OVERVIEW OF THE AgRISTARS RESEARCH PROGRAM (1)

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In 1978, the Secretary of Agriculture identified the following seven information requirements that were of primary importance to the U.S. Department of Agriculture (USDA):

1. Early warning of change affecting production and quality of commodities and renewable resources;
2. Commodity production forecasts;
3. Land use classification and measurement;
4. Renewable resources inventory and assessment;
5. Land productivity estimates;
6. Conservation practices assessment; and
7. Pollution detection and impact evaluation.

These requirements were presented in the form of an initiative issued by the Secretary of Agriculture. The Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing (AgRISTARS) program was established in 1980 in response to this initiative. AgRISTARS was designed as a cooperative research effort of the U.S. Department of Agriculture (USDA), the National Aeronautics and Space Administration (NASA), the U.S. Department of Commerce (USDC), and the U.S. Department of the Interior (USDI). In addition, the Agency for International Development (AID) was to participate as an ex-officio observer and potential future user agency. The purpose of this paper is to provide an overview of the AgRISTARS program in terms of its organization and a brief summary of major accomplishments. Many of the research results mentioned in this summary will be discussed at length in other papers scheduled to be presented at this symposium. ______________

entirely consist of papers uniquely related to AgRISTARS. Also, some results of AgRISTARS funded research will be included in at least three other sessions; Soil Moisture, Commission F--On Scattering from Land and Vegetation, and Scene Radiation and Atmospheric Effect Characterization.

The program utilized a modified matrix management system (Figure 1). Participating agencies were represented in each management level. The Interagency Policy Board, included policy level officials at the Assistant Secretary or equivalent level. This group was responsible for approving major interagency agreements and establishing basic policies and guidelines for the program.

The Interagency Coordinating Committee (ICC) was responsible for: approving program objectives; establishing priorities; assessing progress; identifying problems and developing corrective actions; and coordinating the use of resources assigned to the program.

