CHAPTER I

SUMMARY OF THE ACTIVE MICROWAVE USERS WORKSHOP

INTRODUCTION

In 1974, the National Aeronautics and Space Administration (NASA) conducted the Active Microwave Workshop (AMW) as the first concerted effort to bring together the several elements of the active microwave remote-sensing field in such a way as to demonstrate the applications of this technology. The results of that effort firmly established the following conclusions.

1. An all-weather, day or night remote-sensing capability would significantly improve orbital monitoring of terrain and ocean surfaces.

2. The unique and/or supplementary information obtainable in the microwave region of the electromagnetic spectrum would substantially increase the value of remote-sensing measurements for Earth, ocean, and atmospheric applications.

As a result of these findings, the NASA Office of Applications has initiated a coordinated microwave applications development program. The goals of this microwave program are to improve the capability to (1) identify, monitor, and assess the Earth's resources and (2) monitor the Earth's environment and predict significant changes.

The program consists of the scientific, technical, and programmatic activities required to develop microwave remote sensing into an operational tool for systematic Earth observations. The approach adopted calls for NASA to perform the following tasks.

1. Develop microwave remote sensing for those applications for which this technology provides a unique or complementary source of information.

2. Develop the technology and facilities necessary to test and implement microwave remote-sensing techniques for Earth observations.

3. Develop the means to ensure direct involvement by potential users in the formulation, evaluation, and implementation of the microwave program.

4. Provide coordination among NASA centers, institutions, and agencies to minimize costs and duplication of effort.

5. Facilitate communication throughout the community of scientists, technologists, and microwave data users.

6. Prepare advanced mission plans and identify advanced components and systems development required to meet future needs.

The Active Microwave Users Workshop (AMUW) was an extension of the AMW designed to provide a sharper focus of the applications and to begin the process of converting the general approach described previously into an action plan. The results presented in this report provide the foundation for developing and implementing a plan to establish the measurement potential of active microwave imaging sensors.

The AMUW was conducted to accomplish the following four basic objectives.

1. Obtain an unbiased evaluation of the potential of imaging-radar data to provide unique and/or supplementary information of value to specific Earth resources applications.

2. Determine the potential of the Seasat sensors to provide useful data for land applications and design specific experiments to investigate the information content of Seasat data.

3. Develop preliminary technical and programmatic plans to guide the imaging-radar applications development effort.

4. Define the radar image and data-processing requirements associated with the applications and recommend approaches for the development of an electronic data-processing capability in NASA to support future orbital sensor systems.

The AMUW was composed of approximately 50 scientists and engineers. The group was directed by an eight-man Steering Committee. To fulfill the multifaceted objectives of the AMUW, formation of the following four panels was necessary.

1. Applications Panel

2. Seasat Land Experiments Panel

3. Program Planning Panel

4. Synthetic Aperture Radar (SAR) Data Processing Panel

The panel members were selected by Texas A. & M. University personnel, who organized and conducted the workshop, in consultation with the Steering Committee. Each participant was chosen on the basis of his experience in the topics to be addressed in each panel. The members of the Applications Panel were selected to represent the remote-sensing field in general, rather than the microwave area in particular. Most were discipline specialists with strong backgrounds in the use of visible-infrared data. (See appendix.)

The AMUW was held August 10-12, 1976, in Houston, Texas. All participants were supplied advance material, including a statement of the specific objectives of their panel, background literature, and appropriate bibliographies. During the 3 days of meetings, each panel prepared a draft report of its conclusions and recommendations. This draft formed the basis of the final report.

PANEL RECOMMENDATIONS

The recommendations of each of the four panels are presented in the following subsections.

Applications Panel

The Applications Panel believes that although important and unique applications of active microwave sensing can be identified now, significant research and development is needed in advance of committing large sums of money to sophisticated space systems. The panel strongly recommends that NASA immediately commit major funds for an imaging microwave applications development program supported by development and utilization of a sophisticated airborne multifrequency imaging radar system. The panel recommends that this microwave applications development program be structured around the following seven application areas, which show the most promise for early return on the research and development investment.

