

secutive radar profiles are offset slightly (by amounts much less than  $\Delta r$ ) with respect to each other according to the relative change in geodetic altitude. As a consequence, in a case in which the surface area under examination is homogeneous (e.g., an ocean surface), a sequence of consecutive radar profiles of the surface in that area contains samples of the surface response with range resolution ( $\Delta\rho$ ) much finer than the range-bin increment ( $\Delta\rho \ll \Delta r$ ).

Once the high-resolution surface response has thus become available, the profile of surface clutter can be accurately estimated by use of a conventional maximum-correlation scheme: A trans-

lated and scaled version of the high-resolution surface response is fitted to the observed low-resolution profile. The translation and scaling factors that optimize the fit in a maximum-correlation sense represent (1) the true position of the surface relative to the sampled surface peak and (2) the magnitude of the surface backscatter.

The performance of this algorithm has been tested on CloudSat data acquired over an ocean surface. A preliminary analysis of the test data showed a surface-clutter-rejection ratio over flat surfaces of  $>10$  dB and a reduction of the contaminated altitude over ocean from about 1 km to about 0.5 km (over the ocean).

The algorithm has been embedded in CloudSat L1B processing as of Release 04 (July 2007), and the estimated flat surface clutter is removed in L2B-GEOPROF product from the observed profile of reflectivity (see CloudSat product documentation for details and performance at <http://www.cloudsat.cira.colostate.edu/dataSpecs.php?prodid=1>).

*This work was done by Simone Tanelli, Kyung Pak, Stephen Durden, and Eastwood Im of Caltech for NASA's Jet Propulsion Laboratory.*

*The software used in this innovation is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-44873.*

## MODIS Atmospheric Data Handler

*Stennis Space Center, Mississippi*

A number of science data sets are derived from the observations of the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument onboard NASA's Terra and Aqua satellites. These data typically contain information on retrieval techniques, quality-control flags, and geo-referencing information. These datasets, distributed in HDF (Hierarchical Data Format), must be further processed to extract relevant information for weather analysis studies and numerical models input. The MODIS-Atmosphere Data Handler software converts the HDF data to ASCII format, and outputs: (1) atmospheric profiles

of temperature and dew point and (2) total precipitable water. Quality-control data are also considered in the export procedure.

The package currently consists of programs to process the MOD05 and MOD07 data products from MODIS. The software is written using the C programming language and contains Makefiles for easier compilation and installation. The MODIS-ADH software helps ease the overhead involved in data processing so that the numerical modelers may concentrate on their science and modeling tasks rather than manipulating data for their models.

*This program was written by Valentine Anantharaj and Patrick Fitzpatrick of the Northern Gulf Institute at Mississippi State University for Stennis Space Center.*

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## Multibeam Altimeter Navigation Update Using Faceted Shape Model

**The model is applicable to a body having almost any complex shape.**

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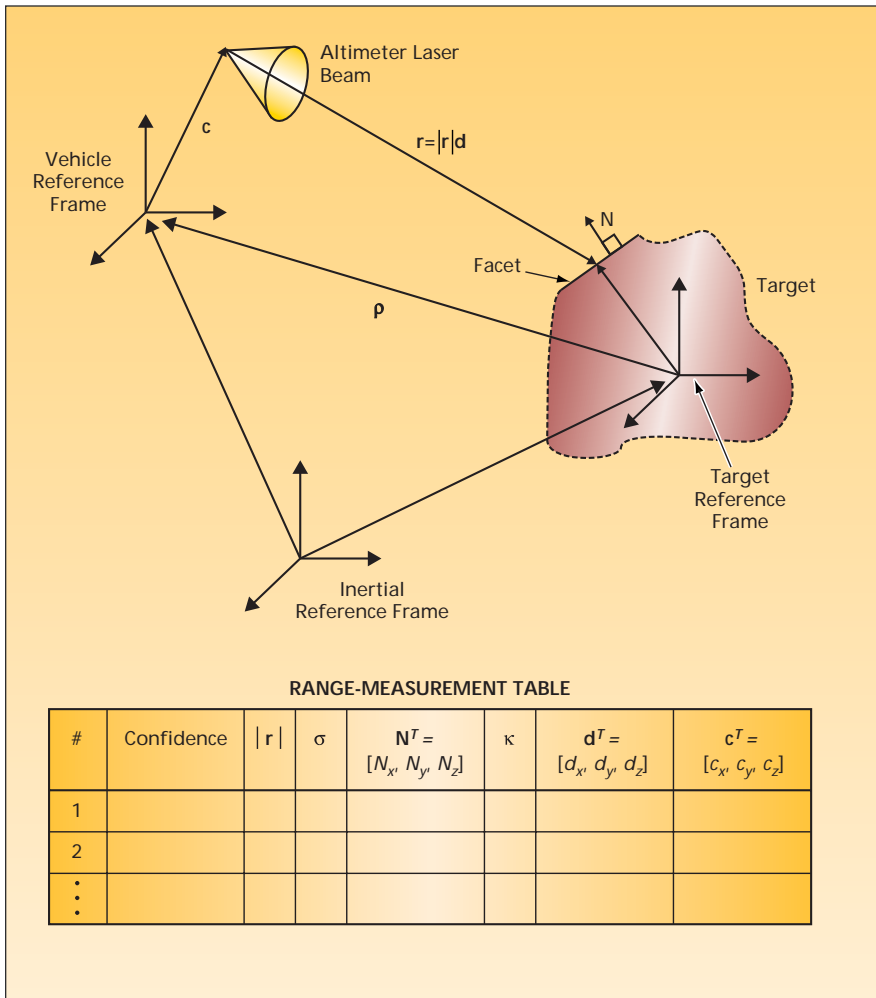
A method of incorporating information, acquired by a multibeam laser or radar altimeter system, pertaining to the distance and direction between the system and a nearby target body, into an estimate of the state of a vehicle upon which the system is mounted, involves the use of a faceted model to represent the shape of the target body. In the original intended application, the vehicle would be a spacecraft and the target body would be an asteroid, comet, or similar body that the spacecraft was required to approach. The method could

