

to remain valid. Molecular methods are better suited to model this region of the flow. Finally, granular and multi-phase flow models must be employed to describe the dust and debris that are displaced from the surface, as well as how a crater is formed in the regolith. At present, standard commercial CFD (computational fluid dynamics) software is not capable of coupling each of these flow regimes to provide an accurate representation of this flow process, necessitating the development of custom software.

This software solves the fluid-flow-governing equations in an Eulerian framework, coupled with the particle transport equations that are solved in a Lagrangian framework. It uses a fourth-order explicit Runge-Kutta scheme for temporal integration, an eighth-order central finite differencing scheme for spatial discretization. The non-linear terms in the governing equations are recast in cubic skew symmetric form to reduce aliasing error. The second derivative viscous terms are computed using eighth-order narrow stencils that pro-

vide better diffusion for the highest resolved wave numbers. A fourth-order Lagrange interpolation procedure is used to obtain gas-phase variable values at the particle locations.

*This work was done by Josette Bellan and Senthilkumaran Radhakrishnan of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov).*

*The software used in this innovation is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-47694.*

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## ➤ Projection of Stabilized Aerial Imagery Onto Digital Elevation Maps for Geo-Rectified and Jitter-Free Viewing

**Projection code is faster, cleaner, and easier to integrate.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

As imagery is collected from an airborne platform, an individual viewing the images wants to know from where on the Earth the images were collected. To do this, some information about the camera needs to be known, such as its position and orientation relative to the Earth. This can be provided by common inertial navigation systems (INS). Once the location of the camera is known, it is useful to project an image onto some representation of the Earth. Due to the non-smooth terrain of the Earth (mountains, valleys, etc.), this projection is highly non-linear. Thus, to ensure accurate projection, one needs to project onto a digital elevation map (DEM). This allows one to view the images over-

laid onto a representation of the Earth.

A code has been developed that takes an image, a model of the camera used to acquire that image, the pose of the camera during acquisition (as provided by an INS), and a DEM, and outputs an image that has been geo-rectified. The world coordinate of the bounds of the image are provided for viewing purposes. The code finds a mapping from points on the ground (DEM) to pixels in the image. By performing this process for all points on the ground, one can "paint" the ground with the image, effectively performing a projection of the image onto the ground. In order to make this process efficient, a method was developed for finding a region of in-

terest (ROI) on the ground to where the image will project.

This code is useful in any scenario involving an aerial imaging platform that moves and rotates over time. Many other applications are possible in processing aerial and satellite imagery.

*This work was done by Adnan I. Ansar, Shane Brennan, Daniel S. Clouse, Yang Cheng, Curtis W. Padgett, and David C. Trotz of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*The software used in this innovation is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at [danielb@caltech.edu](mailto:danielb@caltech.edu). Refer to NPO-46920.*

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## ➤ Iterative Transform Phase Diversity: An Image-Based Object and Wavefront Recovery

*Goddard Space Flight Center, Greenbelt, Maryland*

The Iterative Transform Phase Diversity algorithm is designed to solve the problem of recovering the wavefront in the exit pupil of an optical system and the object being imaged. This algorithm builds upon the robust convergence capability of Variable Sampling Mapping (VSM), in combination with the known success of various deconvolution algorithms. VSM is an alternative method for enforcing the amplitude

constraints of a Misell-Gerchberg-Saxton (MGS) algorithm. When provided the object and additional optical parameters, VSM can accurately recover the exit pupil wavefront. By combining VSM and deconvolution, one is able to simultaneously recover the wavefront and the object.

To recover the exit pupil wavefront, and the unknown object, first one must collect image plane data of the optical

system under test. To increase convergence robustness, diversity images are collected. Next, a guess of the wavefront is made. This can be based on a prior estimate, or a simpler random solution of small values. This guess of the exit pupil and the image data will provide a starting point for VSM phase retrieval.

