved to be surprisingly unsuccessful, the cardinal effect introducing considerable difficulties into the recognition process. Finally, it is stressed that it is necessary to undertake similar experiments using other radar systems.

Author

M1150
Moore, R.K. and D.S. Simonett. 1967. Radar remote sensing in biology. BioScience 17(6):384-390.

Briefly describes some of the fundamental features of side-looking radar and how these features, such as polarization or changing the wave-length, can aid in the identification of agricultural parameters. Presents data from both cultivated and wildland areas to show some applications. Gives some potential agricultural applications.
R.H.G.

M1200 (N67-36024)
Morain, S.A. 1967. Field studies on vegetation at Horsefly Mountain, Oregon and its relation to radar imagery. Center for Res., Inc., Eng. Sci. Div., Kansas Univ., Lawrence, CRES-61-22. 21 p.

Results of field investigations conducted as part of a continuing study of radar--vegetation relationships are presented. Five major types of vegetation: pine forest, juniper woodlands, grasslands, sagebrush and chaparral are discussed in terms of their appearance in the field, their distribution in the study area, and their radar appearance. There is good evidence from the results of field and laboratory interpretation that these five types can be separated at least partially with multiple polarization radar images; and provided images at different times are available it should be possible to make clean consistent separation. Some distinctions between types are inherently more difficult because their geometries in the radar wavelengths are very similar. In these cases is proposed that electronic sensing devices will prove valuable in aiding distinctions invisible to the eye.
Author

M1300 (N67-13509)
Morain, S.A. and D.S. Simonett. 1966. Vegetation analysis with radar imagery. p. 605-622. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

This paper presents vegetation maps prepared from radar imagery obtained over several climatic environments. The maps and imagery have been compared with each other to determine the types of information extractable. Conventional vegetation maps were employed to aid in the comparison. Emphasis was on the K-band and AN/APQ-56 radar systems. Results indicate that it is normally possible, by means of tonal and textural comparisons combined with basic geographic knowledge of the study area, to: (1) prepare regional or reconnaissance vegetation maps either on the basis of physiognomy or vegetation "type"; (2) delimit vegetation zones as they vary with elevation; (3) trace burn patterns of previous forest fires; (4) delimit altitudinal timber line; and (5) identify species from inference in areas characterized by near monospecific stands.

Author

M1400
Morrison, A. and J.B. Bird. 1965. Photography of the earth from space and its non-meteorological applications, p. 357-376. In Proc. of the 3rd symp. on remote sensing of environment, Inst. Sci. and Tech., Univ Michigan, Ann Arbor. Rpt. No. 4864-9-X.

Photography from satellites and rockets constitutes a new source of information about the earth's surface. Advantages of space photography are that (a) an area hundreds of kilometers across can be shown in a single frame, (b) photographic tones are comparable, and a stereo-effect is obtainable over this area, even if it is crossed by a political boundary, (c) uniform and frequent coverage of the entire earth can be obtained. Problems of light transmission through the atmosphere and of cloud cover are only a little

greater than in aerial photography. Some existing space photography is usable, but a specially-designed system would yield better results. Apart from its illustrative value, space photography could assist in mapping: (a) relatively permanent distributions, e.g., geology, landforms, vegetation, generalized land-use, the extent of glaciers; and (b) ephemeral distributions, e.g., snow-cover, ice-cover on rivers, lakes, and the sea, forest fire burns, temporary lakes and streams, and ocean-water masses.

Author

M1500 (N69-28395)
Morrison, R.B. 1968. Preliminary soil classification map of southwestern U.S. and Mexico from space photography. U.S. Geol. Survey, Denver, Colorado. Tech. Letter NASA-111. 16 p.

The soil classification map was compiled from a mosaic of rectified black and white reproductions of space photographs from the Gemini IV and V missions. Unrectified color prints were used first to determine soils colors as portrayed by the photographs, and their distribution. Rectified black and white prints were also used to plot detailed information on topographic base maps at the same scale. This information was then transferred to the small scale mosaic. Most information contained therein is based on many years of field experience in the U.S. portion of the map. Field checking is planned for the coming spring field season, especially in portions of Mexico where previous work has not been done.

Author

M1600 (N68-14987)
Moxham, R.M. 1967. Aerial infrared surveys in water resources studies. U.S. Geol. Survey, Washington, D.C. Tech. Letter NASA-74. 20 p.

New types of infrared line scanning radiometers record very small relative variations in earth

surface radiance. This permits thermal patterns to be mapped in great detail, especially in surface waters. The technique has been useful in finding the location of ground-water discharge into marine coastal waters and in studying the circulation and diffusion of natural waters, and of liquid discharge from industrial plants. The quantity and spectral distribution of infrared radiance from natural surfaces is a function of temperature and emissivity. As emissivity of water is nearly unity, radiance variations are due chiefly to temperature variations. The infrared line scanner, carried in an aircraft, generates a photograph-like image whose gray scale is a measure of the infrared radiance of land and water surfaces along the flight path.

Author

M1700 (N69-28153)
Moxham, R.M., G.W. Greene, J.D. Friedman, and S.J. Gawarecki. 1967. Infrared imagery and radiometry, summary report. Infrared Lab., U.S. Geol. Survey, Washington, D.C. Tech. Letter NASA-105. 72 p.

The primary effort of infrared studies was to develop instrumentation to measure appropriate thermal properties in the field and in the laboratory, and the meteorological parameters that affect infrared transmission. Included are some methods being developed for image processing.

Author

M1800 (N68-11810)
Mullins, B. 1967. Factors and Procedures Influencing the Reliability of Agricultural Data from Earth Orbiting Sensor Systems. Final Report. Systems Technology and Applied Research Corp., Dallas, Texas NASA-CR-90211. 234 p.

Accomplishments are reported in a study of potential economic benefits and data systems from agricultural resource surveys by earth orbiting sensor systems.

Factors influencing the acquisition of statistically reliable satellite obtained data (imagery) for worldwide agricultural development and prediction are discussed. The following areas are considered in detail (1) the nature of the needs and services of the United States Department of Agriculture as a potential user of high altitude imagery in the preparation of agricultural statistics, (2) targets of interest in agriculture and forestry with a potential for high altitude discrimination including emphasis on special and temporal dispersion of select targets, (3) the nature of and requirements for areal sampling, (4) general satellite remote sensing systems capabilities and requirements, and (5) orbital requirements.

C.T.C.

M1900
Myers, V.I. and W.A. Allen. 1968. Electrooptical remote sensing methods as nondestructive testing and measuring techniques in agriculture. Applied Optics 7(9):1819-1838.

Characteristics of plants that influence reflectance and emission of electromagnetic energy are discussed. Four main spectral regions are influenced by plants. These wavelength bands include the visible region of chlorophyll absorption, very near ir wavelengths, where plant structure is of major importance, the near and middle ir wavelengths, where water and $CO_2$ absorption predominate, and the far ir region of thermal ir emission. Soil characteristics that influence reflectance and emission of energy are discussed. Nondestructive testing techniques described include laboratory spectrophotometry, field spectrometry, color photography, radiometry, and generation of line scan imagery. Spectrophotometer and spectrometer reflectance data obtained in the laboratory and field are related to interpretation of remote sensing imagery. Model studies that permit predictions of reflectance from plant canopies are described. The principle of multi-spectral sensing which permits utilization of multiple wavelength channels for establishing unique plant and soil signature is reviewed.

Author

M2000
Myers, V.I., D.L. Carter, and W.J. Rippert. 1966. Photogrammetry and temperature sensing for estimating soil salinity. Int. Comm. on Irrig. and Drainage, 6th Cong., New Delhi, India. Ques. 19:39-49.

Cotton was used as an indicator plant to relate the salinity in the 0 to 1.524 m (0 to 5 feet) profile at some reference locations to that at a number of prediction sites where the salinity was unknown. Aerial photographs were taken using ektachrome infrared aero film for observing the salinity-affected cotton. On the basis of color tones, it was possible to distinguish five levels of salinity.
The level of salinity significantly affected photographic features, making it possible to estimate with reasonable accuracy the degree of salinity in the soil profile from interpretation of film negatives.
Infrared radiometer measurements of cotton leaf temperatures were made on the ground and from an aeroplane. The limited aerial measurements made compared favorably with ground measurements. Statistical studies of the temperature data taken on the ground indicate that soil salinity can be predicted from cotton leaf temperatures with reasonable accuracy.

Author

M2100 (N67-13525)
Myers, V.I., C.L. Wiegand, M.D. Heilman, and J.R. Thomas. 1966. Remote sensing in soil and water conservation research, p. 801-813. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

This paper describes the application of remote sensing to certain soil and water problems. Spectrophotometry as applied to agricultural and desert vegetation is discussed. Spectrophotometer curves serve mainly to establish the pure optical phenomena of plants unaffected by extraneous

conditions. It is important to recognize that other factors such as crop geometry and background soil conditions influence the signal from vegetated areas. An example of the relationships is presented. The use of various crops as indicator plants for detailed detection of subsoil moisture and salinity conditions, using Kodak Ektachrome infrared aerial film is described. The measurement of plant-leaf temperatures as a method for studying energy budgets of agricultural areas, for estimating soil moisture, and for detecting the occurrence and extent of soil salinity is discussed. The potential of multispectral remote sensing for soil surveys is discussed. Certain past limitations in the application of color aerial photography to soil surveying may be surmounted using microwaves, low-frequency radar, infrared thermometry, and sensing in other portions of the electromagnetic spectrum.

Author

N0100 (N69-30352)
National Aeronautics and Space Administration. 1967. Earth resources program: proceedings of ground truth session, final report. Manned Spacecraft Center, Houston, Texas. NASA-TM-X-61729. 179p.

Ground truth capabilities and requirements are discussed including their application to future orbital space missions. The following topics are presented: (1) existing ground truth capabilities, (2) measurements required and measurements currently being made. (3) equipment now being used and future requirements, (4) ground sites now supported and type of support. (5) recommendations relative to the Earth Resources Aircraft Program concerning ground truth, and (6) extrapolations of the above topics for short term (10 to 15 days) and long term (1 to 2 years) orbital missions. Ground truth applied to agriculture, support radar, and oceanographic features is also discussed.

Author

N0200 (N69-28909)
National Aeronautics and Space Administration. 1968. Earth photographs from Gemini 6 through 12. Washington, D.C. NASA-SP-171. 335p.

A representative sampling of color photographs of the earth's surface is presented, chosen from among hundreds taken by the Gemini astronauts in the course of scientific experiments, including synoptic terrain and weather photography. The pictures are grouped geographically and have accompanying explanatory notes.

P.A.B.

N0300 (N69-27962)
National Academy of Sciences. 1969. Useful applications of earth-oriented satellites-forestry, agriculture, geography. National Research Council, Washington, D.C. Forestry-Agric. Geography 1.76p.

The Report contains conservative estimates of the value satellite reporting systems might have to the agriculture and forestry industry, United States and world-wide. These add up to tens of millions of dollars per year. The intangible effects on increasing the efficiency of farming and forestry through new satellite technology are potentially significant, particularly as population pressures will require that the earth be treated as one agricultural cooperative. Remote sensing is now technically feasible for: (1) inventory and productivity evaluation of the world's food, fiber, and other natural resources: (2) assessment of environmental conditions and of man-environment interactions.

F.O.S.

