Testimony
Of
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Subcommittee on Space and Aeronautics
Related to
Remote Sensing Data: Applications and Benefits
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Hon. Mark Udall, Chairman and Members of the Subcommittee:

My name is Jack Byers, Deputy Director and Deputy State Engineer for the Colorado Division of Water Resources. I am submitting this testimony on behalf of the State of Colorado.

The State of Colorado and many other western states have a critical need for High Resolution Thermal Infrared Remote (TIR) Sensing. Colorado and many western water agencies are actively integrating Thermal Infrared Remote (TIR) remote sensing techniques into their management strategies to estimate actual crop evapotranspiration (ET), to classify land cover by vegetation (crop) type, to quantify water consumption by irrigation to support transfer of agricultural water to growing cities and other uses, for estimating aquifer depletion and river/canal transport losses, monitoring water-rights compliance, water modeling, climate change initiatives and for scheduling irrigation diversions and reservoir releases. For these applications, replacing on-the-ground reconnaissance with satellite-based information is highly beneficial in terms of efficient water management, efficient use of limited resources and improved decision-making.

As you know NASA launched the first Landsat satellite in 1972, which makes Landsat the world's longest continuous program to collect digital multispectral data of the earth from space. Landsat 4, launched in 1982, was the first of the Landsat series to carry a thermal imager, and each successive Landsat has had a thermal infrared remote (TIR) sensing capability.

High resolution TIR (approximately 60 m to 120 m pixel resolution) is needed for the water resources management activities identified above. The quantification of water use from Landsat using thermal data is the only way to independently and consistently measure water use on a field-by-field basis over large land areas. Typical field sizes in the U.S. range from 10 to 160 acres, or about 180 meters to 750 meters on a side. These sizes require relatively high resolution images to produce information on an individual field. Other satellite platforms {MODIS, (Moderate Resolution Imaging Spectroradiometer), ASTER, (Advanced Spaceborne Thermal Emission and Reflection Radiometer), AVHRR, (Advanced Very High Resolution Radiometer), GOES, (Geostationary Operational Environmental Satellites), NPOESS National Polar-orbiting Operational Environmental Satellite System)} include TIR capability but at insufficient resolution to be useful at the field scale level, or with inadequate return times or communication downlink constraints.

Irrigation is the largest user of fresh water in the western U.S., and Landsat thermal data is the basis of the best and least expensive way to quantify and locate where water is used and in what quantity. The 20+ year record of continuous high resolution TIR data on future Landsat satellite missions or other platforms is uncertain. Landsat 8 scheduled to launch in 2011 does not contain a thermal imager. The Landsat Data Continuity Mission (LDCM) also doe not currently contain specification of a high resolution TIR.

Irrigated agriculture accounts for 80-85% of the consumptive water use in the West. Increasingly Western States use TIR data to observe land-surface temperature and energy balance differences from evapotranspiration (ET) and calculate water consumption by agriculture and other vegetation. Without FY 2008 funding, a TIR sensor likely can not be built in time to meet the 2011 launch timeline and this increasingly valuable data will be lost. Use of TIR data for water management has only recently exploded, following a drop in the cost of the data after a failed attempt at private commercialization. Landsat 5 and Landsat 7 are the only U.S. sources of this data, but Landsat 5 is nearly 20 years beyond its design life and Landsat 7 equipment failures have left data gaps. Landsat 6 was destroyed when its launch failed. No other U.S. or foreign TIR remote sensing capabilities now, nor for the foreseeable future, can provide the workable features which now allow a growing number of data users to measure and monitor water use.

Currently, higher resolution TIR is available only on Landsat 5 and Landsat 7. Landsat 7 data after 2003 are difficult to use operationally due to failure of the scan-line corrector. Landsat 5 launched in 1984 is 24 years old and has had

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power problems. The satellite was temporarily taken out of service in October 2007 following a cell failure within one of the satellite's two operating on-board batteries. The USGS announced on Feb 29, 2008 that Landsat 5 is once again collecting and downlinking land-image data.

