

**AN OVERVIEW OF THE APPLICATIONS SYSTEMS VERIFICATION TEST  
ON SNOWCOVER MAPPING**

A. Rango, *Goddard Space Flight Center, Greenbelt, Maryland*

**ABSTRACT**

The capability of the LANDSAT and NOAA satellites to accurately measure snowcovered area on various size watersheds has been demonstrated by a number of investigators. Additionally, recent research has shown a highly significant statistical relationship between satellite-derived snowcovered area at the beginning of the snowmelt period and seasonal runoff. The decision was made, therefore, to test the results of several satellite snowcovered area studies in an Applications Systems Verification Test (ASVT) Program where quasi-operational evaluations of total technical capability are performed. The objective of these ASVT's is to provide all the information necessary for a potential user to make effective decisions concerning the implementation of the new remote sensing technology in an operational applications system. The ongoing Operational Applications of Satellite Snowcover Observations (OASSO) Project became part of the ASVT Program in July 1975, and is described in this paper. In cooperation with various operational water management agencies in Arizona, California, Colorado, and Oregon, the OASSO Project is scheduled for completion in September 1978.

**INTRODUCTION**

The capability of the LANDSAT and NOAA satellites to accurately measure snowcovered area on various size watersheds on a repetitive basis has been demonstrated in several research projects sponsored by NASA, NOAA, and other agencies. Other research (Leaf, 1971 and Rango, Salomonson, and Foster, 1975) has provided an indication that snowcovered area, provided either by aerial or satellite surveys, can be employed as an additional parameter in the prediction of snowmelt-derived runoff. Because of positive research results in both snow mapping and runoff correlations, the decision was made to operationally test the use of remotely sensed snowcovered area for improving snowmelt runoff forecasts in an Applications Systems Verification Test (ASVT) Program where quasi-operational evaluations of total technical capability are performed.

NASA ASVT's result from exploratory investigations in the research program that have shown promising conclusions. As a result, when an ASVT is undertaken, most necessary supporting research has already been completed. An ASVT is an integrated test of the capability of a remote sensing based system to accomplish a specific applications objective on an operational basis. To accomplish this, ASVT's directly involve the user community, provide a user oriented assessment of the system and provide in summary form the information necessary for a potential user to make effective decisions concerning the implementation of the technology in an operational framework. Mandatory products from an ASVT are a documented methodology suitable for widespread distribution, a comprehensive user evaluation of the systems accuracy and reliability, and a complete cost-benefit relationship study.

The Operational Applications of Satellite Snowcover Observations (OASSO) project was initiated in July 1974 and formally became a part of the NASA ASVT Program in July 1975. Through December 1975, existing satellite data collected since 1973 will be analyzed. It is planned that analysis of real time satellite data will begin during the 1976 snowmelt season. Being conducted in cooperation with nine operational water management agencies in the Western United States, the OASSO project is scheduled for completion in 1978.

#### GENERAL OBJECTIVES

The OASSO project has the following general objectives.

1. Map snowlines, areal snowcover, and associated changes in snowcover using satellite data for the 1973, 1974 and 1975 snow seasons in four separate Western U.S. study areas in order to evaluate the usefulness of the data had they been available in near real-time.
2. Map snowcover changes through FY 78 in each of the study areas in a near real-time mode (data to user  $\leq$  72 hours) so that the data base can be extended to a total of at least five years.
3. Compare and evaluate satellite-derived snow mapping products with reference to products from conventionally-derived snow data.
4. Develop or modify methods in an operational framework over the study period that will allow incorporation of satellite derived snowpack observations into the prediction of snowmelt-derived streamflow for specific areas.

5. Produce a documented methodology and cost/benefit analysis sufficient for user organizations to make Go/No Go decisions concerning the use of this satellite-assisted snowmelt runoff methodology in their operational responsibilities.

## PROJECT ORGANIZATION

Day to day management of the OASSO project is conducted at NASA's Goddard Space Flight Center (GSFC) in coordination with the Earth Resources Program Office and NASA/Headquarters. The satellite snow investigations are carried out at four Western United States study centers located in Arizona, California, Colorado, and the Northwest as shown in Figure 1. NOAA's National Environmental Satellite Service (NESS) is also participating in OASSO by supplying operational NOAA satellite data and supporting analysis work.