N0400 (N69-28240)
National Academy of Sciences. 1969. Useful applications of earth-oriented satellites. Summaries of panel reports. National Res. Council., Washington D.C. NASA-CR-101388. 96p.

Project summaries are presented on the necessity of exploiting the NASA technological bank.

International applications of space activities consistent with the law and cooperation of other countries are discussed considering cost estimates and benefits on a global scale. Recommendations for new research programs and satellite technology are proposed in the following fields: forestry-agriculture-geography; geology; hydrology; meteorology; oceanography; sensors and data systems; points-to-point communication; systems for remote-sensing information and distribution; broadcasting; navigation and traffic control; and economic analysis.

M.H.E.

N0500 (N67-13514)
Nikodem, H.J. 1966. Effects of soil layering on the use of vhf radio waves for remote terrain analysis, p. 691-703. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Laboratory studies have been conducted to determine the effects of soil layering on the quantity of reflected energy measured from terrain. The results of this study indicate that reflections from subsurface interfaces can have a drastic influence on the quantity of energy measured and that standard monochromatic pulsed-radar systems are not suitable for measuring subsurface soil conditions. Systems employing swept-frequency techniques are needed to allow direct measurement of electrical properties of the soils. These properties then can be correlated with the thickness of the upper layer and the moisture content of the soil. Besides soil layers, such factors as soil conductivity and vegetation determine the usable wavelength region. The effects of each of these are discussed and examples of several soil-layering profiles that might be encountered in natural terrain are given. The limits to which the layering profiles of the soils influence the return energy are illustrated.

Author

N0600 (A69-30454)
Nunnally, N.R. 1969. Integrated landscape analysis with radar imagery. Remote Sensing of Environment 1:1-6.

Experimental use of radar imagers for earth resource studies in the Asheville Basin in North Carolina. It is shown that enough information can be interpreted from the radar image to basically characterize a number of relatively distinct regions in this area. The images are from a K-band multiple polarization radar system (HH, horizontal transmit, vertical receive), and the radar regions which they delimit appear to correlate well with distinctive integrated landscape types. The advantages in cost and amount of terrain that can be covered are noted, and some disadvantages, such as small scale and resolution, are pointed out.

B.H.

00100
Oliver, T.L. and W.H. Peake. 1969. Radar and microwave radiometric techniques for geoscience experiments. ElectroScience Lab., Ohio State Univ., Columbus. Rept. 1903-9. 320 p.

Measurements of the normalized backscattering cross sections of a number of agricultural surfaces are reported for microwave frequencies of 1.8, 10, 15, and 35 GHz. The surfaces include wheat, oats, soybeans, sudan grass, corn, alfalfa, and sorghum. Ground truth data including, for instance, surface location, crop variety and moisture, soil moisture, etc. are provided for most surfaces.

Author

00140
Olsen, C.E., Jr. and R.E. Good. 1962. Seasonal changes in light reflectance from forest vegetation. Photogramm. Engr. 28(1):107-114.

During the 1960 growing season, light reflectance from foliage of nine species of trees was measured

weekly with a G.E. recording spectrophotometer. Hardwood foliage reflected more light than pince foliage in almost all wave-lengths during all parts of the growing season. Differences in reflectance between hardwood and pine foliage decreased steadily from May to the beginning of the hardwood color change in September and October. During the fall color change reflectance from hardwood foliage varied erratically by species.
Author

00150
Olson, C.E., Jr. and Jennifer M. Ward. 1968. Remote sensing of changes in morphology and physiology of trees under stress, ann. prog. rept. Forestry Remote Sensing Lab., Berkeley, California. 35p.

This is the second annual progress report describing results of continuing studies of forest trees subjected to varying types of stress. Greenhouse work with tree seedlings exposed to varying concentrations of NaCl and $CaCl_2$ indicates that the oak species tested were more resistant to salt tolerance of these species decreased in the order listed.
No consistent differences in foliar reflectance or moisture tension between salt-treated and contral plants were observed until leaf mortailty occurred. Radiometric temperatures for seedlings subjected to heavy salt concentrations were between 0.5 and 1.0°C higher than for control plants.
Drought conditions in sugar maple seedlings, created by varying the frequency of watering, were accompanied by increasing foliar reflectance of the stressed plants at all wavelengths from 0.5 to 2.5 micrometers. Radiometric temperatures for stressed plants averaged nearly 2°C higher than for control plants. During this study, it was observed that leaves began to wilt when foliar moisture tensions exceeded 200 lb./sq. in., and leaf margins became dry and brittle after moisture tension exceeded 350 lb./sq.in.

Previsual detection of drought or salt-stress was not achieved using color or infrared-color photography in the laboratory. Field tests of infrared scanning systems for detecting moisture stress in mature trees were also begun during this reporting period. Girdled oaks were successfully detected in daytime imagery obtained from altitudes up to 4,000 feet above mean terrain. The girdled trees showed clearly in aerial photographs on panchromatic, infrared-aerographic, normal color, and infrared-color films; and on infrared imagery in the 8-14 micrometer wavelength band obtained in midafternoon. Detection was unsuccessful from any altitude when the infrared imagery was obtained at night.

Author

00200
Ory, T.R. 1965. Line-scanning reconnaissance systems in land utilization and terrain studies. p. 393-398. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-9-X.

A dual channel line-scan reconnaissance system offers new possiblities for the automatic in-flight separation of certain terrain features from complex backgrounds. The output from this system consists of a normal line-scan image printed beside the separated image so that a line-by-line correlation can be performed. The dual channel system also has the capability for the simultaneous analysis of terrain in two spectral regions. The results of recent studies involving terrain analysis with line-scanning remote sensors are discussed and predictions of future applications in this field are presented. Representative imagery of a variety of terrain features is presented for discussion.

Author

P0100 (A69-10504)
Park, A.B. 1968. Aerospace applications in agriculture and forestry. U.N., Conf. on the Exploration and Peaceful uses of Outer Space, Vienna, Austria, Aug. 14-27, Paper 68-95393. 23 p.

Discussion of the possible applications of aerospace research to gather new information for agriculture and forestry. Rates and methods of acquisition which make world-wide coverage feasible are discussed. The implementation of world-wide coverage, input, analysis, and output would offer developing countries a chance to leap years in the technological cycle.

P.v.T.

P0200
Parker, D.C. 1968. Remote sensing for engineering investigations of terrain-infrared systems, p. 701-709. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

The use of infrared imagery in engineering investigations of terrain has an interesting potential. The inability to cite cases of routine, economical employment of infrared surveys in such investigations only reflects the newness of the technology and its recent availability to the public. Now infrared systems and imagery are in the public domain and available to all who are interested in investigating their utility to the problem. Advances in instrumentation technology will increase the recordable thermal detail and consequently its usefulness in recording important infrared manifestations of terrain that may go undetected by systems possessing the thermal and spatial resolution of those discussed in this paper. However, with what is available now we can investigate applicability of infrared imagery to solving engineering problems involving terrain as a prelude to determining its practicallity as a routine technique.

Author

P0300 (N69-28163)
Pascucci, R.F. and G.W. North. 1968. Mission 73: Summary and data catalog. U.S. Geol. Survey, Washington, D.C. Interagency Rept. NASA-132. 296 p.

During the spring of 1968, the USGS/NASA Remote Sensing Mission 73 was carried out at the Southern California test sites. The objective of the program was to acquire data by means of airborne sensors over an area the properties of which were being measured on the ground. The overall operation of the geography experiments is described. As a result of the program, remote sensing data were acquired by thirteen sensors mounted in seven aircraft. Ground truth activities conducted before, during, and after the flights resulted in the acquisition of the following data: (1) soil moisture samples; (2) thermometric and radiometric surface temperatures at several frequencies; (3) surface reflectance measurements; (4) land use maps; (5) hourly weather readings; (6) hourly readings of atmospheric $SO_2$ and $NO_2$; (7) multispectral ground photography; (8) urban data; (9) calibrated test target readings; (10) atmospheric particle counts; (11) soil bearing strength measurements; and (12) soil electrical resistivity measurements. Preliminary reports based on initial examination of results indicated several tentative conclusions and recommendations.

Author

P0400 (N69-15767)
Peake, W.H. 1969a. The microwave radiometer as a remote sensing instrument. Electroscience Lab., Ohio State Univ., Columbus. Tech. Rept. 1903-8. 43 p.

This report reviews the fundamentals of microwave radiometery, including radiation theory, antenna effects and instrument design. The parameters of a surface which control its brightness temperature at microwave frequencies are reviewed and related to other parameters which characterize the surface. Among these, the role of the complex dielectric

constant and its dependence on moisture and ion content, and the effects of surface roughness are discussed. A number of observations of the brightness temperature of terrestrial surfaces are reviewed, interpreted on the basis of model surface properties, and considered as potential applications of the instrument as a remote sensor.

Author

P0500 (N69-26356)
Peake, W.H. 1969b. Radar and microwave radiometric techniques for geoscience experiments. ElectroScience Lab., Ohio State Univ., Columbus. Tech. Rept. 1903-10. 17 p.

It provides brief descriptions of the equipment developed to measure backscattering cross-sections and brightness temperature of terrestrial surfaces at microwave frequencies, of the measurements made with the equipment, and of the interpretation of the measurements in terms of surface parameters such as dielectric constant and roughness. Techniques for measuring dielectric constant of natural materials at microwave frequencies are described.

Author

P0600 (N67-13522)
Peake, W.H., R.L. Riegler, and C.H. Schultz. 1966. The mutual interpretation of active and passive microwave sensor outputs. p. 771-777. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

The interpretation of surface characteristics from microwave sensor outputs alone is more effective when data is available from both active (radar) and passive (radiometer) sensors. This is because both outputs are determined by the complete scattering pattern of the surface; of which one aspect (backscatter) is estimated by the radar and another (albedo) is estimated by the radiometer. However, because the radiometer

output is the convolution of the desired radiation temperature of the surface and the antenna pattern, it is first suggested that this instrumental bias be removed. An example is given, used to show that the correction is a significant one for current radiometer performance, and should be applied by those investigators wishing to make quantitative interpretations of apparent surface temperatures. As examples of the inter-dependence of active and passive sensor outputs, and their relation to significant surface properties, results are given for two series of measurements, made almost simultaneously with radar and radiometer sensors (at 10 GHz and 35 GHz) over well controlled terrain (vegetation - Purdue Agronomy Farm, Indiana; pumice - Mono Crater, California). In each case the data from one sensor is used to give a more detailed explanation of the output of the other, and the combined sensor outputs interpreted in terms of measurable surface characteristics (roughness scale, dielectric-constant, density, water content).

Author

P0700 (A69-30457)
Pease, R.W. and L.W. Bowden. 1969. Making color infrared film a more effective high-altitude remote sensor. Remote Sensing of Environment 1:23-30.

Use of auxiliary minus-visual filters with the necessary minus-blue filtration to improve high altitude imagery obtainable from Kodak Ektachrome Infrared Aero Film (type 8443 transparency film). Air photographs taken from commercial airliners at altitudes ranging from 14,000 to 41,000 ft are shown as examples of the filter's ability to penetrate more than one atmospheric mass, making infrared sensitive color film a high altitude sensing system capable of yielding a wider variety of information than normal multilayer color film, with better haze-penetrating capabilities. Three auxiliary filters were tested, and their performances are compared and evaluated.

B.H.