Demonstrated water resources planning and management applications include:

- quantifying and monitoring consumptive water use by irrigated agriculture, urban and suburban landscapes, and natural vegetation,
- estimation of transferable water due to land fallowing,
- calibrating ground water models,
- monitoring aquifer depletion,
- computing water budgets for surface water models,
- compliance with limits on water consumption under interstate compacts,
- monitoring the uniformity of irrigation water application,
- crop area, type, pattern and yield estimation,
- monitoring the exercise of water rights, in order to ensure their use according to state and federal laws, decrees, compacts and negotiated agreements, rules and regulations.

The availability of thermal data from satellites, especially Landsat, has enabled the development of energy balance models that compute and map actual crop evapotranspiration (ET). Evapotranspiration is a term used to describe the sum of evaporation and plant transpiration from the earth's land surface to atmosphere. Evaporation accounts for the movement of water to the air from sources such as the soil, canopy interception, and waterbodies. Transpiration accounts for the movement of water within a plant and the subsequent loss of water as vapor through stomata in its leaves. Evapotranspiration is an important part of the water cycle. This application is the first important use of Landsat thermal data, and it has the clear potential grow dramatically.

- ET mapping has been accomplished using the SEBAL (Surface Energy Balance Algorithms for Land) and METRIC (Mapping ET at high Resolution using Internalized Calibration) models in Idaho, Utah, Wyoming, Montana, Washington, New Mexico, Texas, Nevada and California. ET from individual fields is estimated for purposes of water rights and irrigation water management. The use of METRIC, SEBAL and other processes that rely on Landsat's visible, near infrared, and thermal data, are substantially more accurate than are simpler ET

methods that use vegetation indexes, which are a combination of the visible and near infrared spectrum only. The advantage of using thermal data in mapping water use is that land surface temperature can identify fields that are short of water and thus have suppressed ET. This information is important to quantify actual water use by both irrigated agriculture and urban landscaping.

- In Colorado, Colorado State University has developed and applied its own version of the surface energy balance model using TIR data, RESET (Remote Sensing of ET), in the lower South Platte and Arkansas River Basins. Satellite based crop ET estimates will allow the direct estimation of actual crop ET when crops are stressed by lack of water, salinity, or other stress factors. The ability to continue the development and use of models like RESET will be an important complement to the detailed crop ET/lysimeter research being initiated in the Arkansas Valley and supported by DWR.

Data on cropped area/acreage and classification by crop type are periodically updated for use in hydrologic models used to determine compliance with interstate compacts, such as the H-I Model in the Arkansas River Basin. Three remotely sensed Landsat imagery bands are needed in this crop classification work: the visible, near-infrared and thermal. All three bands are used to identify unique crop signatures. The loss of the thermal band would seriously impact this work effort and require greater expenditure of resources in ground-truthing of the remotely sensed estimates. Additionally, the high resolution imagery allows crop and field identification at the scale of most fields in the Basin, with potential several pixels per field.

Colorado joins the Western States Water council and other western states in strong support of increased funding for the National Aeronautics and Space Administration (NASA) Earth Systematic Missions Program and Landsat 8 thermal infrared (TIR) imaging technology needed to better manage water use. This data has been provided since 1982, from NASA Landsat satellites. The Administration has not requested NASA FY 2008 funding for a TIR sensor on Landsat 8, scheduled to be launched in 2011. The total estimated cost is $90-$100 million, with $35 million needed in FY 2008.