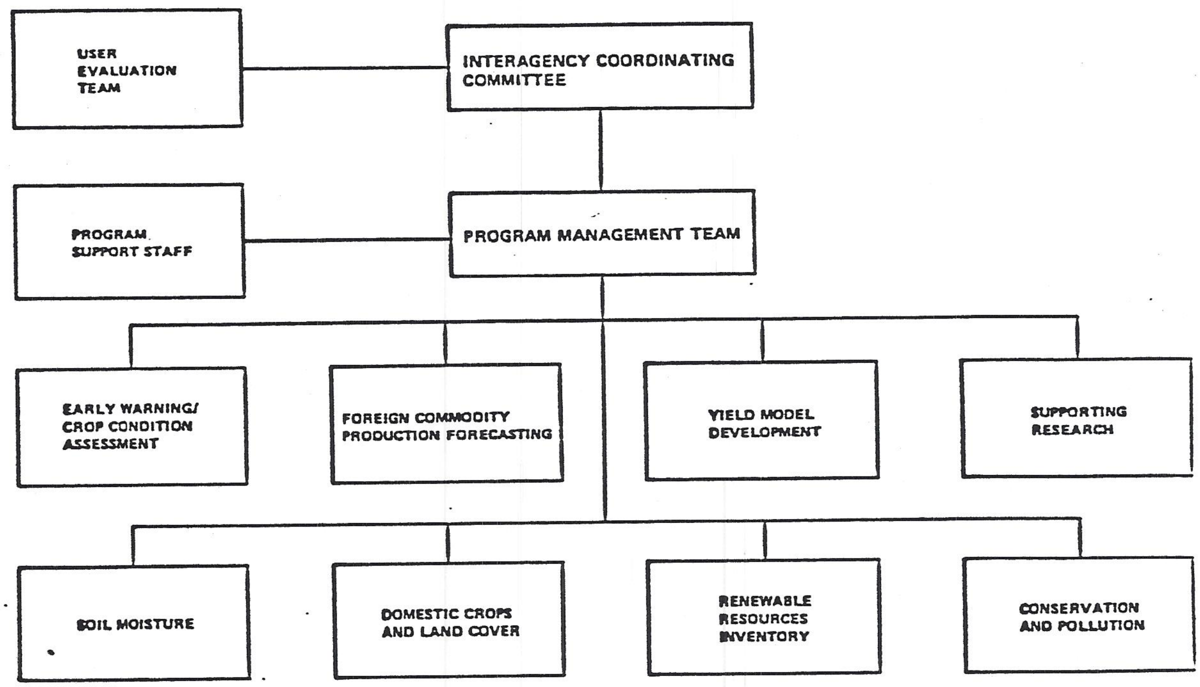

Figure 1. Joint Agency Program Management and Functional Relationships.

The Program Management Team (PMT) represented a joint approach to management, and provided participation, project integration, and needed visibility by all participants while assuring responsiveness to the USDA information requirements included in the Secretary's Initiative. The PMT was responsible to the ICC for preparation of all plans, including the overall program plan as well as annual project implementation plans. In addition, the PMT established project level guidelines, approved project content including funding levels within overall resources allocated by the ICC, and set milestones for the entire program.

Each of the eight projects (Level 3) was headed by a project manager selected from a participating agency, based principally upon consideration of technical expertise and expected levels of agency involvement. Usually several agencies were assigned research tasks in each project. The project managers were responsible to the PMT for planning and managing the day-to-day activities within their projects.

The primary benefit of the AgRISTARS management structure was it assured that research was focused on user (USDA) requirements while permitting agency flexibility to a greater degree than is usually the case in a multiagency program such as AgRISTARS. Also it served to focus remote sensing research for agricultural applications within each of the three involved research agencies, USDA, NASA, and USDC.

The overall goal of AgRISTARS was to determine the feasibility of integrating aerospace remote sensing technology into existing or future USDA data acquisition and analysis systems. Numerous factors had to be assessed in order to determine feasibility. Studies were designed to determine the reliability, costs, timeliness, objectivity, and adequacy of information derived using remote sensing technology to support known USDA missions and information requirements. The overall approach consisted of a balanced program of remote sensing research, development, testing, and evaluation of techniques designed to improve information regarding the supply and demand for food and fiber products. The technical program was structured into eight project areas designed to address all seven of the information requirements identified in the USDA initiative (Figure 2). A clear emphasis was placed on the first two requirements (early warning and commodity production forecasting) because of the immediate need for better and more timely information on global crop conditions and expected crop production. The eight project areas were:

1. Early Warning and Crop Condition Assessment (EW/CCA);
2. Inventory Technology Development (ITD) -- originally called Foreign Commodity Production Forecasting (FCPF);
3. Yield Model Development (YMD);
4. Supporting research (SR);
5. Soil Moisture (SM);
6. Domestic Crops and Land Cover (DCLC);
7. Renewable Resources Inventory (RRI); and
8. Conservation and Pollution (C/P).

Each project had its own specific set of research objectives, funding, and management. The projects were interrelated through mutuality of data