1. Natural vegetation
   a. Range improvement
   b. Range biomass productivity
   c. Range inventory
   d. Forest assessment
   e. Tropical forest inventory
2. Cultivated vegetation
   a. Crop productivity estimates
   b. Identification of stress
3. Water resources
   a. Streamflow forecast
   b. Watershed characteristics
   c. Frozen-lake mapping
4. Mineral-energy resources - mineral and petroleum exploration
5. Oceanography
   a. Ship navigation and routing
   b. Pollution monitoring
   c. Ocean engineering hazards

6. Hazard surveys

   a. Flood mapping

   b. Hurricane damage assessment

   c. Tornado damage assessment

   d. Forest and range fire damage assessment

   e. Landslide and Earth slippage assessment

   f. Earthquake prediction and damage assessment

7. Land use - existing land cover other than vegetation

Seasat Land Experiments Panel

The Seasat Land Experiments Panel concluded that the Seasat mission has significant implications in the area of land applications. The Seasat SAR's all-weather, day or night imaging capability; its possible compatibility with Landsat data; and its potential for providing unique data for a number of key application areas make this system important for exploitation in the Earth observations program. To obtain maximum benefit from this opportunity to conduct land experiments with the first orbital-imaging-radar data available to the public, the Seasat Land Experiments Panel recommends that NASA perform the following tasks.

1. Conduct a number of specific land-applications experiments in the areas of land-cover analysis, food and fiber production, water resources, and geology.

2. Establish a Seasat SAR Land Applications Team to assist in mission planning in the evaluation and management of the land-applications experiments.

3. Initiate a land-applications experiment program at the earliest possible date to facilitate its incorporation into the Seasat mission plan.

4. Employ the 24-day (Cambridge) orbit, which is more suitable for land observations, during at least 1 year of the first 2 years of the Seasat mission.

Program Planning Panel

The Program Planning Panel undertook to develop a detailed programmatic and technical plan for active microwave technology in each of four application areas: (1) vegetation resources, (2) water resources, (3) mineral resources and geologic applications, and (4) oceanographic applications. The following panel recommendations are grouped by activity.

1. User community involvement and cost/benefit analysis

a. Active involvement of the user community on all appropriate levels - Federal, State, and industrial - should be emphasized in the program planning and execution of active microwave research for Earth resources applications.

b. Cost/benefit studies should be conducted to evaluate the potential contributions of active microwave technology to each major application area.

2. System development

a. The development of additional multifrequency, multipolarization radar spectrometers to supplement the existing 1- to 8-GHz and 8- to 18-GHz microwave active spectrometer (MAS) systems at the University of Kansas should be pursued vigorously.

b. An airborne SAR should be developed for soil moisture monitoring. Ground-based measurement results indicate that the system should be a calibrated instrument capable of operating in the 4- to 5-GHz band in the incident angle range of 7° to 17°.

c. An airborne SAR should be developed for monitoring agricultural resources. Ground-based measurement results indicate that the system should be a dual-polarized, calibrated instrument capable of operating in the 14- to 15-GHz band in the incident angle range of 45° to 55°.

3. Measurement program

a. Aircraft-based radar studies over natural and cultivated vegetation should be expanded.

b. Analysis of repetitive aircraft measurements and observations of soil moisture variations over Kansas, Oklahoma, and southern California test sites should be emphasized.

c. Ground-based and aircraft measurement of snow properties with the use of test sites in the central Sierra Nevada Mountains of California and the Rocky Mountains of Colorado should be emphasized.

d. Correlation should be established between aircraft and spaceborne SAR observations and measured runoff coefficients with the use of Oklahoma, Texas, and Pennsylvania test sites.

e. NASA should place renewed emphasis on the definition of optimum system parameters for a wide range of geologic investigations and special emphasis on the development of the polarization capability of the radar measurement system.

Synthetic Aperture Radar (SAR) Data Processing Panel

The recommendations of the SAR Data Processing Panel are as follows.

1. An Imaging Radar Technology Group should be established by NASA to develop and maintain technical expertise applicable to current and proposed NASA imaging-radar systems. This group should meet at least once a year.

2. An imaging-radar-technology study program to conduct investigations related to the gathering, processing, and dissemination of imaging-radar data should be supported by NASA. The following study areas should be supported.

   a. Requirements for antenna pointing and motion compensation for satellite-borne SAR systems

   b. Requirements and processing implications for squint-mode SAR operation

   c. Interpretability versus image parameter trade-offs for digital SAR imagery

   d. Techniques for SAR calibration

   e. The interface between a SAR image formation facility and the users

3. A central SAR image formation processing facility should be established by NASA to provide users with cataloged SAR data in standard formats.

4. The development of onboard processors for dedicated applications requiring timely dissemination of image data should be pursued.

