USRA

UNIVERSITIES SPACE RESEARCH ASSOCIATION

FINAL TECHNICAL REPORT FOR

UNIVERSITIES EARTH SYSTEM SCIENTISTS PROGRAM

SUBMITTED TO THE

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UNIVERSITIES SPACE RESEARCH ASSOCIATION
300 D STREET SW, SUITE 801
WASHINGTON, DC 20024

JOHN E. ESTES
PROGRAM DIRECTOR

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1.0 TECHNICAL SUMMARY

1.1. INTRODUCTION

This document constitutes the final technical report for National Aeronautics and Space Administration (NASA) Grant NAGW-3173. This grant was instituted to provide for the conduct of research under the Universities Space Research Association's (USRA's) Universities Earth System Scientist Program (UESSP) for the Office of Mission to Planet Earth (OMTPE) at NASA Headquarters.

The Universities Space Research Association is a private, nonprofit corporation that was organized in 1969 by the National Academy of Sciences at the request of NASA. Upon incorporation, the Association was vested in a consortium of universities. The consortium now consists of eighty-one member universities. The Association is chartered to provide a means through which universities and other research organizations may cooperate with one another, with the government of the United States, and with other organizations, toward the development of knowledge associated with space science and technology. The Association is further chartered to acquire, plan, construct, and operate laboratories and other facilities, and formulate policies for them, under contract with the government of the United States, for research, development and education associated with space science and technology. In fulfillment of its charter, the Association works to advance research and education relevant to the nation's civil space and aerospace programs through university-coupled activities: (1) as a principal agent for furthering the partnership role of universities; (2) as a recognized leader in selected domains of innovation and research, and (3) as a valued contributor to the advancement of science engineering, and related education.

The work of the Association is designed to serve the entire community. Membership by a university in the Association is undertaken as a responsibility to the community to participate organizationally in the oversight of USRA activities. The corporate authority of the Association is vested in its member universities. Each of these institutions delegates its authority to a representative who serves on USRA's Council of Institutions. This council elects representatives to the USRA board of trustees. The board of trustees establishes policy for USRA, monitors all USRA activities, and is responsible for all funds in the custody of the corporation. The board appoints science councils for each activity and specifically delegates to them authority to act as a scientific board of directors for that activity. Each science council is balanced to provide coverage for the multiple discipline areas of the particular institute or program for which it is responsible. Members are selected on the basis of their scientific area of expertise, and their standing within the academic community.

Background on UESSP participants and their activities on this grant follows. The Appendix is a listing of publications and presentations made by the individual researchers during the period performance of this grant.

1.2 STATEMENT OF WORK

USRA was tasked with the following requirements in support of the Universities Earth System Scientists Programs:

1. Bring to OMTPE fundamental scientific and technical expertise not currently resident at NASA Headquarters covering the broad spectrum of Earth sciences disciplines.

2. Conduct basic research in order to help establish the state of the science and technological readiness, related to NASA issues and requirements, for the following, near-term, scientific uncertainties and data/information needs in the areas of global climate change, clouds and radiative balance, sources and sinks of greenhouse gases and the processes that control them, solid earth, oceans, polar ice sheets, land-surface hydrology, ecological dynamics, biological diversity, and sustainable development.

3. Evaluate the scientific state-of-the-field in key selected areas and to assist in the definition of new research thrusts for missions, including those that would incorporate the long-term strategy of the U.S. Global Change Research Program (USGCRP). This will, in part, be accomplished by study and evaluation of the basic science needs of the community as they are used to drive the development and maintenance of a global-scale observing system, the focused research studies, and the implementation of an integrated program of modeling, prediction, and assessment.

4. Produce specific recommendations and alternative strategies for OMTPE that can serve as a basis for interagency and national and international policy on issues related to Earth sciences.

1.3. SCIENTIFIC OBJECTIVES

NASA centers and their associated research communities have considerable experience and expertise in the conduct of basic process level research and the development of integrated modeling and predictive capabilities. NASA field centers such as the Goddard Space Flight Center, the George C. Marshall Space Flight Center, the Jet Propulsion Laboratory, and the Ames Research Center have well-established scientific teams already involved in global change and related research.

Program assessment and policy planning activities are primarily focused at NASA Headquarters. It is in these areas that USRA felt that NASA could benefit from the in depth experience of a carefully selected cadre of scientific personnel who would provide: (1) expertise and a knowledge base not resident within NASA Headquarters, and who would (2) conduct studies, evaluations, assessments, and syntheses of basic scientific, technical, public policy and natural resources management knowledge related to global change and associated research issues. USRA's UESSP scientists were charged with facilitating the exchange of basic research information between the academic and federal science communities. They provided scientific and technical expertise at national and international levels to help determine and guide the research priorities of the OMTPE and the USGCRP. UESSP scientists, interacting with NASA and other federal agency personnel, brought expertise to bear on global change and related earth viewing satellite sensor and data system research issues. Through research, synthesis, evaluation, and assessment of data and information, UESSP scientists provided background research on specific issues to facilitate the work of NASA Headquarters personnel as they sought to define and implement new, or revised, programs at the NASA field centers.