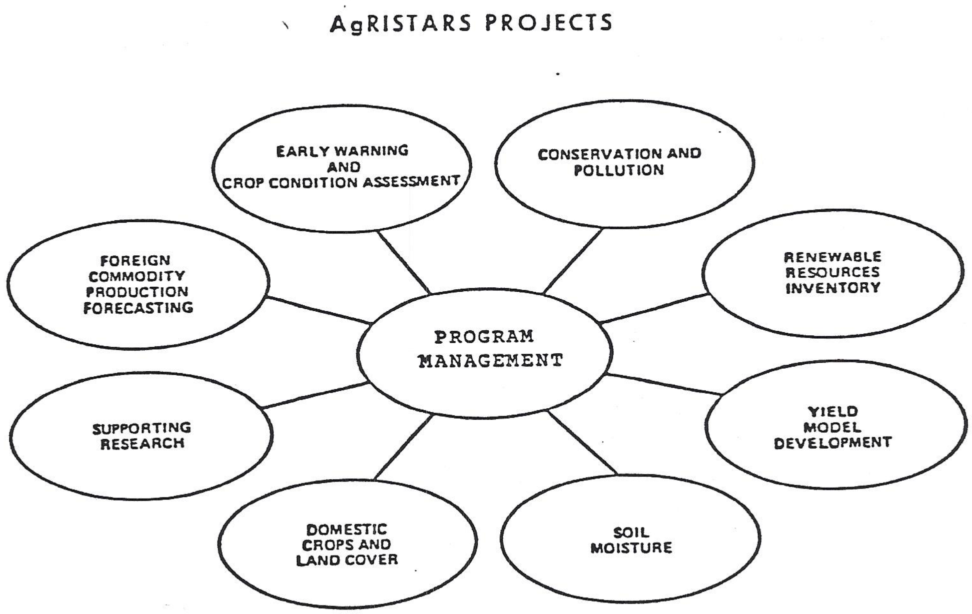

Figure 2. Individual AgRISTARS Projects and Their Relationship to Program Management

needs, common technology, and periodic progress reviews that cut across all projects. The basic approach for all projects, except supporting research which was to provide improved technology, called for exploratory experiments, pilot tests, and user evaluation. Each of the projects are discussed briefly below.

Early Warning and Crop Condition Assessment (EW/CCA)

The EW/CCA project was designed to develop and test remote sensing techniques for new applications or to enhance existing operational crop condition assessment methodologies. Emphasis was placed on developing techniques that were likely to augment and strengthen the basic techniques already implemented by the Foreign Crop Condition Assessment Division (FCCAD) of the Foreign Agricultural Service (FAS). Major accomplishments of the project included:

- Improved and tested a soil/water budget model to assess crop stress due to lack of moisture.

- Initially developed relationships between crop stress due to lack of moisture and information provided by environmental satellites.

- Developed environmental threshold values and background information for other crop-stress models. A satellite, agronomic, and meteorological data base for Missouri, North Dakota, and South Dakota was developed to test and evaluate the accuracy of the wheat, corn, and sorghum stress indicator models. The stress models tracked crop phenology and soil water status and provided stress alerts.

- Developed a crop/water stress index.

- Initiated studies to spectrally quantify crop stress. Initial results indicated that water stress could be detected and measured spectrally before it could be detected visually. When plants are stressed because of insufficient water, both physiological and geometric changes occur. Study results demonstrated that canopy geometry changes caused by stress must be accounted for if plant water stress is to be quantified using reflectance measurements.

- Developed the capability for using environmental satellite data to monitor floods and general crop conditions over large areas.

- Developed, tested, and evaluated the use of meteorological and satellite data with various simulation models to provide timely alerts of abnormal and/or optimal conditions on a global basis (alarm models). Conditions of drought and temperature stress were studied for wheat, corn, sorghum, sugar beets, and soybeans. The wheat, corn, sorghum, and sugar beet models were transferred to FCCAD/FAS/USDA for use in the operational crop production estimation program.

- Provided improved definition of the relationships between plants and their environment and factors affecting the growth cycle.

- Quantified relationships between crop stress and spectral response. The crop water-stress index (difference between plant canopy and ambient air temperature and vapor pressure deficit) appears to predict drought for cotton, wheat, and alfalfa. Initial studies suggested potential for using a vegetation index based on rangeland ground cover as a soil moisture/crop stress indicator.

- Reflectance measurements made at 13 different times of the day at Phoenix, Arizona, indicated that diurnal changes in each of the four Landsat bands and several indices derived from them are related to canopy architecture, percentage of cover, and vertical distribution of green leaves within the canopy. Additional analysis showed that substantial errors could be introduced into the estimate of green leaf area index from spectral observations if the diurnal patterns of reflectance caused by changing sun angles are not properly incorporated.

- A yield reduction model incorporating potential evapotranspiration, temperature, and available soil water was developed and tested for the USSR and the U.S. Great Plains states. A revised model was transferred to the FCCAD/FAS/USDA and was tested for both the USSR and China.