Each of the four study areas in the West have operational agency personnel working in cooperation with remote sensing specialists to adapt the existing technology to water supply forecasting needs. Table 1 lists the Arizona Snow ASVT organization and responsibilities and Figure 2 locates the Arizona study watersheds. Similarly Tables 2, 3, and 4 list the Snow ASVT organization and responsibilities for California, Colorado, and the Northwest respectively, while Figures 3, 4, and 5 locate the study

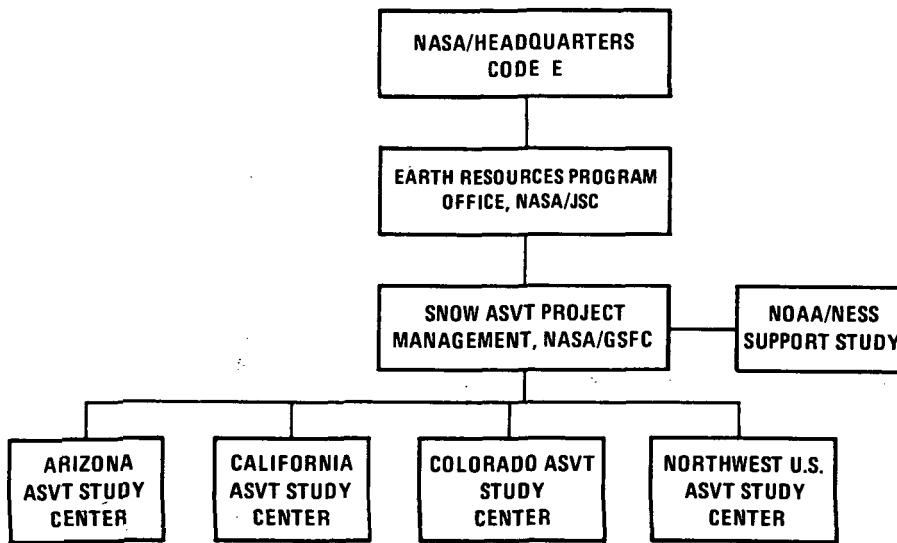


Fig. 1—Snow ASVT project management structure

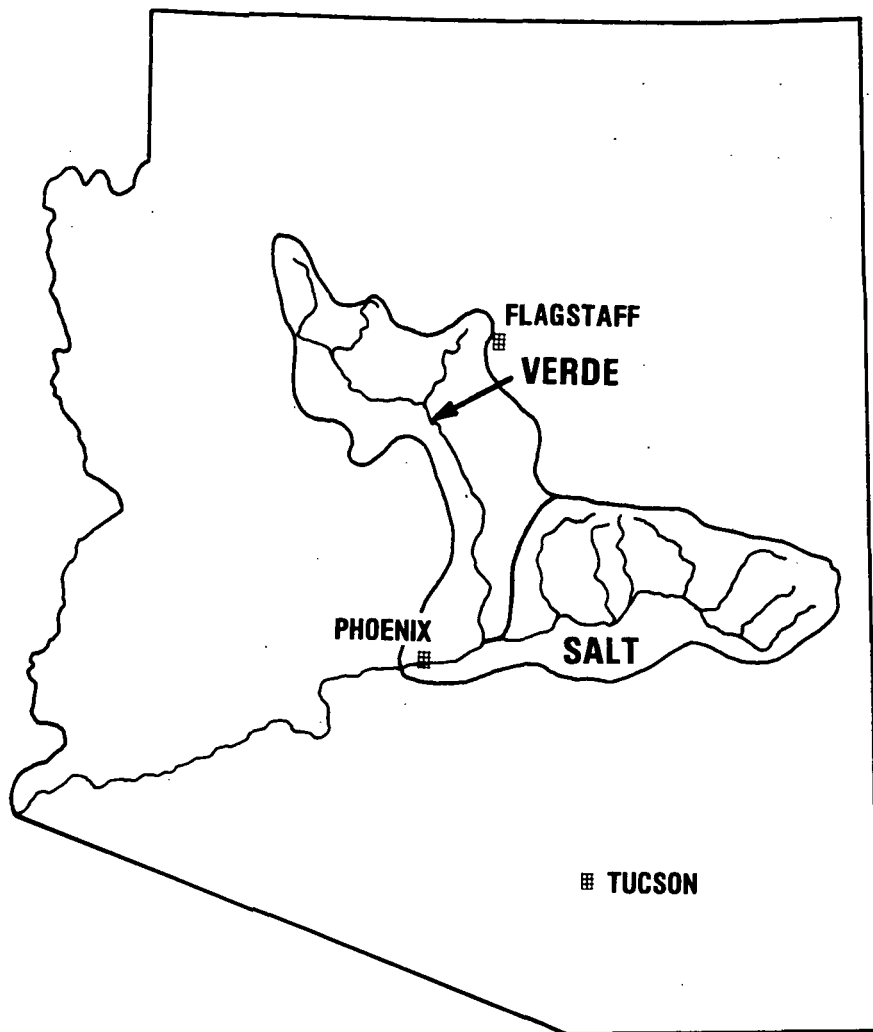


Fig. 2—Arizona snow ASVT study watersheds

watersheds for the same areas. The organization and responsibilities in the NOAA/NESS support study are shown in Table 5.

#### STUDY AREA ACTIVITIES

In Arizona LANDSAT and NOAA imagery, LANDSAT data collection system relayed data, and aircraft flights are being used as a total system for improving short term and seasonal forecasts to benefit Salt River Project operations. In particular the Arizona investigators are interested

Table 1

Arizona Snow ASVT Organization and Responsibilities

A. Project Coordinator	Mr. Herbert H. Schumann USGS, WRD Phoenix, Arizona
B. Operational Agency Cooperators	Mr. William Warskow, Watershed Specialist, Watershed Division Mr. Ted Wilson, Lead Engineer, Water Resource Operations Salt River Project Phoenix, Arizona
C. Remote Sensing Specialist	Mr. Herbert H. Schumann, USGS
D. Study Watersheds	Salt River Verde River
E. Applications of Data	Reservoir Regulation (for power, irrigation, water supply, and flood control in order of priority)  Short Duration Runoff Forecasting

in substituting satellite snowcover measurements for many of their conventional low altitude aircraft surveys, and at the same time using satellite information to identify critical snowmelt situations where it would be advantageous to fly an aircraft mission.