After several iterations of VSM phase retrieval, the algorithm will estimate the point spread function (PSF) based on

the current estimate of the exit pupil wavefront. This estimated PSF is then deconvolved from the image data to provide an estimate of the object. At this point, one has an estimate of the object,

and the estimated wavefront. The process is then repeated with the object included in the model in VSM. The entire process is repeated until a convergence criterion is met.

*This work was done by Jeffrey Smith for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15963-1*

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## ➤ 3D Drop Size Distribution Extrapolation Algorithm Using a Single Disdrometer

**Multiple sensors are not required for successful implementation of the 3D interpolation/extrapolation algorithm.**

*John F. Kennedy Space Center, Florida*

Determining the Z-R relationship (where Z is the radar reflectivity factor and R is rainfall rate) from disdrometer data has been and is a common goal of cloud physicists and radar meteorology researchers. The usefulness of this quantity has traditionally been limited since radar represents a volume measurement, while a disdrometer corresponds to a point measurement. To solve that problem, a 3D-DSD (drop-size distribution) method of determining an equivalent 3D Z-R was developed at the University of Central Florida and tested at the Kennedy Space Center, FL. Unfortunately, that method required a minimum of three disdrometers clustered together within a microscale network ( $\approx 1$ -km separation). Since most commercial disdrometers used by the radar meteorology/cloud physics community are high-cost instru-

ments, three disdrometers located within a microscale area is generally not a practical strategy due to the limitations of these kinds of research budgets.

A relatively simple modification to the 3D-DSD algorithm provides an estimate of the 3D-DSD and therefore, a 3D Z-R measurement using a single disdrometer. The basis of the horizontal extrapolation is mass conservation of a drop size increment, employing the mass conservation equation. For vertical extrapolation, convolution of a drop size increment using raindrop terminal velocity is used. Together, these two independent extrapolation techniques provide a complete 3D-DSD estimate in a volume around and above a single disdrometer. The estimation error is lowest along a vertical plane intersecting the disdrometer position in the direction of wind advection.

This work demonstrates that multiple sensors are not required for successful implementation of the 3D interpolation/extrapolation algorithm. This is a great benefit since it is seldom that multiple sensors in the required spatial arrangement are available for this type of analysis.

The original software (developed at the University of Central Florida, 1998–2000) has also been modified to read standardized disdrometer data format (Joss-Waldvogel format). Other modifications to the software involve accounting for vertical ambient wind motion, as well as evaporation of the raindrop during its flight time.

*This work was done by John Lane of ASRC Aerospace Corporation for Kennedy Space Center. Further information is contained in a TSP (see page 1). KSC-13302*

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## ➤ Social Networking Adapted for Distributed Scientific Collaboration

**Sci-Share provides scientists with a set of tools for e-mail, file sharing, and information transfer.**

*Goddard Space Flight Center, Greenbelt, Maryland*

Sci-Share is a social networking site with novel, specially designed feature sets to enable simultaneous remote collaboration and sharing of large data sets among scientists. The site will include not only the standard features found on popular consumer-oriented social networking sites such as Facebook and MySpace, but also a number of powerful tools to extend its functionality to a science collaboration site.

A Virtual Observatory is a promising technology for making data accessible from various missions and instruments through a Web browser. Sci-Share aug-

ments services provided by Virtual Observatories by enabling distributed collaboration and sharing of downloaded and/or processed data among scientists. This will, in turn, increase science returns from NASA missions. Sci-Share also enables better utilization of NASA's high-performance computing resources by providing an easy and central mechanism to access and share large files on users' space or those saved on mass storage.

The most common means of remote scientific collaboration today remains the trio of e-mail for electronic communication, FTP for file sharing, and per-

sonalized Web sites for dissemination of papers and research results. Each of these tools has well-known limitations. Sci-Share transforms the social networking paradigm into a scientific collaboration environment by offering powerful tools for cooperative discourse and digital content sharing. Sci-Share differentiates itself by serving as an online repository for users' digital content with the following unique features:

- Sharing of any file type, any size, from anywhere;
- Creation of projects and groups for controlled sharing;