- Three black-and-white video cameras, each fitted with different narrowband filters, were used together in an aircraft to obtain information about agricultural and soil conditions. Results of the study suggest that a modified color video camera system and appropriate narrowband filters can enhance the information needs of agricultural managers in near real time.

- Developed interactive and fully automated techniques using mapped AVHRR data, climatic rainfall analyses, and conventional cloud and rainfall observations from the global telecommunications system to analyze precipitation over major crop growing regions. Implemented techniques provided a more accurate distribution of daily rainfall than was previously possible with conventional rain gauge data.

- Developed a practical method of computer screening cloud-contaminated pixels from satellite data. A Fortran subroutine was designed to perform a hierarchical classification of NOAA-7 AVHRR data into clouds, haze, water, bare soil, and vegetation. Adjustments are automatically made for time of year and scene location.

- Tracked the increase of atmospheric haze caused by El Chicon volcanic eruption products. Results of the study demonstrate the importance of monitoring the AVHRR data for transient atmospheric haze effects that could potentially interfere with early warning crop stress detection activities.

Inventory Technology Development (ITD) -- formerly called Foreign Commodity Production Forecasting (FCPF)

The objective of the Inventory Technology Development project was to develop and test procedures for using aerospace remote sensing technology to provide objective, timely, and reliable forecasts of foreign crop production. Prospective users of the technology were FAS/USDA and various international organizations concerned with the world's food and fiber supply. Research in the ITD project was designed to build on technology developed in previous experiments (e.g., the Large Area Crop Inventory Experiment). Major accomplishments were:

- Successfully adapted analytical techniques initially developed for spectral identification of wheat for use in identifying corn and soybeans.

- Improved analytical techniques for identifying spring planted small grains and tested the improved techniques in Canada and the U.S.

- Improved the efficiency of existing analytical techniques by making them less labor intensive. Ultimate result was the development of efficient automated methods for producing area estimates of spring planted small grains.

- Increased the accuracy of corn and soybean estimates by making substantial improvements in the techniques used for area estimation.

- Designed and implemented an area/production estimation simulator to allow more comprehensive performance assessment of technology components.

- Supported the gathering of ground data in Argentina to use in evaluating area measurement techniques in a foreign situation.

- Developed, tested, and evaluated uses of NOAA-6 and NOAA-7 AVHRR data for identifying and monitoring abnormal situations.

- Conducted a "quick-look" analysis of the initial thematic mapper (TM) scene over Detroit, Michigan, acquired on July 20, 1982. Preparatory research was conducted using Thematic Mapper Simulator (TMS) data acquired by a NASA airborne scanner. Specific studies were designed to address spatial resolution, sensitivity of the instrument as reflected by the signal-to-noise ratio, spectral content of the data, spectral separability of agricultural features, crop proportion estimation, and a principal components analysis. The increased performance accuracy observed when using TM data versus Multi-Spectral Scanner (MSS) data was due to a combination of better resolution, improved wavelength coverage, and a better signal-to-noise ratio. The improved spectral and spatial resolution of TM offers the potential to separate important soil properties, even in regions with similar soils and under a dense vegetation canopy.

- Developed a technique for estimating the area of spring small grains early in the season based on a relationship between growing degree days and the response of a Landsat sample segment in terms of a weighted summation of the responses of the ground cover classes in the segment. This technology was transferred to FCCAD/FAS/USDA for possible use in their operational crop area estimation program.

- Developed improved sampling and aggregation techniques.

- Performed preliminary analyses to estimate the feasibility of using AVHRR data to distinguish land surface characteristics for use in a multistage sampling approach to land cover inventory and mapping.

Yield Model Development (YMD)

The Yield Model Development (YMD) project was designed to use measurements of environmental and plant characteristics to project crop yield potential within a specified region. This research was a key component of commodity production forecasting methodology and contributed to both the domestic and foreign crop estimation processes. Major accomplishments of the YMD project during the course of AgRISTARS were:

- Selected and developed a uniform testing approach for simple predictive models for the yields of barley, soybeans, and corn in key U.S. growing regions.

