Symposium Proceedings

# MACHINE PROCESSING OF REMOTELY SENSED DATA

June 21-23, 1977

IEEE Catalog No.
77 CH 1218-7 MPRSD

Laboratory for Applications of Remote Sensing
Purdue University West Lafayette, Indiana

# THE SYMPOSIUM AT A GLANCE

| TUESDAY, JUNE 21 | | WEDNESDAY, JUNE 22 | | THURSDAY, JUNE 23 | |
|---|---|---|---|---|---|
| Time | Event and Location | Time | Event and Location | Time | Event and Location |
| 8:00-9:00 | Registration - East Foyer (All events will occur in Stewart Center unless otherwise noted) | 8:15-9:45 | 5.1 PROCESSING SYSTEMS I<br>Room 210<br>5.2 SCENE MODELING<br>Room 214 | 8:15-9:45 | 8.1 DATA ANALYSIS II: CLASSIFICATION METHODS AND SYSTEMS<br>Room 210<br>8.2 APPLICATIONS OF MACHINE PROCESSING TO LAND USE MAPPING I<br>Room 214 |
| 9:00-10:45 | 1.1 PLENARY SESSION<br>Fowler Hall | 9:45-10:15 | Break | 9:45-10:15 | Break |
| 10:45-11:00 | Break | 10:15-11:45 | 6.1 PROCESSING SYSTEMS II<br>Room 210<br>6.2 APPLICATIONS OF MACHINE PROCESSING TO HYDROLOGY/GEOLOGY<br>Room 214 | 10:15-11:45 | 9.1 DATA ANALYSIS III: CLASSIFICATION METHODS AND SYSTEMS<br>Room 210<br>9.2 APPLICATIONS OF MACHINE PROCESSING TO LAND USE MAPPING II<br>Room 214 |
| 11:00-11:45 | Discussion Sessions with Plenary Speakers<br>Fowler Hall, Rooms 210 and 214 | | | | |
| 12:00-1:25 | Lunch | 12:00-1:25 | Lunch | 12:00-1:25 | Lunch |
| 1:30-3:00 | 2.1 PREPROCESSING I<br>Room 210<br>2.2 APPLICATIONS OF MACHINE PROCESSING TO AGRICULTURE I<br>Room 214 | 1:30-3:00 | 7.1 DATA ANALYSIS I: NONPARAMETRIC CLASSIFICATION<br>Room 210<br>7.2 APPLICATION OF MACHINE PROCESSING TO FORESTRY<br>Room 214 | 1:30-3:00 | LARS Open House<br>Flexlab II, Purdue Research Park<br>Informal Discussions with LARS Staff<br>Flexlab I, Purdue Research Park |
| 3:00-3:30 | Break | | | | |
| 3:30-5:00 | 3.1 PREPROCESSING II<br>Room 210<br>3.2 APPLICATIONS OF MACHINE PROCESSING TO AGRICULTURE II<br>Room 214 | 4:00-5:30 | Hyde Park Corner Discussion Session<br>The Trails | | |
| | | 6:00-8:00 | Banquet<br>The Trails | | |
| 7:30-9:30 | 4.1 RESEARCH FRONTIERS: MACHINE PROCESSING<br>Room 210<br>4.2 RESEARCH FRONTIERS: APPLICATIONS<br>Room 214 | | | | |

Fourth Annual Symposium
on

# Machine Processing of Remotely Sensed Data

The Laboratory for Applications of Remote Sensing

Purdue University
West Lafayette, Indiana

June 21-23, 1977

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## PROCEEDINGS OF THIS AND PRIOR SYMPOSIA

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1973 CH 0834-2 GE
*
1975 CH 1009-0-C
1976 CH 1103-1 MPRSD
1977 CH 1218-7 MPRSD

* There was no symposium in 1974.

# FOREWORD

These Proceedings serve as the written record of the Fourth Symposium on Machine Processing of Remotely Sensed Data. It contains the full text of the long paper presentations and abstracts of the short papers. Attendees of the symposium will realize however that no written record can do an adequate job of recording the information exchange that takes place on a more informal basis -- luncheon, coffee break and other conversations with the authors, session chairmen, symposium committee members and fellow attendees; discussions stimulated by questions from the audience; or controversial comments exchanged at the Hyde Park Corner session. To stimulate a continuing interchange of ideas between symposium attendees and readers of these Proceedings we have included the names and addresses of session organizers, session chairmen, and paper authors.

