Active Project (2012 - 2012)

Surface Spectroscopy Center Of Excellence Project

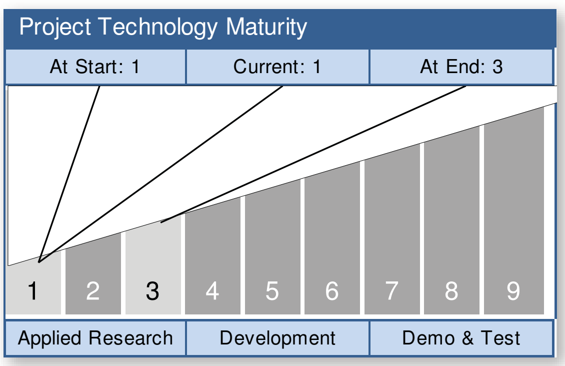
Center Innovation Fund: ARC CIF Program

Space Technology Mission Directorate (STMD)

National Aeronautics and Space Administration

ABSTRACT

We propose to develop a national center of excellence in Regolith Radiative Transfer (RRT), i.e., in modeling spectral reflectivity and emissivity of grainy or structured surfaces. The focus is the regime where the structural elements of grainy surfaces have grain sizes and separations of tens of microns, comparable to the wavelengths carrying diagnostic compositional information. This regime is of fundamental interest to remote sensing of planetary and terrestrial surfaces.



Technology Area: Modeling, Simulation, Information Technology & Processing TA11 (Primary)
Science Instruments, Observatories & Sensor Systems TA08 (Secondary)

ANTICIPATED BENEFITS

To NASA funded missions:

The New Horizons Mission plans to flyby a Kuiper Belt Object (KBO) after the flyby of Pluto. The analyses of the surface composition of a KBO requires modeling of spectral information derived from scattered light measurements. Models for KBO surfaces in scattered light can be improved by the RRT approach in the regime where the particle size on the surface is similar to the wavelength.

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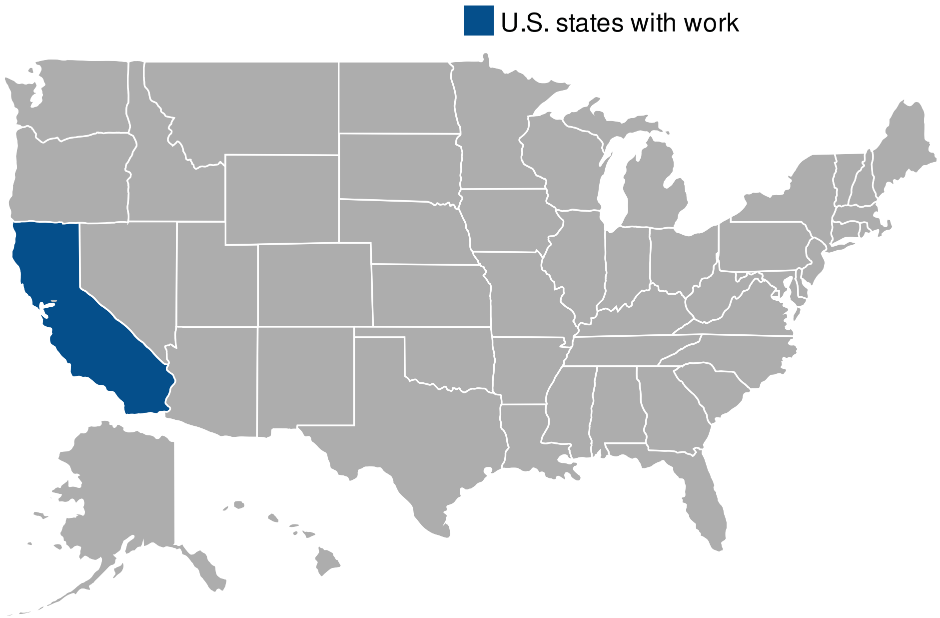
Read more on the last page.



Lead center: Ames Research Center

Supporting centers: Ames Research Center

DETAILED DESCRIPTION

The core capability on which we will build is an innovative numerical model of a surface composed of grains of arbitrary size, shape, composition, and porosity (Vahidinia et al 2010, 2011, 2012). Our code is an extension of the well-known “Discrete Dipole Approximation” (DDA; Draine and Flatau 1994), expanded to determine the near-field emergent intensity from a “surface” using periodic horizontal boundary conditions. Over the past four years, we have parallelized the code with MPI and OpenMP for efficient operation on the NAS HEC machines. Currently we have shown how increasing particle filling factor alone can affect the scattering properties of ensembles of otherwise identical particles. This effect sets in at surprisingly low filling factors (a few percent or less). The code can handle embedded nanoparticles by using suitable models of how their size changes their refractive indices (for instance, the Drude model for metals). It also can handle compositionally heterogeneous surfaces. In fact, it can handle any surface structure in complete generality. The code is currently limited primarily by memory per processor on the NAS machines, which will grow with time, but we have successfully modeled many cases each containing millions of dipoles to date.