One of the principal goals for all the study areas is to use satellite information to reduce existing streamflow forecast error. In California, the Department of Water Resources is focusing on using the satellite data for updating forecasts after April 1 through the end of the snowmelt season. Procedural forecast errors would thus be treated rather than the early season, weather-variability errors. Additionally, California is particularly interested in using satellite snowcover data to obtain additional snowpack knowledge from ever increasing restricted-access wilderness areas and other remote regions.

In the attempt to reduce forecast errors, historical records are being analyzed and correlated to conventional watershed and snowpack

Table 2

California Snow ASVT Organization and Responsibilities

<p>A. Project Coordinator</p>	<p>Mr. A. J. Brown, Chief Snow Surveys Branch California Department of Water Resources Sacramento, California</p>
<p>B. Operational Agency Cooperators</p>	<p>Snow Surveys Branch California Department of Water Resources Sacramento, California</p>
<p>C. Remote Sensing Specialist</p>	<p>Mr. Barry Brown, California Department of Water Resources</p>
<p>D. Study Watersheds</p>	<p>Feather River Upper Sacramento River San Joaquin River Kings River Kern River Kaweah River Tule River</p>
<p>E. Applications of Data</p>	<p>Supply various California Snow Survey Cooperators with Seasonal Runoff Forecasts. Irrigation Power Generation Flood Control</p>

measurements. It is hoped that with five years of satellite data as a base, meaningful snowcovered area indices could be used in normal regression approaches to streamflow forecasting. Additionally, various numerical watershed models are being employed with the snowcovered area estimates in Colorado and the Northwest to attempt to improve shorter duration runoff forecasts. The Streamflow Simulation and Reservoir Regulation (SSARR) model used by the Columbia River Forecasting Service, as an example, requires the input of snowcovered area for generating daily streamflows. Satellite snowcover data will be input to the SSARR model for studying possible improvements in streamflow forecasts for past and current years resulting from use of actual data as opposed to model

