using CloudSat radar measurements. It uses a statistical method called maximum likelihood estimation to estimate the probability density function of the cloud water content.

A crude treatment of sub-grid scale cloud processes in current climate models is widely recognized as a major limitation in predictions of global climate change. At present, typical climate models have a horizontal resolution on the order of 100 km and a variable vertical resolution between 100 m and 1 km. Since climate models cannot explicitly resolve what happens at the sub-grid scales, the physics must be parameterized as a function of the resolved motions. The fundamental problem of cloud parameterization is to characterize the distributions of cloud variables at sub-grid scales and to relate the sub-grid variations to the resolved flow. This software solves the problem by estimating the probability density function of cloud water content at the sub-grid scale using CloudSat measurements.

This work was done by Seungwon Lee of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47248.

Autonomous Planning and Replanning for Mine-Sweeping Unmanned Underwater Vehicles

NASA's Jet Propulsion Laboratory, Pasadena, California

This software generates high-quality plans for carrying out mine-sweeping activities under resource constraints. The autonomous planning and replanning system for unmanned underwater vehicles (UUVs) takes as input a set of prioritized mine-sweep regions, and a specification of available UUV resources including available battery energy, data storage, and time available for accomplishing the mission. Mine-sweep areas vary in location, size of area to be swept, and importance of the region. The planner also works with a model of the UUV, as well as a model of the power consumption of the vehicle when idle and when moving.

The planner begins by using a depth-first, branch-and-bound search algorithm to find an optimal mine sweep to maximize the value of the mine-sweep regions included in the plan, subjected to available resources. The software issues task commands to an underlying control architecture to carry out the activities on the vehicle, and to receive updates on the state of the world and the vehicle. During plan execution, the planner uses updates from the control system to make updates to the predictions of the vehicle and world states. The effects of these updates are propagated into the future and allow the planner to detect conflicts ahead of time, or to identify any resource surplus that might exist and could allow the planner to include additional mine-sweep regions.

This work was done by Daniel M. Gaines of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47018.

Dayside Ionospheric Superfountain

NASA's Jet Propulsion Laboratory, Pasadena, California

The Dayside Ionospheric Superfountain modified SAMI2 code predicts the uplift, given storm-time electric fields, of the dayside near-equatorial ionosphere to heights of over 800 kilometers during magnetic storm intervals. This software is a simple 2D code developed over many years at the Naval Research Laboratory, and has importance relating to accuracy of GPS positioning, and for satellite drag.

This work was done by Bruce T. Tsurutani, Olga P. Verkhoglyadova, and Anthony J. Mannucci of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47209.

In-Situ Pointing Correction and Rover Microlocalization

NASA's Jet Propulsion Laboratory, Pasadena, California

Two software programs, marstie and marsnav, work together to generate pointing corrections and rover micro-localization for *in-situ* images. The programs are based on the PIG (Planetary Image Geometry) library, which handles all mission dependencies. As a result, there is no mission-specific code in either of these programs. This software corrects geometric seams in images as much as possible (some parallax seams are uncorrectable).

First, marstie is used to gather tiepoints. The program analyzes the input image set, determines which images overlap, and presents overlapping pairs to the user. The user then manually creates a number of tiepoints between each pair, by identifying the locations of features that are common to both images. An automatic correlator assists the user in getting subpixel accuracy on these tiepoints. Tiepoints may also be edited.

The tiepoints are then used by the second program, marsnav, to generate pointing corrections. This works by projecting one half of each tiepoint to a surface model and back into the other image. This projected location is then compared to the measured tiepoint and a residual error is determined. A global minimization process adjusts the pointing of each input frame until the optimal pointing is determined. The pointing is typically constrained to match possible physical camera motions, although the pointing model is selectable via the PIG library. The resulting "nav solution" is then input into the mosaic programs, which apply the pointing adjustment in order to make seamless mosaics.

In addition to adjusting the pointing, marsnav can also adjust the surface model (helpful when dealing with an unknown terrain), and the position and/or orientation of the rover itself. The latter results in a "micro-localization" — determining where the rover is and how it is oriented on a very fine scale.

Commercial mosaic-stitching programs exist. However, they typically perform unconstrained warping of the images in order to achieve a match. This results in an unknown geometry and unacceptable distortion. By correcting the seams using this pointing-correction method, the result is constrained to be physically meaningful, and is accurate enough to be acceptable for use by science and ops teams. This method does, however, require *a priori* camera calibration information. The techniques are not limited to mast-mounted cameras; they have been successfully applied to arm cameras as well.

This work was done by Robert G. Deen and Jean J. Lorre of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-46696.

Operation Program for the Spatially Phase-Shifted Digital Speckle Pattern Interferometer — SPS-DSPI

Goddard Space Flight Center, Greenbelt, Maryland

SPS-DSPI software has been revised so that Goddard optical engineers can operate the instrument, instead of data programmers. The user interface has been improved to view the data collected by the SPS-DSPI, with a real-time mode and a play-back mode. The SPS-DSPI has been developed by NASA/GSFC to measure the temperature distortions of the primary-mirror backplane structure for the James Webb Space Telescope. It requires a team of computer specialists to run successfully, because, at the time of this reporting, it just finished the prototype stage. This software improvement will transition the instrument to become available for use by many programs that measure distortion.

Dead code from earlier versions has been removed. The tighter code has been refactored to improve usability and maintainability. A prototype GUI has been created to run this refactored code. A big improvement is the ability to test the monitors and real-time functions without running the laser, by using a data acquisition simulator.

This work was done by Peter N. Blake, Joycelyn T. Jones, and Carl F. Hostetter of Goddard Space Flight Center and Perry Greenfield and Todd Miller of AURA Space Telescope Science Institute. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15709-1

GOATS - Orbitology Component

NASA's Jet Propulsion Laboratory, Pasadena, California

The GOATS Orbitology Component software was developed to specifically address the concerns presented by orbit analysis tools that are often written as stand-alone applications. These applications do not easily interface with standard JPL first-principles analysis tools, and have a steep learning curve due to their complicated nature. This toolset is written as a series of MATLAB functions, allowing seamless integration into existing JPL optical systems engineering modeling and analysis modules. The functions are completely open, and allow for advanced users to delve into and modify the underlying physics being modeled. Additionally, this software module fills an analysis gap, allowing for quick, high-level mission analysis trades without the need for detailed and complicated orbit analysis using commercial stand-alone tools.

This software consists of a series of MATLAB functions to provide for geometric orbit-related analysis. This includes propagation of orbits to varying levels of generalization. In the simplest case, geosynchronous orbits can be modeled by specifying a subset of three orbit elements. The next case is a circular orbit, which can be specified by a subset of four orbit elements. The most general case is an arbitrary elliptical orbit specified by all six orbit elements. These orbits are all solved geometrically, under the basic problem of an object in circular (or elliptical) orbit around a rotating spheroid. The orbit functions output time series ground tracks, which serve as the basis for more detailed orbit analysis. This software module also includes functions to track the positions of the Sun, Moon, and arbitrary celestial bodies specified by right ascension and declination. Also included are functions to calculate line-of-sight geometries to ground-based targets, angular rotations and decompositions, and other line-of-site calculations.

The toolset allows for the rapid execution of orbit trade studies at the level of detail required for the early stage of mission concept development.