Introduction by Vice President, Engineering, Eli Gai

The Draper Technology Digest is published annually to highlight the achievements of Draper Laboratory's technical staff through their publications and patents. Committees established by the Vice President of Engineering reviewed papers that were published and patents that were issued during the calendar year 2003. This eighth issue of the Digest includes five papers spanning Draper's capabilities in spacecraft control systems, biomedical engineering, Microelectromechanical Systems (MEMS) technologies, signal processing, and autonomous flight systems.

The first paper by Amy Duwel and Neil Barbour surveys the results of the Laboratory's research and development work in MEMS during the past 20 years. It covers the initial development of MEMS inertial sensors, the subsequent drive to increase performance and reduce size, and the integration of those sensors into a miniaturized Inertial Navigation System/Global Positioning System (INS/GPS) for guided munitions. The paper also describes the Laboratory's development of various other MEMS devices for environmental, surveillance, radio frequency (RF) communications, signal processing, and biomedical engineering applications. Finally, the paper surveys the extensive facilities and capabilities that support the design, fabrication, and evaluation of Draper's MEMS devices and prototype systems.

The second paper by Leena Singh, John Plump, Marc McConley, and Brent Appleby extends previous work that was reported in the Draper Technology Digest in 2001. This paper describes a novel methodology to design agile, realizable trajectories for autonomous aircraft. The guidance trajectory is synthesized by optimally combining trajectory elements from a database of trim and agile maneuver flight primitives. The current paper extends the previous work to three dimensions in real time. New results are presented to demonstrate the performance of Draper's trajectory design methodology for collision avoidance in the context of autonomous missions in urban terrain. These results were obtained by integrating Draper's guidance software with Georgia Tech's GTMAX flight control and simulation system, one of the platforms used to showcase DARPA's software-enabled control (SEC) technologies.

The third paper, "Living Three-Dimensional Microfabricated Constructs for the Replacement of Vital Organ Function," authored by Jeff Borenstein, Eli Weinberg, et al., was selected for the Engineering Vice President's Award for the Best Paper published in 2003. This paper reports the first demonstration of high-resolution, 3-dimensional constructs of living tissue suitable for transplantation for vital organ replacement devices. The vascular supply is fabricated by replica molding of thin sheets of biopolymers stacked to form 3-dimensional channel networks. These vascular networks provide the blood supply needed to support organ function. Initial results demonstrate that rat hepatocytes can be sustained and retain their function for periods of weeks. This work was done as part of Draper's participation in the Center for the Integration of Medicine and Innovative Technology (CIMIT) and reflects the Lab's increasing involvement in biomedical engineering.

The fourth paper by Lee Yang and Ernie Griffith deals with the International Space Station's Attitude Control System (ACS) during altitude reboost. During this mode of operation, structural flex can interfere with the operation of the controller. These flex/controller interactions were studied via simulation, and it was found that by imposing delays between adjacent jets firing using the ACS software, the problem can be mitigated. These results are representative of the high-quality, high-fidelity analytical services that Draper continues to provide to NASA's manned space programs in the areas of spacecraft dynamics and control.

The final paper was authored by Mukund Desai and Rami Mangoubi. It addresses the problem of matched-filter and subspace detection in the presence of arbitrary noise and interference, or in the presence of interfering signals that may lie in an arbitrary unknown subspace of the measurement space. A minimax methodology is developed to deal with this uncertainty that can also be adapted to situations where partial information on the interference or uncertainties is available. The result is a robust hypothesis test that is applicable to a large class of noise density functions. The matched-filter expressions are simple and computationally efficient. It is also shown that, compared with the conventional detector, the robust detector trades off some detection performance in the absence of interference for robustness in its presence.

Four patents were nominated for the Vice President's Award for the Best Patent issued in calendar year 2003. The winning patent was authored by Marc Weinberg, Daniel Merfeld, Steve Rauch, and Conrad Wall, III for "Balance Prosthesis." This prosthesis aids the wearer's spatial orientation by sensing body motion and providing feedback signals to correct the wearer's intuitive response.