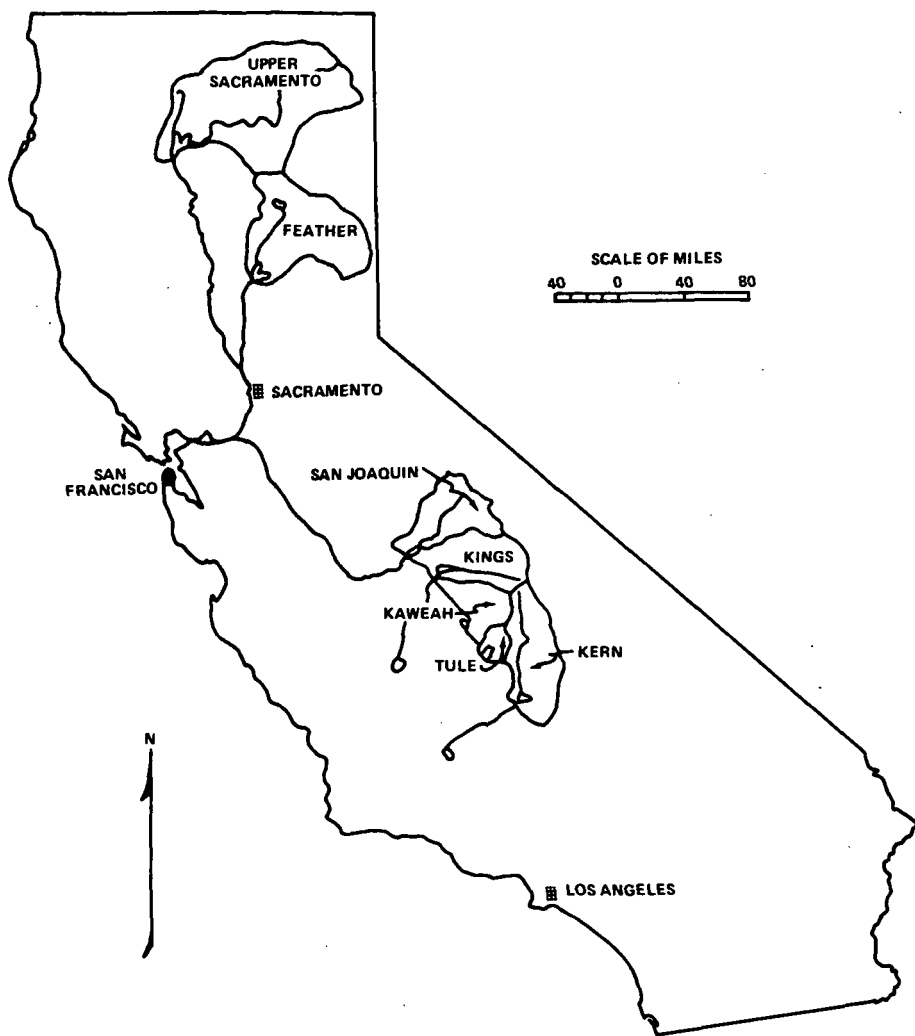


Fig. 3—California snow ASVT study watersheds

calculated snowcovered area. The utility of the remotely sensed data for the various models being tested will be assessed and documented.