- Developed empirical models for corn, soybeans, wheat, and barley for specific crop reporting districts.

- Selected and tested a physiologically-based wheat yield model that accounts explicitly for key plant processes.

- Developed and implemented procedures to provide current worldwide, quality-checked meteorological data to the Johnson Space Center through the Joint Agricultural Weather Facility (JAWF).

- Evaluated available wheat, corn, barley, and soybean regression-type yield models; selected the most responsive model for each crop; prepared the required yield estimates for each crop; and delivered the recommendations and estimates to the Inventory Technology Development project for use in production estimation tests.

- Developed new methodology using AVHRR data to estimate solar radiation at the surface and validated the accuracy of these estimates.

- Compiled five wheat growth simulation models; tested two of the five simulation models; and documented recommendations for improvement.

- Developed a model that relates water stress caused by low soil moisture or high energy input levels to photosynthesis limitation in soybeans.

- Adapted the wheat simulation model to barley.

Supporting Research (SR)

The Supporting Research project was designed to provide technological components and procedures for testing in the other AgRISTARS projects, especially those projects that addressed crop inventory activities. Research specifically focused on (1) the development and initial testing of techniques to extract information from Landsat data that could be used to estimate the area planted to different crops, (2) improving existing capabilities to estimate the growth stage of wheat, barley, corn, and soybeans, and (3) the evaluation of crop condition as determined by analysis of the spectral data acquired by Landsat. Major accomplishments of the SR project were:

- Developed a new nonsupervised classification program (CLASSY) that decreased the time it takes to discriminate crops and reduced the amount of manual inputs required for classification.

- Improved the estimation of growth stage for wheat by developing and incorporating a moisture stress index into the model that accounts for the effects of drought on the crop development stage (simulation of daily crop moisture stress and phenological development). Growth stage models were also developed and tested for barley and corn.,

- Simulated data to be collected by the Landsat thematic mapper using both an aircraft scanner and a field spectrometer.

- Improved the multitemporal data registration capabilities for Landsat MSS data to an accuracy at or below 0.5 pixel, compared with an earlier capability of 1.0 pixel.

- Developed a crop temporal profile technique that permits multidate Landsat spectral data to be interpreted in terms of key vegetation growth parameters (e.g., date of emergence, peak greenness, length of growing season, and maturity stage) that can be uniquely related to specific crop types. This highly automated technique was applied to corn and soybeans in the U.S., as well as for Argentina.

- Developed a technique for using crop temporal profiles in conjunction with statistically-developed mixture models to identify small grains and to estimate the proportion of small grains in a sample segment.

- Used the Fisher information function to quantify the spectral separability of the various boreal forest species. Conifers were spectrally very distinct from deciduous trees. However, species within the conifer and deciduous categories were not very separable.

- o Results based on TMS data revealed that conventional digital image processing, incorporating maximum likelihood classification, provides a readily available technology for TM data analysis. The increased number of spectral channels on TM improved classification accuracy significantly.

Soil Moisture (SM)

The Soil Moisture project focused on developing, testing, and evaluating a capability to gather soil moisture data remotely and with in situ devices. Research addressed sensor development and capabilities, field measurements (ground and airborne), and modeling and analysis. Specific accomplishments of the Soil Moisture project were:

- o Found substantial agreement between theory and measurements of the penetration depth of certain microwave bands. Time of day appeared to be an important consideration in the remote sensing of soil moisture.

- o Developed a portable surface soil moisture measuring instrument to be used for rapid ground-truth measurements over large areas.

- o Quantified the effects that vegetation has on microwave soil moisture measurements. Vegetation effects must be considered when making soil moisture measurements. Surface changes (such as crop harvesting and tillage) had a major effect on measurements at any one point.

- o Assessed the utility of Seasat data for measuring soil moisture.

- o Evaluated methods for estimating profile moisture content from remotely sensed surface measurements.

- o Analyses of model simulation and microwave data obtained from truck-mounted radiometers verified the concept of using time series microwave measurements to distinguish between soil types based on their hydraulic properties (such as ponded infiltration rates and water holding capacities). Relative classification of the hydrologic soil type can be accomplished with a one-time measurement if it is known that the surface soils were subjected to significant rainfall from one-half to two days prior to measurement.