UESSP scientist's research activities focused on specific problems identified by the OMTPE staff that resulted in well-identified deliverables. UESSP scientists conducted research relevant to the state of the science and evaluation of uncertainties and data needs deemed essential by top-level management with the OMTPE. The research involved short-term studies and the results were presented to NASA. Regular reports of progress on these specific research topics were presented to the OMTPE personnel.

For example, in support of NASA, the Environmental Protection Agency, the United Nations Development Programme, and the United Nations Environmental Programme, USRA

assisted in organizing an International Symposium on Core Data Needs for Environmental Assessment and Sustainable Development Strategies. The symposium was held in Bangkok, Thailand, in November 1994. The purpose of the symposium was to: (1) seek consensus on priority environmental assessment and sustainable development issues and the core data sets needed to respond to these issues; (2) define the minimum characteristics of these data in relation to national and international purposes; (3) establish collaborative mechanisms to foster the harmonization of core environmental data; and (4) examine the barriers to general access and use of these data. Sixty-five individuals from 28 nations participated in the symposium, including policy makers, scientists, and researchers from developing and industrialized countries. Also present were representatives from the United Nations, industry, aid-to development agencies, and data suppliers. A two volume report was published in late February 1995. Copies of this report were provided directly to NASA Headquarters.

2.0 PERSONNEL AND ACTIVITIES

2.1 MANAGEMENT AND ADMINISTRATION

Technical management of the overall grant was the responsibility of the Program Director. When the grant was awarded in July 1992, Dr. John Estes of the University of California at Santa Barbara was appointed as Program Director of the Universities Earth System Sciences Program. Dr. Estes worked closely with the scientific and management staff in the Office of Mission to Planet Earth in identifying the specific scientific research and technical areas where scientific expertise was desired, the time frames in which results were needed, and how those reports would be reviewed and disseminated.

Ms. Elizabeth Pentecost was the Deputy Director of the program and reported directly to Dr. Estes. She worked part-time for the operation of the Program and served as the focal point of contact for the scientists on details relating to their tenure, including dislocation/relocation, employee benefits, travel, and time reporting. Ms. Pentecost was also responsible for the financial management at the program level and submitted budgetary data for input into the computerized accounting system at USRA Headquarters. She worked with Dr. Estes in all aspects of the recruiting process and interacted with the OMTPE staff at NASA Headquarters on administrative matters routine in the operation of the program.

2.2 SCIENTIFIC PERSONNEL AND RELEVANT ACTIVITIES

For more than two decades, USRA has fostered harmonious and productive collaborations among USRA, NASA, and the scientific community. USRA's success in responding to the scientific requirements of the Government is largely due to USRA's capability to attract top quality scientists within the United States and from abroad via its network with the university community and its foreign visitor exchange program with the United States Information Agency.

To accomplish the research activities discussed in the previous section, USRA drew upon its network in the university community to bring top scientific talent to USRA's Universities Earth System Sciences Program (UESSP). Whenever possible, scientists from universities were encouraged to come to the UESSP on sabbatical leave or under an arrangement that otherwise maintained their academic status at their home institutions. USRA believed that such an arrangement enhanced the contributions that this program was making to the scientific disciplines supported by the OMTPE. This particular scientific community was inextricably associated with the space program, and NASA science managers needed to have the benefit of expertise not readily available within NASA as they charted the future for the conduct of earth sciences from space. The visiting scientists that came to USRA made this program an ideal model that was wholly consistent with USRA's goal of facilitating collaboration among USRA, NASA and the scientific community.

Professor John Estes served as a USRA Senior Visiting Scientist working as a liaison between NASA and the United States Geological Survey. Professor Estes received his B.A. from San Diego State College in 1962 and his doctorate from the University of California, Los Angeles in 1969. Dr. Estes is a Professor of Geography at the University of California, Santa Barbara and Director of the Remote Sensing Research Unit at UCSB. His research interests focused primarily around the fundamental and applied aspects of the use of remote sensing and geographic information systems (GIS) technology for the analysis of earth resources, image analysis, and the design of knowledge-based systems utilizing artificial intelligence concepts. Dr.

Estes's work has included conducting research/studies for NASA on land use change, crop identification, water demand modeling, and advanced soil moisture conditions. He has over 250 publications ranging from his work on the detection, identification, and monitoring of marine oil spills, to the analysis of agricultural crops and water demand determination and urban expansion, to the preservation of biological diversity and monitoring of environmental pollution, to the development of advanced image analysis procedures and the integration of remote sensing, information systems and expert systems.

Under this Grant, Professor Estes conducted information science studies related to the use of land processes data/information, and developed recommendations of alternative coordination mechanisms involving the land processes data/information systems between the U.S. Geological Survey (USGS) National Mapping Division (NMD) and NASA. Professor Estes travelled with both NASA/OMTPE and USGS/NMD personnel to meet with directors of a number of National Mapping Organizations (NMOs). During these visits, improving exchange of data and better coordination were topics of considerable discussion. Professor Estes also served as the chairman of the Steering Committee for the Bangkok symposium described above. He worked with OMTPE personnel for several years to develop plans for an applied remote sensing research program to compliment OMTPE's basic research and analysis programs. This program was felt to be an essential bridge between basic research and the commercial programs of NASA Code X.

