

Additionally, once orbit parameters are settled upon, the same tools can be used to model system performance, and execute more focused trade studies as requirements are being developed and analyzed. This toolset offers a cohesive

model-based systems engineering tool to be used as mission concepts are developed and in the development and analysis of top-level system requirements.

*This work was done by Benjamin M. Haber and Joseph J. Green of Caltech for*

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*This software 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-47236.*

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## Hybrid-PIC Computer Simulation of the Plasma and Erosion Processes in Hall Thrusters

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

HPHall software simulates and tracks the time-dependent evolution of the plasma and erosion processes in the discharge chamber and near-field plume of Hall thrusters. HPHall is an axisymmetric solver that employs a hybrid fluid/particle-in-cell (Hybrid-PIC) numerical approach. HPHall, originally developed by MIT in 1998, was upgraded to HPHall-2 by the Polytechnic University of Madrid in 2006. The Jet Propulsion Laboratory has continued the development of HPHall-2 through

upgrades to the physical models employed in the code, and the addition of entirely new ones.

Primary among these are the inclusion of a three-region electron mobility model that more accurately depicts the cross-field electron transport, and the development of an erosion sub-model that allows for the tracking of the erosion of the discharge chamber wall. The code is being developed to provide NASA science missions with a predictive tool of Hall thruster performance and

lifetime that can be used to validate Hall thrusters for missions.

*This work was done by Richard R. Hofer, Ira Katz, and Ioannis G. Mikellides of Caltech and Manuel Gamero-Castano of the University of California, Irvine for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This software 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-46513.*

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## BioNet Digital Communications Framework

*John H. Glenn Research Center, Cleveland, Ohio*

BioNet v2 is a peer-to-peer middleware that enables digital communication devices to "talk" to each other. It provides a software development framework, standardized application, network-transparent device integration services, a flexible messaging model, and network communications for distributed applications. BioNet is an implementation of the Constellation Program Command, Control, Communications and Information (C3I) Interoperability specification, given in CxP 70022-01.

The system architecture provides the necessary infrastructure for the integra-

tion of heterogeneous wired and wireless sensing and control devices into a unified data system with a standardized application interface, providing plug-and-play operation for hardware and software systems.

BioNet v2 features a naming schema for mobility and coarse-grained localization information, data normalization within a network-transparent device driver framework, enabling of network communications to non-IP devices, and fine-grained application control of data subscription bandwidth usage. BioNet directly integrates Disruption Tolerant Networking

(DTN) as a communications technology, enabling networked communications with assets that are only intermittently connected including orbiting relay satellites and planetary rover vehicles.

*This work was done by Kevin Gifford, Sebastian Kuzminsky, and Shea Williams of the University of Colorado at Boulder for Glenn Research Center.*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18415-1*

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## Real-Time Feature Tracking Using Homography

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

This software finds feature point correspondences in sequences of images. It is designed for feature matching in aerial imagery. Feature matching is a fundamental step in a number of important image processing operations: calibrating the cameras in a camera array, stabilizing im-

ages in aerial movies, geo-registration of images, and generating high-fidelity surface maps from aerial movies.

The method uses a Shi-Tomasi corner detector and normalized cross-correlation. This process is likely to result in the production of some mismatches. The

feature set is cleaned up using the assumption that there is a large planar patch visible in both images. At high altitude, this assumption is often reasonable. A mathematical transformation, called an homography, is developed that allows us to predict the position in

image 2 of any point on the plane in image 1. Any feature pair that is inconsistent with the homography is thrown out. The output of the process is a set of feature pairs, and the homography.

The algorithms in this innovation are well known, but the new implementation improves the process in several ways. It runs in real-time at 2 Hz on 64-megapixel imagery. The new Shi-Tomasi corner detector tries to produce the re-

quested number of features by automatically adjusting the minimum distance between found features. The homography-finding code now uses an implementation of the RANSAC algorithm that adjusts the number of iterations automatically to achieve a pre-set probability of missing a set of inliers. The new interface allows the caller to pass in a set of predetermined points in one of the images. This allows the ability to track the

same set of points through multipleframes.

