



### Quantifying Traversability of Terrain for a Mobile Robot

A document presents an updated discussion on a method of autonomous navigation for a robotic vehicle navigating across rough terrain. The method at an earlier stage of development was described in "Navigating a Mobile Robot Across Terrain Using Fuzzy Logic" (NPO-21199), *NASA Tech Briefs*, Vol. 27, No. 2 (February 2003), page 5a. To recapitulate: The method involves, among other things, the use of a measure of traversability, denoted the fuzzy traversability index, which embodies the information about the slope and roughness of terrain obtained from analysis of images acquired by cameras mounted on the robot. The improvements presented in the report focus on the use of the fuzzy traversability index to generate a traversability map and a grid map for planning the safest path for the robot. Once grid traversability values have been computed, they are utilized for rejecting unsafe path segments and for computing a traversal-cost function for ranking candidate paths, selected by a search algorithm, from a specified initial position to a specified final position. The output of the algorithm is a set of waypoints designating a path having a minimal-traversal cost.

*This work was done by Ayanna Howard, Homayoun Seraji, and Barry Werger 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 (818) 393-2827. Refer to NPO-30744.*

### More About Arc-Welding Process for Making Carbon Nanotubes

A report presents additional information about the process reported in "Manufacturing High-Quality Carbon Nanotubes at Lower Cost" (GSC-14601) *NASA Tech Briefs*, Vol. 28, No. 9 (September 2004), page 62. To recapitulate: High-quality batches of carbon nanotubes are produced at relatively low cost in a modified atmospheric-pressure electric-arc welding process that does

not include the use of metal catalysts. What would normally be a welding rod and a weldment are replaced by an amorphous carbon anode rod and a wider, hollow graphite cathode rod. Both electrodes are water-cooled. The cathode is immersed in ice water to about 0.5 cm from the surface. The system is shielded from air by flowing helium during arcing. As the anode is consumed during arcing at 20 to 25 A, it is lowered to maintain it at an approximately constant distance above the cathode. The process causes carbon nanotubes to form on the lowest 5 cm of the anode. The arcing process is continued until the anode has been lowered to a specified height. The nanotube-containing material is then harvested. The additional information contained in the instant report consists mostly of illustrations of carbon nanotubes and a schematic diagram of the arc-welding setup, as modified for the production of carbon nanotubes.

*This work was done by Jeanette M. Benavides and Henning Leidecker of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center; (301) 286-7351. Refer to GSC-14435.*

### Controlling Laser Spot Size in Outer Space

Three documents discuss a method of controlling the diameter of a laser beam projected from Earth to any altitude ranging from low orbit around the Earth to geosynchronous orbit. Such laser beams are under consideration as means of supplying power to orbiting spacecraft at levels of the order of tens of kilowatts apiece. Each such beam would be projected by use of a special-purpose telescope having an aperture diameter of 15 m or more. Expanding the laser beam to such a large diameter at low altitude would prevent air breakdown and render the laser beam eye-safe. Typically, the telescope would include an adaptive-optics concave primary mirror and a convex secondary mirror. The laser beam transmitted out to the satellite would remain in the near

field on the telescope side of the beam waist, so that the telescope focal point would remain effective in controlling the beam width. By use of positioning stages having submicron resolution and repeatability, the relative positions of the primary and secondary mirrors would be adjusted to change the nominal telescope object and image distances to obtain the desired beam diameter (typically about 6 m) at the altitude of the satellite. The limiting distance  $D_L$  at which a constant beam diameter can be maintained is determined by the focal range of the telescope  $4\lambda f^2$  where  $\lambda$  is the wavelength and  $f$  the  $f$ /number of the primary mirror. The shorter the wavelength and the faster the mirror, the longer  $D_L$  becomes.

*This work was done by Harold E. Bennett of Bennett Optical Research, Inc., for Marshall Space Flight Center.*

*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 MFS-32039-1, volume and number of this NASA Tech Briefs issue, and the page number.*

### Software-Reconfigurable Processors for Spacecraft

A report presents an overview of an architecture for a software-reconfigurable network data processor for a spacecraft engaged in scientific exploration. When executed on suitable electronic hardware, the software performs the functions of a physical layer (in effect, acts as a software radio in that it performs modulation, demodulation, pulse-shaping, error correction, coding, and decoding), a data-link layer, a network layer, a transport layer, and application-layer processing of scientific data. The software-reconfigurable network processor is undergoing development to enable rapid prototyping and rapid implementation of communication, navigation, and scientific signal-processing functions; to provide a long-lived communication infrastructure; and to provide greatly improved scientific-instrumentation and