P0800 (A69-10509)
Pecora, W.T. 1968. Geologic Applications of earth orbital satellites. U.N., Conf. on the Exploration and Peaceful Uses of Outer Space, Vienna, Austria, Aug. 14-27. Paper 68-95441. 22p.

Analyses of Gemini photographs illustrating several qualitites, unique to orbital photography, that are of importance to geologists and other scientists in assessing natural resources. These qualities of orbital photographs include the synoptic overview of a large area within a single exposure frame, water penetration superior to that acheived on conventional aerial photographs, and near orthographic positioning of topographic and cultural features. The Earth Resources Observational Satellite program was conceived in 1966 largely as a direct result of the demonstrated utility of Gemini orbital photography in earth resources studies. The first satellite is proposed to have a useful life of one year, and could be considered to be an operational prototype in a continuing program. This satellite would be primarily an imaging satellite, and it is expected that a major benefit to the geologists will be the use of the high-resolution television imagery as base maps in regions that are inadequately mapped or where dynamic changes have taken place.
P.v.T.

P0900 (n68-25120)
Pierce, K.L. 1968. Evaluation of infrared imagery applications to studies of surficial geology. Yellowstone Park. U.S. Geol. Survey, Denver, Colorado. NASA-CR_94789. 34 p.

Infrared imagery, in the 3-5 micron band, was obtained during afternoon and post-sunset hours of August 1966. Analysis of these data reveals that known thermal features such as hot and cold springs, glaciers and snow fields and lakes are readily identified on day and night images but that areas of known "hydrothermal" alteration are not detectable by the system employed. Surficial deposits such as talus and frost rubble are generally light toned but

commonly darker than outcrops warmed by solar radiation. Sharp contrasts were noted between forest and grassland areas. Attempts were made to use the imagery in mapping surficial deposits in several areas but results were variable due to the overriding effects of outcrop-forest-grassland contrasts. Recommendations for future missions are presented. Author

P1000 (N68-10284)
Pierson, W.J., Jr., B.B. Scheps, and D.S. Simonett. 1965. Some applications of radar return data to the study of terrestrial and oceanic phenomena. Center for Res., Inc., Remote Sensing Lab., Kansas Univ., Lawrence. CRES-TR-61-3. 49p.

The possibilities for scientific and practical research with imaging and altimeter-type radar mounted in orbiting spacecraft are discussed. An all-weather day-or-night capability for high resolution mapping and scattering cross-section studies is shown to be within the current state of the art and sophisiticated multifrequency ploypolarization coherent imaging systems are currently under study. Terrestrial applications of space-borne radar in geology, glaciology, geomorphology, pedology, and agriculture, and oceanic applications related to sea-state sensing are examined.

R.N.A.

P1100 (N68-10268)
Polcyn, F.C. 1967. Investigations of spectrum-matching sensing in agriculture, volume 1, semiannual report, Dec. 1, 1965 - Sept. 30, 1966. Infrared and Optical Sensor Lab., Michigan Univ., Ann Arbor. NASA CR-89993. 126 p.

A spectrum-matching imaging system for agricultural survey purposes is being evaluated. A 12-channel spectrometer for the visible region was combined

with an optical-mechanical scanner to obtain calibrated simultaneous multispectral data in the same electronic format so that real-time automatic recognigition processes might be used. Multispectral data in 18 channels from the 0.3- to 15- region have been obtained with a combination of two scanners mounted in a C-47 aircraft. The research data are tape recorded to facilitiate the development of spectrum-matching schemes and to permit subsequent extraction of the signatures of vegetation types of interest. Analysis of data collected in 1964 over agricultural sites has shown the non-Lambertian reflection characteristics of different crop species and the importance of the scanner calibration techniques for current data-acquisition programs. Statisitical variations of crop signatures and the effects of reflectance geometry and instrumental parameters on the reliability of a spectrum-matching system are being investigated.

Author

P1200 (N69-16390)
Poulton, C.E., B.J. Schrumph, and E. Barcia-Moya. 1968. The feasibility of inventorying native vegetation and related resources from space photography, annual progress report. Dept. of Range Management, A.E.S., Oregon State Univ., Corvallis. 47p.

Space photography taken during the Gemini IV overflight of southern Arizona is being studied to assess the appropriateness of this system of remote sensing of inventorying native megetation and related resources. Close examination of fram S-65-34681 and experience in relating images to their vegetation and soil subjects indicate that a meaningful inventory of these resources can be accomplished through the use of space photography. Indeed, the synoptic coverage makes this system unique among those alternatives readily available at this time. The need for a more accurate small-scale representation is real. A work flow chart presents ways to proceed toward this goal. The

goal--an inventory--can be obtained through strict adherence to specified mapping concepts and ecological principles as they apply to several steps in the flow chart. In this way, photo images can be delineated and identified in a meaningful manner. Production of an inventory only follows successful solution of several problems in the development of ground-truth and image interpretation. Subsampling aerial photography has been investigated as a means for solving subject discrimination problems. Image to subject relationship problems are resolved by developing a phytosocialogical interpretation of the vegetation that is consistent with the scale and resolution of the space photography.

Author

P1300 (N69-28394)
Pratt, W.P. 1968. Infrared imagery of Lordsburg-Silver City area. New Mexico. Manned Spacecraft Center, NASA, Houston, Texas NASA-71. 17p.

Nightime infrared imagery of the area between Lordsburg and Silver City, New Mexico, indicates numerous applications for studies of geology and hydrology of desert regions. Tertiary volcanic rocks consisting of flows and welded tuffs show good tonal contrasts within themselves. Precambrian granites and gneisses appear mottled. Water courses appear as dark streaks, cold water springs as dark patches, and water standing in ponds and reservoirs is bright in contrast to the darker (cooler) surrounding materials.

Author

P1400(N67-29134)
Prentice, Virginia L. 1967. Remote Sensing of environment, Prog. rept., 1 Aug. 1965--31 Dec. 1966. Infrared Physics Lab., Univ. Michigan. Rept.- 4864-12. 28 p.

This document reports investigation of progress in the unclassified areas in the technology of

remote sensing of environment. It includes a synopis of progress in the field as reported at the Fourth Symposium on Remote Sensing of Environment, a discussion of the existence and availability of unclassified imagery, and a summary of related activities. A selected bibliography of material published in the open literature is also included. TAB

P1490
Purdue University. 1967a. Interpretation of remote multispectral imagery of agricultural crops. Lab. for Agr. Remote Sensing, Agr. Exp. Stat., Res. Bul. No. 831 36 p.

Results of work conducted in 1964-1965 indicates that multispectral sensing can be useful in identifying and mapping major agricultural surface features such as vegetation, bare soil and water. There is the possibility of differentiating between crop species under certain conditions of crop maturity with multispectral data. Variations in conditions of crop maturity with multispectral data. Variations in response were studied and procedures were recommended which would minimize or at least account for much of the variation. Micrometeorological and ground truth data were evaluated to determine which parameters were of value in multispectral imagery interpretation. R.H.G.

P1500 (N68-30772)
Purude Univ. 1967b. Remote multispectral sensing in agriculture. Lab. for Agr. Remote Sensing, Agr. Exp. Sta. Bul. No. 832. 75 p.

Use of aerospace platforms and other means for remote multispectral sensing of radiation characterisitics of important agricultural features over widespread areas is under investigation in a many-faceted university program and the processing of

data obtained through such sensing is considered. Current and potential test sites are noted, along with the analysis of multispectral imagery and spectroreflectometer data from a preliminary feasibility study. Data collection, reduction, and handling procedures are noted. Effect of moisture contact on feature measurement of the area; corelation between the features; and preliminary classification of corn, wheat, and oates were made from the spectroreflectometer data. Twenty-three color photographs are included to show the areas under investigation.

M.W.R.

P1600
Purdue University. 1968. Remote multispectral sensing in agriculture. Lab. for Agr. Remote Sensing, Agr. Exp. Sta., Res. Bul. No. 844. 175p.

Outlines objectives of LARS. Data are presented from research conducted in 1966-1967. The agricultural remote sensing research program involves the statistical analysis of collected data from both field and laboratory experiments designed to determine the capabilities and limiations of remote multispectral sensing. Instrumentation and data collection are discussed along with data processing techniques and data analysis. The identification and mapping of crop species was accomplished by the use of pattern recognition techniques. Possible agricultural applications programs and aerospace programs are proposed.

R.H.G.

R0100
Rao, C.R.N. and Hsi-shu Chen. 1969. An atlas of polarization features of light reflected by desert sand, white sand, and soil. Dept. Meteor., California Univ., Los Angles. Rept. No. Scientific-3 AFCRL-69-0005. 278 p.

The results of an extensive series of measurements of the degree of linear poloarization of light bi-

directionally reflected by samples of desert sand, white sand and soil under various conditions of illumination are presented in graphical form. Measurements have been made in three spectral intervals (bandwidth approximately 150A) centered on wavelengths 3970, 4865 and 5890A and'white light' with a simple rotating analyzer type reflectometer. Simple Fourier series representations have been established for the azimuthal dependence for the degree of linear polarization of the reflected light for 'white light' measurements. The results of the corresponding error analysis are shown in an error curve.

Author

R0200 (N67-13481)
Raydstrom, H.O. 1966. Interpreting local geology from radar imagery. p. 193-201. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

The intensity of radar return energy, as modified by the factors of radar illumination, surfece roughness, and the geometry of objects, is discussed as applicable to local geologic interpretation. The principles involved are described and applied to analyses of local geology in the southwestern United States. Consideration is given to the use of return intensity in conjunction with geomorphical features to obtain a maximum of information. Local geologic interpretations of radar imagery are applicable to military terrain intelligence, natural resources exploration, and planetary exploration.

Author

R0300
Rib, H.T. 1968. Remote Sensing applications to highway engineering. p. 725-736. In Proc. 5th symp. remote sensing of enviroment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

The availability of new remote sensors (e.g., radar, infrared, multichannel) to highway

engineers in recent years has initiated a new era in the application of interpretation techniques to highway engineering. The data provided by the various sensors furnish information previously unobtainable, or available only at great expense. In this paper the areas of possible application of remote sensors in the highway field are discussed. Several examples are included in this report to demonstrate the value of remote sensors in various aspects of highway engineering Also included is a discussion of the Bureau of Public Road's research program in remote sensing.

Author

R0350

Richter, D.M. 1967. An airphoto index to physical and cultural features in the western United States. Photogramm. Engr. 33(12): 1402-1419.

Cultural geographers, physical geographers, geomorphologists, and photo interpreters should find that this infra provides a representative number of examples of physical and cultural features in the western United States. More than 250 of these features have been located on contact prints available from the USDA's photo laboratories at Salt Lake City and Asheville, Descriptions and pertinent data for ordering the photographs has been supplemented with the inclusion of corresponding USGS topographic map coverage for each photo grouping.

Author

R0400 (N67-13466)

Robinove, C.J. 1966. Remote-sensor applications in hydrology, p. 25-32. IN Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

The feasibility and effective utilization of remote sensing devices for hydrological applications are specified. The assessment of hydrologic phenomena

such as water temperature in various contexts including ground-water discharge into surface water, pollution, lake classification, and an estimation of evaporation and transpiration, is related to remote sensing techniques. Along with radar and passive microwave techniques, the prospectives of color photography are mentioned.

R.L.1.

R0500

Robinove, C.J. 1968a. The status of remote sensing in hydrology, p. 827-831. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor Rep. 4864-18-X.