A large measure of the success of this symposium goes to the groups and organizations that co-sponsor this symposium with the Laboratory for Applications of Remote Sensing. Our program committee members were selected for their dual qualifications of subject expertise and affiliation with one or more of our co-sponsors. As you page through the Proceedings you will note that many of the session organizers and chairmen hold responsible positions within the co-sponsoring organizations.

As you examine the session titles you will note that there are two main thrusts carried throughout the program -- sessions reporting on machine processing research and techniques, i.e., sessions in which the primary end product is an algorithm or computer hardware, and sessions centered around the utilization of machine processing hardware/software for the solution of particular remote sensing applications problems.

The cooperation of the contributing authors, session chairmen and session organizers is greatly appreciated. Their help has made it possible to produce the Proceedings in a timely manner thus making them available to symposium attendees at registration time.

Additional copies of the Proceedings may be obtained from the Institute of Electrical and Electronics Engineers, Single Copy Sales, 445 Hoes Lane, Piscataway, New Jersey, 08854. Please refer to catalog number 77CH 1218 - 7 MPRSD.

--John C. Lindenlaub
Symposium Chairman

Dr. Lindenlaub joined the LARS staff in 1969. Prior to that time, his research interests were in the area of statistical communication theory. Dr. Lindenlaub worked in the data handling and analysis area at LARS until June 1974 when the Technology Transfer program area was formed. As program leader he is responsible for the development of education and training materials related to remote sensing and conducting ongoing technology transfer activities such as short courses, visiting scientist programs, and technical symposia. He developed the initial training materials for the LARS Remote Terminal Experiment and co-authored a series of 19 slide-tape studyguide modules on the fundamentals of remote sensing. Dr. Lindenlaub is active professionally having held offices in the Education Research and Methods Division of the American Society of Engineering Education and the Education Group of the Institute of Electrical and Electronics Engineers.

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# 1.1
# Plenary Session

SESSION CHAIRMAN: JOHN C. LINDENLAUB

Dr. Lindenlaub joined the LARS staff in 1969. Prior to that time, his research interests were in the area of statistical communication theory. Dr. Lindenlaub worked in the data handling and analysis area at LARS until June 1974 when the Technology Transfer program area was formed. As program leader he is responsible for the development of education and training materials related to remote sensing and conducting ongoing technology transfer activities such as short courses, visiting scientist programs, and technical symposia. He developed the initial training materials for the LARS Remote Terminal Experiment and co-authored a series of 19 slide-tape studyguide modules on the fundamentals of remote sensing. Dr. Lindenlaub is active professionally having held offices in the Education Research and Methods Division of the American Society of Engineering Education and the Education Group of the Institute of Electrical and Electronics Engineers.

SESSION ORGANIZER: MARION F. BAUMGARDNER

Marion F. Baumgardner obtained a B.S. from Texas Tech University; an M.S., Ph.D. from Purdue University. He currently serves as Program Leader for Earth Resources Research Programs, LARS, Purdue University. Dr. Baumgardner also holds teaching and research appointments in the Agronomy Department at Purdue. He is a Danforth Associate and Fellow of the American Society of Agronomy and Indiana Academy of Sciences; member of Sigma Xi, Gamma Sigma Delta and a dozen national and international scientific societies. Primary research interest is in the relationships between the spectral characteristics and the physical/chemical properties of soils.

# 2.1
# Preprocessing I

SESSION CHAIRMAN: RALPH BERNSTEIN

Ralph Bernstein has a BSEE and MSEE from the University of Connecticut and Syracuse University respectively, and joined IBM in 1956. He was a Principal Investigator on the Landsat-1 program. The title of his investigation was "Precision Processing (Scene Correction) of ERTS Data Using Digital Image Processing Technology. In this investigation he demonstrated the feasibility and accuracy of digitally correcting Landsat Multispectral Scanner and Return Beam Vidicon data. He received the NASA Medal for Exceptional Scientific Achievement for this effort. During his career he has been involved in numerous image processing R&D activities and geoscience applications. He was instrumental in the development of a computer system for oceanographic data acquisition, processing and sensor control. Mr. Bernstein has written a number of technical papers, is a contributor to several books, and has several patents granted and published.