At the end of the OASSO project the user agencies will evaluate the utility of the satellite data in light of their own unique requirements and comment upon possible continuing application of the data. Recommendations will also be made for changes and improvements necessary to make the data more applicable to operational functions. The required cost-benefit study will produce results regarding the worth of using satellite

Table 3

Colorado Snow ASVT Organization and Responsibilities

<p><b>A. Project Coordinator</b></p>	<p>Mr. Jack Washichek Snow Survey Supervisor Soil Conservation Service Denver, Colorado</p>
<p><b>B. Operational Agency Cooperators</b></p>	<p>Mr. Jack Washichek Soil Conservation Service Dr. Jerry Danielson, Deputy - State Engineer Colorado Division of Water Resources Mr. Bob Hansen U.S. Bureau of Reclamation</p>
<p><b>C. Remote Sensing Specialist</b></p>	<p>Mr. Bob Hansen, USBR</p>
<p><b>D. Study Watersheds</b></p>	<p>Rio Grande River Above Del Norte Conejos River Above Mogote Culebra River Above San Luis San Juan River Above Carracus Arkansas River Above Salida</p>
<p><b>E. Applications of Data</b></p>	<p>Better Flow Forecasts on the Rio Grande River so that the State of Colorado can Better Regulate Reservoir Releases of Water to the State of New Mexico as Required by Law. Reservoir Regulation for Irrigation and Power Requirements.</p>

snowcover data for operational purposes based upon the results obtained in each of the four study centers. Documentation and dissemination of the results from the OASSO project for informational purposes will include widespread distribution of handbooks, workshop proceedings volumes, final reports, and scientific papers.



Table 4

Northwest Snow ASVT Organization and Responsibilities

<p>A. Project Coordinator</p>	<p>Mr. Fred A. Limpert, Head Hydrology Section Bonneville Power Administrator Portland, Oregon</p>
<p>B. Operational Agency Cooperators</p>	<p>Columbia River Forecast- ing Service, (CRFS) Portland, Oregon CRFS is composed of:</p> <ol style="list-style-type: none"> <li>1) Bonneville Power Administration</li> <li>2) U.S. Army Corps of Engineers</li> <li>3) NOAA/National Weather Service</li> </ol>
<p>C. Remote Sensing Specialist</p>	<p>Dr. Mark Meier, USGS</p>
<p>D. Study Watersheds</p>	<p>Boise River North Santiam River Snake River Kootenai River Clearwater River Flathead River</p>
<p>E. Applications of Data</p>	<p>Power Generation Flood Control</p>

SUMMARY

As a result of promising conclusions derived in several remote sensing snowcover studies, an Application Systems Verification Test (ASVT) has been initiated in the Western United States to evaluate under operational conditions the overall utility of satellite snowcover observations for streamflow forecasts. A total of six federal agencies and three state agencies are cooperating in four regions centered in Arizona, California, Colorado, and Oregon. These agencies are employing earth resources satellite data, data collection system relayed information, aircraft flights, conventional ground information, and regression and

**Table 5**  
**NOAA/NESS Snow ASVT Support Study**

<p><b>A. Study Coordinator</b></p>	<p><b>Mr. Russ Koffler, Chief  Environmental Products  Group NOAA/NESS  Washington, D.C.</b></p>
<p><b>B. Operational Agency Cooperator</b></p>	<p><b>Mr. Jack Bottoms,  Manager NOAA/NESS  Satellite Field Services  Station  Redwood City, California</b></p>
<p><b>C. Remote Sensing Specialists</b></p>	<p><b>Mr. Don Weisnet  Dr. David McGinnis  NOAA/NESS  Environmental Sciences  Group  Mr. Stan Schneider  NOAA/NESS  Environmental Products  Group</b></p>
<p><b>D. Operational Services</b></p>	<p><b>Support in the Form of Im-  agery for Each of the ASVT  Study Watersheds from the  Satellite Field Services Sta-  tion and Supplemental Snow-  cover Analyses for Several  other Rivers in the West.  Snowcover Values are sent  by Teletype to NWS River  Forecast Centers.</b></p>
<p><b>E. Research Study</b></p>	<p><b>Investigate Effect of Vegeta-  tion, Tree Lines, and Moun-  tainous Terrain on Snow Map-  ping. Digital Enhancements  of Snow/Terrain Interfaces.  Examination of Sources of  Snow Mapping Errors.</b></p>