Remote-sensing research in hydrology, in spite of its potential fields of science. A speedup in the pace of reasearch and the development of operational remote-sensing methods is needed. Areas of application of major importance are ground-water exploration, mapping of snow and ice, description of the dynamic physical and chemical parameters of water bodies, measurement of evaporation and tranpiration, and erosion and sedimentation studies. Aerial-photographic data on hydrologic phenomena are not being extracted from aerial photographs at the present time. Sensors in other regions of the electromagnetic spectrum are also proving of value. Rigorous physical and chemical research provides the best chance for successful evaluation and development of remote-sensing techniques in hydrology. Empirical studies of available data, while of great importance in education and training, fall short of providing the rigorous quantitative methods needed by the hydrologist.

Author

R0600(A69-10487)

Robinove, C.J. 1968b. Space applications in water resource development. U.N., Conf. on the Exploration and Peaceful Uses of Outer Space, Vienna, Austria, Aug. 14-27, Paper 68-95333. 19p.

Discussion of the use of passive and active transmitters and receivers of electromagnetic radiation

in earth-orbital satellites to collect pictorial or numerical data on earth features and phenomena which can be applied to the study of hydrology. The use of narrow-angle lenses (less than 20°) and synoptic coverage of large areas are treated. The use of infrared-color photography for interpretation of vegetated areas, and side-looking airborne radar for all-weather hydrologic coverage of large areas are discussed.

M.G.

R0700
Rosenfield, G.H. 1964. Final report of American society of photogrammetry to Commission V, special applications of the international society of photogrammetry for the period 1960 through 1963. Photogramm. Engr. 30: 735-745.

The report is a listing of articles concerned with special applications of photogrammetry found in various U.S. technical publications within the reporting period. The 3 major subjects covered were: Satellites and Space, Geodesy, and Instrumentation. 277 technical papers under 28 subject areas are listed.

R.H.G.

R0750 (A69-24692)
Rouse, J.W., Jr., H.C. MacDonald, and W.P. Waite. 1969. Geoscience applications of radar sensors. IEEE Trans. on Geosci. Electronics GE-7:2-19.

Survey of the use of the properties of radar to provide geoscience information. The geoscience applications of radar are summarized. The techniques used to record, interpret, and extract the geoscience information content of a radar return are examined. These techniques are: (1) scatterometry - a newly defined field of study dealing with the scattering coefficients of terrain targets; (2) imagery - a photo-like presentation of the radar return; (3) altimetry; and (4) penetration measurements. It is shown, by examples, how and why the radar return character is useful to the geoscientist.

P.v.T.

R0800 (N66-36512)
Rouse, J.W., Jr., W.P. Waite, and R.L. Walters. 1966. Use of orbital radaras for geoscience investigations. Remote Sensing Lab., Center for Research Inc., Univ. Kansas, Lawrence, CRES Rept. No. 61-8. 31 p.

The applicability of remote sensing by radar in fields related to earth sciences, agriculture, and oceanography, and space exploration is discussed. The character of radar return is examined; and techniques used to record, interpret, and extract the geoscience information content of the radar return are presented. Experiments in scatterometry conducted to define the interactions of electromagnetic waves with rough surfaces are reported. Several radar images which contain information applicable to geology, agriculture, and sea-ice studies are described. Radar altimeters are discussed with respect to their use to provide data for improved orbit calculation and reconstruction of the size and shape of the planetary or lunar body; for determining sea slope and small scale undulations of the geoid; and for defining the mass budget of the Antarctic and Greenland ice sheets. The value of radar penetration measurement for sub-surface investigation by spacecraft in lunar orbit altitudes is mentioned.

S.P.

R0900 (N69-27213)
Rvachev, V.P. 1968. The structure of light beams reflected by the leaves of vegetation. (Transl. from Russión) Foreign Tech. Div., Air Force Systems Command, Wright-Patterson AFB, Ohio. FTD-HT-23-369-68. 15 p.

Results are presented of a study on the structure of light flux reflected from leaves. The dependence of the brightness curves of its components on the wavelength and on the incidence angle of the beam in the spectral interval 400- 1100 nm was investigated.

Author

S0100 (N69-19137)
Sabatini, R.R. and J.E. Sissala. 1968. Nimbus Earth Resources Observations, Project NERO. Allied Research Assoc., Inc., Concord, Mass. Rpt. no. 9G45-24. 75p.

A survey of non-meteorological investigations completed with Nimubus photographic and infrared data are reported. Only a minimal portion of the voluinous amounts of data have been analyzed for non-meteorological applications presented herein are definitively pertinent to the assessment of many proposed experiments for future Earth Resources satellites.

Author

S0200
Sattinger, I.J. and F.C. Polcyn. 1966. Peaceful uses of earth-observation spacecraft Vol. I: Introduction and summary. WRL, Inst. Sci. and Tech., Univ. of Michigan, Ann Arbor. Rpt. No. 7219-1-F(1). 57 p.

Earth-observation spacecraft have many potential applications in the fields of geography, agriculture, forestry, hydrology, wildlife management, oceanography, geology, air pollution, and archaeology. Substantial scientific and economic benefits could result from the use of sensors carried aboard earth-orbiting spacecraft for earth mapping, collection of agricultural census data, forest inventroy, wildlife habitat assessment, detection of sea ice, measurement of sea surface temperatures, and many other uses.
Types of sensors to be considered for these purposes include photographic cameras with focal lengths ranging from 0.5 to 20 ft., infrared scanners, multispectral sensing systems, noncoherent and synthetic-aperture radar, microwave radiometers, and laser altimeters. The development of operational systems of observation spacecraft would require a research and development program which included preliminary ground-based and airborne experiments followed by a series of manned earth-orbiting experiments. The preliminary experiments would provide information on sensor characteristics and capabilities for observing natural and cultural phenomena on the

earth's surface which would be necessary for design of experimental orbiting sensors and planning of orbital experiments. The objective of the manned earth-orbiting experiments would be to ascertain the optimum conditions for sensor operation and to demonstrate the feasibility of future operational systems. In the manned earth-orbiting experiments, predicted characteristics of the atmosphere would be checked, individual sensors calibrated, sensor performance measured, and imagery and other data collected over both land and water, which would be analyzed to determine the feasibility of detection and identification of earth-based objects and the best methods for employing future operational earth observation spacecraft.

Author

S0300 (A69-10352)
Sayn-Wittgenstein, L. and A.H. Aldred. 1968. Avionics in forest resource inventories. Can. Aeronautics and Space J. 14:315-317.

Forest resource managers are relying to an increasing degree on developments in avionics. A special radar altimeter for low-level aerial photography has been successfully designed. Other promising devices would include a double-recording radar altimeter and improved position indicators.

Author

S0400 (N68-13146)
Schaber, G.G. 1967. Earth resources survey program. Radar images: San Francisco Volcanic Field, Arizona: a preliminary evaluation. U.S. Geol. Survey, Flagstaff, Arizona. NASA-TL-84. 20 p.

The airbonre radar image system used employed a high frequency (K-band) side-looking radar with a multipolarization capability and recorded polarized and depolarized images simultaneously on

each strip. Distortion is reported in the form of signal ripples parallel to the direction of flight of the aircraft. Cultural features except secondary roads showed moderately well to well, and topographic features were distinct. The depolarized image showed less tonal contrast but resolved the vegetation boundaries and defoliated better in dense pine areas than the polarized image. The geologic implications are discussed, and it is felt that the most useful attributes are the topographic enhancement capability and the ability to differentiate moisture retention unit of soil and bedrock.

N.E.N.

S0500

Schwarz, D.E. and F. Caspall. 1968. The use of radar in the discrimination and identification of agricultural land use, p. 233-247. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

Radar imagery, because it may be obtained through cloud cover, at night, and over large areas as desired, can provide valuable data for agricultural land use mapping. It appears that normal variation in soil or crop moisture are much subordinant to the unique combination of gross plant geometry, micro-roughnesses, and other inherent properties particular to each crop type. Since it is the kind of crop which most influences radar return, discrimination by crop type is feasible.

The two universes, cropped and uncropped agricultural land, are usually separable on K-band radar imagery. Further distinctions by crop type can be made with varying probability. Combined information from multiple polarized images or imagery collected at more than one time in the growing season greatly enhances the probability for correct crop identification.

These several data sets are readily reduced to clusters comparing favorably to crop type categories. Both numerical cluster analysis and electronic data combining techniques are used.

Author

S0600 (N67-13467)
Shay, J.R. 1966. Some needs for expanding agricultural remote sensing research. p. 33-36. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. of Michigan, Ann Arbor. Rept. 4864-11-X.

The merits of the identification of crop species and of crop damaging agents as a basis of yield forecasts are examined. The approach to agricultural research, as well as data handling and analysis studies emphasize remote sensing, particularly from aircraft or spacecraft, and sophisticated instrumentation. Cost factors and other technical details proposed for the agricultural research program are also listed.
R.L1.

S0700 (AD-685 267)
Shilin, B.V. 1969. Physical basis and technical means of aerial methods. (Transl. from Russioan). Naval Oceanographic Office, Washington, D.C. Rept. No. NOO-Trans 436. 19p.

Aerial radar methods; Aerial methods utilizing the infrared band of electromagnetic waves; Aerial methods utilizing ultraviolet radiation; Aerial gravity reconnaissance; Possibilities and prospects of joint utilization of aerial methods.
Author

S0800
Shockley, W.G., S.J. Knight, and E.B. Lipscomb. 1963. Identifying soil parameters with an infrared spectrophotometer, p. 267-288. In Proc. of the 2nd Symp. remote sensing of environment, Inst. Sci. and Tech. Univ. Michigan, Ann Arbor. Rep. 4864-3-X.

The Terrain Analyzer Project of the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, is aimed at exploiting the electromagnetic spectrum as a means of identifying and quantifying those elemens of the terrain that have

an effect on military operations. In the initial studies emphasis will be placed on soil trafficability elements. The first phase of the project will be to examine the feasibility of the general principles by carefully controlled studies in the laboratory using infrared and radar. Upon valid proof of the feasibility of the principles under laboratory conditions, the studies will be extended to field conditions (phase two); and if the principles are further demonstrated to be feasible in the field, the third and final phase, that of developing the instruments and techniques for use under actual combat conditions, will be undertaken. Results of controlled laboratory tests using an infrared spectrophotometer to determine the relationships between the quantity of infrared energy reflected from prepared soil samples and variations in the soil parameters will be discussed.

Author

S0900 (A69-10489)
Sibert, W. 1968. Space applications in support of cartography and geography. U.N., Conf. on the Exploration and Peaceful Uses of Outer Space, Vienna, Austria, Aug. 14-27. Paper 68-95401. 8 p.

Discussion of the potential applications of satellite photograph to geographic and cartographic considerations, based on the photographs obtained in 1965 during the NASA Gemini 7 flight over the Cape Kennedy area. It is suggested that photographic data collected by satellites with cartographic camera systems could be adequate for large-scale map revision. The possibility of compiling synoptic maps of the whole world to show its vegetation, population, economic activities, resources, etc., is considered.

M.G.

S1000 (A69-24266)
Silvestro, F.B. 1969. Multispectral photographic determination of reflectance. Phtogramm. Engr. 35:258-262.