SESSION ORGANIZER: CLARE D. MCGILLEM

Clare D. McGillem, B.S.E.E., University of Michigan, M.S.E. and Ph.D., Purdue University, worked with Diamond Chain Company, Inc., U.S. Naval Avionics Facility in Indianapolis, various divisions of General Motors, concluding with Section Head in the Land Operations Dept. Lunar Program Manager and Executive Engineer, before joining the faculty of Purdue University. Presently he is Professor of Electrical Engineering. From 1968 to 1972 he served as Director of the Engineering Experiment Station and Associate Dean of Engineering. Dr. McGillem is active in teaching, research and consulting. He is co-author of three widely used textbooks on signal and system theory. He holds a number of patents and is a Fellow of IEEE, past president of the IEEE Geoscience Electronics Group and past chairman of IEEE Central Indiana Section.

# 2.2
# Applications of Machine Processing to Agriculture I

SESSION CHAIRMAN: DONALD P. FRANZMEIER

D.P. Franzmeier earned the B.S. and M.S. degrees from the University of Minnesota and the Ph.D. from Michigan State University, all in Soil Science. He mapped soils in Minnesota, Michigan, and Indiana. From 1962 to 1967 he was with the Soil Conservation Service Soil Survey Laboratory in Beltsville, Md., and in 1967 he joined the Agronomy staff at Purdue. Here he teaches and does research in Soil Genesis and Classification and represents Purdue in the Cooperative Soil Survey. Some of his research involves Remote Sensing as it relates to soils of Indiana as well as other parts of the world.

SESSION ORGANIZER: JOHN B. PETERSON

Dr. Peterson received his B.S. from Oregon State University; M.S., Ph.D., Soil Science, from Iowa State University. He was a Rockefeller Fellow, Geology, at the University of California, Berkeley. He received the Soil Science Research Award from the American Society of Agronomy; he was also elected President, Fellow and Honorary Member. He served as a Professor of Soil Science at Iowa State University; Head, Dept. of Agronomy, Purdue University; and consultant on soil science, land use and research administration for American-based foundations and foreign governments.

# 3.1
# Preprocessing II

SESSION CHAIRMAN: RALPH BERNSTEIN

Ralph Bernstein has a BSEE and MSEE from the University of Connecticut and Syracuse University respectively, and joined IBM in 1956. He was a Principal Investigator on the Landsat-1 program. The title of his investigation was "Precision Processing (Scene Correction) of ERTS Data Using Digital Image Processing Technology. In this investigation he demonstrated the feasability and accuracy of digitally correcting Landsat Multispectral Scanner and Return Beam Vidicon data. He received the NASA Medal for Exceptional Scientific Achievement for this effort. During his career he has been involved in numerous image processing R&D activities and geoscience applications. He was instrumental in the development of a computer system for oceanographic data acquisition, processing and sensor control. Mr. Bernstein has written a number of technical papers, is a contributor to several books, and has several patents granted and published.

SESSION ORGANIZER: CLARE D. MCGILLEM

Clare D. McGillem, B.S.E.E., University of Michigan, M.S.E. and Ph.D., Purdue University, worked with Diamond Chain Company, Inc., U.S. Naval Avionics Facility in Indianapolis, various divisions of General Motors, concluding with Section Head in the Land Operations Dept., Lunar Program Manager and Executive Engineer, before joining the faculty of Purdue University. Presently he is Professor of Electrical Engineering. From 1968 to 1972 he served as Director of the Engineering Experiment Station and Associate Dean of Engineering. Dr. McGillem is active in teaching, research and consulting. He is co-author of three widely used textbooks on signal and system theory. He holds a number of patents and is a Fellow of IEEE, past president of the IEEE Geoscience Electronics Group and past chairman of the IEEE Central Indiana Section.