Ms. Nancy Douglas began her appointment in November 1992. She received her B.S. from the Massachusetts Institute of Technology's Earth, Atmospheric and Planetary Sciences Department in 1983 and her M.S. from the Rosenstiel School of Marine and Atmospheric Science at the University of Miami in 1988. She also completed graduate course work in management and information systems at the University of Maryland at College Park in 1995.

Prior to her visiting scientist appointment, Ms. Douglas was a research faculty member at the University of Maryland, College Park. Her primary areas of research included solid earth geophysics, tectonic plate kinematics, and space geodesy and she worked closely with the NASA Satellite Laser Ranging Analysis Group at Goddard Space Flight Center in these areas.

Ms. Douglas was working in the area of information system technologies as they can be applied to make science data more available to the user community. This included work with the Crustal Dynamics Data and Information System (CDDIS) and the International Geosphere-Biosphere Program Data and Information System (IGBP-DIS).

Ms. Douglas accepted a position with MCI in March 1995.

Dr. Kathleen Eisenbeis began her appointment in August 1993. She received her B.A. from East Texas State University in 1970 and her doctorate from the University of Texas at Austin in 1992. Prior to her appointment with USRA, Dr. Eisenbeis was a consultant specializing in public policy, library administration, evaluation, organization, and planning for staffing, collection development and use of government information resources. Her areas of expertise included research methods and collection and dissemination of information by federal agencies.

Dr. Eisenbeis was involved in a study to examine the role of libraries in the dissemination and use of Earth and space science data from the EOSDIS and the Global Change Data and Information System (GCDIS). Libraries and information centers, both within the federal government and the nation as a whole, provide a gateway for the public's access to global change data and information resources. The issue of public access is especially critical in the area of electronic resources on the Internet which are now available only to a select set of users. This research was accomplished in part by working within the Library Information Subgroup of the Intergovernmental Working Group on Data Management for Global Change (IWGDMGC). A

prototype project was conducted by the Library and Information Subgroup in one state using library networks within a variety of educational institutions. The goal was to demonstrate access to and use of the data and information in the GCDIS to educators from the university level to K-12 through library systems. The research also involved evaluating the use and effectiveness of Version Alpha of the GCDIS available to the public through the Internet as of April 1994, describing uses and users of the system, and developing methods for facilitating access to these data for the public through libraries.

Dr. Eisenbeis accepted a position as Director of the Social Science Library and Information Services at Yale University in August 1994.

Mr. George Esenwein began his appointment in May 1993. He received his B.S. from the University of Cincinnati in 1956 and his M.S. from George Washington University in 1968. Mr. Esenwein had over thirty years experience in the development of NASA projects ranging from the Apollo and Saturn V launch vehicle and lunar exploration program to more recent remote sensing space platforms. Before his association with USRA, he worked in research and development activities associated with Spacelab Payloads and instrument development programs including data analysis. Mr. Esenwein was a key member of the science planning/execution team for the major Shuttle mission series named ATLAS. He also worked on the very successful Joint US-USSR Meteor-3/ TOMS program. This included research and technology development activity assessment of the hardware, engineering and science teams. Since the TOMS launch, he participated in the research and development efforts associated with four new instruments on Russian missions. He also worked on the joint program to fly two U.S. science experiments on the Japanese ADEOS/HII mission.

Mr. Esenwein was involved in basic research for the MTPE Global Change Research Flight Program. In this capacity, he was assessing and evaluating the priorities associated with the wide range of scientific and technical goals and objectives involved in the mission planning and data processing and analysis portion of the Atlas mission series, with special emphasis on the Atlas-3/ CRISTA-SPAS Space Shuttle mission planned for flight in late 1994, and the TOMS Earth Probe missions. He participated in the NASA-RSA MTPE and the NASA-Russian Academy of Science Joint Working Group meeting held in Moscow in mid May. He conducted research in preparation for the proposed joint investigations.

Mr. Esenwein accepted a position with BDM Corporation in October 1994.

Dr. Paul Filmer began his appointment in April 1993. He received his B.Sc. from Caltech in 1985 and his doctorate in Marine Geophysics from the Massachusetts Institute of Technology in 1992. Dr. Filmer maintained an active role in his scientific field, regularly attending professional meetings and international workshops on issues in the earth sciences, and had several scientific articles published.

Dr. Filmer's research was concentrated in three areas: the international implications of information policy on earth science, the policy relevance of current U.S. earth science plans, and the effective use of EOS data in solid earth studies. He studied information policy implications by observing the development of NASA's Earth Observing System Data and Information System (EOSDIS) within the federal government's Global Change Data and Information System (GCDIS) and the international community's International Coordination Working Group (ICWG) and International Earth Observing System (IEOS) frameworks. His research on policy relevance centered on activities initiated by Harvard University and the Consortium for International Earth Science Information Network (CIESIN) in the form of the Commission on Global Environmental Change Information Policy, and other CIESIN-related activities that were tied in to the Human Dimensions of Global Environmental Change Programme (HDP) and the International Geosphere-Biosphere Programme (IGBP). All of these programs sought to use highly networked

computer technologies coupled with remote sensing techniques to provide new research tools for the physical and social sciences. Dr. Filmer researched how the development of these structures and tools could aid decision- and policy-makers.

Dr. Filmer accepted an IPA appointment at the National Science Foundation as Program Director of the InterAmerican Institute for Global Change Research in June 1994.

