**Flipperons for Improved Aerodynamic Performance**

For a given airfoil design, lift is increased and drag reduced.

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Lightweight, piezoelectrically actuated bending flight-control surfaces have shown promise as means of actively controlling airflows to improve the performances of transport airplanes. These bending flight-control surfaces are called “flipperons” because they look somewhat like small ailerons, but, unlike ailerons, are operated in an oscillatory mode reminiscent of the actions of biological flippers.

The underlying concept of using flipperons and other flipperlike actuators to impart desired characteristics to flows is not new. Moreover, elements of flipperon-based active flow-control (AFC) systems for aircraft had been developed previously, but it was not until the development reported here that the elements have been integrated into a complete, controllable prototype AFC system for wind-tunnel testing to enable evaluation of the benefits of AFC for aircraft.

The piezoelectric actuator materials chosen for use in the flipperons are single-crystal solid solutions of lead zirconate and lead titanate, denoted generically by the empirical formula \((1 - x)[Pb(Zn_{1/3}Nb_{2/3})O_3]:x[PbTiO_3]\) (where \(x<1\)) and popularly denoted by the abbreviation “PZN-PT.” These are relatively newly recognized piezoelectric materials that are capable of strain levels exceeding 1 percent and strain-energy densities 5 times greater than those of previously commercially available piezo-

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**Figure 1.** The **Piezoelectric Crystal** in a lightweight bending actuator is maintained in compressive preload by a spring-steel substrate.

**Figure 2.** Flipperons on the **Upper Surface** of a wing are made to oscillate at amplitude, frequency, and phase chosen to obtain increased lift and reduced drag.
System Estimates Radius of Curvature of a Segmented Mirror

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A system that estimates the global radius of curvature (GROC) of a segmented telescope mirror has been developed for use as one of the subsystems of a larger system that exerts precise control over the displacements of the mirror segments. This GROC-estimating system, when integrated into the overall control system along with a mirror-segment-actuation subsystem and edge sensors (sensors that measure displacements at selected points on the edges of the segments), makes it possible to control the GROC mirror-deformation mode, to which mode contemporary edge sensors are insufficiently sensitive. This system thus makes it possible to control the GROC of the mirror with sufficient precision to obtain the best possible image quality and/or to impose a required wavefront correction on incoming or outgoing light.

In its mathematical aspect, the system utilizes all the information available from the edge-sensor subsystem in a unique manner that yields estimates of the states of the segmented mirror. The system does this by exploiting a special set of mirror boundary conditions and mirror influence functions in such a way as to sense displacements in degrees of freedom that would otherwise be unobservable by means of an edge-sensor subsystem, all without need to augment the edge-sensor system with additional metrological hardware. Moreover, the accuracy of the estimates increases with the number of mirror segments.

This work was done by John Rakoczy of Marshall Space Flight Center.

This invention has been patented by NASA (U.S. Patent No. 7,050,161). 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-31807-1.