# 3.2
# Applications of Machine Processing to Agriculture II

SESSION CHAIRMAN: JAMES E. NEWMAN

James E. Newman is Professor of Agronomy - Bioclimatology, Dept. of Agronomy and Dept. of Geosciences, Purdue University. Degrees from Ohio State University; advanced studies at Purdue University and University of Wisconsin. Author of numerous semi-technical, technical and review papers; editor translated textbooks, Office of Technical Services. Editorial Board International Journal of Agricultural Meteorology; Fellow in AAAS; 1965 chairman of ASA Division A-3; 1965-66. Visiting Prof., University of California, Riverside Soils and Crops Award, '65. Faculty chairman, School of Agriculture Study Committee for developing curriculum in Meteorology and Climatology, 1966-67. Elected "fellow" ASA 1968. Visiting Scientist, University of Alaska, Institute of Agricultural Sciences, Summer of 1970; "fellow," Indiana Academy of Science 1972. Editor-in-Chief, Agricultural Meteorology 1974-77.

SESSION ORGANIZER: JOHN B. PETERSON

Dr. Peterson received his B.S. from Oregon State University; M.S., Ph.D., Soil Science, from Iowa State University. He was a Rockefeller Fellow, Geology, at the University of California, Berkeley. He received the Soil Science Research Award from the American Society of Agronomy; he was also elected President, Fellow and Honorary Member. He served as a Professor of Soil Science at Iowa State University; Head, Dept. of Agronomy, Purdue University; and consultant on soil science, land use and research administration for American-based foundations and foreign governments.

# 4.1
# Research Frontiers: Machine Processing

SESSION MODERATOR: C. ROYAL SAND

C. Royal Sand obtained a B. S. in mathematics at Nebraska State College and performed graduate work in mathematics and computer science at the University of Missouri at Columbia, Missouri. While at the University of Missouri he received extensive experience in systems analysis and system programming, principally in the areas of time sharing and problem oriented software systems. He was responsible for system coordination and user communications in the Campus Network facilities. He taught high school mathematics and science prior to his Missouri University experience and computer science at the University.

# 4.2
# Research Frontiers: Applications

SESSION MODERATOR: RICHARD P. MROCZYNSKI

Richard P. Mroczynski received a B.S.F. in Forest Production and an M.S. in Forestry from the University of Illinois. He joined LARS in 1969 and has been involved with photo-interpretation and LANDSAT Analysis. He is a member of the Society of American Foresters, active in that organization's Working Group on Photogrammetry and Remote Sensing. In addition, he has served in various capacities with the American Society of Photogrammetry, and is a member of the American Forestry Association and American Management Association.

# 5.1
# Processing Systems I

SESSION CHAIRMAN: JOHN J. QUANN

John J. Quann has been with NASA since graduating from Manhatten College, Riverdale, N.Y., in 1959. From 1970 to 1974 he was the Head of the Data Analysis Branch, Laboratory for Planetary Atmospheres. From 1974 to present he has been the Chief of the Information Extraction Division. A principle function of this division is the processing and analysis of remotely sensed earth observation data obtained from spacecraft and the conversion of this data into products such as land use or crop maps, temperature maps, severe storm analysis, water run-off potential, sea surface topography, wind vector fields, ozone profiles, etc. which are directly useable by scientists engaged in the monitoring and analysis of the earth's environment. A major part of this activity involves the computer processing of imagery.

SESSION ORGANIZER: TERRY L. PHILLIPS

Terry L. Phillips, Deputy Director of LARS, received his B.S. and M.S. degrees in Electrical Engineering from Purdue in 1964 and 1966 respectively. He has held positions in Purdue's EE Department, National Cash Register Co., and the U.S. Navy. He has also consulted for the Computer Sciences Corp., the U.S. and Iowa Geological Surveys, and the Colorado Intergovernmental ADP Council. He is engaged in the development of Data Handling and Processing Systems and has been active in the application of these systems for remote sensing since 1966. Mr. Phillips is the author of several publications in the area of remote sensing, data systems, information systems, and earth resources, and he is responsible for the design and implementation of LARSYS. Recognized by NASA for the creative development of technology, he is principal investigator of several of LARS' contracts. Mr. Phillips is a member of IEEE, the Association of Computer Machinery, Tau Beta Pi, and Eta Kappa Nu.

# 5.2
# Scene Modeling

SESSION CHAIRMAN: VERN C. VANDERBILT

V. C. Vanderbilt earned the B.S., M.S., and Ph.D. degrees in Electrical Engineering from Purdue University. As an undergraduate he worked for the Department of Agronomy at Purdue assisting in a study of factors relating to crop growth. During this period, he designed, constructed and calibrated twenty thermopile net radiometers. As a graduate student at LARS, he designed and constructed numerous electro-optical devices including a portable spectrometer. He participated in LARS field measurement activities and designed experiments to measure the angular reflectance characteristics of crop canopies. His Ph.D. thesis involved a laser technique for characterizing the geometry of plant canopies. His post doctoral research at LARS includes geometrical and spectral modeling of plant canopies.