Discussion of techniques for analyzing aerial spectral photographs in order to obtain the spectral reflectance of environmental features. The experimental and analytical techniques used to obtain reflectance values with standard deviations of the order of 7% are discussed. Particular emphasis is placed on the use of calibrated ground control panels to remove the effects of atmospheric scattering from the reflectance determinations. The effects of system resolution are presented as part of the accuracy discussion, because resolution effects alter the reflectance values. This alteration is due to the inclusion of shadow and the mixing of difference environental features within the ground resolution element. The averaging caused by resolution may determine the limits of the detectability of subtle differences in practical application, such as the study of earth resources from a satellite (EROS Program).

M.G.

S1100
Simakova, M.S. 1964. Soil mapping by color aerial photography. (Transl. from Russioan) Israel Prog. for Sci. Transl., Jerusalem. 81 p.

Compares various film-filter combinations, photographs scales, and seasons for obtaining photographs to derive at a method of soil identification.

R.H.G.

S1150(N67-13468(
Simonett, D.S. 1966. Present and future needs of remote sensing in geography. p. 37-47. In Proc. 4th symp. remote sensing of environment, Inst. Sci and Tech. Univ. Michigan, Ann Arbor. Rep. 4864-11_X.

The problem of interpretation and evaluation of geographical information obtained from the

electromagnetic spectrum recorded by existing sensors is examined. The development of spec ialized instrumentation, together with information requirements and alisting of present needs for remote sensing utilization are highlighted Specific problem areas emphasized are: the development of hardware and software to encompass multiple alternative routes to automated to data handling and manipulation, the development of operational real-time data recall and handling both for research and classroom use, the optiminzation of all-weather data collection systems, and the development of new instruments for remote sensing based on the use of proxies or surrogates for conventional data.

R.L1

S1190 (N69-16255)
Simonett, D.S. 1968a. The utility of radar and other remote sensors in Thematic land use mapping from spacecraft, annual report, 1 Mar. 1967 - 30 Apr. 1968. Dept. of Geography, Kansas Univ., Lawrence. NASA-CR_99239, 120p.

Studies are described which seek to evaluate for different climatic environments in the Unites States and Puerto Rico the various ways in which spacecraft and aircraft borne radar imagery, color and flase color photography, high-resolution television, and other sensing and enhancing techniques can be used to complement and supplement one another for producing thematic land use maps. Investigations at field study sites and work with the Image Discrimination Enhancement Combination and Sampling system (IDECS) are summarized. Detailed reports are presented on four specific studyes: (1) an evaluation of classified radar imagery of landform regions obtained by flight over Puerto Rico; (2) an urban land use study of Lawrence, Kansas, using K band radar; (3) a correlation of population and radarderrived areas of 19 urband locations; and (4) radar imagery observations of geomorphology and land use in a part of the Wasatch Range, Utah.

K.W.

S1200 (N69-28154)
Simonett, D.S. 1968b. Potential of radar remote sensors as tools in reconnaissance geomorphic, vegetation and soil mapping. U.S. Geol. Survey, Washington D.C., Tech. Letter NASA-125. 19p.

The focus of this report is on the side-looking radar as a tool for ground reconnaissance. A review is given recent radar studies on the mapping of lineaments, and lithologic units and its use as a surrogate for 1: 24,000 scalemaps in hydrologic analysis; the mapping of vegetation types, especially in types and structure; and its success and short comings as an adjunct to photographs in soil reconnaissance surveys.

Author

S1210
Simonett, D.S. 1968c. Potential of radar remote sensors as tools in reconnaissance geomorphic, vegetation and soil mapping. Int. Congr. Soil Sci., Trans., 9th (Adelaide, Austrilia) IV:271-280.

In reconnaissance mapping of vegetation, soils and geomorphic surfaces in remote, difficult-of-access and under-developed areas in tropical and arctic latitudes, aerial photographs have been used extensively to aid ground studies. Over recent years, studies using nonphotographic remote sensors, particularly infrared and radar have shown that these systems, used in concret with photography, may add materially to the information available and thereby improve the efficienty of ground reconnaissance. This report focuses attention on side-looking radar as a tool for such reconnaissance. Since radar imagery may be obtained in swaths up to 40 miles wide, laregly independent of the weather, its usefulness for reconnaissance-mapping needs careful evaluation. A review is given of recent studies with radar on: (1) the mapping of lineaments, and lithologic units and its use as a surrogate for 1:24,000 scale maps in hydrologic analysis; (2) the mapping of vegetation types, expecially in relation to structure; and (3) its successes and shortcomings as an adjunct to photographs in soil reconnaissance surveys.

Author

S1300 (N67-36003)
Simonett, D.S. J.E. Engleman, A.B. Erhart, D.C. Rhodes, and D.E. Schwarz. 1967. The potential of radar as a remote sensor in agriculture: 1. A study with K-band imagery in western Kansas. Center for Research, Inc., Kansas Univ., Lawrence. CRES-61-21. 14 p.

This study is aimed at extracting information on crops form radar imagery, and is confined to an analysis of monopolarization (HH, horizontal transmit and receive), K-band radar. Crop and soil parameters of approximately 400 fields in a 48 square mile test site near Garden City, Kansas, were statistically compared with average film density values from each field. Film densities were obtained from imagery taken during three late summer and autumn imaging flights. Results indicate that percent of ground covered by vegetation, crop height, surface geometry, and moisture content of crops and surface soils significantly affect radar return signal strength. Some agricultural fields, notably sugar beets and bare ground, can be identified with an acceptable probability of accuracy on September (1965) imagery. Others may be discriminated with much less certainty at this time. Accuracy is improved if time (time of planting, maturation, and harvest) is added as a discriminant tool, by obtaining images from difference months.

Author

S1400
Simons, J.H. 1965. Some applications of side-looking airborne radar, p. 563-571. In Proc. of the 3rd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-(-X.

The applicability of the AN/APQ-56 system to observation of geological structure, geomorphologic features, and cultural patterns of land uses is investigated.

Author

S1500
Skiles, J.J., T.A. Grzelak, R.S. Dixon, R.A. Ragotzkie, and J.D. McFadden. 1963. An airborne instrumentation system for microwave and infrared radiometry, p. 175-185. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-3-X.

A U.S. Navy P2V aircraft was employed in July 1962 for instrumented flights over portions of Wisconsin, Michigan, and the Canadian subarctic and arctic using a variety of sensors of surface parameters. The instrumentation included color movie photography, solarimeters to determine albedo, an infrared bolometer for measurements of surface temperatures, and a scanning microwave radiometer for sensing surface radiometric temperatures and mapping, and selected vertical movie photography of the terrain scanned by the microwave radiometry. The instrumentation and data recording methods are given primary attention to this paper. Brief qualitative discussion is given comparison of the infrared and radiometric surface temperatures observed and illustrative sensor responses are included in this paper.

Author

S1600 (A69-30453)
Slater, P.N. 1969. Apollo 9 provides multispectral photography for comparison studies. Optical Sci. Newsletter 3: 24-25.

Evaluation of the multispectral-photography experiment carried out during the second hald of the 1-day Apollo 9 mission. The purpose of the experiment was to allow scientists to make a preliminary evaluation of the potential benefit of space multispectral photography to earth resources studies. To learn more about the effects of altitude on multispectral photography, the photographs taken by the spacecraft crew from an altitude of 100 miles are compared with photographs taken at the same time with the same film-filter combinations by crews of aircraft flying at altitudes of 3500 to about 60,000 ft.

P.v.T.

S1700 (N69-25024)
Snavely, P.D., Jr. and N.S. MacLeod. 1968. Preliminary evaluation of infared and radar imagery. Washington and Oregon coasts. U.S. Geol. Survey, Washington, D.C. Tech. Letter NASA-124. 23p.

This report summarizes the preliminary interpretation of infrared and radar imagery of parts of the Washington and Oregon coast. This coastal area is an ideal testing site for remote sensing techniques inasmuch as, in contrast to other imagery testing sites, it has dense cover of vegetation and bedrock is poorly exposed. This it serves to define liminations of imagery in areas not ideally suited for gelogic interpretation of conventional aerial photography. Much of the geology of this coastal area has been mapping as part of the U.S. geological Survey's regional geologic mapping program. More recently, detailed investigations of the geology of the Oregon and Washington coast have been undertaken as part of the study of the stratigraphy, structure, economic potential and origin of the continental shelf extending from the continental margin to the Coast Ranges.

Author

S1720
Sorem, A.L. 1967. Principles of aerial color photography. Photogramm. Engr. 33(9): 1008-1018.

The addition and subtraction of the three primary colors are basic concepts in the design and use of color photographic materials. A reproduction need not, and almost never does, have the same spectral characteristics as the original scene. Color-negative materials may offer significant advantages of flexibility over color-reversal types. Color diapositive plates are used successfully in stereoscopic mapping. An exposure computer is available to aid the aerial photographer, and the proer use of filters may require difficult decisions, whereas color processing may impose no real difficulty. The color characteristic of the viewing light may limit the amount of information retrievable from a system.

Author

S1730 (N68-38066
Sperry Microwave Electronic Co. 1965. AN/AAR-33 airborne radiometer system, final report. Clearwater, Florida. SJ-230-4980-1.

An airborne, microwave radiometric search set for the detection of icebergs was developed and flight tested. In this report, basic specifications are reviewed, radiometric theory and practice are discussed, design details and development problems are reviewed, radiometer specifications, characterisitics, instullation and operation are described, and the service approval tests are summarized. The particularly vexing problem with radome aerodynamic characteristics and the solution of the problem are disccues in some detail. Samples of radiometric data over icebergs, ships, and sea ice and over land are given.

Author (TAB)

S1800 (N68-13412)
Stanford Univ. 1967. Field infrared analysis of terrain, annual report, 1 Nov. 1966-31 Oct. 1967. Remote Sensing Lab., Palo Alto, California. AR-2 44p.

The relationship of ground truth measurements to the infrared analysis of the terrain is outlined. The status, changes, and updatings of computer programs connected with the project are presented. CORRCO 360 replaced INTERIM 360 and NSCP programs. The TRIFID tape format description is given. Results of computer programs used for calculations in several meteorological problems are presented. The status of laboratory and field recording equipment (digital recording system, SG-4 spectrometer, CVF spectrometer, IT3 radiometer, and Mark IX radiometer) is described. Cost information concerning the total program effort is given.

L.S.

S1900 (PB-183 089)
Stanford Univ. 1968. Demeter, an earth resources satellite system, final report. School of Engr. Palo Alto, Calif. 526p.

The Demeter satellite system would observe the earth in the optical, near infrared, and thermal infrared wavelengths and produce real time multi-

band pictures approximately every two weeks for distribution to the various users. Studies presented in this report indicate annual benefits on the order of billions of dollars which make the six satellite, four year cost of 103 million dollars well justified. The study also presents the economic and political as well as technical point of view. The technical studies are based on an operational date of 1973 and anticipate modest advancement of the state-of-the-art. They pursue the design of new systems through most of the theorectical problems to a point where production seems feasible. Technical designs cover the scanning sensors, the communcation system, the data reducation and distribution, and the satellite configuration.

Author

S2000 (A69-17119)
Stearns, B. 1968. A new picture of the world. Engr. Bull. 16(3):4-11, 30,31.

