structural loads in real time while the structure is in service.

The amount of structural information can be maximized through the use of highly multiplexed fiber Bragg grating technology using optical time domain reflectometry and optical frequency domain reflectometry, which can provide a local strain measurement every 10 mm on a single hair-sized optical fiber. Since local strain is used as input to the algorithms, this system serves multiple purposes of measuring strains and displacements, as well as determining structural bending moment, shear, and loads for assessing real-time structural health.

The first step is to install a series of strain sensors on the structure's surface in such a way as to measure bending strains at desired locations. The next step is to perform a simple ground test calibration. For a beam of length l (see example), discretized into n sections and subjected to a tip load of P that places the beam in bending, the flexural rigidity of the beam can be experimentally determined at each measurement location x. The bending moment at each station can then be determined for any general set of loads applied during operation.

This work was done by W. Lance Richards and William L. Ko of Dryden Flight Research Center. Further information is contained in a TSP (see page 1). DRC-008-023

Mission Analysis, Operations, and Navigation Toolkit Environment (Monte) Version 040

NASA's Jet Propulsion Laboratory, Pasadena, California

Monte is a software set designed for use in mission design and spacecraft navigation operations. The system can process measurement data, design optimal trajectories and maneuvers, and do orbit determination, all in one application. For the first time, a single software set can be used for mission design and navigation operations. This eliminates problems due to different models and fidelities used in legacy mission design and navigation software.

The unique features of Monte 040 include a blowdown thruster model for GRAIL (Gravity Recovery and Interior Laboratory) with associated pressure models, as well as an updated, optimal-search capability (COSMIC) that facilitated mission design for ARTEMIS. Existing legacy software lacked the capabilities necessary for these two missions. There is also a mean orbital element propagator and an osculating to mean element converter that allows long-term orbital stability analysis for the first time in compiled code.

The optimized trajectory search tool COSMIC allows users to place constraints and controls on their searches without any restrictions. Constraints may be user-defined and depend on trajectory information either forward or backwards in time. In addition, a long-term orbit stability analysis tool (morbiter) existed previously as a set of scripts on top of Monte.

Monte is becoming the primary tool for navigation operations, a core competency at JPL. The mission design capabilities in Monte are becoming mature enough for use in project proposals as well as post-phase A mission design.

Monte has three distinct advantages over existing software. First, it is being developed in a modern paradigm: object-oriented C++ and Python. Second, the software has been developed as a toolkit, which allows users to customize their own applications and allows the development team to implement requirements quickly, efficiently, and with minimal bugs. Finally, the software is managed in accordance with the CMMI (Capability Maturity Model Integration), where it has been appraised at maturity level 3.

This work was done by Richard F. Sunseri, Hsi-Cheng Wu, Scott E. Evans, James R. Evans, Theodore R. Drain, and Michelle M. Guevara 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-48184.

Autonomous Rover Traverse and Precise Arm Placement on Remotely Designated Targets

NASA's Jet Propulsion Laboratory, Pasadena, California

This software controls a rover platform to traverse rocky terrain autonomously, plan paths, and avoid obstacles using its stereo hazard and navigation cameras. It does so while continuously tracking a target of interest selected from 10–20 m away. The rover drives and tracks the target until it reaches the vicinity of the target. The rover then positions itself to approach the target, deploys its robotic arm, and places the end effector instrument on the designated target to within 2–3-cm accuracy of the originally selected target.

This software features continuous navigation in a fairly rocky field in an outdoor environment and the ability to enable the rover to avoid large rocks and traverse over smaller ones. Using point-and-click mouse commands, a scientist designates targets in the initial imagery acquired from the rover's mast cameras. The navigation software uses stereo imaging, traversability analysis, path planning, trajectory generation, and trajectory execution. It also includes visual target tracking of a designated target selected from 10 m away while continuously navigating the rocky terrain.

Improvements in this design include steering while driving, which uses continuous curvature paths. There are also several improvements to the traversability analyzer, including improved data fusion of traversability maps that result from pose estimation uncertainties, dealing with boundary effects to enable tighter maneuvers, and handling a wider range of obstacles.

This work advances what has been previously developed and integrated on the Mars Exploration Rovers by using algorithms that are capable of traversing more rock-dense terrains, enabling tight, thread-the-needle maneuvers. These algorithms were integrated on the newly refurbished Athena Mars research rover, and were fielded in the JPL Mars Yard. Forty-three runs were conducted with targets at distances ranging from 5 to 15 m, and a success rate of 93% was achieved for placement of the instrument within 2–3 cm of the target.

This work was done by Issa A. Nesnas and Mihail N. Pivtoraiko of Caltech, Alonzo Kelly of Carnegie Mellon University, and Michael Fleder of MIT 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. Refer to NPO-48062.

Computing Radiative Transfer in a 3D Medium

NASA's Jet Propulsion Laboratory, Pasadena, California

A package of software computes the time-dependent propagation of a narrow laser beam in an arbitrary three- dimensional (3D) medium with absorption and scattering, using the transient-discrete-ordinates method and a direct integration method. Unlike prior software that utilizes a Monte Carlo method, this software enables simulation at very small signal-to-noise ratios. The ability to simulate propagation of a narrow laser beam in a 3D medium is an improvement over other discrete-ordinate software. Unlike other direct-integration software, this software is not limited to simulation of propagation of thermal radiation with broad angular spread in three dimensions or of a laser pulse with narrow angular spread in two dimensions. Uses for this software include (1) computing scattering of a pulsed laser beam on a material having given elastic scattering and absorption profiles, and (2) evaluating concepts for laser-based instruments for sensing oceanic turbulence and related measurements of oceanic mixed-layer depths. With suitable augmentation, this software could be used to compute radiative transfer in ultrasound imaging in biological tissues, radiative transfer in the upper Earth crust for oil exploration, and propagation of laser pulses in telecommunication applications.

This program was written by Paul Von Allmen and 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-44719.

Architectural Implementation of NASA Space Telecommunications Radio System Specification

NASA's Jet Propulsion Laboratory, Pasadena, California

This software demonstrates a working implementation of the NASA STRS (Space Telecommunications Radio System) architecture specification. This is a developing specification of software architecture and required interfaces to provide commonality among future NASA and commercial software-defined radios for space, and allow for easier mixing of software and hardware from different vendors.

It provides required functions, and supports interaction with STRS-compliant simple test plug-ins ("waveforms"). All of it is programmed in "plain C," except where necessary to interact with C++ plug-ins. It offers a small footprint, suitable for use in JPL radio hardware.

Future NASA work is expected to develop into fully capable software-defined radios for use on the space station, other space vehicles, and interplanetary probes.

This work was done by Kenneth J. Peters, James P. Lux, Minh Lang, and Courtney B. Duncan of Caltech 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. Refer to NPO-47328.

Journal and Wave Bearing Impedance Calculation Software

John H. Glenn Research Center, Cleveland, Ohio

The wave bearing software suite is a MALTA application that computes bearing properties for user-specified wave bearing conditions, as well as plain journal bearings. Wave bearings are fluid film journal bearings with multi-lobed wave patterns around the circumference of the bearing surface. In this software suite, the dynamic coefficients are outputted in a way for easy implementation in a finite element model used in rotor dynamics analysis. The software has a graphical user interface (GUI) for inputting bearing geometry parameters, and uses MATLAB's structure interface