MANAGEMENT

Program Executive:
Minoo Dastoor

Program Manager:
John Hines

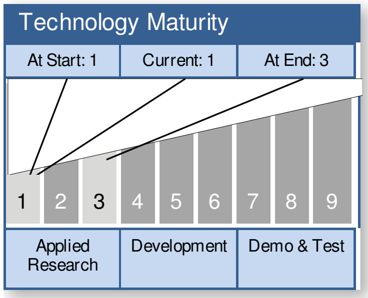
Project Manager:
Diane Wooden

Principal Investigator:
Diane Wooden

Co-Investigators:
Jeffrey Cuzzi
Sanaz Vahidinia

TECHNOLOGY DETAILS

Surface Spectroscopy Center of Excellence



TECHNOLOGY DESCRIPTION

The core capability on which we will build is an innovative numerical model for Regoligth Radiative Transfer (RRT) of a surface composed of grains of arbitrary size, shape, composition, and porosity (Vahidinia et al 2010, 2011, 2012). Our code is an extension of the well-known “Discrete Dipole Approximation” (DDA; Draine and Flatau 1994), expanded to determine the near-field emergent intensity from a “surface” using periodic horizontal boundary conditions. Over the past four years, we have parallelized the code with MPI and OpenMP for efficient operation on the NAS HEC machines. Currently we have shown how increasing particle filling factor alone can affect the scattering properties of ensembles of otherwise identical particles. This effect sets in at surprisingly low filling factors (a few percent or less). The code can handle embedded nanoparticles by using suitable models of how their size changes their refractive indices (for instance, the Drude model for metals). It also can handle compositionally heterogeneous surfaces. In fact, it can handle any surface structure in complete generality. The code is currently limited primarily by memory per processor on the NAS machines, which will grow with time, but we have successfully modeled many cases each containing millions of dipoles to date.

This technology is categorized as a software macro for ground scientific research or analysis

- Technology Area
    - TA11 Modeling, Simulation, Information Technology & Processing (Primary)
    - TA08 Science Instruments, Observatories & Sensor Systems (Secondary)
    - TA10 Nanotechnology (Additional)

CAPABILITIES PROVIDED

RRT codes compute the spectral reflectivity and emissivity of grainy surfaces of airless bodies in the regime where the grain sizes and separations are comparable to the wavelengths that carry diagnostic compositional information.

Surface composition is key to understanding their ...

TECHNOLOGY DETAILS

POTENTIAL APPLICATIONS (CONT'D)

origins.

ANTICIPATED BENEFITS

To NASA unfunded & planned missions: (CONT'D)

A future mission to a trojan asteroid is prioritized by the National Academy of Science New Worlds New Horizons 2011 decadal report. Robotic missions to asteroids also are in the NASA Global Exploration Roadmap.

Interpreting spectroscopy of Trojan Asteroids, Centaurs, and Kuiper Belt Objects, for example, sets the stage for analyzing the surfaces of outer bodies that probe the formation and evolution scenarios for these primitive bodies. Outer bodies often appear to have surfaces with dark red materials or with crystalline silicates, and these components of their surfacce compositions may be a product of surface evolution or of the collection of debris from collisions of other bodies. Standard models can be tuned to fit spectra of Trojan asteroid surfaces by embedding crystalline silicates in a optically transparent matrix (Emery et al. 2006, Icarus 182, 496) or by assuming that top mm-thickness of the surface is so highly porous that the grains in this layer are assumed to be emitting at a single temperaure (Vernazza et al. 2012, Icarus 221, 1162). The RRT models allow for an improved sophisitication over assuming a transparent medium or a single temperature in the near-surface layers. Drawing a more intricate picture with RRT of how the structure and composition of the surface allows for the wavelength-dependent penetration and reflection of sunlight, as well as emission of thermal radiation, will deepen our understanding of the origins and evolution of these solar system bodies.

Further advances in RRT require revision of radiative transfer models so that these models can propagate the amplitude and phase dependence of light passing through thin layers as the thin layers compromise the regolith/surface. The publicly available DISORT model is found inadequate to the task; a model with Ames' heritage by J. Pollack is the next avenue for approach. Regolith Radiative Transfer may be fundable through SMD Planetary Division under the Solar System Workings or Emerging Worlds (Cuzzi as PI, Wooden, Vahidinia as Co-Is), and to NSF (Vahidinia as PI).

To other government agencies:

The National Science Foundation has a Astronomy and Astrophysics Research Grants (AAG) program that supports studies of the detailed characterization, structure and composition of the surfaces and the nature of small bodies (asteroids, comets, and Kuiper-belt objects).