14 September 2006

Dear Member of the NRC Decadal Survey Panel:

We are writing to express our concern that the value of thermal infrared (TIR) remote sensing, and in particular moderately high-resolution (<100m) TIR, is not being given sufficient emphasis in the upcoming Decadal Survey Panel report. Over the past 5-10 years, we have dramatically expanded our understanding of how TIR can be used effectively. Landsat thermal imagery is being used operationally around the world to map mineral resources, and to monitor fire and scarce water resources, catastrophic geological events, thermal pollution, and vector-borne disease outbreaks. The attached pdf briefly summarizes current important application areas using high-resolution TIR imagery (see also additional supporting documents and letters at http://www.idwr.idaho.gov/gisdata/landsat-thermal-band.htm).

In particular, water management in the western United States has benefited greatly from recent advances in TIR technology. The accuracy of Landsat-scale TIR-based evapotranspiration (ET) estimates has improved to the extent that consumptive use and water rights can be reliably monitored from space at the scale of a single irrigation system. Western water agencies are actively integrating TIR remote sensing techniques into their management strategies for estimating aquifer depletion and river/canal transport losses, monitoring water-rights compliance, water modeling, and for scheduling irrigation diversions and reservoir releases. TIR-based information is also used to quantify water consumption by irrigation to support transfer of agricultural water to growing cities and for endangered species needs. For these applications, replacing on-the-ground reconnaissance with satellite-based information is highly beneficial in terms of cost reductions and improved decision-making. For many of these applications, the ability to spatially resolve individual fields and riparian waterways is critical and requires TIR data with a pixel size of <100m, and preferably at 10-60m – MODIS/AVHRR data at 1km resolution are not sufficient.

In addition to their utility in water resource management applications, spaceborne high-resolution TIR data provide information vital to answering several of NASA's Earth science questions:

- How are global precipitation, evaporation, and the cycling of water changing?
- How are global ecosystems changing?
- What changes are occurring in the mass of the earth's ice cover?
- What changes are occurring in global land cover and land use, and what are their causes?
- How is the earth's surface being transformed and how can such information be used to predict future changes?
- How do ecosystems respond to and effect global environmental change and the carbon cycle?
- What are the consequences of land cover and land use change for the sustainability of ecosystems and economic productivity?

Specific examples of how TIR data contribute to these study areas are outlined in the Addendum to this letter.

Despite these advances, we face an impending crisis in our ability to collect routine high-resolution TIR data. Currently, we are limited to Landsats 5 (120m) and 7 (60m), and ASTER (90m). Landsat 7 data after 2003 are difficult to use operationally due to the scan-line corrector failure, and the 22 year old Landsat 5, with a design life of 5 years, is likely to fail at any moment. ASTER data are available only on demand and are therefore not useful for routine applications. *There are no new missions planned by any nation to routinely collect high-resolution TIR data.* Continuing the more than 20-year data record of TIR on Landsat will be extremely important for monitoring impacts of past and future land use and vegetation change on ET at local scales.

Representatives of water management agencies in the western U.S. have recently communicated with OSTP in support of the proposed 120m resolution TIR sensor on the Landsat Data Continuity Mission (LDCM). Those representatives recognize the unique value of Landsat: it is an operational system with large areal coverage, a relatively small pixel size, a thermal band, and an unmatched archive of data. If the LDCM does not carry a thermal band, the development of TIR-based applications will cease and it will be difficult or impossible to regain the enormous momentum that we currently have. While the LDCM may not be the ideal platform for this type of data collection, it will keep things moving forward until more optimal (higher spatial, temporal, and spectral resolution) solutions can be implemented.

We strongly urge you to add language to the NRC Decadal Survey Report supporting the value of TIR remote sensing in Earth resource monitoring. In particular, a statement acknowledging the societal benefits of the proposed LDCM TIR imager will be important in encouraging NASA and Congress to ensure continuity of high-resolution satellite TIR imaging. We do not feel that inclusion of this statement will in any way jeopardize the overall LDCM mission.

We realize that the window to final release of the panel report is short, and we very much appreciate the time you will take to consider this request. Please do not hesitate to contact any of the undersigned sponsors for more information.

Sincerely,

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Addendum: NASA Earth Science Questions Addressed by High-Resolution Spaceborne TIR Data

