

DEAN F. EITEL

U.S. Dept. of the Army Engineer Agency
for Resources Inventories, Washington, D.C. 20016

Remote Sensing Education in the U.S.A.

NO READILY available survey exists of courses offered in remote sensing in spite of many years of research and scientific applications. At a time when environmental and interdisciplinary applications of remote sensing are at their zenith, there should be such a compendium to assist concerned students and research personnel in their desire for knowledge. Only through indirect contacts have interested persons been made aware of existing remote sensing courses and programs within the various disciplines.

With the overwhelming interest that domestic and international scientific organizations have expressed in the NASA-sponsored Earth Resources Technology Satellite (ERTS)

Iowa State University: Civil Engineering Dept.
University of Wisconsin: Civil Engineering Dept.

It is interesting to note that remote-sensing courses have been expanded into a variety of disciplines including geography, forestry, mineral/mining engineering, electrical engineering, civil engineering, geology/geological engineering, optical sciences, meteorology, geophysics/geophysical engineering, watershed management, physics, and oceanography.

The author derived the following course information from extensive catalogue research and through personal contacts. In view of the fact that the science of remote sensing is constantly expanding, additional schools may

ABSTRACT: This article is designed to survey the available educational opportunities in the multi-disciplinary field of remote sensing. The demand for such a comprehensive study has been substantial indicating both the rapid expansion of remote sensing and the desire for individual specialized programs. The projected ERTS and SKYLAB programs have generated additional interest in remote sensing instruction. It is to these objectives that this survey is directed.

and the SKYLAB Earth Resources Experiment Package programs, comes both the need and desire for continued training of key scientists. More than 30 countries have responded to the latest NASA remote-sensing proposal invitation and it is anticipated that future satellite systems (ERTS-B, C, D, E, F) will engender a far greater response.

This study is designed to serve as a guide to present U.S. university and college-level courses in remote sensing. Individual descriptions for specific remote sensing courses are listed. In addition to these specialized courses, schools offering remote sensing topics within the more traditional subjects are included at the conclusion of the article.

Several universities have established remote sensing as an area of specialization within selected graduate programs. A list of some of these schools is:

University of Arizona: Optical Sciences Dept.
Cornell University: Civil Engineering Dept.
East Tennessee State University: Geography Dept.

havelisted course offerings since the completion of this survey. If other formal courses are offered, they should be brought to the attention of the American Society of Photogrammetry for inclusion in later listings; the Society encourages information for the benefit of the entire profession.

REMOTE SENSING COURSES

UNIV. OF ARIZONA, Tucson, Ariz.

Dept. of Geological Engineering

#307 *Applied Multispectral Imagery*. (2 cr). Application to mineral exploration, engineering, geology, groundwater location, and pollution monitoring.

Dept. of Optical Sciences

#231 *Aerial and Space Photography*. (3 cr). Film recording characteristics; physical characteristics; atmospheric effects; systems and subsystems.

#239 *Infrared Techniques*. (3 cr). The

radiant environment; atmospheric properties; optical materials; optical systems; detector description and use; data processing; displays; systems design and analysis.

BELOIT COLLEGE, Beloit, Wis.

Dept. of Geography

#320 *Descriptive Interpretation of Remote Sensors*. Descriptive interpretation of remote sensing images (infrared, thermal, etc.), with emphasis on the interpretation of aerial photography; applications of aerial photography and photographic interpretation to the solution of geographic problems.

UNIV. OF CALIFORNIA at Berkeley

Dept. of Interdepartmental Studies

#186 *Remote Sensing of Earth Resources*. (5 cr). The identification and classification of data on air photographs and other remote sensing imagery; the solution of selected problems in photogrammetry.

UNIV. OF CALIFORNIA at Los Angeles

Dept. of Geography

#274 *Photo Interpretation and Remote Sensing*. The study of aerial photographs and other remote sensing images as tools for geographical research. Particular attention is placed on the analysis of landscapes and the interpretation of interrelationships of individual features in their physical and cultural complex.