Dr. Joseph Landsberg, on sabbatical from the Commonwealth (of Australia) Scientific and Industrial Research Organization (CSIRO) Division of Wildlife and Ecology, began his visiting scientist appointment in April 1993. Dr. Landsberg received his B.Sc. from the University of Natal, South Africa in 1961 and his doctorate from the University of Bristol, UK in 1974. He was Director of Natural Resources Management (NRM) for the Murray Darling Basin Commission and was responsible for interaction and collaboration with State agencies and officers in departments concerned with water, land, and the environment. He chaired several committees and had been instrumental in altering the basis on which the inter-state NRM projects are funded. His research interests included ecological research, forest modeling, rain forest ecology, and the physics of forest-environmental interactions. He had numerous publications ranging from his work on grain production, to orchard climatology, to the effects of weather on the growth and production cycles of apple trees, to the role and importance of whole-plant physiology in plant improvement, to research in forest management.

Dr. Landsberg investigated the scope and dimensions of the science issues being addressed in a program concerned with trace gas fluxes and carbon/nitrogen pools in the biosphere, ecosystem function on landscape and regional scales, and links between ecosystem structural properties and function. He provided scientific and technical advice in the evaluation of this program and continues to assess the science content and quality of analysis being accomplished in the conduct of the program.

Dr. Landsberg was also doing basic research, evaluation, and coordination of key scientific and technical issues for the Boreal Ecosystem-Atmosphere Study (BOREAS) program, a major NASA campaign aimed at providing improved information about the biophysical processes in the boreal forests of the world. This campaign included a setting-up and testing period in 1993. Dr. Landsberg made site visits in Canada and took part in the research development and planning activities. He also held discussions with most of the participants in BOREAS to evaluate the degree to which the various scientific aspects of the project were coordinated and the science thrusts effectively implemented.

Dr. Landsberg travelled to various laboratories and sites around the country where NASA-funded research was being carried out. These visits had the dual objective of helping him assess and synthesize work being done, and to evaluate its effectiveness so that Dr. Landsberg could contribute to the current discussions about future directions and emphases for NASA-funded research exploiting the space technology deployed by the agency.

Dr. Landsberg returned to Australia in July 1994 to resume his position at CSIRO.

Dr. Leslie Meredith began his appointment in August 1992. He received his doctorate from the State University of Iowa in 1954. His graduate research involved the first launching of rockets in the Arctic to study auroral processes. He served in various capacities within NASA including heading science and earth observations research programs serving as Assistant Director and Associate Director at Goddard Space Flight Center.

Dr. Meredith's research involved the study of methods to improve interagency cooperation with particular reference to data/information sharing. Issues associated with data sharing are key to the success of MTPE and the USGCRP. This is an area of critical concern in

the EOS era, where there is the need for fundamental research directed towards significant impediments to data sharing being important. Dr. Meredith provided scientific research and technical expertise to the Operation, Data, and Information Systems Branch in its relationship to the Interagency Working Group on Data Management for Global Change (IWGDMGC). The goal of this group was to make it as easy as possible for users to access and use the global change data and information that they need. The IWGDMGC worked toward this goal by both providing an information exchange mechanism for interagency coordination and cooperation and by acting as the global change and information element of the USGCRP. Dr. Meredith provided both strategic scientific and technical advice to NASA for the agency's participation in the IWGDMGC.

Dr. Meredith's research was transferred to USRA's Center of Excellence in Data and Information Sciences (CESDIS) in August 1994.

Mr. D. Wayne Mooneyhan began his appointment in February 1993. Mr. Mooneyhan had a long history of research and development and practical project experience in the analysis and application of remotely sensed data, both in the developed and developing world. In his previous position as Director of the United Nations Environmental Programme/Global Resource Information Database (UNEP/GRID) project, Mr. Mooneyhan was responsible for the planning, development, and management of all UNEP/GRID related activities at the newly opened North America GRID Center in Sioux Falls, South Dakota. These activities included the development of datasets for North America as a part of the global datasets being assembled by GRID for UNEP and environmental studies for the continent as part of UNEP's global state-of-the-environment assessment. Mr. Mooneyhan also served as Director of UNEP/GRID Asia Pacific Region in Bangkok, Thailand, and prior to that established the primary GRID data processing center in Geneva, Switzerland. In part, because of this unique experience, Mr. Mooneyhan acted as a liaison with officials of UNEP on research and technology development activities related to the operation of GRID. He was also researching the precedents associated with the NASA, USGS/UNEP joint agreement regarding the GRID unit located at the USGS Earth Resources Observation System (EROS) Data Center, Sioux Falls, South Dakota.

Mr. Mooneyhan was investigating the development of an applications research and development program to bridge the gap between NASA's basic scientific research programs and the ultimate users of satellite based information in the EOS time frame. Emphasis in this fundamental research study was to be on environmental issues that could be addressed through advanced information extraction techniques from existing data sources such as Landsat, SPOT and ERS as well as future data sources that are being developed for MTPE, e.g. the Earth Observing System (EOS). His work indicated that the program should also include a technology transfer element in order to ensure that operational agencies and industry would have direct and immediate access to the new technology currently being developed under NASA program management.

Mr. Mooneyhan left USRA in February 1995 to return to his home in Mississippi.