SESSION ORGANIZER: JOHN C. LINDENLAUB

Dr. Lindenlaub joined the LARS staff in 1969. Prior to that time, his research interests were in the area of statistical communication theory. Dr. Lindenlaub worked in the data handling and analysis area at LARS until June 1974 when the Technology Transfer program area was formed. As program leader he is responsible for the development of education and training materials related to remote sensing and conducting ongoing technology transfer activities such as short courses, visiting scientist programs, and technical symposia. He developed the initial training materials for the LARS Remote Terminal Experiment and co-authored a series of 19 slide-tape studyguide modules on the fundamentals of remote sensing. Dr. Lindenlaub is active professionally having held offices in the Education Research and Methods Division of the American Society of Engineering Education and the Education Group of the Institute of Electrical and Electronics Engineers.

# 6.1
# Processing Systems II

SESSION CHAIRMAN: JOHN J. QUANN

John J. Quann has been with NASA since graduating from Manhatten College, Riverdale, N.Y., in 1959. From 1970 to 1974 he was the Head of the Data Analysis Branch, Laboratory for Planetary Atmospheres. From 1974 to present he has been the Chief of the Information Extraction Division. A principle function of this division is the processing and analysis of remotely sensed earth observation data obtained from spacecraft and the conversion of this data into products such as land use or crop maps, temperature maps, severe storm analysis, water run-off potential, sea surfact topography, wind vector fields, ozone profiles, etc. which are directly useable by scientists engaged in the monitoring and analysis of the earth's environment. A major part of this activity involves the computer processing of imagery.

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# 6.2
# Applications of Machine Processing to Hydrology/Geology

SESSION CHAIRMAN: VIRGINIA CARTER

Virginia Carter is a biologist with the U.S. Geological Survey, specializing in wetland ecology, remote sensing of wetlands, and spectral reflectance studies of marsh vegetation. Ms. Carter received her B.A. from Swarthmore College and her M.S. from American University. She was a co-investigator on both a Landsat and SKYLAB investigation of wetland ecology. She is currently utilizing high altitude photography and Landsat digital data for studies of wetland classification, mapping and hydrology. She is a co-author of the new national wetland classification system in cooperation with the Fish and Wildlife Service.

SESSION ORGANIZER: ROGER M. HOFFER

Dr. Hoffer has been involved full time in remote sensing research and teaching since 1964, and was a co-founder of LARS in 1966. His research interests have focused on the interpretation and analysis of multispectral scanner data and color infrared photography, with emphasis on forestry, water resource, and land use applications. Professor Hoffer teaches three different courses on remote sensing and natural resources. He has served as a principal investigator on LANDSAT, Skylab, and several other remote sensing projects; has authored over 80 scientific papers and publications on remote sensing; and has lectured and worked on remote sensing projects in a number of countries throughout South America, Asia, and Europe. He is a member of the Society of American Foresters, the American Society of Photogrammetry, and several other professional and honorary societies.

# 7.1
# Data Analysis I:
# Nonparametric Classification

SESSION CHAIRMAN AND ORGANIZER: PHILIP H. SWAIN

Philip H. Swain is a professor in the School of Electrical Engineering, Purdue University, and program leader for data processing and analysis research at the University's Laboratory for Applications of Remote Sensing (LARS). B.S. Lehigh University; M.S., Ph.D., Purdue University. Prof. Swain has been affiliated with LARS since its inception in 1966 and has contributed extensively to the development of data processing methods and systems for the management and analysis of remote sensing data. His areas of specialization include theoretical and applied pattern recognition and methods of artificial intelligence.

# 7.2
# Applications of Machine Processing to Forestry

SESSION CHAIRMAN: JAMES A. SMITH

Dr. Smith is an Associate Professor in the College of Forestry and Natural Resources at Colorado State University where he is specializing in the utilization of computer-assisted techniques for remote sensing applications. Current projects include studies of spectral variability in high elevation forests in Central Colorado and the potential utilization of digitized medium scale color infrared imagery to assessing land cover or condition classes in the S.E. Montana-N.E. Wyoming area. His academic training is in mathematics and physics from the University of Michigan. Between 1964 and 1966 he was employed by the Environmental Research Institute of Michigan. He worked in the Earth Observations Division at NASA/JSC during the summer of 1971. He was Associate Director for research at the Colorado State University Computer Center between 1974 and 1976.