Discussion of the use of SLR (side-looking radar) for earth resources se sing. The characteristics of SLR imagery are considered to be especially suited to geological surveys and mapping; oceanographic observations such as ocean waves, shoals, and coastal mapping; coastal marine processes; and air/sea interactions. Other applications include the determination of vegetation characteristics and hydrographical studes - e.g. location of drainage areas for potential soil cultrivation.

B.H.

S2100

Stingelin, R.W. 1968. An application of infrared remote sensing to ecological studies: Bear Meadows Bog, Pennsylvania, p. 435-440. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

Comparative analysis of infared line scan imagery and panchromatic photography of the newly established (1967) national landmark, Bear Meadows Bog, Centre County, Pennsylvania, reveals thermal tonal signatures that may be correlated with existing vegetation patterns and specific ground conditions. Summer and wintertime imagery are compared and the responce of ericaceous and confierous vegetation to trans-freezing temperatures studied. Strongest wintertime signals were being emitted by Rhododendron maximum L. which is concentrated along the margin of the bog. The location and distribution of the low ericaceous shrub Chamaedaphne calyculata (L.) Moench var. angustifolia (Ait.) Rehd. may be traced on the imagery. Drastic changes in the emitted signal from the bog are recorded for nights with sub-freezing air temperatures. A loss of the strong emitted signal from the ericaceous vegetation is attributed to the minimal absorbance of solar radiation during the day due to the curled attitude of the leaves. Such an attitude was acquired as a physiological reaction to the intense cold. Coniferous trees, however, continued to emit a warm signal with the large pines and hemlocks providing strong returns. During both seasons detailed delineation of vegetational communities under daylight imaging conditions appears inferior to nighttime imaging. Early evening flights on nights with temperatures above freezing appear to be optimum for vegetational studies.

Author

S2200 (PB-183 300)
Stoeckeler, E.G. 1968. Color airphotos for terrain analysis in Maine, final report. Materials and Res. Div., Maine State Highway comm. Tech. Paper 68-5R 26 p.

Three types of aerial color film flown over a variety of terrain types were evaluated. Ektachrome Infrared Aero positive transparencies were considered best for terrain studies. The resolution of the color transparencies were found to be superior to color prints made from color negative film.

Author

S2300
Strandberg, C.H. 1967. Aerial discovery manual. John Wiley & Sons, Inc., N.Y. 249 p.

An introduction to aerial photographic interpretation and reconnaissance. Divided into three major sections (1) aerial photographic interpretation, which contains background information that is basic to all applications of image interpretation; (2) photogeology, which includes land forms, drainage patterns soil classification and terrain analysis; (3) photohydrology, which includes ground water, streams, reservoirs and the identification of water pollutation.

R.H.G.

S2400
Strangway, D.W. and R.C. Holmer. 1965. Infrared geology, p. 293-319. In Proc. of the 3rd Symp. on Remote Sensing of Environment, Inst. Sci. and Tech. Univ. Michigan, Ann Arbor. Rep. No. 4864-9-X.

Bear Creek Mining Company has conducted several months of airborne infrared work in an attempt

to detect patterns related to geology or the presence of oxidizing sulphides. The results encountered have shown that certain micro-climatological effects are very important. Among these are the hill effect shown by small topographic features bathed in warm air under thermal inversion conditions. Major faults are evidently reflected in some cases as are areas of subterranean hot water. These observations have been confirmed by ground temperature measurements in holes 2-3 feet deep. The feasibility of using microwave systems has also been investigated. Some limited experiments on the absorption of microwave energy by sand and water mixtures indicate that such measurements would be useful.

Author

T0100

Thomas, J.R., V.I. Myers, M.D. Heilman, and C.L. Wiegand, 1966. Factors affecting light reflectance of cotton, p. 305-312. In Proc. 4th symp. on remote sensing of environment. Willow Run Lab., Inst. Sci. and Tech., Univ. of Michigan, Ann Arbor. Rep. 4864-11-X.

Field and greenhouse experiments were conducted to determine the effects of plant height, percentage of ground cover, and soil salinity on the spectral characteristics of cotton. Comparison of Ektachrome infrared and black-and-white infrared photographs indicated that salt-affected cotton could be detected earlier in the season with the Ektachrome infrared film. Density of both film types was significantly correlated with plant height, percentage of ground cover, and salinity. The degree of correlation changed as the crop matured, and with the type of filter used in measuring the film density. Reflectance of individual leaves was affected by leaf age, moisture content, nitrogen fertilization, and salinity. An increase in the total moisture content or relative turgidity of the leaf significantly decreased infrared reflectance, while salt increased reflectance.

Author

T0200
Thomas, J.R., C.L. Wiegand, and V.I. Myers, 1967. Reflectance of cotton leaves and its relation to yield. Agron. J. 59: 551-554.

A study was made of the effects of soil salinity, cotton leaf relative turgidity, and Cl content on reflectance and transmittance of radiation by single leaves. The relation of color film density to soil salinity, percentage ground cover, and cotton yield was also investigated. Reflectance from single leaves increased as soil salinity, leaf moisture deficit, and Cl content increased. Aerial photographs of field cotton on saline and nonsaline soils showed greater reflectance from cotton not affected by salt. (Kodak Ektachrome infrared aero film was used.) Multiple regression analyses indicated that under field conditions reflectance measured as film density was influenced by soil salinity and percentage ground cover. Since the same plant and soil factors that affect reflectance from the crop canopy also affect cotton yield, regression equations were calculated to express yield, as a function of film density. The regression equations accounted for from 51 to 75% of the variation in yield.

Author

T0300
Tomlinson, R.F. and W.G.E. Brown. 1962. The use of vegetation analysis in the photo interpretation of surface material. Photogramm. Engr. 28:584-592.

A geographic approach to photo interpretive studies, stressing the interdependence of natural features, rather than their isolation is postulated. As an example, the relationships between natural vegetation and surface materials observed during photo interpretation over a period of years are presented. For various

types of surface material, in each of several major climatic zones, indicator species, and indicator associations of species are advanced. It is proposed that the recognition of this relationship can be used as a valuable criterion in the photo interpretation of surface material. While for the purpose of this paper the examples have been restricted to parts of Canada, it is suggested that the concept is valid in other areas, and may be used to advantage in surface material interpretation.

Author

V0100 (Ad-808 904)
Van Lopik, J.R. 1966. A remote sensing survey of areas in central coastal Louisiana. Part I - discussion. final report. Sci. Services Div., Texas Instruments, Inc., Dallas. 101 p.

A remote sensing survey of selected areas in coastal central Louisiana was conducted for the Office of Naval Research. Program objectives were to evaluate and compare the acquired conventional and nonconventional aerial photography and 8 to 14 micron infrared imagery as to their utility in detecting and delineating landforms, land/water contacts, vegetation types, and surface expressions of subsurface structure and features in a deltaic region. The survey areas are characterized by large expanses of marsh and swamp of recent age dissected or bordered by relict streams flanked with firm, tillable levees; tidal bayous; man-made canals; and beaches and marsh stranded beaches (i.e., cheniers). Pleistocene exposures, in the form of coastal terraces and upthrust salt-dome islands, also are present. Night coverage of the survey areas with an RS-7 infrared (IR) mapping system was obtained in addition to simultaneous IR AND PHOTOGRAPHIC COVERAGE DURING DAYTIME PERIODS. Photographic films used in

this program were; aerial panchromatic (standard black and white)/W12 filter; infrared aero (black and white IR)/ W88A filter; aerial ektachrome (standard color)/HF3 and 4 filters; and ektachome infrared aero (caouflage detection)/W12.

Author

V0200 (N67-13469)
Van Lopik, J.R. and L.A. Yarbrough. 1966. Comments on remote sensing needs in geoscience engineering and exploration, p. 49-54. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rept. 4864-11-X.

Geoscience engineering requirements for remote sensing instruments are briefly reported. Some areas to benefit from the optiminzation of valid sensor data acquisition and interpretation are identified as petroleum and minerals exploration, soil type determination, varying data patterns from geologically or pedologically analogous areas, and soils mapping. Details are also given on a soils exploration program.

R.L.1

V0300 (N69-27533)
Vinogradova, A.I. et. al 1968. Physical principles and technical means of aerial surveying, Chapter 4 and 5. (Transl. from Russian). Foreign Tech. Divi., Air Force Sys. Command, Wright-Patterson AFB, Ohio. FTD-MT-24-316-68. 135 p.

The book deals with the physical principles and technical means of various aerial surveying methods. It presents the fundamentals of aerial photography, photogrammetry, aerial photo-interpretation, aerial geophysical, and other methods. Modern equipment (Soviet and non-Soviet) used in aerial photography and aerial geophysical

surveying is described. The greatest attention has been paid to aerial photographic surveying because of its increasing importance among aerial surveying methods. This book is divided into three parts covering aerial photography, photograph processing and photograph analysis, each of which is analyzed separately with respect to methods, equipment and theorectical fundamentals. Geophysicists, aerial surveyors, and specialists working in allied fields should find this work useful.

Author

V0400
Vivian, W.E. 1963. Application of passive microwave techniques in terrain analysis, p. 119-125. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-2-X.

Problems of passive microwave radiometer data interpretation are discussed, and three methods of data acquisition are described. The need for plausible physical models of terrain types and the importance of ascertaining the geophysical requirements for passive microwave radiometer data are two factors that are stressed.

Author

W0100 (N69-30303)
Walters, R.L. 1968. Radar bibliography for geoscientists. Remote Sensing Lab., Center for Res. in Engr. Sci., Univ. Kansas, Lawrence. CRES-61-30. 34 p.

A comprehensive source of background information is provided, emphasizing geological agricultural geographical, and related interpretations of high-resolution, side-looking airborne radar imagery. Two hundred sixty-six references are cited and indexed, covering a broad spectrum of subjects from applied imagery analyses and interpretations to selected theorectical studies.

Author

0200 (N68-28872)
Washington, Jean P. 1968. Remote detection of terrain features from Nimbus 1 high resolution infrared radiometer nighttime measurements. Goddard Space Flight Center, NASA, Greenbelt, Maryland. NASA-TN-0-4603. 12p.

Brightness temperature analyses were made from nighttime Nimbus high resolution infrared data in the 3.5-4.2 region. Data for the northeast Sahara Desert and the Nile delta regions, obtained during September 1964, were selected. The brightness temperatures were found very useful because they detect; (1) the widespread humidity in the upper soil horizons, and (2) the heat storage capacity in various rock formations such as sands and alluvial deposits.
Author

W0300 (N66-39405)
Weber, F.P. 1966. Multi-spectral imagery for species identification. Pacific SW Forest and Range Exp. Sta., Berkeley, California. NASA-CR-78756. 47 p.

Replicated density readings were taken from line-scan imagery of tree plantations of eight commercially important tree species for four diurnal periods and four seasonal periods. Four spectral regions were used in the comparison: (1) 0.32-0.38 microns, (2) 2.0 to 2.6 microns, (3) 4.5 to 5.5 microns, and (4) 8.2 to 14.0 microns. Standard errors of the mean and coefficients of variation were computed for each species for each wavelength, time of day, and season. The tonal density in the line-scan imagery of each species was ranked by species and the likelihood of separating one tree species from another 19 out of 20 tries (t=0.05) was computed. These results are shown in Appendixes "A" and "B".

It was found that all four spectral bands were needed to separate all species, one from another. Some species could not be identified, however, even when the four spectral ranges were used in concert. The concept of tree species separation by differing density responses in several channels of the electromagnetic spectrum appears feasible from our findings.