- o Thermal-infrared data acquired by the AVHRR on NOAA satellites were evaluated in conjunction with the visible through the near-infrared reflectances, meteorological data, and land use maps. Examination of Landsat data and conventional maps of land use showed that the major variability apparent in the AVHRR image data was associated with topography, differences in soil characteristics and farming practices, cities and residential areas, and other similar factors. Inclusion of these factors in an analysis procedure require a more sophisticated approach involving the extraction of map-type data from large-scale, centralized data bases.

Domestic Crops and Land Cover (DCLC)

The Domestic Crops and Land Cover project addressed issues related to improving state and substate crop acreage estimates by integrating Landsat data with ground data from the existing USDA crop estimation program. Land cover research tasks explored methods for meeting USDA needs for land cover inventories, land use change estimates, and mapping products associated with land cover estimates. Specific accomplishments were:

- Developed, tested, and evaluated operational procedures for estimating the acreages of major crops over large areas (e.g., at the state level). Estimates were made for major crops (winter wheat, corn, soybeans, rice, and cotton) in seven states (Arkansas, Colorado, Illinois, Iowa, Kansas, Missouri, and Oklahoma). These estimates were provided annually to the Crop Reporting Board as input to the operational estimation program.

- Conducted a study designed to develop remote sensing procedures applicable to both agricultural surveys and irrigation inventories. The study was conducted in cooperation with the California Departments of Agriculture and Water Resources and the University of California at Berkeley. Results indicated that with minor modifications the DCLC procedure was applicable to California agriculture. County estimates of crop acreages and resource maps based on calculated values called "crop odds" were produced.

- Assessed and improved existing techniques for registration and processing of Landsat data. Compared USDA/SRS and NASA data registration techniques.

- Assessed existing techniques for clustering and classification and for evaluating alternatives. The cost of classifying an entire MSS scene (four channels) into twelve categories was reduced from over $1000 on the ILLIAC IV to $35 on the Cray 1S.

- Conducted experiments to determine the feasibility of integrating basic land cover classes into USDA operational surveys.

- Completed a crop acreage classification study using TMS data.

- Evaluated several change detection procedures for one test site.

- Conducted statewide land cover surveys in Kansas, Missouri, and Arkansas in conjunction with exiting surveys.

- Developed procedures for estimating crops in small areas such as counties. This included both improved remote sensing analysis techniques and new statistical estimators.

- Evaluated new sensors (TM, SAR, etc.) for their potential ability to distinguish crop and land cover classes.

Renewable Resources Inventory (RRI)

The general objectives of the Renewable Resources Inventory project were to develop, test, and evaluate methods for applying new remote sensing techniques to the inventory, monitoring, and management of forest and rangeland renewable resources. The primary user of technology developed in the RRI project would be the U.S. Forest Service; new technology would be used to support the national renewable resource assessment process which is part of the Forest Service legislated responsibility. Major accomplishments were:

- Improved methods for the collection, display, and use of resource information for forest management and planning.

- Evaluated Landsat technology as a tool for supporting multiresource inventories and forest planning. The Multiresource Inventory Methods Pilot Test (MIMPT) provided information to support resource planning activities, as well as forest inventory and assessment activities, at the national, state, and multicounty levels. Results of this work led to changes in the forest management policy in California.

- Demonstrated the capability to monitor, classify, and measure disturbances and changes in forests and rangeland. Developed new procedures for change detection, classification, and measurement of disturbances and changes. Results demonstrated that computer-aided analysis of Landsat MSS data can delineate areas of change in a forest (especially major changes such as logging, fire, and avalanche), as well as areas of no change. Therefore, the resources required for a more detailed conventional analysis of the changed areas were reduced.

- Improved the capability to map and characterize natural and managed habitats. A test was conducted to evaluate the utility of single-date classified Landsat data as a source of land cover information in assessing elk habitat quality.