Mr. Martin Ruzek began his appointment in March 1993. He received his B.S. from Caltech in 1981 and his M.S. in Geology from Caltech in 1986. In his previous position, Mr. Ruzek worked with personnel involved in the following programs and projects: the Upper Atmosphere Research Satellite (UARS), Nimbus 7, ERBS, Meteor-3 TOMS, aircraft data processing and Shuttle Imaging Radar-C science portions of NASA's Mission Operations and Data Analysis (MO&DA) program. He developed data visualization and information management capabilities in a networked workstation environment. As an experimental scientist he also worked on direct mission planning efforts for the Shuttle Radar Imaging-C instrument.

Mr. Ruzek was involved in scientific and technical research directed at the assessment of mission operation and data analysis requirements and effectiveness. Missions analyzed in this

way included the Upper Atmosphere Research Satellite (UARS), Nimbus 7, Meteor 3 and the Earth probes TOMS and Earth Radiation Budget Satellite (ERBS). He analyzed the operational aspects of aircraft instrument data processing in order to make recommendations for process improvements. He evaluated alternatives for the OMTPE with respect to the scientific and technical requirements for developing data visualization and information management capabilities. These capabilities focused on research and educational users in a networked environment. All programs were assessed and evaluated in the broader context of NASA's Mission to Planet Earth and in close coordination with EOSDIS.

Mr. Ruzek's research was transferred to USRA's Earth System Sciences Education Program in April 1995.

Dr. Anne Marie Schmoltner began her appointment in November 1993. She received her B.S. in Chemistry from the Universität Wein, Austria in 1982 and her doctorate from the University of California at Berkeley in 1989. Prior to her USRA appointment, Dr. Schmoltner was a postdoctoral research associate with the Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder. She studied reaction rate coefficients of OH radicals with methyl chloroform, methyl bromide, hydrofluorocarbons and peroxyacetyl nitrate using pulsed photolysis-laser induced fluorescence. She determined the photolysis pathways of chlorine nitrate using laser photolysis-atomic resonance fluorescence.

Dr. Schmoltner was involved in a study to conduct in-depth reviews of the Upper Atmospheric Research Program (UARP) program elements. The study involved preparation of documents evaluating past accomplishments, current priorities, and possible alternative future directions of each of the four main UARP elements: aircraft-borne measurements, balloon-borne measurements, ground-based measurements, and laboratory kinetics, photochemistry, and spectroscopy. These reports were employed by NASA Headquarters personnel in the process leading to a refocusing of UARP. This refocusing was necessitated by increasing budget constraints and redefined priorities within the OMTPE Science Division strategic plan. The study also involved the evaluation of program elements for their relevance to newly established Code R science programs designed to assess the impact of subsonic and supersonic aircraft. The evaluation included an identification of overlap areas between Code R programs and related activities in Code Y with the goal of developing alternative strategies for maximizing the scientific progress through synergistic cooperation of the community of researchers associated with OMTPE.

Dr. Schmoltner accepted an IPA appointment to the National Science Foundation as Associate Program Director for the Atmospheric Chemistry Program in April 1995.

Mr. Edwin Sheffner began his appointment in March 1993. He received his B.A. from the University of California, Berkeley in 1969 and his M.A. from the University of California at Davis in 1975. In his previous position as a Senior Research Scientist with the TGS Technology Corporation, he was responsible for the liaison between TGS and the Landsat Pathfinder Science Working Group, the Surfaces Processes Airborne Research Management and Operations Working Group and development of on-line bibliographies of the Land Processes. He also served as a principal investigator on several research projects in the agricultural applications of remote sensing.

Mr. Sheffner conducted scientific and technical analyses of the Landsat program, with emphasis on supporting development of a Landsat 7 data policy plan, implementing a technology demonstration program, and evaluating options for successor land remote sensing systems. His fundamental research was directed at investigating the requirements and designs for the Landsat 7 ground segment, especially the alternatives involved in the development of data acquisition strategies and standard products. He focused his basic research activities on issues related to

the requirements and design of the Landsat 7 ground segment, especially data acquisition strategies and standard products. Mr. Sheffner published on the history development status and future plans for the Landsat program.

Mr. Sheffner accepted a position at the NASA Ames Research Center in September 1994.

Dr. Jeffrey Star of the University of California Santa Barbara, began his appointment in July 1993. He received his B.S. degree from the Massachusetts Institute of Technology in 1975 and his doctorate from the Scripps Institution of Oceanography, U.C. San Diego, in 1981. He was a Research Fellow of the National Center for Geographic Information and Analysis (NCGIA), and a Lecturer in the Department of Geography, University of California, Santa Barbara. He was involved in the development of the NCGIA Core Curriculum and co-leader of a research initiative on the integration of remote sensing and geographic information systems. Dr. Star's research interests revolved around the spatial distributions of environmental parameters. Research focused on remote sensing and GIS research and development, decentralized information systems for the earth sciences, and algorithm development for remote sensing applications. Dr. Star had papers under review in satellite data compression and visualization and was editor of a research monograph on remote sensing-GIS integration now in progress.

