that when powder was not being fed, the outer pipe would be rotated to a shaft angle at which the windows in the two pipes would occlude each other. The thread on the outer pipe would engage a threaded fitting on the bottom of the bellows, so that rotation of the outer pipe would compress the bellows as the powder was consumed.

The lower tank would serve as both a reactor and chamber for storing the solid waste end product (MgO) of the hydrogen-generating reactions. As the powder was fed from the upper tank to the lower tank and the bellows was compressed, the volume of the lower tank would grow, making room for the growing amount of waste material. Because fresh fuel would be dropped over the most recently reacted portion of the consumed fuel, it would always come in contact with the hottest part. There would be ample time for the fuel to react as nearly completely as possible because once the fuel was in the reactor, it would stay there. A thermally insulating layer (not shown in the figure) on the bottom of the bellows would reduce the undesired flow of heat from the reactor to the storage volume, thereby helping to suppress undesired decomposition of the MgH_2 in the storage volume.

As described thus far, the apparatus would operate in a batch mode. The upper tank could be refilled with MgH_2 powder from the top, and the MgO solid waste could be removed from the bottom. However, it would be necessary to interrupt operation during such refilling and emptying and during concomitant reverse rotation of the threaded outer pipe to reset the bellows to full storage volume. Thus, truly continuous operation would not be possible: The apparatus would operate in a quasi-batch, quasi-continuous mode.

This work was done by Andrew Kindler and Yuhong Huang of Caltech for NASA's Jet Propulsion Laboratory.

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 NPO-46058, volume and number of this NASA Tech Briefs *issue, and the page number.*

Strain System for the Motion Base Shuttle Mission Simulator

Lyndon B. Johnson Space Center, Houston, Texas

The Motion Base Shuttle Mission Simulator (MBSMS) Strain System is an innovative engineering tool used to monitor the stresses applied to the MBSMS motion platform tilt pivot frames during motion simulations in real time. The Strain System comprises hardware and software produced by several different companies. The system utilizes a series of strain gages, accelerometers, orientation sensor, rotational meter, scanners, computer, and software packages working in unison. By monitoring and recording the inputs applied to the simulator, data can be analyzed if weld cracks or other problems are found during routine simulator inspections. This will help engineers diagnose problems as well as aid in repair solutions for both current as well as potential problems.

The system is located with a line-of-sight to the Motion Base for real-time on-site monitoring. In addition to local monitoring, several off-site engineering computers are loaded with software allowing the user to remotely log onto the Strain System computer, monitor the system, and adjust the software settings as required. Additional commercial software products have been programmed to automate the Strain System software. This removes the typical daily manual interaction required by the system to boot, record, stop, and save the resultant motion data for future analysis.

This work was done by David C Huber, Karl G. Van Vossen, Glenn W. Kunkel, and Larry W. Wells of United Space Alliance for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC 24386-1

Ko Displacement Theory for Structural Shape Predictions

Prediction system enables real-time aero-elastic aircraft wing-shape control.

Dryden Flight Research Center, Edwards, California

The development of the Ko displacement theory for predictions of structure deformed shapes was motivated in 2003 by the Helios flying wing, which had a 247-ft (75-m) wing span with wingtip deflections reaching 40 ft (12 m). The Helios flying wing failed in midair in June 2003, creating the need to develop new technology to predict in-flight deformed shapes of unmanned aircraft wings for visual display before the ground-based pilots.

Any types of strain sensors installed on a structure can only sense the surface strains, but are incapable to sense the overall deformed shapes of structures. After the invention of the Ko displacement theory, predictions of structure deformed shapes could be achieved by feeding the measured surface strains into the Ko displacement transfer functions for the calculations of out-of-plane deflections and cross sectional rotations at multiple locations for mapping out overall deformed shapes of the structures. The new Ko displacement theory combined with a strain-sensing system thus created a revolutionary new structure-shape-sensing technology.

The formulation of the Ko displacement theory stemmed from the integrations of the beam curvature equation (second order differential equation). The beamlike structure (wing) was first discretized into multiple small domains so that beam depth and surface strain distributions could be represented with piecewise linear functions. This discretization approach enabled piecewise integrations of the beam curvature equation in closed forms to yield slope and deflection equations for each domain in recursion formats. The final deflection equations in summation forms (called Ko displacement transfer functions), which contain no structural properties (such as bending stiffness), were then expressed in terms of domain length, beam depth factor, and surface bending strains at the domain junctures. In fact, the effect of the structural properties is absorbed by surface strains.

For flying wing structures, the two-line strain-sensing system is a powerful method for simultaneously monitoring the bending and cross sectional rotations. The two-line strain-sensing system eliminates the need for installing the shear strain sensors to measure the surface distortions through which the wing structure cross sectional rotations could be determined.

The Ko displacement theory combined with onboard fiber-optic strain-sensing system forms a powerful tool for in-flight deformed shape monitoring of flexible wings and tails, such as those often employed on unmanned flight vehicles by the ground-based pilot for maintaining safe flights. In addition, the real-time wing shape monitored could then be input to the aircraft control system for aero-elastic wing-shape control.

This work was done by William L. Ko of Dryden Flight Research Center. Further information is contained in a TSP (see page 1). DRC-006-024

Pyrotechnic Actuator for Retracting Tubes Between MSL Subsystems

NASA's Jet Propulsion Laboratory, Pasadena, California

An apparatus, denoted the "retractuator" (a contraction of "retracting actuator"), was designed to help ensure clean separation between the cruise stage and the entry-vehicle subsystem of the Mars Science Laboratory (MSL) mission. The retractuator or an equivalent mechanism is needed because of tubes that (1) transport a heat-transfer fluid between the stages during flight and (2) are cut immediately prior to separation of the stages retractuator. The role of the retractuator is to retract the tubes, after they are cut and before separation of the subsystem, so that cut ends of the tubes do not damage thermal-protection coats on the entry vehicle and do not contribute to uncertainty of drag and consequent uncertainty in separation velocity.

The retractuator was conceived as a less massive, less bulky, and more powerful alternative to a traditional spring-actuated retractor. The retractuator is a modified version of a prior pyrotechnically actuated cutter. The modifications include alterations of the geometries of pyrotechnic charges, piston, and cylinder; replacing the cutter blade with a push rod; and other changes to reduce weight, arrest the piston at the end of its stroke, and facilitate installation.

This work was done by John C. Gallon, Richard G. Webster, Keith D. Patterson, and Matthew A. Orzewalla of Caltech, Eric T. Roberts of Raytheon Co., and Andrew J. Tuszynski of Columbus Technologies and Services, Inc. for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-45680