Aeolian dunes have been used for more than a century as tools of scientific inquiry. Holocene and Pleistocene dunes around the world preserve clues to Quaternary climate changes and human activities from Ice Age hunting to Twentieth Century warfare. Modern dunes contain the sedimentary textures and structures necessary for interpreting ancient aeolian sandstones, and they provide natural laboratories for investigation of aeolian physics and desertification processes. Remote sensing is likewise a tool, one which can offer a synoptic view of a dune field, sand sea, or desert region.

The use of satellite remote sensing to visualize, map, and monitor aeolian dynamic processes is still a relatively new approach. Early work focused on the use of visible and near infrared images to map dune morphology and examine regional trends in sand transport and deposition [1–4]. In 1988, Blount [5] presented one of the first studies demonstrating the power of multispectral images for interpreting the dynamic history of an active aeolian sand sea. Blount’s work on the Gran Desierto of Mexico used a Landsat thematic mapper scene and a linear mixing model to spectrally unmix the image and show where different sand populations occur and along what paths these sands may have traveled before becoming incorporated into dunes [5, 6].

While previous work has utilized visible and near infrared spectral images, most minerals have stronger diagnostic spectral features (owing to fundamental vibration frequencies) in the thermal infrared [7, 8]. It is anticipated that a study similar to that of Blount [5, 6] using thermal infrared instead of visible/near infrared images will demonstrate an even more powerful way to study and monitor desert aeolian processes. In the laboratory, samples of sand-sized minerals and lithic fragments have well-characterized thermal infrared spectra [7, 8], and their spectral mixing properties are nearly linear for grains larger than about 100 microns [9, 10].

The first Earth Observing System Platform (EOS–A) is expected to be launched into orbit in 1998. One instrument, the Japan–U.S. Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER), includes a 5–channel thermal infrared (8–12 microns) imaging capability [11]. The ASTER design is well suited to mapping and monitoring of aeolian processes in arid regions all over the world, particularly in areas with active sand transport and deposition.

To understand how thermal infrared observations will be used in aeolian studies, we have obtained and begun to examine Thermal Infrared Multispectral Scanner (TIMS) images of four dune fields in the western United States: The Shifting Sand Dunes of Christmas Lake Valley, Oregon, the Moses Lake dunes of Washington State, the Great Sand Dunes of Colorado, and the Kelso Dunes of California. The TIMS has six channels between 8 and 12 microns and is flown on an airborne platform [12].

Ramsey and Christensen [13] developed a linear unmixing model which is used to examine the distribution of various mineral or lithic materials (endmembers) in a thermal infrared spectrum or image. The linear unmixing model is best applied to surfaces with grains
Vegetation and minerals which do not have spectral features in the 8–12 micron region (such as magnetite) are treated as black—or gray—body spectral endmember units. The model has been applied to the Kelso Dunes TIMS image [9]. The Kelso Dunes image was obtained in September 1984, and has a resolution of 17 m/pixel. Application of the unmixing model to the Kelso Dunes image reveals that different quantities of feldspar, quartz, and magnetite can be mapped over the dune surfaces. Ramsey et al. [9] suggest that the dune composition is less mature than previously thought [14], perhaps indicating greater contributions from local sand sources.

TIMS images of the Shifting Sand Dunes, in eastern Christmas Lake Valley, Oregon, were acquired on three separate dates. These and other TIMS images described below were obtained under the NASA C–130 Earth Resources Aircraft Program operated at the NASA Ames Research Center. Two images (9 m/pixel resolution) of the dune field were obtained in September 1991; an additional image showing the dunes covered by snow was acquired in October 1991; and the same flight lines were reflown in July 1992. When enhanced (principal component analysis) the images show variations which probably indicate both the contribution of sand from local sources and the sorting of sand on individual dunes. The sand is composed of volcanoclastic materials: feldspar crystals, pumice, basalt fragments, and aggregated volcanic ash [15, 16]. The sands were previously deposited in the pluvial Fort Rock Lake [15, 17]. Spectral unmixing and validation using sand samples from this dune field are currently in progress. Higher resolution TIMS images are planned to be obtained in mid–1994.

The Moses Lake dunes of central Washington may be ideal for a simple thermal infrared unmixing study because the grains are composed of two very different materials: basalt fragments and quartz [18]. Petrone [18] suggested that there was a general downwind decrease in the amount of quartz incorporated in the sands; this result can be examined using a TIMS image. A set of TIMS images (resolution ~ 15 m/pixel) were obtained in September 1991. These images show strong spectral signatures wherever there is an exposed patch of sand, thus giving a good indication of which dunes are currently active. Inactive dunes in this region are vegetated and were covered by a 2–4 cm blanket of ash following the 1980 eruptions of Mt. St. Helens (240 km SW of Moses Lake). Both vegetation and fine volcanic ash have 8–12 micron emissivities near unity while the active dunes have emissivities as low as 0.89 between 9 and 10 microns. A second set of TIMS images (3 m/pixel resolution) were obtained in July 1992. Unfortunately, the data for the hottest surfaces (mostly active dune slip faces) were saturated in the 1992 images. However, the images are sufficient to again show which dunes are active and they will probably yield surface grain sorting results once examined in detail.

The northern half of the Great Sand Dunes, Colorado, was imaged at 16 m/pixel in June 1992. Although there are clouds in the scene, preliminary examination of the image shows color variations attributed to the aeolian sorting of materials of different composition. This volcanoclastic dune field was studied in detail by Wiegand [19], who showed that it was common for concentrations of quartz–rich granule ripples to form on the dunes. Sorting by composition is apparently detectable in TIMS data and will have important implications for the application of ASTER observations to aeolian dynamic studies.

Examination of TIMS images of dune fields and validation of spectral unmixing models is currently underway [9]. The ability to map and monitor the dynamic processes along aeolian sand transport paths and among depositional sites such as the giant ergs in Asia, Africa, and Australia, is soon to become possible with the projected 1998 launch of the EOS–A platform.
Rather than concentrating on single dune fields (the only approach currently possible with TIMS), we will be able to begin tracing sand from source to sink over entire desert regions.