

- terminated when stable compressor operation returns; or
3. Closed-loop or feedback-controlled operation, in which compressor stability is monitored and the number of active injectors and the injection rate are continually adjusted, using a dynamic control model and controlled valves.

In each of these operating modes, the injected working fluid can be supplied from an external source or from a downstream compressor stage where the total pressure is sufficient to produce the injected stream(s).

*This work was done by Gary J. Skoch of the U.S. Army Research Laboratory for Glenn Re-*

*search Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17560-1.*

## ✿ Inertial Measurements for Aero-assisted Navigation (IMAN)

*NASA's Jet Propulsion Laboratory, Pasadena, California*

IMAN is a Python tool that provides inertial sensor-based estimates of spacecraft trajectories within an atmospheric influence. It provides Kalman filter-derived spacecraft state estimates based upon data collected onboard, and is shown to perform at a level comparable to the conventional methods of spacecraft navigation in terms of accuracy and at a higher level with regard to the availability of results immediately after completion of an atmospheric drag pass. A benefit of this architecture is that this technology is conducive to onboard data processing and estimation and thus can compute near real-time spacecraft state estimates making it suitable for autonomous operations and/or closed-loop guidance, navigation, and control strategies.

This tool can be used to reliably predict subsequent periapsis times and locations over all aerobraking regimes. It also yields accurate peak dynamic pressure and heating rates, which are critical for a successful corridor control strategy. These data are comparable to radiometric-based navigation team reconstructed values. IMAN also provides the first instance of the use of the Unscented Kalman Filter (UKF) for the purpose of estimating an actual spacecraft trajectory arc about another planet. A significant advantage to the implementation of this type of filter is that the UKF is a non-linear filter and thus accurate to at least second order. It provides more meaningful and realistic covariances and has been shown to be robust in the presence of sparse data sets.

Currently, IMAN is being used in an experiment to demonstrate Inertial Measurement Unit (IMU)-based aerobraking navigation for the Mars Reconnaissance Orbiter (MRO). It also can be used in other operational missions such as those using the atmosphere for entry-descent-landing or solar sail missions that experience significant solar radiation pressure for propulsion.

*This program was written by Moriba Jah, Michael Lisano, and George Hockney 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 Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-43677.*

## ✿ Analysis of Complex Valve and Feed Systems

*Stennis Space Center, Mississippi*

A numerical framework for analysis of complex valve systems supports testing of propulsive systems by simulating key valve and control system components in the test loop. In particular, it is designed to enhance the analysis capability in terms of identifying system transients and quantifying the valve response to these transients. This system has analysis capability for simulating valve motion in complex systems operating in diverse flow regimes ranging from compressible gases to cryogenic liquids. A key feature is the hybrid, unstructured framework with sub-models for grid movement and phase change including cryogenic cavitations.

The multi-element unstructured framework offers improved predictions of valve performance characteristics under steady conditions for structurally complex valves such as pressure regulator valve. Unsteady simulations of valve motion using this computational approach have been car-

ried out for various valves in operation at Stennis Space Center such as the split-body valve and the 10-in. ( $\approx 25.4$ -cm) LOX (liquid oxygen) valve and the 4-in. ( $\approx 10$  cm) Y-pattern valve (liquid nitrogen). Such simulations make use of variable grid topologies, thereby permitting solution accuracy and resolving important flow physics in the seat region of the moving valve.

An advantage to this software includes possible reduction in testing costs incurred due to disruptions relating to unexpected flow transients or functioning of valve/flow control systems. Prediction of the flow anomalies leading to system vibrations, flow resonance, and valve stall can help in valve scheduling and significantly reduce the need for activation tests. This framework has been evaluated for its ability to predict performance metrics like flow coefficient for cavitating venturis and valve coefficient curves, and could be a valuable tool in predicting and under-

standing anomalous behavior of system components at rocket propulsion testing and design sites.

*This program was written by Vineet Ahuja, Ashvin Hosangadi, Jeremy Shipman, Peter Cavallo, and Sanford Dash of Combustion Research and Flow Technology (CRAFT), Inc. for Stennis Space 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:*

*Dr. Vineet Ahuja*

*Combustion Research and Flow Technology (CRAFT Tech), Inc.*

*6210 Keller's Church Road*

*Pipersville, PA 18947-1020*

*Phone No.: (215) 766-1520*

*Fax: (215) 766-1524*

*E-mail: vineet@craft-tech.com*

*Refer to SSC-00245, volume and number of this NASA Tech Briefs issue, and the page number.*