Dr. Star conducted a scientific and technical analysis of the Earth Observing System Data Information System (EOSDIS). He modeled remote sensing data and researched ways to facilitate the coordination of the individual EOSDIS Distributed Active Archive Centers through the Earth Sciences Data and Information Systems Program (ESDISP) Office. Dr. Star researched the approaches used by other U.S. agencies and international agencies involved in data and archiving (including the Interagency Working Group on Data Management for Global Change, the International Earth Observing System partnership, and the Committee on Earth Observing Satellites Working Group on Data), to understand the potential implications of new technologies and new information science concepts on the evaluation of the EOSDIS.

During his one year leave of absence from the University of California at Santa Barbara to work on this Grant, Dr. Star passed away.

Dr. Michael Van Woert began his appointment in January 1993. Dr. Van Woert received his B.S. from the University of California at Davis in 1976 and his doctorate in Physical Oceanography from the Scripps Institution of Oceanography, U.C. San Diego in 1984. His graduate studies focused on developing the then newly-emerging field of ocean remote sensing. He served as a Staff scientist for SeaSpace Corporation while maintaining an academic affiliation as an Adjunct Professor of Physics at San Diego State University. In these previous positions he was involved in research activities focused on the application of the Defense Military Satellite Program (DMSP) and the National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellite data to the oceanography and meteorology of Antarctica. He was also involved in research activities focused on the combination of remotely sensed data from the Geodesy Satellite (GEOSAT) altimeter, Advanced Very High-Resolution Radiometer (AVHRR), ARGOS DCS, and Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) with in-situ data in the vicinity of the Hawaiian Islands. All of these studies were aimed at improving our fundamental understanding of air/sea interaction and better describing the wind-forced general ocean circulation using space-borne sensors. Several publications in the *Journal of Geophysical Research* and *Remote Sensing of the Environment* were published during his tenure as a USRA visiting scientist.

Dr. Van Woert was researching air/sea interactions and general ocean circulation using space-borne sensors. These studies utilized data from the TOPEX/POSIEDON, GEOSAT and European Remote-Sensing Satellite-1 (ERS-1) altimeters, the ERS-1 scatterometer, and

AVHRR/DMSP data from civilian and defense operational satellites. In addition, he worked on the NASA Scatterometer (NSCAT) sensor, which will be launched on the Japanese Advanced Earth Observing Satellite (ADEOS) in 1996. Dr. Van Woert provided scientific assessments to NASA for the Oceans AVHRR Pathfinder program, the Tropical Ocean Global Atmosphere (TOGA) program, and the World Oceanographic Circulation Experiment (WOCE). He conducted basic research on the TOPEX/POSEIDON and NSCAT and the proposed TOPEX Follow-On (TPFO) mission. He continued to provide input concerning the scientific requirements for NASA's Physical Oceanography Research and Analysis program.

Dr. Van Woert accepted a position with the Office of Naval Research in September 1994.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 CONCLUSIONS

USRA considers the Universities Earth System Scientist Program (UESSP) a success. The successes evolved from the scientific and technical achievements (see Section 2.2) and the publications and presentations (see Appendix I) of the USRA sponsored scientists who participated in this program. These scientists augmented and extended the expertise of NASA personnel and helped provide understanding and helped develop policies that have been implemented within the Office of Mission to Planet Earth (OMTPE). Inter-Agency and international coordination has been facilitated; data systems designs and program planning and analysis are better understood; and, understanding of a number of basic research issues has been enhanced.

3.2 RECOMMENDATIONS

Two major recommendations can be drawn from the experience of this grant.

1. NASA should re-examine and re-evaluate its need for mechanisms for bringing in expertise from the university community; and

2. NASA should work with USRA or other organizations to insure that the expertise of this important community is provided in an unbiased and appropriate fashion.

Appendix I
Scientific Publications and Presentations

Publications

Backlund, P. and Estes, J.E., "Very Large Environmental Databases, the Challenge for Mission to Planet Earth," in Proceedings of Workshop on Developing Large Environmental Databases, Nairobi, July 1994.

Butler, D. and Estes, J.E., "Background," in EOSDIS Potential User Group Conference," Lansdowne Conference Center, June 19-22, 1995, Washington, DC, NASA, 11p. (in press).

Butler, D., Estes, J.E., Campbell, J., Crane, R., Eisenbeis, K., Firestone, N., Green, K., Lauer, D., McDougal, D., Miller, A., Prather, M., Rossow, W., Scott, M., Townshend, J., Frohn, R., Kemp, K., and Scepan, J. (ed. comm.), 1995, "EOSDIS Potential User Group Conference," Lansdowne Conference Center, June 19-22, 1995, Washington, DC, NASA (in press).

Cayocca, K., McGwire, K., Fairbanks, D., and Estes, J., "Map-Assisted Spectral Characterization of an Ecotone for Long Term Monitoring," in Proceedings of GIS 94, Vancouver, Canada, February 22-24, 1994, Boulder, Colorado, GIS World.

Ehrlich, D., Estes, J., Scepan, J., and McGwire, K., :Agricultural Crop Area Monitoring with an Advanced Agricultural Information System," GeoCarto Int'l. **4**, 1-12 (1994).

Ehrlich, D., Estes, J.E., and Singh, A., "Applications of NOAA: AVHRR 1Km. Data for Environmental Monitoring," Int. J. Remote Sensing **15**, 145-161 (1994).

Eisenbeis, K., "The Effect of Public Policy on Access to Landsat Data," Chapter in Geographic Information Systems Applications in Natural Resources Management, College of Forestry, Stephen F. Austin State Univ., Nacogdoches, TX.