5. Existing airborne SAR measurement facilities should be modified to include the recording of raw sensor data in digital form.

6. Raw aircraft and Seasat data should be made available to support the recommended imaging-radar-technology study program.

7. The development of high-density data storage devices such as the RCA 240-Mbps magnetic tape recorder should be continued.

PANEL SUMMARIES

The accomplishments of each of the four panels are summarized in the following subsections.

Applications Panel

The Applications Panel was composed of remote-sensing specialists with strong discipline-oriented backgrounds but with limited experience in microwave remote sensing. The composition of this panel was especially selected to eliminate any possible bias that may have existed in earlier studies of this kind.

The panel surveyed existing literature and documentation on potential microwave sensor applications. Over 200 potential applications were identified and rated relative to priority and feasibility on a scale of 1 to 6. Twenty-five applications were found to have a high priority-high feasibility rating (scale factor 1). These applications were grouped into seven application or discipline areas.

1. Natural vegetation

2. Cultivated vegetation

3. Water resources

4. Mineral and energy resources and geologic applications

5. Oceanography

6. Hazard surveys

7. Land use

The user requirements were identified, and an active microwave development program is suggested for each area. The program recommendations include ground-based, aircraft, and spacecraft measurements. Within each major discipline area, a number of specific tasks are identified.

The panel expressed the opinion that the greatest potential for microwave remote sensing in the near future is in the heretofore lightly explored areas of natural vegetation, hazard surveys, and land use. Each of these important areas is currently being addressed with other remote-sensing techniques; however, in each case, microwave sensing can contribute significantly with complementary data required to satisfy the information needs.

Seasat Land Experiments Panel

The following experiments involving the use of Seasat data were identified and defined.

1. Mapping and land-cover analysis

   a. Assessing the planimetric accuracy of Seasat-A SAR images

   b. Land-cover mapping in metropolitan regions

2. Food and fiber

a. Rangeland and forest biomass assessment

b. Soil moisture/crop yield monitoring

c. Monitoring aquatic vegetation

d. Crop discrimination and stress evaluation

e. Saline seep/soil salinity detection and monitoring

3. Water resources

a. Watershed runoff estimation

b. Surface-water and flood mapping

c. Snowfield mapping

d. Alaskan lakes mapping

4. Geology

a. Alaskan Placer Gold Belt mapping

b. Assessment of glacial ice dynamics

c. Evaluation of utility of SAR data for mineral and petroleum exploration in forested areas

d. Geomorphic mapping in coastal wetlands and marshes

e. Evaluation of utility of SAR data for potash exploration

f. Discrimination of hydrothermal alterations

g. Identification of construction materials

h. Evaluation of terrain roughness

i. Examination of Arctic coastal ice structure and dynamics

j. Evaluation of SAR data for high-relief, mineral rich areas

k. Evaluation of utility of SAR data for base metals exploration

l. Evaluation of utility of SAR data in sulphur deposit exploration

m. Interpretation of geologic structures in areas of low relief

Program Planning Panel

The Program Planning Panel concluded that orbital, multiparameter imaging-radar data are essential for development of the application of SAR technology. In this report (ch. 4), the following information is provided.

1. Identification of the primary information needs within each of four application areas: vegetation resources, water resources, mineral resources and geologic applications, and oceanographic applications

2. Evaluation in general terms of the impact of each application in terms of social and economic gains and specification of the technical requirements of the user community

3. Summarization of the present state of knowledge of the applicability of active microwave sensing to each application area and evaluation of its role relative to other remote-sensing techniques

4. Identification of the analysis and data acquisition techniques needed to resolve the effects of interference factors in order to establish an operational capability in each area

5. Flow charts of accomplished and required technical activities in each application area leading to operational capability

6. Programmatic guidelines to support the applications development tasks

Synthetic Aperture Radar (SAR) Data Processing Panel

The SAR Data Processing Panel undertook to identify the available and optimal methods for generating SAR imagery for NASA applications. The major conclusions of the panel were as follows.

1. The SAR data processing of interest to NASA falls into three categories: onboard processing for special applications requiring timely dissemination of data, ground image formation processing into standard formats for general applications, and postprocessing of image data to derive specific quantitative information.

2. The early radar (including the Seasat SAR and the spaceborne imaging radar) NASA ground image formation processing requirements are within the present state-of-the-art of both optical and digital technology.

3. Onboard processors are presently not within the state-of-the-art but probably will be when such processors are actually needed.

