by the more-efficient, less-expensive technique. It would not be necessary to address the fault-tolerance issue explicitly in writing an application program to be executed in such a system. Instead, ABFT and replication would be managed by middleware containing hooks.

This work was done by Raphael Some and David Rennels 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-43842.

Targeting and Localization for Mars Rover Operations

NASA's Jet Propulsion Laboratory, Pasadena, California

A design and a partially developed application framework were presented for improving localization and targeting for surface spacecraft. The program has value for the Mars Science Laboratory mission, and has been delivered to support the Mars Exploration Rovers as part of the latest version of the Maestro science planning tool. It also has applications for future missions involving either surface-based or low-altitude atmospheric robotic vehicles.

The targeting and localization solutions solve the problem of how to integrate localization estimate updates into operational planning tools, operational data product generalizations, and flight software by adding expanded flexibility to flight software, the operations data product pipeline, and operations planning tools based on coordinate frame updates during a planning cycle. When acquiring points of interest (targets) for the rover, instead of using a temporal method for reusing previously acquired targets, this system uses a spatial method to avoid tedious and repetitive target re-designation needed to keep target relevance accurate. Instead of creating a target that is reusable only for a sol (Martian day), the target is defined in a way to make it reusable for a planning position (the vehicle position indicated by a Site and Drive index pair) from which the vehicle will begin a command cycle.

This work was done by Mark W. Powell, Thomas Crockett, Jason M. Fox, Joseph C. Joswig, Jeffrey S. Norris, and Kenneth J. Rabe of 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-43847.

Terrain-Adaptive Navigation Architecture

NASA's Jet Propulsion Laboratory, Pasadena, California

A navigation system designed for a Mars rover has been designed to deal with rough terrain and/or potential slip when evaluating and executing paths. The system also can be used for any off-road, autonomous vehicles. The system uses more sophisticated terrain analysis, but also converges to computational complexity similar to that of currently deployed navigation systems when the terrain is benign. The system consists of technologies that have been developed, integrated, and tested onboard research rovers in Mars analog terrains, including goodness maps and terrain triage, terrain classification, remote slip prediction, path planning, high-fidelity traversability analysis (HFTA), and slip-compensated path following.

The system enables vehicles to autonomously navigate different terrain challenges including dry river channel systems, putative shorelines, and gullies emanating from canyon walls. Several of the technologies within this innovation increase the navigation system's capabilities compared to earlier rover navigation algorithms.

This work was done by Daniel M. Helmick, Anelia Angelova, Larry H. Matthies, and Daniel M. Helmick 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- 44588.

Self-Adjusting Hash Tables for Embedded Flight Applications

NASA's Jet Propulsion Laboratory, Pasadena, California

A common practice in computer science to associate a value with a key is to use a class of algorithms called a hash-table. These algorithms enable rapid storage and retrieval of values based upon a key. This approach assumes that many keys will need to be stored immediately. A new set of hash-table algorithms optimally uses system resources to ideally represent keys and values in memory such that the information can be stored and retrieved with a minimal amount of time and space. These hash-tables support the efficient addition of new entries. Also, for large data sets, the look-up time for large data-set searches is independent of the number of items stored, i.e., O(1), provided that the chance of collision is low.

Like arrays, hash-tables provide constant time O(1) look-up on average, regardless of the number of items in the table. However, the rare worst-case look-up time can be as bad as O(n). Compared to other associative array data structures, hash-tables are most useful when large numbers of records are to be stored, especially if the size of the data set can be predicted.

These algorithms may be used as in-memory data structures and may also be adopted for use with persistent data structures. Hash-tables are used in thousands of instances of flight code, and this approach could improve the efficiency of those applications, allowing them to run in smaller memory footprints and to autonomously evolve with time if and when their data demands a more efficient representation.

This work was done by Mark James of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-40363, volume and number of this NASA Tech Briefs *issue, and the page number.*

Schema for Spacecraft-Command Dictionary

NASA's Jet Propulsion Laboratory, Pasadena, California

An Extensible Markup Language (XML) schema was developed as a means of defining and describing a structure for capturing spacecraft command-definition and tracking information in a single location in a form readable by both engineers and software used to generate software for flight and ground systems. A structure defined within this schema is then used as the basis for creating an XML file that contains command definitions. The schema is divided into three sections:

- Header information, including information about the project and XML file to be derived from the schema;
- Project-specific definitions of types, roles, and allowable values of data; and
- The information necessary for defining the command structure, including the information necessary for generating all pertinent software.

Among the advantages afforded by XML for such applications are the following:

- There exist commercial off-the-shelf (COTS) software tools and standard scripting-language modules for parsing XML schemata. These tools and modules facilitate the ingestion of XML files for use.
- By use of COTS software tools, the structures of, and some properties of the data in, XML files can be validated against their parent XML schemata to detect errors early.

This work was done by Sharon Laubach, Celina Garcia, Scott Maxwell, and Jesse Wright of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.
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