Author

W0400 (N68-17247)

Weber, F.P. and C.E. Olson, Jr. 1967. Remote sensing implications of changes in physiologic structure and function of tree seedlings under moisture stress. Pacific SW Forest and Range Exp. Sta., Berkeley, California NASA-CR-93175. 67 p.

Changes in reflection and emission characteristics of coniferous and broadleaved foliage on tree seedlings subjected to varying degrees of moisture stress were studied under greenhouse conditions. Moisture stress in the foliage was measured by a Scholander hydrostatic pressure chamber. A heater source probe and detector, inserted into the active xylem, measured the rate what water was transolocated upward in the trees. An infrared filtered radiometer measured changes in thermal response under various solar energy inputs. The level of water stress during leaf formation was found to exert a greater influence on foliar reflectance than the level of water stress at the time of the reflectance measurements were made. Pine foliage affected by moisture shortage underwent structural changes as a result of physiologic stress. However, these changes did not alter the spectral signature of foliage enough to permit pre-visual detection of moisture stress. Water loss did not affect reflectance directly except in the region of the infrared water absorption bands.

R.N.A.

W0500
Webster, R. and I.F.T. Wong. 1969. A numerical procedure for testing soil boundaries interpreted from air photographs. Phtogrammetra 24:59-72.

A numerical procedure for determining the goodness of soil boundaries drawn by airphoto interpretation is described. Multiple correlated attributes of the soil profile are reduced to a single variate expressing a large proportion of available information by component analysis. This variate, the first principal component, is plotted against distance on a linear transect and approximte positions of maximum (positive) and minimum (negative) slope found by inspection. These positions are then pin-pointed using S t. They represent the points where the soil boundaries, the maximum rates of change of soil with respect to distance, cross the transect. The procedure is illustrated by an example in which the soil boundaries in a part of the upper Thames Valley, England, were interpreted from air photographs and then compared with those determined by numerical analysis.

Author

S0600
Weiss, M. 1963. Sea and earth surface temperature measurement using infrared, p. 343-357. In Proc. of the 2nd symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-3-X.

Two infrared rediation measuring instruments have been developed to measure sea and land surface temperatues. One instrument, designed for airborne use, measures temperatures in the range of -2°C to +35°C with an accuracy of ±0.2°C. The second instrument, of a less complex design, measures to an accuracy of 0.5°F, and has been used as an airborne, as well as shipbased equipment. Both instruments have already collected considerable quantities of surface temperature data. A few of the methods used for data accumulation are described, and portions of the data are presented.

Author

W0700

Wiegand, C.L., M.D. Heilman, and A.H. Gerberman. 1968. Detailed plant and soil thermal regime in agronomy, p. 325-342. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan Ann Arbor. Rep. 4864-18-X.

Variables in crop species, plant spacing, tillage irrigation regime and special features such as highways and water reservoir were used to study the thermal behavior of 40 sites on a 50-acre experimental research farm near Weslaco, Texas during overflights made by the University of Michigan thermal scanner-bearing plane June 1, 1966. The thermal scanner imagery was interpreted from microdensitometer film densities calibrated against Stoll-Hardy radiometer measurements made on the ground at the same time the scanner-bearing airplane was overhead.
Freshly irrigated crops ranging in percent ground cover from 37%(peppers) to 70% (corn) were up to 20 C cooler under midday conditions than non-irrigated portions of the same fields. At the 0606 flight time, the nonirrigated crops were 1 to 2°C cooler than the freshly irrigated portions of the same fields. Equivalent blackbody temperature in the tinned grain sorghum at the midday overflight (1359 CST) was a linear inverse function of leaf area index (LAI). Temperature differences among tilled areas were small and could not be accounted for by arbitrary roughness categories. The results illustrate the range in temperature expected in the agricultural landscape in a subhumid climatic zone and the magnitude of influence of time day, crop cover conditions, tillage, and irrigation on the thermal behavior of plants and soils. The data also point out the need for internal calibration of the thermal scanner and for knowledge of the insolation conditions associated with the imagery.

Author

W0720
Wiegand, C., V. Myers, and N. Maxwell. 1966. Thermal patterns of solid fule block-heated citrus trees. J. Rio Grande Valley Hort. Soc. 20: 21-30.

An infrared camera and a radiation thermometer were used to study the thermal pattern of citrus foliage associated with the use of solid fuel blocks under one moderatly windy and one calm conditions. Single fuel blocks on the W and NE sides of the tree were insufficient to warm the S side of the tree when the wind was 6-10 mph from the NE. Under conditions of slight draft of wind from the NW, overcast sky, and 4 fuel blocks under a large tree with full skirt, air temperatures at the 5-foot height, 3 and 6 feet from the center of the tree were 8 to 14 above outside air temperature on the downwind side whereas external foliage temperatures were within 2°F of air temperature. Under lear sky conditions external foliage temperatues was as much as 5°F colder than the air.
The results demonstrate the usefulness of the noncontact infrared techniques for measuring the complex foliage thermal patterns which result when under-the-tree solid block energy sources are used. The instruments may be particularly suited to studies under windy conditions.
Author

W0770
Williams, R.S., Jr. and T.R. Ory. 1967. Infrared imagery mosicas for geological investigations. Phtogramm. Engr. 33(12):1377-1380.

The usefulness of infrared imagery for geological investigations has been handicapped by the 'strip' characterisitcs of the imagery which is generally used in the line-scan technique for recording thermal

properties of terrain features. Although the geometry of line-scan infrared imagery presents difficulty in constructing mosaics, many of the distortions can be minimized by careful planning and execution of the infrared survey. The complation of an infrared mosaic is of considerable value for regional interpretation on thermal anolaies.

Author

W0800 (N67-13510)
Williamson, A.N. 1966. Laboratory investigations of the gamma-ray spectral region for remote determination of soil trafficability conditions, p. 623-633. In Proc. 4th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-11-X.

Gamma radiation from soil samples was measured, and the results were analysed to evaluate the use of gamma rays in remotely determining soil parameters useful in estimating trafficability. Gamma-ray spectra were obtained from presentative samples of sand, silt, and clay placed in a low-background inclusure. Photopeak counting rates and photopeak ratios of thorium, uranium, and potassium were considered in the analysis. Results indicated that photopeak counts of the ratio-isotopes of primary interest were proportional to moisture content of the soil samples, but rations of the photopeaks were nearly independent of moisture content, although different for each soil tested. Gamma-ray measurements were also made on soil samples obtained from all 50 states in an attempt to correlate the rations of their photopeaks of thorium, uranium, and potassium with soil type and other morphological, genetic, and physical-chemical characteristics of the soils.

Author

W0900
Williamson, A.N. 1968. Gamma-ray measurements to evaluate soil properties, p. 737-746. In Proc. 5th symp. remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. 4864-18-X.

Gamma radiation from soil samples obtained from nearly all of the states and Puerto Rico was measured in the laboratory and the results were analyzed to evaluate the use of gamma-ray measurements to convey certain information about the soil. The data were arranged according to land usage, i.e. cultivated or uncultivated, and into classifications according to the following systems; geological material type, geological material age, U.S. Department of Agriculture (USDA) Great soil Group, and USDA Soil Order based on the Seventh Approximation. By plotting the gamma-ray photopeak count rations of $TH^{232}/K^{40}$ versus $U^{238}/K^{40}$ and the normalized photopeak counts for $U^{238}$ and $Th^{232}$ versus sand content, it was shown that the criteria for separating the soils were either too broad or not significant to the gamma-ray emissive characteristics of soil. However, the data showed that the $TH^{232}$ and $U^{238}$ photopeak counts depended upon the particale size distribtuion in the soil and indicated that gamma-ray measurements can provide a qualitative indication of sand content.

Author

W1000
Winkler, E.M. 1963. Relationship of airphoto tone control and moisture content in glacial soils, p. 107-118. In Proc. of the 2nd symp. on remote sensing of environment, Inst. Sci. and Tech., Univ. Michigan, Ann Arbor. Rep. No. 4864-3-X.

Airphotos frequently show light tones on high points of morainal systems but darker tones in depresssions which are primarily

caused by different soil moisture contents. Experiments were conducted on the ground with glacial soils at different water contents. The relationship between the tone of air-photos and the water content of soils was established with the following commercial aerial films: Super XX-Aerographic, Infrared-Aerographic, Aero-Ektachrome, Aero-Ektachrome Camouflage Detection (Infrared color). The densities of the developed films were measured on the negatives with a standard Western Photographic analyzer (desnitometer). Results obtained from ground experiments did not match the density-moisture contents up to near the Atterberg Plastic Limit of the soil, but sharply decreased again towards the Atterberg Liquid Limit. Darker tones through concentration of organic matter in terrain depressions and rapid drying of wet soil in thin sheets on the surface in contract to darker wet soil below do not permit the calculation of moisture contents from presently available photographic emulsions.

Author

W1100 (68-13043)
Witmer, R.E. 1967. Waveform analysis of geographic patterns recorded on visible and infared imagery. Ph.D. Thesis, Florida Univ. 236 p. Univ. Microfilms, Ann Arbor, Michigan (Diss. Abstr. 68-13042).

This study is part of a long-range program of investigation into the methodology and application of research techniques which objectively measure geographic patterns and distributions using electronic instrumentation. The primary objectives of this study were (1) the application and refinement of an electronic technique for scanning visible and infrared imagery, and (2) the development of a methodology which would allow discrimination between various terrain types recorded on such imagery. Two sets of multispectral imagery were chosen for waveform analysis. Each set represented a sampling of different portions of the visible and infrared wavelengths, and also represented a different group of sensors.

Dissert. Abstr

W1150 (A69-15993)
Wobber, F.J. 1967. Space photography - a new analytical tool for the sedimentologist. Sedimentology 9:265-317

Discussion of the use of orbital remote sensing, and particularly space photography, to provide synoptic environmental data for geoscientists, especially in the analysis of sedimentary environments. Color space photographs obtained incident to the Gemini program provide unique tools for analyzing sedimentray environments and processes, and provide data that cannot be duplicated by conventional aerial photographic techniques. The advantages of orbital sensing include synoptic overview, frequent seasonal worldwide coverage, and a data-collection capability in otherwise inaccessible areas or under hostile environmental conditions.

B.H.

W1200(N69-25018)
Wolfe, E.W. 1968. Geologic evaluation of thermal infrared imagery. Caliente and Temblor Ranges, southern California. U.S. Geol. Survey, Flagstaff, Arizona. Tech. Letter NASA-113. 43p.

Thermal infrared (8 to 13 micron) imagery was obtined in the Caliente and Temblor Ranges and Carrizo Plain, southern California, in the pre-dawn and post-sunrise hours of June 18, 1965. Field observations; measurements of moisture and specific gravity of the regolith, and radiation temperatures; and comparison with geologic maps and aerial photographs lead to the following conclusions: (1) The specific gravities of surficial materials (Usually not bedrock) influcence tonal desnities in the pre-dawn imagery. (2) by topographic, atmospheric, and vegetative effects on pre-dawn radiation. (3) Geologic features such as outcrop patterns and some faults are recognizable in the infrared imagery as well as in aerial photographs. (4) local radiative anomalies, previously suggested to be caused by the occurrence of ground water at shallow depths, may be caused by night-time entrapment of cold air in poorly drained, topographically low areas.