also be used in navigating aircraft at low altitudes over terrain that is rough and/or occupied by objects of significant structure.

Fundamentally, what one seeks to measure is the distance from the vehicle to the target body. The present method is the product of a generalization of a prior method of altimetry, in which the target body has a simple shape represented by a spherical or ellipsoidal model. In principle, the estimate of distance or altitude obtained by use of a multibeam altimeter can be more robust

than that obtained by use of a single-beam altimeter, but if the surface of the target body has a complex and/or irregular shape, then it becomes more difficult to define the distance and compute the distance from readings of a multibeam altimeter.

The faceted shape model of the present method facilitates the definition and computation of distance to a target object having almost any shape, no matter how irregular and complex. The use of faceted shape models to represent complex three-dimensional objects is com-



The Laser or Radar Altimeter measures the magnitude of the vector ( $r$ ) from the origin of each beam to the intersection of the beam with a target body represented by a multifaceted shape model. There are multiple beams, but only one is shown here for simplicity. The measurement data and associated model data are listed in the range-measurement table.

mon in the computer-graphics literature and in the movie and video-game industries. In this method, the distance to be measured is defined as the length of the vector ( $\rho$ ) from the center of mass of the multifaceted shape model to the center of mass of the vehicle, as depicted in the upper part of the figure.

The state-update information derived from the most recent set of multibeam-

altimeter measurements is listed systematically in a range-measurement table (RMT), depicted in the lower part of the figure, in which the planar facets of the shape model are represented in Hesse's normal form. Each row of the table contains the data from one of the altimeter beams. The first column contains the row index ( $i$ ), which is the cardinal number of the affected beam. The second

column contains a number, between 0 and 1, representing the degree of confidence in the measurements. At the present state of development of the method, the confidence is taken to be either 0 (signifying complete rejection) or 1 (representing complete acceptance) of the data in the row. The third column contains the scalar range measurement  $|r|$  of the  $i$ th beam; the fourth column contains the standard deviation ( $\sigma$ ) of the range measurement.

The fifth column contains the Cartesian components  $[N_x, N_y, N_z]$  of the transpose of the unit vector ( $N^T$ ) normal to the model facet containing the intersection of the  $i$ th laser beam with the surface of the target object. Typically, this intersection point is not known exactly and must be estimated, on the basis of the current state estimate, by a previously developed method that lies beyond the scope of this article. The sixth column contains the facet constant,  $\kappa$  (the perpendicular distance from the center of mass of the target body to the affected facet). The seventh column contains the Cartesian components  $[d_x, d_y, d_z]$  of the unit vector along the  $i$ th laser beam. The seventh column contains the Cartesian components  $[c_x, c_y, c_z]$  of the position vector from the center of mass of the vehicle to the origin of the  $i$ th laser beam.

The entries in the RMT are mapped into a measurement equation for use by a Kalman filter that incorporates altimetry information into the final estimate of the state of a spacecraft or other vehicle maneuvering in the vicinity of a target body. The relative position vector,  $\rho$ , is part of the state vector that is updated by use of the Kalman filter.

*This work was done by David S. Bayard, Paul Brugarolas, and Steve Broschart of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-44428*