4. The output imagery from a large ground-based image formation processor should be provided in the same manner and format as Landsat imagery to facilitate SAR image acquisition and correlation with optical imagery.

5. There is no optimum SAR-data-processing architecture, because the processor architecture depends on the application (which determines the imaging geometry) and the technology utilized.

6. The selection of a technology for SAR data processing is presently driven by memory considerations, not arithmetic considerations. Other important considerations are power, weight, size, flexibility, and cost.

7. In a large ground-based SAR-data-processing facility, some form of real-time quick-look processing capability should be provided to allow prescreening of the data to be processed.

CONCLUDING REMARKS

The Active Microwave Users Workshop (AMUW) satisfied four specific needs of the NASA microwave program.

1. An objective evaluation of the relative worth of microwave-sensing capabilities for Earth observations applications

2. A definitive experiment plan for use of Seasat data in land-applications studies

3. An examination of the research, equipment, and resources required to develop the applications potential of microwave remote sensing and a preliminary plan to coordinate these elements over the next 5 years

4. An assessment of the technology and techniques available to solve the important synthetic aperture radar data processing problem and a recommended course of action in this area

The AMUW results provide an independent endorsement for the conclusions of the Active Microwave Workshop, which confirmed that orbital microwave remote sensing is both feasible and highly desirable and that there are several important applications for which the unique, supplementary or complementary capabilities of this approach are extremely valuable.

APPENDIX

ORGANIZATION AND ADDRESSES OF THE ACTIVE MICROWAVE USERS WORKSHOP GROUP

The AMUW group consisted of a Steering Committee and the following four panels: (1) the Applications of Active Microwave Imagery Panel, (2) the Seasat Land Experiments Panel, (3) the Microwave Program Planning Panel, and (4) the SAR Data Processing Panel.

STEERING COMMITTEE

Frederick L. Beckner
Head, Microwave Systems Branch
Radio Sciences Division
Applied Research Laboratory
University of Texas
P.O. Box 8029
Austin, Tex. 78712

John E. Estes
Department of Geography
University of California
Santa Barbara, Calif. 93106

Richard E. Matthews, Chairman
Code HC
NASA Lyndon B. Johnson Space Center
Houston, Tex. 77058

Samuel W. McCandless, Jr.
Code ESE
NASA Headquarters
Washington, D.C. 20546

John W. Rouse, Jr.
Remote Sensing Center
Texas A. & M. University
College Station, Tex. 77843

Bruton B. Schardt
Code ERF
NASA Headquarters
Washington, D.C. 20546

Fawwaz T. Ulaby
Center for Research, Inc.
University of Kansas
2291 Irving Hill Drive-Campus West
Lawrence, Kans. 66045

Frederick P. Weber, Program Manager
Forestry Application Program
USDA Forest Service
Code TF5
NASA Lyndon B. Johnson Space Center
Houston, Tex. 77058

APPLICATIONS OF ACTIVE MICROWAVE IMAGERY PANEL

Richard Gilbert
USDA Soil Conservation Service
1943 Newton Square East
Reston, Va. 22090

James C. Harlan
Remote Sensing Center
Texas A. & M. University
College Station, Tex. 77843

Roger Hoffer
Purdue University
LARS
West Lafayette, Ind. 47907

John M. Miller
Assistant Director
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

Fabian Polcyn
Environmental Research Institute
of Michigan
P.O. Box 618
Ann Arbor, Mich. 48107

Bruton B. Schardt
Code ERF
NASA Headquarters
Washington, D.C. 20546

James L. Smith
USDA Forest Service
P.O. Box 245
Berkeley, Calif. 94701

Frederick P. Weber, Panel Chairman
Program Manager, Forestry Application
Program, USDA Forest Service
Code TF5
NASA Lyndon B. Johnson Space Center
Houston, Texas 77058

John Parsons
Building A2, Room 1251
Aerospace Corporation
2350 E. El Segundo Boulevard
El Segundo, Calif. 90009

Robin I. Welch
Remote Sensing Center
Texas A. & M. University
College Station, Tex. 77843

SEASAT LAND EXPERIMENTS PANEL

Nevin Bryant
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, Calif. 91103

P. J. Cannon
Geophysical Institute
University of Alaska
Fairbanks, Alaska 99701

Charles Elachi
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, Calif. 91103

John E. Estes, Panel Chairman
Department of Geography
University of California
Santa Barbara, Calif. 93106