SESSION ORGANIZER: ROGER M. HOFFER

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# 8.1
# Data Analysis II:
# Classification Methods & Systems

SESSION CHAIRMAN: WILLIAM ALFORD

William Alford is the Information Extraction Manager for the Information Transfer Laboratory (Intralab), a NASA/GSFC activity to transfer remote sensing technology to operational users. For the past seven years he has worked with image systems, including the Landsat processing facility (NDPF), and was responsible for the design and implementation of IDAMS, an interactive image analysis system. His previous experience has been communications including satellite telemetry processing and position location systems at GSFC and data collecting and processing systems at the Naval Research Laboratory. He received his B.S. in physics at Clemson University and performed graduate studies in communication theory at Maryland University.

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# 8.2
# Applications of Machine Processing to Land Use Mapping I

SESSION CHAIRMAN: JOHN E. ESTES

John E. Estes, Associate Professor, Department of Geography at the University of California, Santa Barbara received his Ph.D. in Geography from the University of California, Los Angeles in 1969. Dr. Estes has experience in both private industry and government. His areas of specialization include agriculture, land use and water resources applications of remote sensing and the interpretation of remotely sensed data. In addition to more than 60 remote sensing publications Dr. Estes has directed and/or participated in remote sensing workshops for the International Geographical Union and Association of American Geographers. Dr. Estes has received a National Merit Teacher Award from the National Council on Geographic Education, and a presidential citation from the American Society of Photogrammetry.

SESSION ORGANIZER: ROGER M. HOFFER

Dr. Hoffer has been involved full time in remote sensing research and teaching since 1964, and was a co-founder of LARS in 1966. His research interests have focused on the interpretation and analysis of multispectral scanner data and color infrared photography, with emphasis on forestry, water resource, and land use applications. Professor Hoffer teaches three different courses on remote sensing and natural resources. He has served as a principal investigator on LANDSAT, Skylab, and several other remote sensing projects; has authored over 80 scientific papers and publications on remote sensing; and has lectured and worked on remote sensing projects in a number of countries throughout South America, Asia, and Europe. He is a member of the Society of American Foresters, the American Society of Photogrammetry, and several other professional and honorary societies.

# 9.1
# Data Analysis III:
# Classification Methods & Systems

SESSION CHAIRMAN: WILLIAM ALFORD

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# 9.2
# Applications of Machine Processing to Land Use Mapping II

SESSION CHAIRMAN: RONALD L. SHELTON

Co-designer, New York State Land Use and Natural Resources Inventory and similar projects in Hudson River Valley, Puerto Rico, El Salvador. Remote sensing applications research for NASA and USDA since 1966. Chairman, Geography and Land Use Committee, American Society of Photogrammetry. Professor of environmental policy and planning. Department of Resource Development, Michigan State University.

SESSION ORGANIZER: ROGER M. HOFFER

Dr. Hoffer has been involved full time in remote sensing research and teaching since 1964, and was a co-founder of LARS in 1966. His research interests have focused on the interpretation and analysis of multispectral scanner data and color infrared photography, with emphasis on forestry, water resource, and land use applications. Professor Hoffer teaches three different courses on remote sensing and natural resources. He has served as a principal investigator on LANDSAT, Skylab, and several other remote sensing projects; has authored over 80 scientific papers and publications on remote sensing; and has lectured and worked on remote sensing projects in a number of countries throughout South America, Asia, and Europe. He is a member of the Society of American Foresters, the American Society of Photogrammetry, and several other professional and honorary societies.

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## ABOUT THE COVER

The cover photo is a composite image of a portion of a Level 1 LARSYS "ECHO" classification of the Lafayette area. The image is a combination of a computer printout and a picture from the LARS digital display. The information is presented in this fashion to highlight the capability of LANDSAT digital data and computer-aided analysis techniques. (LANDSAT Scene ID 1069-15585, LARS run Number 72053609, September 30, 1972.)