*This work was done by Daniel S. Clouse, Yang Cheng, Adnan I. Ansar, David C. Trotz, and Curtis W. Padgett 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-46916.*

## ▶ Sparse Superpixel Unmixing for Hyperspectral Image Analysis

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

Software was developed that automatically detects minerals that are present in each pixel of a hyperspectral image. An algorithm based on sparse spectral unmixing with Bayesian Positive Source Separation is used to produce mineral abundance maps from hyperspectral images. A "superpixel" segmentation strategy enables efficient unmixing in an interactive session.

The algorithm computes statistically likely combinations of constituents based on a set of possible constituent minerals whose abundances are uncertain. A library of source spectra from laboratory experiments or previous remote observations is used. A superpixel segmentation strategy improves analysis time by orders of magnitude, permitting incorporation into an interactive user session (see figure).

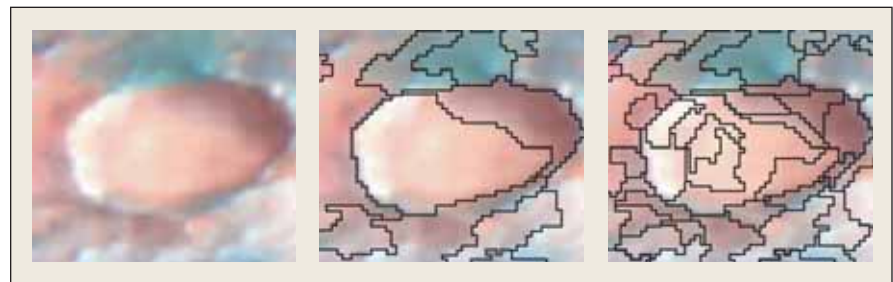
Mineralogical search strategies can be categorized as "supervised" or "unsupervised." Supervised methods use a detec-

tion function, developed on previous data by hand or statistical techniques, to identify one or more specific target signals. Purely unsupervised results are not always physically meaningful, and may ignore subtle or localized mineralogy since they aim to minimize reconstruction error over the entire image. This algorithm offers advantages of both methods, providing meaningful physical interpretations and sensitivity to subtle or unex-

pected minerals.

*This work was done by Rebecca Castano and David R. Thompson of Caltech and Martha Gilmore of Wesleyan University 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-47038.*



Here a Subwindow of Observation demonstrates superpixel segmentation. Left: original subimage. Center: coarse segmentation, minimum region size 100. Right: fine segmentation, minimum region size 20.

## ▶ Intelligent Patching of Conceptual Geometry for CFD Analysis

*Langley Research Center, Hampton, Virginia*

The iPatch computer code for intelligently patching surface grids was developed to convert conceptual geometry to computational fluid dynamics (CFD) geometry (see figure). It automatically uses bicubic B-splines to extrapolate (if necessary) each surface in a conceptual geometry so that all the independently defined geometric components (such as wing and fuselage) can be intersected to form a watertight CFD geometry. The software also computes the intersection curves of surface patches at any resolution (up to  $10^{-4}$  accuracy) specified by

the user, and it writes the B-spline surface patches, and the corresponding boundary points, for the watertight CFD geometry in the format that can be directly used by the grid generation tool VGRID.

iPatch requires that input geometry be in PLOT3D format where each component surface is defined by a rectangular grid  $\{(x(i,j), y(i,j), z(i,j)): 1 \leq i \leq m, 1 \leq j \leq n\}$  that represents a smooth B-spline surface. All surfaces in the PLOT3D file conceptually represent a watertight geometry of components of an aircraft

on the half-space  $y \geq 0$ . Overlapping surfaces are not allowed, but could be fixed by a utility code "fixp3d". The fixp3d utility code first finds the two grid lines on the two surface grids that are closest to each other in Hausdorff distance (a metric to measure the discrepancies of two sets); then uses one of the grid lines as the transition line, extending grid lines on one grid to the other grid to form a merged grid.

Any two connecting surfaces shall have a "visually" common boundary curve, or can be described by an inter-