UNIV. OF CALIFORNIA at Riverside

Dept. of Geography

#108 *Interpretation of Remotely Sensed Imagery*. (3 cr). In addition to aerial photo interpretation in the panchromatic range, attention will be given to imagery sensed from other parts of the electromagnetic spectrum.

UNIV. OF CALIFORNIA at Santa Barbara

Dept. of Geography

#115B *Geographic Remote Sensing Techniques*. (4 cr). Interpretation of environmental phenomena recorded by orbital and aerial multispectral sensing systems with emphasis on non-visual and multi-band sensing techniques.

CATHOLIC UNIVERSITY OF AMERICA, Washington, D.C.

Dept. of Geography

#708 *Remote Sensing*. (2 cr). Land use

determination, resource evaluation, and other uses of imagery from remote sensors, such as satellite photography, infrared scanners, and sideviewing (side-looking) airborne radar.

Dept. of Electrical Engineering

#771 *Detection, Estimation, and Modulation*. (3 cr). The course is a systematic treatment of the statistical decision theory relevant to sophisticated signal processing in radar-sonar, communication, control, and pattern recognition/signal classification. Linearly-modulated signals. Review of classical detection/estimation theory, representation of random processes, integral equations. Fixed-interval and sequential detection/signal classification, detector sensitivity, parameter estimation. Waveform estimation, linear modulation and optimum demodulation in noise.

CLARK UNIV., Worcester, Mass.

Dept. of Geography

#290b *Remote Sensing Systems and Image Interpretation*. (3 cr). Examination of the means of acquisition, the interpretation, and the utilization of different forms of remote sensing imagery. Emphasis will be placed upon air photo interpretation; attention will also be given to use of non-conventional imagery (infrared, radar, microwave, multispectral), data sampling and processing.

COLORADO SCHOOL OF MINES, Golden, Colo.

Dept. of Geological Engineering

#545 *Introduction to Remote Sensing*. (3 cr). Theory of active and passive remote sensing systems and techniques using energy-path concept in the ultraviolet through ultrahigh frequency (radar) portions of the electromagnetic spectrum. Introduction to remote sensors and interpretation of data. Survey of applications in geology.

#546 *Geologic Applications of Remote Sensing*. (3 cr). Application of remote sensing to regional geologic and mineral (including petroleum) resources investigations. Detailed study of remote sensing techniques, including field and laboratory experiments and data reduction, analysis, and interpretation. Case studies of demonstrated applications and exami-

nation of potential uses. Selection of optimum sensor(s) and systems for specific geology targets and investigations.

#600 *Seminar on Geologic Remote Sensing*. (2 cr). Review of current literature and research. Use of selected remote sensors and sensing systems for specific geologic studies. Group discussion and individual participation.

COLORADO STATE UNIV., Fort Collins, Colo.

Dept. of Engineering

Imagery Interpretation. Practical application of remote sensing for obtaining and interpreting imagery of significance in engineering.

Dept. of Watershed Resources

#480 *Principles of Remote Sensing of Environment*. (2 cr). A junior-senior elective course discussing the remote sensing equipment currently in use and the energy regimes measured. Primary emphasis is placed on a review of the application of remote sensors in detecting, identifying and monitoring the activities of man and nature.

#680 *Passive Remote Sensing of Natural Resources*. (3 cr). Application of multi-band, color, and ektachrome infrared photography in natural resources. Heaviest emphasis is placed on reflective and thermal scanning and multispectral scanning of natural resources. Surface properties of natural materials and interpretation of data from typical systems are covered.

#682 *Active Remote Sensing of Natural Resources*. (3 cr). Application of radar, microwaves and low frequencies to the collection of natural resource information. Electromagnetic properties of natural materials and interpretation of data from typical systems are covered.

#684 *Automatic Analysis of Remote Sensing Data*. (4 cr). A study of the techniques for data handling and the automatic extraction of natural resource and ecological information from remote sensing imagery using computer analysis.

#697 *Seminar in Remote Sensing*. (2 cr). Remote sensing as a watershed management research technique.

#789 *Advances in Remote Sensing of Natural Resources*. (2 cr). Exploring the concept of remote sensing as a management and research technique. All aspects of current ground or aerial remote sensing projects will be considered from mission planning to image processing and display.