- ***How are global precipitation, evaporation, and the cycling of water changing?***
  High-resolution TIR imagery provide key data for more accurate measurement of soil moisture and evaporation across the Earth's surface at scales approaching that of the natural heterogeneity within vegetation communities. Thermal energy fluxes are an integral component of evaporative response and can be used to track the uptake and distribution of water within the global hydrologic cycle.
- ***How are global ecosystems changing?***
  High-resolution TIR data are paramount for assessing changes in ecosystems related to evapotranspiration, plant stress and chemical status, net primary productivity, soil moisture, and ecosystem health. TIR data are absolutely critical for assessing the linkage between ecosystem processes (i.e., energy flow) and responses (i.e., temperature change), and can contribute valuable information on how energy flux characteristics are changing as a result of climate change or variability, and impacts by humans and invasive species.
- ***What changes are occurring in the mass of the earth's ice cover?***
  High-resolution TIR images provide key data on characteristics related to land and sea ice. Factors such as temperature and latent heat of evaporation are of value to developing a better understanding of ice dynamics, temperature gradients near the water-ice interface, and how these characteristics are affected by climate change and variability and other factors.
- ***What changes are occurring in global land cover and land use, and what are their causes?***
  High-resolution TIR data obtained over a continuous time period are highly useful for understanding the temporal nature of changes occurring in land cover and land use, and even more importantly, what these changes mean in regard to the energy balance associated with biophysical, hydrologic, and human-induced processes. Maps of temporal changes in energy and water balance at high spatial resolution provide unique insights into the cause and impact of landcover/landuse changes.
- ***How is the earth's surface being transformed and how can such information be used to predict future changes?***
  The entire relationship of high-resolution TIR data to changes in surface thermal energy regimes, as noted in the question above, is directly related to this science question. Moreover, from a geological perspective, high-resolution TIR data can be used to address a host of geologic processes such as global assessment of terrestrial geology, monitoring dynamic geologic phenomena, assessment of volcanic activity, evaluation of groundwater resources, evaluation of geologic hazards, and exploration for nonrenewable resources (e.g., minerals and energy). Of particular importance is the ability to measure and map the thermal inertia of geologic materials, a quantity of significant importance to a host of solid earth applications. Much information is needed on processes near the interfaces of areas of contrasting surface conditions, thus high-resolution imagery is imperative.
- ***How do ecosystems respond to and affect global environmental change and the carbon cycle?***
  Canopy transpiration and carbon assimilation fluxes are tightly coupled, both regulated by stomatal conductance. Reduced transpiration due to stomatal closure results in elevated vegetation temperatures, and therefore TIR imagery can be used to map both canopy stress and carbon. Surface temperature also modulates soil respiration fluxes. Thermal data are therefore an invaluable tool for monitoring the global carbon cycle and ecosystem health from space. To adequately resolve the agricultural field scale and typical variability in forest ecosystems requires TIR data at the 100m scale or finer. Thus, high-resolution TIR imagery is of great importance to assessing how environmental changes affect ecosystem functioning and carbon sequestration over regional scales.
- ***What are the consequences of land cover and land use change for the sustainability of ecosystems and economic productivity?***

Inclusion of satellite-derived surface temperature data has been demonstrated to greatly improve the accuracy of crop yield forecasts. To be most useful, TIR data are required at the sub-field scale, minimizing pixels containing mixtures of crops. Forest health and production can also be monitored using TIR imagery. Climate and land cover/land use change influence land-atmosphere interactions and these in turn impact ecosystem functioning. The long-term record of high-resolution TIR data in the Landsat archive help us to document and understand the trends and patterns of land cover and land use change, and to assess how these changes impact sustainability and economic productivity of agricultural, forest and natural ecosystems.

What other NASA Earth science research programs will benefit from high-resolution TIR data?

Hydrology: Accurate, high-resolution estimates of evapotranspiration and soil moisture content are critical for assessment of the hydrologic cycle. High- resolution TIR sensors provide surface temperature data that are critical to modeling rates of evapotranspiration for heterogeneous land covers, crop, vegetation, and forest types under a myriad of environmental conditions. Soil drying under the influence of sunlight is often detectable by an increase in surface radiant temperature. Hence, high spatial resolution TIR data will provide data that can be used to estimate soil drying and wetness factors that are a critical link in analysis of water availability, uptake and distribution within the overall purview of terrestrial hydrologic assessment.

Carbon: Ecosystem health is highly related to carbon uptake and carbon sequestration. Forest and crop canopy temperatures are valuable indicator of healthy ecosystem functioning, plant physiology, and biomass production. Thus, high resolution TIR data will be extremely useful for monitoring the regional carbon balance. Large-scale carbon flux networks, such FluxNet, require robust methodologies for upscaling and integrating observations made at individual towers to be able to draw regional inferences regarding terrestrial carbon cycles. Remote-sensing based carbon flux maps can greatly facilitate this upscaling, but it will be necessary to have TIR data at scales resolving the tower footprint ($\sim 10^2$m).

Solid Earth: TIR data have been used extensively by the geological community for detection and identification of mineral and nonrenewable resources. Measurement of the thermal inertia of solid earth materials using TIR data is a key factor in assessing mineralogy and other geological characteristics. High-spatial-resolution TIR data are also of importance for detecting changes in surface thermal characteristics that have implications for assessing volcanic activity and potentially for assistance in earthquake detection. It is also perceived that high-resolution TIR data can complement the proposed NASA Interferometric Synthetic Aperture Radar (InSAR) instrument by providing thermal information applicable to the detection of precursor deformation phenomena for either earthquakes or volcanoes

Climate Variability and Change: The impacts of climate variability and change will potentially elevate ground-level surface temperatures. In turn, increases in temperature will be reflected by subsequent changes in rates of evaporation, evapotranspiration, and soil moisture that ultimately impact a host of ecosystem processes and land-atmosphere energy exchanges. Changes in these parameters can be measured via high-spatial-resolution TIR data and subsequently, these data can be used to measure the changes in energy fluxes for land covers and biophysical processes as they are affected by climate change and variability. Additionally, as urbanization increases around the world, these TIR data can be used to assess the impact of urban growth on the environment. This includes assessing the impacts of climate change and variability on urban surface temperatures via changes in the urban heat island effect, and on evaluating how urbanization changes local and regional meteorology and climate.

USGEO: USGEO has identified land and sea surface temperature as a "High level of importance area" for Earth observation for all nine of its Societal Benefit areas (i.e., Weather, Disasters, Oceans, Climate, Agriculture, Human Health, Ecology, Water, and Energy). Thus, high-spatial-resolution TIR data will directly complement the overall USGEO strategic plan across all of its critical observation areas.