# Books & Reports

## Mars-Approach Navigation Using *In Situ* Orbiters

A document discusses the continuing development of a navigation system that would enable a spacecraft to approach Mars on a trajectory precise enough to enable the spacecraft to land within 1 km of a specified location on the Martian surface. This degree of accuracy would represent an order-of-magnitude improvement over that now obtained in radiometric tracking by use of the Deep Space Network. The navigation system would be implemented largely in software running in digital processors in the Electra transceiver, the Mars Network's standard radio transceiver, that would be in both the approaching spacecraft and Mars Network orbiter. The Mars Network is an *ad hoc* constellation of existing and future Mars science orbiters and dedicated telecommunication orbiters that has been established as a communication and navigation infrastructure to support the exploration of Mars. The software would exploit the sensory and data-processing capabilities of the Electra transceivers to gather Doppler-shift and other radiometric tracking data and process those data into trajectories data that would be accurate to within 0.3 km at the point of entry into the Martian atmosphere (as needed to land within 1 km of a target surface location).

*This work was done by Courtney Duncan and Todd Ely of Caltech and E. Glenn Lightseyof the University of Texas at Austin 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 Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-43092.*

## Efficient Optimization of Low-Thrust Spacecraft Trajectories

A paper describes a computationally efficient method of optimizing trajectories of spacecraft driven by propulsion systems that generate low thrusts and, hence, must be operated for long times. A common goal in trajectory-optimization problems is to find minimum-time, minimum-fuel, or Pareto-optimal trajectories (here, Pareto-optimality signifies that no other solutions are superior with respect to both flight time and fuel consumption). The present method utilizes genetic and simulated-annealing algorithms to search for globally Pareto-optimal solutions. These algorithms are implemented in parallel form to reduce computation time. These algorithms are coupled with either of two traditional trajectory-design approaches called "direct" and "indirect." In the direct approach, thrust control is discretized in either arc time or arc length, and the resulting discrete thrust vectors are optimized. The indirect approach involves the primer-vector theory (introduced in 1963), in which the thrust control problem is transformed into a co-state control problem and the initial values of the co-state vector are optimized. In application to two example orbit-transfer problems, this method was found to generate solutions comparable to those of other state-of-the-art trajectory-optimization methods while requiring much less computation time.

*This work was done by Seungwon Lee, Wolfgang Fink, Ryan Russell, Richard Terrile, Anastassios Petropoulos, and Paul von Allmen 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 Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-42975.*

## Cylindrical Asymmetrical Capacitors for Use in Outer Space

A report proposes that cylindrical asymmetrical capacitors (CACs) be used to generate small thrusts for precise maneuvering of spacecraft on long missions. The report notes that it has been known for decades that when high voltages are applied to CACs in air, thrusts are generated — most likely as a result of ionization of air molecules and acceleration of the ions by the high electric fields. The report goes on to discuss how to optimize the designs of CACs for operation as thrusters in outer space. Components that could be used to enable outer-space operation include a supply of gas and a shroud, partly surrounding a CAC, into which the gas would flow. Other elements of operation and design discussed in the report include variation of applied voltage and/or of gas flow to vary thrust, effects of CAC and shroud dimensions on thrust and weight, some representative electrode configurations, and several alternative designs, including one in which the basic CAC configuration would be modified into something shaped like a conventional rocket engine with converging/diverging nozzle and an anode with gas feed in the space that, in a conventional rocket engine, would be the combustion chamber.

*This work was done by Jonathan W. Campbell of Marshall Space Flight Center. Further information is contained in a TSP (see page 1).*

*This invention has been patented by NASA (U.S. Patent No. 6,775,123). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31887-1.*

## Protecting Against Faults in JPL Spacecraft

A paper discusses techniques for protecting against faults in spacecraft designed and operated by NASA's Jet Propulsion Laboratory (JPL). The paper addresses, more specifically, fault-protection requirements and techniques common to most JPL spacecraft (in contradistinction to unique, mission specific techniques), standard practices in the implementation of these techniques, and fault-protection software architectures. Common requirements include those to protect onboard command, data-processing, and control computers; protect against loss of Earth/spacecraft radio communication; maintain safe temperatures; and recover from power overloads. The paper describes fault-protection techniques as part of a fault-management strategy that also includes functional redundancy, redundant hardware, and autonomous monitoring of (1) the operational and "health" statuses of spacecraft components, (2) temperatures inside and outside the spacecraft, and (3) allocation of power. The strategy also provides for preprogrammed automated responses to anomalous conditions. In addition, the software running in almost every