



System Finds Horizontal Location of Center of Gravity

Mass and center-of-mass data are updated at a rate of ≈ 267 Hz.

Marshall Space Flight Center, Alabama

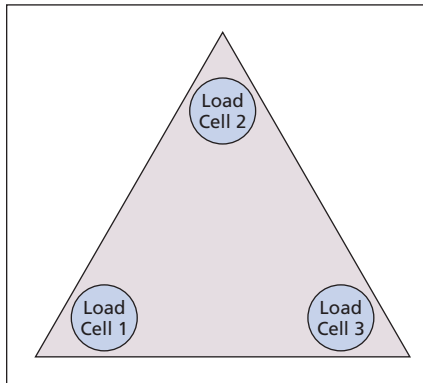


Figure 1. Three Load Cells measure the weights applied to three air bearings at the corners of a triangle.

An instrumentation system rapidly and repeatedly determines the horizontal location of the center of gravity of a laboratory vehicle that slides horizontally on three air bearings (see Figure 1). Typically, knowledge of the horizontal center-of-mass location of such a vehicle is needed in order to balance the vehicle properly for an experiment and/or to assess the dynamic behavior of the vehicle.

The system includes a load cell above each air bearing, electronic circuits that generate digital readings of the weight on each load cell, and a computer equipped with software that processes the readings. The total

weight and, hence, the mass of the vehicle are computed from the sum of the load-cell weight readings. Then the horizontal position of the center of gravity is calculated straightforwardly as the weighted sum of the known position vectors of the air bearings, the contribution of each bearing being proportional to the weight on that bearing. In the initial application for which this system was devised, the center-of-mass calculation is particularly simple because the air bearings are located at corners of an equilateral triangle. However, the system is not restricted to this simple geometry.

The system acquires and processes weight readings at a rate of 800 Hz for each load cell. The total weight and the horizontal location of the center of gravity are updated at a rate of $800/3 \approx 267$ Hz.

In a typical application, a technician would use the center-of-mass output of this instrumentation system as a guide to the manual placement of small weights on the vehicle to shift the center of gravity to a desired horizontal position. Usually, the desired horizontal position is that of the geometric center. Alternatively, this instrumentation system could be used to provide position feedback for a control system that would cause weights to be shifted automatically (see Figure 2) in an effort to keep the center of gravity at the geometric center.

*This work was done by Albert S. Johnston, Richard T. Howard, and Linda L. Brewster of Marshall Space Flight Center. Further information is contained in a TSP (see page 1).
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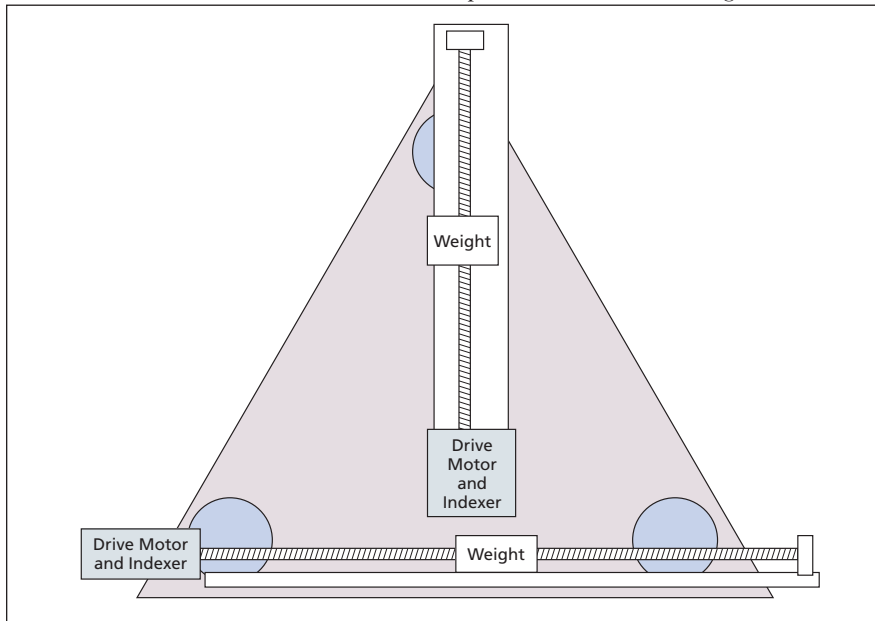


Figure 2. Motor-Driven Lead Screws would reposition weights, in response to load-cell readings, to counteract any deviation of the center of gravity from the geometric center.