Alex Goetz
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, Calif. 91103

Kumar Krishen
Code TF5
NASA Lyndon B. Johnson Space Center
Houston, Tex. 77058

Harold C. MacDonald
Geology Department
University of Arkansas
Fayetteville, Ark. 72701

Allen Marmelstein
Fish and Wildlife Service/OBS
U.S. Department of the Interior
Washington, D.C. 20240

Stanley A. Morain
Technology Applications Center
University of New Mexico
Albuquerque, N. Mex. 87131

Dick Phelps
Anderson Clayton & Co.
P.O. Box 2538
Houston, Tex. 77001

Paul Teleki
U.S. Geological Survey
National Center
Mail Stop 915
Reston, Va. 22092

Gene A. Thorley
USGS - EROS Program
1925 Newton Square East
Reston, Va. 22090

I. L. Turner
Texas Gulf, Inc.
5934 McIntyre Street
Golden, Colo. 80401

MICROWAVE PROGRAM PLANNING PANEL

Janet Bare
Center for Research, Inc.
University of Kansas
2291 Irving Hill Drive-Campus West
Lawrence, Kans. 66045

W. E. Brown, Jr.
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, Calif. 91103

Leo F. Childs
Code TF
NASA Lyndon B. Johnson Space Center
Houston, Tex. 77058

Louis F. Dellwig
Center for Research, Inc.
University of Kansas
2291 Irving Hill Drive-Campus West
Lawrence, Kans. 66045

John E. Heighway
Aerospace Research Engineer
Code 5422
NASA Lewis Research Center
Cleveland, Ohio 44135

Rigdon Joosten
Code TF6
NASA Lyndon B. Johnson Space Center
Houston, Tex. 77058

Anthony J. Lewis
Department of Geography
& Anthropology
Louisiana State University
Baton Rouge, La. 70808

William Linlor
NASA Ames Research Center
Moffett Field, Calif. 94035

Jerry R. Lundien
U.S. Army Corps of Engineers
Waterways Experiment Station
P.O. Box 631
Vicksburg, Miss. 39180

R. O. Ramseier
Department of the Environment
562 Booth Street
Ottawa, ON, KIAOE7
Canada

Vincent Salomonson
Code 651
NASA Goddard Space Flight Center
Greenbelt, Md. 20771

Ted K. Sampsel
Code ED6
NASA Lyndon B. Johnson Space Center
Houston, Tex. 77058

Omar H. Shemdin
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, Calif. 91103

David S. Simonett
Department of Geography
University of California
Santa Barbara, Calif. 93106

Fawwaz T. Ulaby, Panel Chairman
Center for Research, Inc.
University of Kansas
2291 Irving Hill Drive-Campus West
Lawrence, Kans. 66045

William P. Waite
Department of Electrical Engineering
University of Arkansas
Fayetteville, Ark. 72701

SAR DATA PROCESSING PANEL

Homer A. Ahr
Federal Systems Division
IBM
1322 Space Park Drive
Houston, Tex. 77058

D. A. Ausherman
Environmental Research Institute of Michigan
P.O. Box 618
Ann Arbor, Mich. 48107

Frederick L. Beckner, Panel Chairman
Head, Microwave Systems Branch
Radio Sciences Division
Applied Research Laboratory
University of Texas
P.O. Box 8029
Austin, Tex. 78712

Lewis J. Cutrona
University of California
P.O. Box 109
La Jolla, Calif. 92037

Sherman Francisco
Federal Systems Division
IBM
18100 Federick Pike
Gaithersburg, Md. 20760

Robert E. Harrison, E-1/B184
TRW - Defense and Space Systems Group
1 Space Park
Redondo Beach, Calif. 90278

Janeth S. Heuser
Code ERF
NASA Headquarters
Washington, D.C. 20546

Rolando L. Jordon
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, Calif. 91103

Jim Justus
Mail Code DD19
Rockwell International
3370 Miraloma Avenue
Anaheim, Calif. 92803

Bob Manning
Goodyear Aerospace Corporation
Litchfield Park, Ariz. 85340

R. K. Moore
Center for Research, Inc.
University of Kansas
2291 Irving Hill Drive-Campus West
Lawrence, Kans. 66045

Ralph Thoene
Building 12, Mail Station X155
Hughes Aircraft
Centinela and Teale Streets
Culver City, Calif. 90230

Richard C. Webber
68 St. Andrews Road
Severna Park, Md. 21146