DARTMOUTH COLLEGE, Hanover, N. H.

Dept. of Geography

#72 *Terrain Imagery Interpretation*. Physical, economic, cultural and urban geography of the earth as seen from the air and space. Imagery from radar, infrared scanners and other advanced sensors is utilized, in addition to conventional photography, and evaluated in terms of its ability to contribute to the solution of a variety of problems in the physical and social sciences. Emphasis is on study of actual imagery, supplemented by lectures, discussions, field work and readings.

UNIVERSITY OF DELAWARE, Newark, Del.

College of Marine Studies and Depts. of Geology and Geography

Remote Sensing of Environment.

DREXEL INSTITUTE OF TECHNOLOGY, Philadelphia, Pa.

Dept. of Physics

#P872 *Satellite Observations*. (3 cr). Orbits; attitudes; viewing geometry; earth and atmospheric reflection, emission and transmission of electromagnetic radiation; observed parameters; sensing and other subsystems; data acquisition and processing.

#P873 *Meteorological Interpretation of Satellite Data*. (3 cr). Interpretation of television (visual) and radiometric observations, including cloud types and patterns, vortices and mesoscale features; integration of satellite and conventional data.

#N765 *Satellite Applications*. (3 cr). Satellite orbits; sensor view geometry and data acquisition; atmospheric radiation; analysis, interpretation and application of data.

EAST TENNESSEE STATE UNIV., Johnson City, Tenn.

Dept. of Geography

#4817 *Interpretation of Remote-Sensor*

Images. (3 cr). A study of types of images produced by various electromagnetic sensors and their interpretation. These sensors include, among others, multi-lens photography, color photography, infra-red, and radar.

FRESNO STATE COLLEGE, Fresno, Calif.

Dept. of Geography

#113 *Advanced Aerial Photo Interpretation and Remote Sensing of the Environment.* (3 cr). Interpretation of airborne and orbital imagery: panchromatic, color, infrared, color infrared, radar, multispectral.

UNIV. OF HAWAII, Honolulu, Hawaii

Dept. of Geography

#370 *Airphoto and Image Interpretation.* (2 cr). Quantitative and qualitative interpretation of photographic, infrared, radar imagery. Use of aerial photography, space photography, other remote sensors as tools for research in physical and social sciences.

UNIV. OF IDAHO, Moscow, Idaho

Dept. of Geography

#452 *Advanced Cartography and Remote Sensing.* (2 cr). Scribing, reproduction, color, infrared, thermal, and radar imagery, airbrush, computer cartography and model construction.

UNIV. OF ILLINOIS, Urbana-Champaign, Ill.

Dept. of Geography

#378 *Descriptive Interpretation of Remote Sensors.* (4 cr). Descriptive interpretation of remote-sensing images with emphasis on interpretation of aerial photographs. Applications of aerial photography and photographic interpretations to the solution of problems in the major field of the individual student.

UNIV. OF KANSAS, Lawrence, Kan.

Dept. of Electrical Engineering

#331 *Remote Sensing Devices.* (3 cr). A course dealing with the principles of remote sensing in the ultraviolet, infrared, and microwave regions of the electromagnetic spectrum. Topics to be discussed are: theoretical concepts of energy emission, techniques for the detection of this energy, and detection devices commonly used.

Dept. of Geography

#190 *Fundamentals of Remote Sensing of Environment.* (3 cr). A systematic study of multiband spectral reconnaissance of the environment. Emphasis is given to multispectral photography, infra-red and microwave scanning systems and multi-frequency radar systems and their uses.

UNIV. OF KENTUCKY, Lexington, Ky.

Dept. of Geography

#635 *Fundamentals of Remote Sensing of Environment.* (3 cr). A systematic study of the application of remote sensors in geographic investigation with particular reference to integrated landscape analysis, land use classification, cluster analysis, and multisensor survey of physical environments.

LONG ISLAND UNIVERSITY, Greenvale, N.Y.

Dept. of Marine Science

#682 *Marine Instrumentation.* A detailed study of the development and design of marine instruments with emphasis on electronic sensor techniques and recording and processing of the data obtained. The course is oriented toward those students who require a detailed knowledge of instrument operation either to pursue development or research activities in the area of marine instrumentation.