Eisenbeis, K., "The Effect of Public Policy on Access to Landsat Data," in Proceedings of 96th Annual Meeting of the Texas Academy of Science, 1994, Texas Academy of Science.

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Stoms, D.M. and Estes, J.E., "A Remote Sensing Research Agenda for Mapping and Monitoring Biodiversity," Int. J. Remote Sensing **14**, 1839-1860 (1993).

Van Woert, M.L., "Satellite Observations of the Filchner/Ronne Ice Shelf Front and Their Implications for Bottom Water Formation," Flicher-Ronne Ice Shelf Programme Report, No. 7, edited by Hans Oerter, Cambridge, England, June 11-13, 1993.

Van Woert, M.L. and Klaes, K.D., "A Case Study of Hawaiian Convective Systems using Complementary DMSP and NOAA Satellite-derived Meteorological Fields," Seventh International TOVS Study Conference, edited by J. Eyre and J. LeMarshall, February 1993, Toulouse, France, 530-542.

Van Woert, M.L. and Price, J.M., "GEOSAT and AVHRR Observations of Oceanic Planetary Waves Adjacent to the Hawaiian Islands," J. Geophys. Res. **98(C8)**, 14619-14631 (1993).

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Zibordi, G., Van Woert, M.L., Meloni, G.P., and Canossi, I., "Intercomparisons of Sea Ice Concentration from SSM/1 and AVHRR Data of the Ross Sea," Remote Sensing of the Environment, 1994.

Presentations

Angelici, G.L. and Sheffner, E.J., "A Military Database and Its Applicability to Earth Science Research," Twenty-fifth International Symposium on Remote Sensing and Global Environmental Change, Graz, Austria, April 1993.

Eisenbeis, K. "Government Funding Issues in Networking," Internetworking Rural Libraries Institute, Univ. of Wis. Milwaukee, School of Library and Information Science, May 1994. (Invited)

Eisenbeis, K. "Public Access to NASA Earth and Space Science Data," Navy Research Laboratory, Colloquium Series, Washington, DC, May 1994. (Invited)

Eisenbeis, K., "Sources of Environmental Information from NASA's Mission to Planet Earth Program," Defense Technical Information Center, November 4, 1993.

Eisenbeis, K., "Know the First Thing: What You Need to Know About NASA's Mission to Planet Earth Data Resources," Louisiana/Southern Mississippi Chapter, Special Libraries Association, LSU, November 13, 1993.

Eisenbeis, K., "Public Access to NASA Earth and Space Science Data over the Internet," Coalition for Networked Information, November 19, 1993.

Estes, J.E., "Mission to Planet Earth: An Information Science Challenge," 7th Annual Symposium on GIS in Forestry Environmental and Natural Resources Management, Vancouver, BC, February 15-18, 1993.

Estes, J.E., U.S. Congress Office of Technology Assessment Workshop on the Future of Remotely Senses Data, April 27, 1993 (Invited).

Estes, J.E., speaker, NASA's Mission to Planet Earth, UNEP/IUFRO/FAO sponsored international workshop on "Developing Large Environmental Databases for Sustainable Development," Nairobi, Kenya, July 14, 1993.

Estes, J.E., "Need for Baseline Data for Early Detection of Global Environmental Change," Aspen Global Change Institute Workshop on Early Detection of Global Change, Sioux Falls, August 1993.

Estes, J.E., invited speaker, "The Mythical Map," Pecora 12 Symposium, Land Information from Space Based Remotely Senses Data, August 24-26, 1993.

Estes, J.E., "Potential Applications of Remote Sensing for Global Change Early Signal Detection," Workshop on Global Change Research Using Remote Sensor Technologies," Glen Arbor, Michigan, September 13-17, 1993.

Estes, J.E., "Remote Sensing and GIS Keys to NASA's Mission to Planet Earth," Second International Conference on Integrating Geographic Information Systems and Environmental Modeling, Breckenridge, Colorado, September 26-30, 1993.

Estes, J.E., "Applications of Satellite Remote Sensing, New Technologies for Understanding Sustainable Development," Symposium on Earth Observations, 44th International Astronautical Congress, Graz, Austria, October 16-22, 1993.

Estes, J.E., "The Need for Verified Land Cover Data," IGBP/DIS Land Cover Working Group Workshop, Las Vegas, Nevada, February 23-24, 1994 (Invited).

Estes, J.E., "The Mythical Map," Geography Department Colloquia Series, University of Maryland, March 28, 1994 (Invited).

Estes, J.E., invited speaker, "On the Existence of Global Mapping," Washington Map Society, Library of Congress, April 19, 1994.

Estes, J.E., "Global Change in Terrestrial Ecosystems: What Should be Measured," ASPRS Annual Convention, Opening Plenary Session, Reno, Nevada, April 25, 1994 (Invited).

Estes, J.E., Global Change in Terrestrial Ecosystems: What Should be Measured," ASPRS Annual Convention, Reno, Nevada, April 25, 1994 (Invited).

Estes, J.E., invited speaker, "What Do We Know About the Earth's Surface," Conference on International Cooperation on Monitoring Environmental Change and Sustainable Development, U.S. Department of State, June 1, 1994.