Author

W1300(N69-28255)
Wu, S.T. and A.K. Fung. 1969. Ionospheric sounder as a means of monitoring ground moisture. Engr. Sci. Divi., Center for Res., Inc., Univ. Kansas, Lawrence. CRES-TR-37-3. 13p.

An experimental investigation was carried out on the possibility of monitoring the moisture content M of the ground by measuring its effective reflection coefficient R. This was done via the use of an ionospheric sounder. In addition, the effect of temperature change on M and R was also examined. It is found that the correltation coefficient between M and R os 0.82 indicating a reasonably high possibility of monitoring M by R. As a by-product, it is found that no further magnetic splitting occurs on the ionospheric echoes beyond the first.

Author

Y0200
Yost, E.F. and Sondra Wenderoth. 1967. Multispectral color aerial photography. Photogramm. Engr. 33(9): 1020-1033.

A camera has been constructed to obtain multispectral photography in four bands in the 360 to 980 nm, portion of the spectrum. Photo-interpretation is accomplished on a companion viewer which presents a composite color rendition of the four photographs by additive color techniques. This camer-viewer system combines spectrophotometric sensing with principles of colorimetry to enable detection of subtile reflectance differences on the ground. Numerous experiments have been performed using models of equipment based on these techniques. The promising results obtained indicate potential applications of this sytem to agriculture, forestry, water pollution, soil analysis, determination of shallow water depths, as well as to military problems of target acquistion and camouflage detection. The successful application of multispectral technology under great variations of

photographic conditions encountered in practical remote sensing depends on precision of the techniques used. Accurate photographic processing is essential for repeatable results.

Author

Y0250

Yost, E.F. and Sondra Wenderoth. 1968. Precision multispectral photography for earth resources applications. Sci. Engr. Res. Group, Long Island Univ., Brookville, New York. SERG-TR-04. 153 p.

The experiment was designed to evaluate the utility of multiband color photography for earth resource applications. A multispectral system was used in which most of the known image forming errors were minimized. The choice of spectral bands was limited by lack of definitive spectral data on environmental objects and was constrained to approximate the spectral sensitivity of color films. Photography, using conventional color films sensitive to the visible and infrared spectrum, was simultaneously taken. Ground control was incorporated for the test site of each discipline which included: calibrated color and grey scale target panels, incident solar radiation, reflectance spectra, and colorimetric measurements. Some of the test results showed: (1) chromatic image errors due to camera, processing and viewer tolerances can be decreased to apoint where colorimetric analysis can be reliably performed; (2) variations in the intensity and spectral distribution of solar a radiation can be eliminated; and (3) the directional (non-lambertain) spectral reflectance characteristics of objects and the dynamic nature of en vivo reflectance spectra are critical residual environmental parameters.

Author

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C1900, R0400, R0500

FORESTRY

B0020, C0300, C0400, C0500, C0800, D0400, D0410, H0400, H0410, H0500, J0200, L0010, L0200, L0300, L0310, L0700, L0710, L0800, N0300, N0400, O0140, O0150, P0100, Ro700, S0200, S0300, W0300, W0400, Y0200

GAMMA RAYS

C1290, F0200, L1700, W0800, W0900

GEOGRAPHY

S0100, S0200, S0900, S1150, W0100

GEOLOGY

C1100, D0200, M0400, M0500, M0600, M0700, M0800, R0700, S0100, S0200, S1700, S2400, W0100, W0770, W1100, W1200

HYDROLOGY

H1200, H1250, J0100, L1200, R0500, R0700, S0100, S0200, S2000

INFRARED DETECTORS

C0110, K0300, M1600, M1700, M2000, M2100, O0150, R0300, W0600

INFRARED PHOTOGRAPHY

C0700, C0800, F0250, H0400, H0410, H0500, L0310, M1000, M1900, M2000, M2100, O0150, P0700, R0600, S1190, T0100, T0200, V0100, W1000, Y0250

INFRARED RADIATION

B0600, C1890, C1900, M1700, M2000, W0600

INFRARED REFLECTION

A0100, D0100

INFRARED SPECTROMETERS

E0500, H1100, L1800, L1900

INFRARED SPECTROPHOTOMETERS

G0600, S0800

LAND USE

B0490, C1180, D0290, D0300, D0350, E0600, E0601, G0660, G0880, G0900, H0050, H0100, H0200, H1000, H1200, L1000, M1110, M1400, N0300, N0400, O0200, P0300, S1190, S1400, W0900

LEAVES

A0100, D0500, G0120, G0200, G0210, G0310, R0900, T0100, T0200

MAPPING

A0200, B0300, C0800, C2000, E0400, E0450, F0200, F0300, G0610, G0880, H0200, K0500, L0900, L1300, L1500, M0100, M0150, M0200, M1500, P0800, P0900, P1490, P1500, P1600, S0200, S0700, S0900, S1100, S1210, S1400, S1500, S2000

MICROWAVE RADIOMETERS

C1000, C2000, C2100, C2200, E0100, E0200, E0500, H0600, J0100, K0050, M2100, O0100, P0400, P0500, P0600, R0400, R0600, S0200, S1500, S1730, S2400, V0400

MILLIMETER WAVES

A0200, C1000, E0100, H0600, J0100, L0900

MOISTURE CONTENT (plant)

O0150, T0100, T0200, W0400

MULTISPECTRAL SENSING

B0100, C0600, C0400, C0800, C1200, C1250, C1290, C1400, C1500, C1600, C1700, C1800, D0400, D0410, H0200, H0400, H0410, H0500, H0700, H0750, H0950, J0300, K0200, L0300, L0310, L0400, L0500, L0800, L1310, L1400, L2000, M1000, M1100, M1900, O0200, P0300, P1100, P1490, P1500, P1600, R0300, S0200, S1000, S1600, S1900, W0300, W1100, Y0200, Y0250

NATURAL RESOURCES

B010, B020, C0900, C1100, C1290, C1300, C1600, D0400, E0400, G0880, H0800, J0200, J0300, L0010, L0400, L0800, M100, N0100, N0600, P0800, P1200, S0900, S1000, S1600, S1900, S2000, T0300, Y0250

NEAR INFRARED RADIATION (0175 - 3μ)

A0100, C0200, D0100, D0400, G0200, G0210, G0300, G0600, H1100, L1400, L2000, S1900, W0300

OPTICAL MECHANICAL SCANNERS

B0100, C0200, C0300, C0600, C1290, H0400, H0410, H0500, L0710, L0800, L1350, P1100, P1490, P1500, P1600

PATTERN RECOGNITION

E0400, F0400, F0490, F0500, H0100, H0200, H0750, L0710, P1490, P1500, P1600

PHOTOINTERPRETATION

C0700, C0800, C1190, C1400, D0290, D0300, D0400, D0410, G0650, G0660, G0700, G0900, H0050, H0410, H0500, H1200, H1250, J0100, K0500, L0010, L0200, L0300, L0310, L0400, L1350, M150, M0350, M1100, P0700, P1200, R0350, S0900, S2300, T0300, V0100, V0300, Y0200

POLARIZATION

M1110, M1150, M1200, N0600

RADAR

A0200, B0200, C0200, C0400, C0500, C0600, C0800, C1290, D0200, D0400, E0400, G0500, H0100, H0200, H0700, J0300, K0100, L0600, L0800, L0900, L1000, L1300, L1600, M0200, M0950, M1000, M1110, M1150, M1200, M1300, N0100, N0600, O0100, P0500, P0600, P1000, R0200, R0300, R0400, R0600, R0750, S0200, S0300, S0400, S0500, S0700, S0800, S1190, S1200, S1210, S1300, S1400, S1700, S2000, W0100

RADIOMETERS

A0200, B0300, B0500, C1000, C2000, C2100, C2200, E0100, E0500, H0600, J0100, K0050, M2000, O0100, O0150, P0300, P0400, P0500, P0600, S1730, S1800

RADIO SPECTRA

B0200, N0500

SOILS (General)

B020, C0300, C1350, C1500, H0800, H1200, M0150, M0200, M1500, P1200, S1200, S1210, S1300, S2000, S2200, W0100, Y0200

SPACEBORNE PHOTOGRAPHY

C0600, C1100, C1290, C1300, C1800, H0410, J0100, K0400, L0300, L1500, M0100, M1400, M1500, N0200, P0800, P1200, R0600, S1190, S1600, W1150

SPECTRAL ENGERGY DISTRIBUTION

G0100, G0120

SPECTRAL REFLECTANCE

A0100, B0400, C1800, G0120, H0500, H1100, L1350, M1100, O0140, S1000

SPECTROMETERS

E0500, H1100, L1350, L1800, L1900, M1100, M1900, P1100, S1800

SPECTROPHOTOMETERS

A0100, B0400, B0600, G0200, G0600, H0700, L0500, M0300, M1900, M2100, O0140, S0800

SURFACE PROPERTIES

C1000, C2100, E0200, E0300, G0100, G0400, G0800, L1600, P0600

SURFACE ROUGHNESS

P0400, P0500, P0600, R1000, R0200

SURFACE TEMPERATURE

C1890, C1900, G0400, K0300, M0900, M1600, P0300, W0600

TERRAIN ANALYSIS

A0300, B0100, C0110, C0400, C0500, C1800, C2000, D0100, D0200, E0400, F0100, F0300, G0500, G0610, G0700, H0300, H1000, K0100, K0200, K0400, L0050, L0100, L0600, L0710, L1600, L1700, L1800, L1900, L2000, M0200, M0950, M1000, M1100, M1150, M1400, M1800, N0200, N0500, N0600, O0200, P0200, P0500, P0600, P1300, Ro200, R0300, R0750, R0800, S0100, S0200, S0400, S0500, S0800, S1150, S1200, S1800, S2200, S2300, S2400, V0200, V0300, V0400, W 200, W0770, W1100

THERMAL EMISSION

C0110, C0200, D0410, G0800, L2100, M1700, M1900, S1500, S2400, W0400

THERMAL INFRARED IMAGERS

C0100, C0200, C0300, C0400, C0500, C0600, C0800, C1400, C1700, D0400, E0450, E0600, E0601, G0500, H0200, H0300, H0550, H0700, J0100, K0100, L0050, L0100, L0900, L1300, L1310, L1400, L2000, M0900, M1000, M1600, M1700, O0150, P0200, P0900, P1300, S0100, S0200, S0700, S1700, S1900, S2100, V0100, V0200, W0200, W0300, W0700, W0750, W0770, W1100, W1200

TOPOGRAPHY

D0200, K0100

TRANSMITTANCE

A0100, G0120, G0200, G0210, T0200

TRANSPIRATION

H0500, R0400, R0500

TREES (Citrus)

C0850, W0750

ULTRAVIOLET RADIATION

S0700, W0300

VEGETATION (mapping)

C0200, C0300, C0400, C0500, C0800, C1100, C1400, C1700, C2100, C2300, D0200, E0601, F0400, F0490, F0500, G0650, G0660, G0880, H0100, H0700, H0750, H0800, L0310, L0710, L0800, L1000, L1200, L1400, L2000, M1100, M1200, M1300, M1400, M2100, P0900, P1100, P1200, P1490, P1500, P1600, R0600, S0400, S0500, S0600, S0900, S1200, S1210, S2000, S2100, T0300, V0100, W0300

WATER (General)

B0020, B0300, C1000, C1500, D0410, H1200, H1250, L2000, M1600, R0400, R0500, S2300

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