LOUISIANA STATE UNIV., Baton Rouge, La.

Dept. of Geography

#145 *Remote Sensing: Sensors and Applications.* (3 cr). A lecture-lab course structured around understanding (1) fundamentals of basic energy and matter relationships, (2) the working principles of the primary remote sensors, and (3) the geoscience applications of remote sensing.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, Mass.

Dept. of Earth and Planetary Sciences

#12.141 *Remote Sensing of the Earth.* (3 cr). A review and discussion of methods and motives for studying the earth's surface from airplanes, balloons, and spacecraft. The application of remote sensing techniques to problems of geology, geophysics, resources, ecology and environment preservations.

Dept. of Electrical Engineering

#6.39 *Image Transmission Systems.* (3

cr). Efficient design of image transmission systems, which differ from other information systems both in the multi-dimensional nature of the inputs and the destination of the outputs and therefore depend on a study of the properties of pictures, the properties of observers, and the effect of the parameters of the system or the quality of the transmission. Topics including historical developments, mathematical description of images, objective measures of picture quality, scanning and quantizing, picture processing and coding, color systems and relevant properties of human vision.

#6.501 *Principles of Environmental Sensing*. (3 cr). Physical and physical chemical principles underlying detection of atmospheric pollutants. Types of pollutant, their origin, stability, and toxicity: gases, aerosols, and particulates. Optical absorption methods: electronic, vibrational and rotational molecular states; laser sources; tuneable infrared lasers; detectors; light scattering techniques; Raman scattering. Principles and applications of chromatography. Discussions of existing and proposed detection systems.

#6.613 *Image Processing*. (3 cr). Basic digital computer, optical and electro-optical image processing techniques with applications to image quality enhancement, pattern recognition, and efficient coding of pictures for storage and transmission. Two-dimensional Fourier analysis. Nature of light-coherence and polarization. Geometrical optics and projective transformations. Diffraction theory. Optical Fourier transform and spatial filtering. Holography. Computer generation of optical spatial filters and holograms. Film scanners. Image digitizers—sampling and quantization. Digital computer Fourier transform and linear filtering. Nonlinear operations and techniques pertaining to pattern recognition. Applications.

UNIV. OF MICHIGAN, Ann Arbor, Mich.

Dept. of Forestry

#518 *Remote Sensing of Environment*. (3 cr).

UNIV. OF MINNESOTA, Minneapolis, Minn.

Dept. of Forestry

#146 *Remote Sensing of Natural Resources*. (3 cr). Photogrammetric sys-

tems, flight planning, contracting, contract inspection, advanced photo interpretation, mapping and measurement problems.

Dept. of Geography

#183 *Elements of Remote Sensing*. (3 cr). Consideration of the theory, information content, and geographical interpretation of imaging systems which sense in non-visible portion of the electromagnetic spectrum.

UNIV. OF MONTANA, Missoula, Mont.

Dept. of Forestry

#451 *Aerial Remote Sensing*. (3 cr).

UNIV. OF NEVADA, Reno, Nev.

Dept. of Geology

#904 *Remote Sensing of Environment*. (3 cr). Principles applied to gathering of data for agriculture, geography, geology, hydrology, and oceanography from air/space platforms. Instrumentation is considered, data interpretation emphasized.

STATE UNIV. OF NEW YORK AT BINGHAMTON

Dept. of Geography

#227 *Remote Sensing of the Environment*. Analysis of principles and techniques of remote electromagnetic sensing including photography, infrared, radar imagery. Emphasis on geographic research through human and automated interpretation of physical and cultural data from aerial imagery. Introduction to photogrammetric theory and applications.

UNIV. OF OREGON, Eugene, Ore.

Dept. of Geography

#484 *Aerial Photo Interpretation and Remote Sensing*. (3 cr). Introduction to the use of aerial photographs and other forms of imagery.

PURDUE UNIV., Lafayette, Ind.