- Improved the capability of high-flying sensors.

- Simulated TM data using panoramic cameras. Results indicated that the accuracy of forestry-type mapping almost doubled and that existing software could be used to process TM data. In addition, a Seasat synthetic aperture radar (SAR) study showed improved delineation of deciduous forests.

- Emphasized the transfer of remote sensing techniques to the field users in the Forest Service, as well as to other state and Federal agencies, by conducting several advanced remote sensing and photointerpretation workshops at the field office level and by assisting field units with local remote sensing projects.

- Evaluated the extent of oak wilt in central Texas, the extent of the southern pine beetle outbreak in east Texas, and determined the extent of hardwood defoliation caused by the gypsy moth in the Northeastern United States.

Conservation/Pollution (C/P)

The conservation assessment portion of the Conservation/Pollution project addressed applications in three areas: (1) inventory of conservation practices, (2) estimation of water runoff using hydrologic models, and (3) determination of the physical characteristics of snowpacks. The pollution portion of the project provided an assessment of conservation practices through the use of remote sensing techniques to quantitatively assess sediment runoff, gaseous and particulate air pollutants, and the impacts of these factors on agricultural and forestry resources. Major accomplishments during the course of AgRISTARS were:

- Evaluated aerial photography for use in the inventory of existing conservation practices and in the planning of new conservation practices.

- Derived water runoff parameters from Landsat data for use as factors in hydrologic and watershed models. Developed a usable infiltration model that could be defined in terms of surface soil moisture and soil parameters that can be derived from available USDA maps. An equation was used to generate a synthetic infiltration series for an array of conditions that could be encountered in the field. Experiments were successfully conducted using this equation to simulate infiltration by relating cumulative infiltration capacity to the amount of storage used.

- Used microwave data and radiative transfer models to remotely measure snowpack properties important for agricultural water supplies and water management practices. Significant results were obtained from the Scanning Multichannel Microwave Radiometer (SMMR) data acquired by the Nimbus-7 environmental satellite. For example, horizontal and vertical polarizations can be useful for analyzing the structure of a snowpack. Analysis of data from 10 satellite overpasses of the midwestern United States revealed that horizontally polarized radiation temperature data correlate better, in general, with snow depth than do vertically polarized data.

- Conducted spectral studies of suspended sediments in reservoirs. Results indicated that band 4 of the TM appeared to have good potential for monitoring high sediment loads in reservoirs and rivers.

- Watershed runoff studies showed an extreme sensitivity to the amount of soil moisture in the surface layers.

- Developed procedures for using Landsat images to determine curve numbers for input to the SCS water runoff model.

- Tested a snowmelt model on U.S. river basins. Modified the National Weather Service River Forecast System model and the associated National Weather Service snowmelt model to accept remote sensing input, specifically snow cover extent, surface water extent, snow water equivalent, and soil moisture. The new model makes optimum use of the spatial and temporal characteristics of the remote sensing data and employs a geographic information system (GIS) as an integral feature for overlaying data, merging data of different characteristics, and performing hypothetical basin treatments for design studies.

- Improved a model relating snow depth to microwave brightness.

- Measured spectral differences in plants exposed to 0.6 parts per million (ppm) ozone for two hours. Ozone promotes early senescence in soybean plants. Injury is not obvious until later in the growing season. Visible injury occurs earlier in the growing season, but it is generally limited to the lower leaves and is therefore not as apparent to the overhead sensor of the spectroradiometer.

Summary and Conclusions

The discussion above provides a fairly concise summary of the major accomplishments of the individual AgRISTARS projects during the course of the research program. Individual scientists have performed admirably and have conducted many excellent research studies. On behalf of all levels of AgRISTARS management, I would like to publicly acknowledge their efforts and thank each one for participating. Because of their dedication, foresight, and application of knowledge, significant advances have been made in aerospace remote sensing since 1980. One can conjecture that even more significant progress could have been made if all agencies had been able and willing to support the program at resource levels specified initially.

REFERENCES

(1) "AgRISTARS Annual Reports, 1980-1983."