Estes, J.E., invited speaker, "Mapping and the Verification of Terrestrial Hyperspectral Information,:" International Symposium on Spectral Sensing Research '94, San Diego, CA, July 11, 1994.

Estes, J.E., invited speaker, "Land Information: Baselines for Environmental Monitoring and Modeling," 1994 International Geoscience and Remote Sensing Symposium, Opening Plenary Session, Caltech, Pasadena, August 8, 1994 (Invited).

Estes, J.E., "The Mythical Map: Current Conditions and Future Considerations," Symposium on Mapping and Remote Sensing Tools for the 21st Century, Washington, DC, August 28, 1994.

Estes, J.E., overview speaker, "Core Data Needs, Availability and Accessibility," International Symposium on Core Data Needs for Environmental Assessment and Sustainable Development Strategies, Bangkok, Thailand, November 15, 1994.

Estes, J.E., invited participant, International Workshop on Global Mapping, organized by the Geographic Society Survey Institute, Ministry of Construction, Izumo, Japan, November 21-22, 1994.

Estes, J.E., invited panelist/speaker, "International Forum on Infrastructure," Commemorative Symposium on a New Approach to Global Environmental Management: Geographic Information on a Global Scale, International Cooperation Day, organized by the Ministry of Construction of Japan, supported by the Ministry of Foreign Affairs, Tokyo, Japan, November 24, 1994.

Estes, J.E., invited keynote speaker, "The Importance of Core Data," Advanced Computer Studies Workshop on Advances in Geographic Information Systems, Gaithersburg, MD, December 1-2, 1994.

Estes, J.E., invited participant, White House Conference on Technology for a Sustainable Future, Member of panel on Environmental Monitoring and Information Access, Washington, DC, December 11-14, 1994.

Estes, J.E., speaker, "The Mythical Map," Colloquia honoring Dr. Jeffrey Star, University of California, San Barbara, February 23, 1995.

Estes, J.E., invited speaker, "Geography and the Mapping Myth," Colloquia, University of South Carolina, February 23, 1995.

Estes, J.E., invited concluding speaker, "A Perspective on Current Trends in Conservation and a Vision for the Future of Biodiversity Management Areas," GAP Analysis Symposium, American Society of Photogrammetry and Remote Sensing Convention, Charlotte, NC, March 1, 1995.

Estes, J.E. and Mooneyhan, D.W, "Core Data Needs for Environmental Assessments and Sustainable Development," International Workshop on Baseline Data Needs for Environmental Assessment and Sustainable Development, Nairobi, Kenya, July 1994.

Filmer, P.E., "Plate Rigidity and the Development of Volcanic Rift Zones," International Workshop on Intraplate Volcanism: The Polynesian Plume Province, Tahiti, August 1-7, 1993.

Mooneyhan, D.W., "International Science Dataset Acquisition for Early Detection," Aspen Global Change Institute Workshop on Early Detection of Global Change, Sioux Falls, August 1993.

Ruzek, M., "NASA's Mission to Planet Earth and Access to Data", HPCC K-12 Education Workshop, Greenbelt, MD, March, 1993.

Ruzek, M., Session Chair - "GEOSCOPE, A Global Change Encyclopedia", National Science Teachers Association Annual Meeting, Kansas City, MO, March , 1993

Ruzek, M., "Internet Access to Earth Science Data," USRA Earth System Science Education Workshop, College Park, MD, January 12, 1994.

Ruzek, M., "Network Tools and Data for Earth Science Education" and demonstrations, International Technology Education Association Annual Meeting, Kansas City, MO, March 21, 1994.

Ruzek, M., "Earth Science Data from the Internet " and demonstrations, National Science Teachers Association Annual Meeting, Anaheim, CA, March 31, 1994.

Ruzek, M., "NASA's Global Change Data - Live from the Internet", U.S. Global Change Policy Symposium, Washington, DC, April 13, 1994.(invited)

Ruzek, M., "Internet Tools and Data for Global Change Education", U.S. Global Change Education Conference, Washington, DC, August 9, 1994.(invited)

Ruzek, M., "The Internet and Access to Earth Science Data", Federal Geographic Technology Conference, Washington, DC, September 26, 1994.(invited)

Ruzek, M., Wickizer, D., "Demonstration of Computer Tools for Earth Science Education", National Academy of Science Convocation on Educational Technology , Washington, DC, May, 1993.

Sheffner, E.J., "Status of the Landsat Program," University of Wisconsin, Surface Processes Airborne Research Management and Operations Working Group, June 22, 1993.

Sheffner, E.J., "Landsat 7 - Data Policy and Advisory Process," Pecora 12 Symposium on Land Information from Space-based Systems, Sioux Falls, South Dakota, August 27, 1993.

Sheffner, E.J., "The Landsat Program: Recent History and Current Status," Plenary Session, American Society for Photogrammetry and Remote Sensing Annual Convention," Reno, Nevada, April 25, 1994 (Invited Talk).

Van Woert, M.L., "Oceanography from Space," University of Delaware, November 19, 1993.

Van Woert, M.L., "Satellite Observations of the Filchner/Ronne Ice Shelf Front and Their Implications for Bottom Water Formation," Filchner-Ronne Ice Shelf Project (FRISP) Meeting, June 8-12, 1993.