Dept. of Forestry and Conservation

#558 *Remote Sensing of Natural Resources*. (3 cr). Applications of remote sensor systems in forestry, conservation, agriculture, and other discipline areas. Interpretation of color infrared film, thermal and multispectral scanner imagery, radar, and multiband photographic data. Study of spectral characteristics of vegetation, soils, water, and other materials.

UNIVERSITY OF RHODE ISLAND, Kingston, R.I.

Dept. of Electrical Engineering/Photo Electronics Section.

Principles of Remote Sensing. Topics include radiation processes, film properties, image quality, remote sensing devices and techniques; and applications in meteorology, oceanography, agriculture, hydrology, geology, and data processing.

ST. LOUIS UNIV., St. Louis, Mo.

Dept. of Geophysics and Geophysical Engineering

#261 *Satellite Meteorology.* (3 cr). Lectures on satellite instrumentation. Lectures and exercises in rectification, analysis and interpretation of satellite radiation measurements and cloud photographs. The use of these data in the solution of specific meteorological problems.

SAN DIEGO STATE COLLEGE, San Diego, Calif.

Dept. of Geography

#187 *Remote Sensing of the Environment.* (3 cr). Multiband spectral reconnaissance of the environment. Emphasis on multi-spectral photography, infrared, microwave scanning systems and multi-frequency radar systems and their uses in the study of cultural and bio-physical phenomena.

#188 *Advanced Remote Sensing of the Environment.* (3 cr). Current research in geographic remote sensing and related fields. Applications of remote sensing in the study of man's cultural and bio-physical environment. Practice in planning, design, execution and interpretation of remote sensing studies.

#288 *Seminar in Remote Sensing of the Environment.* (3 cr). The use of remote sensing techniques in the study of man's cultural and bio-physical environment.

STANFORD UNIV., Stanford, Calif.

Dept. of Mineral Engineering

#296B *Airborne Exploration: Infrared and Radar.* (3 or 4 cr). Examination of physics of relationship between ultraviolet, visible, infrared, microwave, and electromagnetic signatures from rocks, soils, vegetation, and oceanography. Analysis in laboratory of spectral data and imagery with specific reference to exploration for minerals and minerals

fuels, work with infrared instrumentation.

U.S. DEPT. OF AGRICULTURE GRADUATE SCHOOL, Washington, D.C.

Dept. of Technology/Surveying and Mapping

#8-427 *Introduction to Remote Sensing.* (3 cr). Broad spectrum, including photographic systems, infrared scanners, multi-spectral scanners, television systems, radar, scatterometers, and radiometers. Consideration to properties of electromagnetic spectrum, environmental effects, data recording, and data analysis. Practical consideration and review of current satellite and earth resources investigations.

#8-428 *Advanced Remote Sensing.* (3 cr). In-depth discussion of selected topics in remote sensing. Topics to be discussed selected from the following: multi-spectral sensing systems, radar systems, spectral signature analysis techniques, satellite systems, aircraft platforms. Applications of remote sensing to agriculture, cartography, geology, geography, oceanography, and hydrology. Ground investigations to support remote sensing. Several tours of facilities in Washington area.

Dept. of Physical Sciences

#5-407 *Environmental Satellites—Their Application to Meteorology, Oceanography, and Hydrology.* (2 cr). Existing and planned environmental satellite systems, including TIROS, Nimbus, Applications Technology, and Earth Resources Technology Satellites. Orbital geometry; control systems; sensors. Ground coverage; data characteristics. General and specific applications of environmental satellite data to research and operational problems in meteorology, oceanography, and hydrology.

#5-429 *Oceanographic Remote Sensing.* (2 cr). Introduction to principles of remote sensing measurements in microwave, infrared, visible, and near ultraviolet portions of the spectrum. Applications to biological and sea ice observations, and measurements of temperature, salinity, wave, and water color.

U.S. DEPT. OF COMMERCE, NATIONAL BUREAU OF STANDARDS, Gaithersburg, Md.