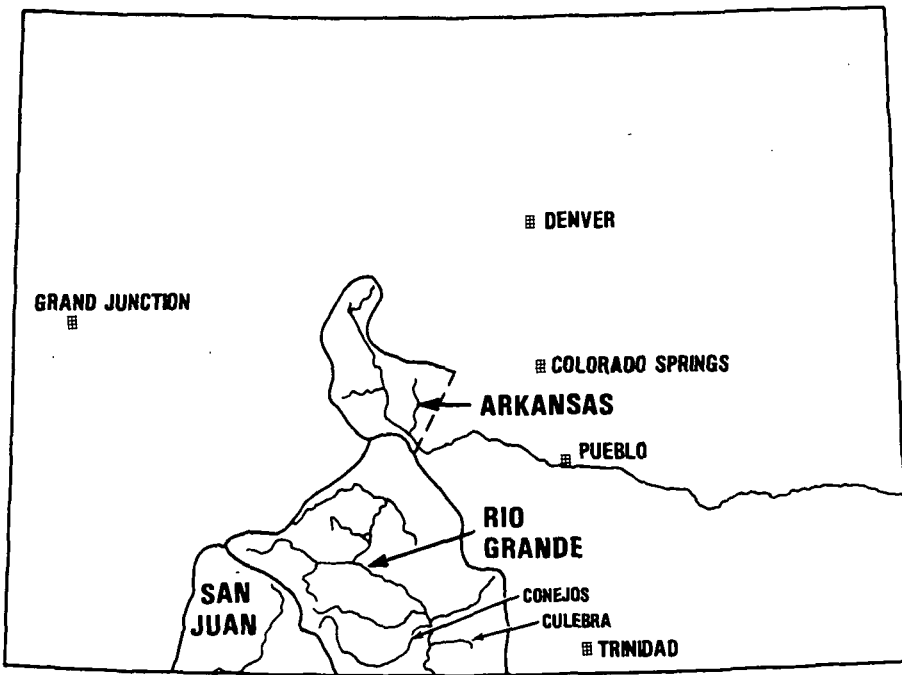


Fig. 4—Colorado snow ASVT study watersheds

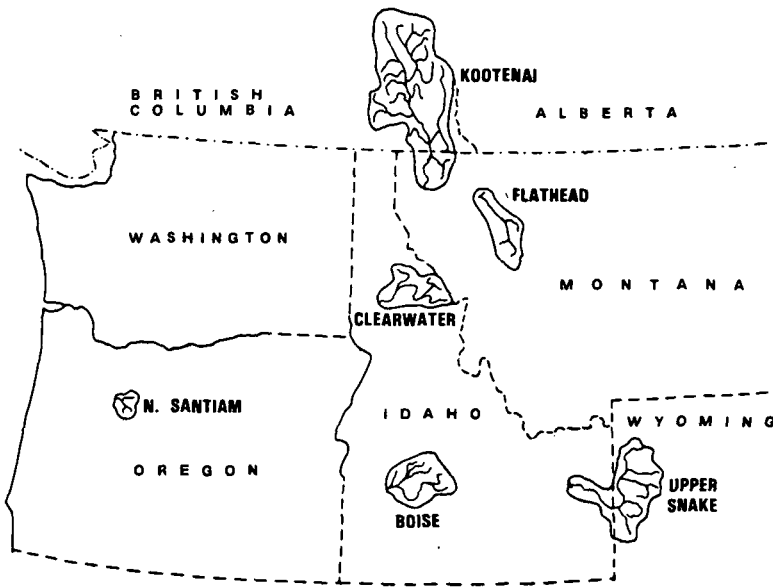


Fig. 5—Northwest snow ASVT study watersheds

numerical streamflow prediction models in an attempt to quantitatively determine the usefulness of the timely remotely sensed information. At the conclusion of the ASVT, handbooks, workshop proceedings, final reports, and scientific papers produced in conjunction with this project will be disseminated so that all interested parties may evaluate the overall results and assessments of the application of satellite snowcover observations.

#### REFERENCES

- Leaf, C. L., Areal snow cover and disposition of snowmelt runoff in Central Colorado, USDA Forest Service Research Paper RM-66, 19 pp., Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, 1971.
- Rango, A., V. V. Salomonson, and J. L. Foster, Seasonal Streamflow Estimation Employing Satellite Snowcover Observations, Document X-913-75-26, 27 pp., National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, 1975.