Predicting Tail Buffet Loads of a Fighter Airplane

Airframes can be designed to be more robust.

Langley Research Center, Hampton, Virginia

Buffet loads on aft aerodynamic surfaces pose a recurring problem on most twin-tailed fighter airplanes: During maneuvers at high angles of attack, vortices

emanating from various surfaces on the forward parts of such an airplane (engine inlets, wings, or other fuselage appendages) often burst, immersing the tails

in their wakes. Although these vortices increase lift, the frequency contents of the burst vortices become so low as to cause the aft surfaces to vibrate destructively.

This type of buffeting has reduced the airframe fatigue lives and the system reliabilities of several legacy aircraft. This situation has been brought on largely because tail buffet loads have generally been ignored in the design of twin-tailed fighter airplanes. There are several reasons for this oversight: Fundamentally, tail buffet loads have not been identified as a major concern in designing fighter airframes. More practical reasons are that, until recently, (1) there was a lack of quantitative data on buffet forces; and (2) no readily available and cohesive analysis method could be used to predict buffet

loads during the design of fighter airplanes.

Now, there exists a new analysis capability for predicting buffet loads during the earliest design phase of a fighter-aircraft program. In effect, buffet pressures are applied to mathematical models in the framework of a finite-element code, complete with aeroelastic properties and working knowledge of the spatiality of the buffet pressures for all flight conditions. The results of analysis performed by use of this capability illustrate those vibratory modes of a tail fin that are most likely to be affected by buffet loads. Hence, the results help in identifying

the flight conditions during which to expect problems. Using this capability, an aircraft designer can make adjustments to the airframe and possibly the aerodynamics, leading to a more robust design.

This capability has been utilized in the design of the Joint Strike Fighter, leading to better understanding of buffet loads and to total redesign of the airframe to avoid fatigue-life issues.

This work was done by Robert W. Moses and Anthony S. Pototzky of Langley Research Center. For further information, contact the Intellectual Property Team at (757) 864-3521. LAR-16515

Water-filled containers are stacked like bricks.

John H. Glenn Research Center, Cleveland, Ohio

Water-filled containers are used as building blocks in a new generation of containment systems for testing high-speed flywheels. Such containment systems are needed to ensure safety by trapping high-speed debris in the event of centrifugal breakup or bearing failure. Traditional containment systems for testing flywheels consist mainly of thick steel rings. While steel rings are effective for protecting against fragments from conventional and relatively simple metal flywheels, they are also expensive. Moreover, it is difficult and expensive to configure steel-ring containment systems for testing of advanced flywheel systems that can include flywheels made of composite materials, counter-rotating flywheels, and/or multiple flywheels rotating about different axes. In contrast, one can quickly, easily, and inexpensively stack water-filled containers like bricks to build walls, (and, if needed, floors, and ceilings) of sufficient thickness to trap debris traveling in any possible direction at the maximum possible kinetic energy that could be encountered in testing a given flywheel system.

Water is remarkably effective in decel-

erating high-speed debris: In an analysis performed in 1998, it was found that for a fragment that has a characteristic dimension L and an initial kinetic energy E_0 , the kinetic energy E after traveling a distance d through water is approximated by $E = E_0 e^{-d/L}$. For typical fragment sizes and speeds expected to be encountered in tests of advanced flywheel systems, this equation leads to the expectation that a wall of water only 0.6 m thick would suffice to dissipate practically all the kinetic energy.

The effectiveness of this approach to shielding against high-speed debris was demonstrated in a series of tests, including one in which a bullet was fired into a stack of two cubic cardboard boxes, 0.28 m on each side, containing water-filled bladders (see figure). The bullet had a mass of 9.7 g and an initial speed of 790 m/s. Upon impact, the first container was split, the water in the container was widely dispersed, and the bullet was deformed. The bullet did not reach the second container. In other words, the bullet was stopped by less than 0.28 m of water. Limited composite fragment testing was also performed in the Ballistics Impact



A Bullet Was Fired from the left toward two cubic water-filled containers. The bullet was stopped by the first container.

Laboratory at Glenn Research Center, which demonstrated the ability to stop a $2.5 \times 2.5 \times 1.0$ cm fragment with a velocity of approximately 730 m/s within 30.5 cm of water.

This work was done by Larry Trase and Dennis Thompson of Glenn Research 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, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17608-1.