Colloquium: Environmental Instrumentation. A seminar series on environmental

instrumentation will emphasize the applications of modern instrumentation to a wide variety of environmental problems. The properties of basic semiconductor devices; survey of basic devices suitable for physical parameter measurements; optical devices, acoustic devices, pressure sensitive elements, chemical response, thermal devices; environmental factors affecting measurement devices; stability of measurement devices; accuracy of measurement; data accumulation; noise, correlation and signal extraction; application of computer systems to environmental measurement; data presentation; unattended data accumulators; reliability of measurement systems; design criteria; special problems in measurement and remote data acquisition under severe environmental conditions; biological instrumentation problems. This series will include presentations by people involved in specific problem areas (e.g. air and water pollution measurement).

UNIV. OF WASHINGTON, Seattle, Wash.

Dept. of Civil Engineering

#565 *Remote Sensing of Environment*. (3 cr). Use of aerial photographs and other sensors for terrain evaluation and environmental studies. Factors in system design and target signature evaluation, transportation, construction materials, engineering.

WEST VIRGINIA UNIV., Morgantown, W. Va.

Dept. of Forestry

#226 *Remote Sensing of Environment*. (2 cr). Principles of measurement and interpretation of natural resources and environment from photography, radar, infrared, and microwave imagery.

UNIV. OF WISCONSIN, Madison, Wis.

Dept. of Civil Engineering

#406 *Remote Sensing of the Environment*. (3 cr). Principles, characteristics, and applications of remote sensing of the environment. Emphasis on airborne sensing of the earth's environment. Characteristics and uses of photography, electrooptical scanners, multispectral imagery, radar imagery, passive microwave sensing, and other sensors. Applications to air and water quality studies, geography and geology, highway and traffic engineering, soils mapping and evaluation, urban and regional planning and other fields.

SCHOOLS OFFERING REMOTE SENSING
WITHIN FRAMEWORK OF OTHER COURSES

UNIV. OF ARIZONA, Tucson, Ariz. Dept. of Watershed Management, *Aerial Photography Interpretation* (2 cr).

UNIV. OF CALIFORNIA at Santa Barbara. Dept. of Geography, *Geographic Photo Interpretation* (4 cr).

COLORADO SCHOOL OF MINES, Golden, Colo. Dept. of Geophysical Engineering, *Airborne Geophysical Prospecting* (2 cr).

COLUMBIA UNIV., New York, N. Y. Dept. of Geography, *Cartography* (3 cr).

CORNELL UNIV., Ithaca, N. Y. Dept. of Civil Engineering, *Advanced Physical Environment Evaluation* (3 cr).

DUKE UNIV., Durham, N. C. School of Forestry, *Interpretation of Aerial Photographs* (3 cr).

FLORIDA ATLANTIC UNIV., Boca Raton, Fla. Dept. of Geography, *Special Topics in Geography* (4 cr).

UNIV. OF GEORGIA, Athens, Ga. Dept. of Geography, *Use and Interpretation of Aerial Photos* (5 cr).

HUMBOLDT STATE COLLEGE, Arcata, Calif. Dept. of Forestry, *Advanced Principles of Photogrammetry and Aerial Photo Interpretation* (3 cr).

UNIV. OF IDAHO, Moscow, Ida. Dept. of Geology, *Advanced Photogeology* (3 cr).

IOWA STATE UNIV., Ames, Iowa. Dept. of Civil Engineering, *Airphoto Interpretation of Engineering Soils* (4 cr).

MICHIGAN STATE UNIV., East Lansing, Mich. Dept. of Geography, *Aerial Photographic Interpretation* (4 cr).

NORTHERN ARIZONA UNIV., Flagstaff, Ariz. Dept. of Forestry, *Interpretation of Aerial Photographs* (3 cr).

OREGON STATE UNIV. Corvallis, Ore. Dept. of Forestry, *Aerial Photo Interpretation* (3 cr).

STANFORD UNIV., Stanford, Calif. Dept. of Mineral Engineering, *Airborne Exploration: Photogeologic Techniques* (3 cr).

STEPHEN F. AUSTIN STATE UNIV., Nacogdoches, Texas. Dept. of Forestry, *Advanced Photogrammetry* (3 cr).

UNIV. OF TEXAS, Austin, Texas. Department of Geography, *Seminar in Cartography* (var. cr).

UNIV. OF WISCONSIN, Madison, Wis. Department of Meteorology, *Intermediate Synoptic Laboratory* (3 cr).