At present, TIR data is used for defining field boundaries, crop-type and water consumption in Colorado, California, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, Texas, Utah, Washington and Wyoming, while other states are considering its future use. Related activities have been undertaken or

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proposed in the Arkansas, South Platte, Bear, Boise, Upper and Lower Colorado, Lemhi, Milk, North Platte, Upper and Middle Rio Grande, Russian, Salmon, San Juan, Snake, and Yakima River Basins. This important data gathering tool is now used or can be used in the future for or to:

- Calculate water use on a field-by-field and regional scale and encourage water conservation;

- More accurate water supply and demand planning, including multi-basin water balances and budgets;

- Measure consumptive use of surface and ground water resources and impacts of diversions/pumping;

- Administer water rights and evaluated proposed uses, changes in use and water right transfers;

- Ensure compliance with interstate compacts, international treaties and other water use agreements;

- Plan, mitigate and respond to drought, wildfire and other heat-related events;

- Monitor and assess the impact of climate change on water, wetlands, vegetation, land uses, etc;

- Evaluate the impact of changing water/land uses on wetlands, fish, wildlife, and endangered species; and

- Many other natural resources, emergency management, military, and other uses of national interest.

The 2000 Census reported that one third of all Americans live in the West, and that the West accounted for half of the overall U.S. population growth over that decade. The arid U.S. West is experiencing explosive population growth. As Colorado and the West grows, water conservation is key, the increased demand for scarce water supplies has shifted water management strategy to developing innovative concepts for sustainable use, developing more effective

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methods to allocate limited water supplies. Water resources managers must understand water consumption patterns over large geographic areas; Landsat provides an important tool for effective, sustainable water management.

Colorado is involved in the allocation and administration of water rights, Interstate compact compliance and planning for future water needs related to population growth. For example, in the Colorado River Basin, which supplies the myriad water needs of millions of people in seven western states, ongoing discussions over sharing water shortages and balancing future needs depend to a large extent on measuring and monitoring consumptive water use governed by international treaties, interstate compacts and state and federal laws. Landsat thermal imagery is a tool with the potential to help smooth the way towards a present and future water rights balance.

There are many other examples of such uses or potential uses of Landsat TIR imagery in water management in the West. In California, Landsat data and ET-related information help farmers determine their actual irrigation needs. In New Mexico, Landsat data and ET maps are helping water managers strike a balance between irrigation demands and riparian vegetation, as well as the habitat needs of endangered species. In the State of Washington, water users have used ET estimates, again derived from Landsat thermal data, to encourage conservation of water resources and increase streamflows for fish while maintaining crop production and farm income. Colorado, Kansas and Nebraska are exploring the use of Landsat data and ET to better monitor and manage ground water uses in order to control overdrafting. Montana uses Landsat data for water quality monitoring. Wetlands delineation, habitat identification and soil moisture monitoring are other Landsat uses.

In conclusion, Colorado strongly supports NASA spending for the thermal sensor on Landsat 8 and urges the Subcommittee to remedy this critical omission. We are thankful that Congressman Udall, Senators Allard and Salazar, as well as others in the Colorado delegation and west-wide continue to work toward resolution of this critical problem. I would be happy to answer any questions or provide any further information the Subcommittee might request.

Thank you for the opportunity to submit this testimony.

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Jack Byers is the Deputy Director and Deputy State Engineer for the Colorado Division of Water Resources. Responsible for the leadership and management of the Intrastate Water Supply, Development and Public Safety which includes the Engineering, Technology and Investigations Division, Water Supply and Well Permit Division and Budget management office. Jack oversees the safety of dams program, hydrographic and Stream measurement program, well construction programs and the enforcement and compliance with applicable decrees, statutes, rules and regulations. He serves on the National Dam Safety Review Board, Dept. of Homeland Security - Government Coordinating Council on Dam Security, Co-chair of the Governor's Water Availability Task Force, and serves on the Governor's flood hazard mitigation task force, Colorado homeland security task force, and provides technical support to the Colorado Commission on Indian Affairs. Jack also is the co-author of the Colorado Water Law Benchbook. Jack is a Colorado native, with a BS in Civil Engineering and a MS in Water Resources, Geotechnical and Structural Engineering from Kansas State University. A Licensed Professional Engineer in Colorado and Montana. Prior to the State of Colorado he was the Director for Indian Affairs and Wyoming Office State Manager for MSE Inc. He also worked 18 yrs with the US Bureau of Reclamation in a variety of management and leadership positions in Denver, CO; Bismarck, ND and Billings, MT.

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