case, two pairs of SAW piezoelectric transducers would be oriented orthogonally on a concave spherical stator instead of a flat stator, and the slider would be a sphere of nearly equal radius pressed against the stator.

In general, the minimum actuation step size would be approximately inversely proportional to the SAW excitation frequency. At contemplated maximum excitation frequencies of the order of tens of megahertz, minimum step sizes of nanometers could be achieved. Another advantage of using high excitation frequencies is that it would make it possible to achieve high force densities, thereby enabling the design of relatively small, lightweight actuators.

This work was done by Yoseph Bar-Cohen, Xiaoqi Bao, Anthony Hull, and John Wright of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

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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Propulsion Flight-Test Fixture

Subscale engines can be flight-tested early in the development cycle.

Dryden Flight Research Center,
Edwards, California

NASA photo by Jim Smolka

Figure 1. The **PFTF Holds the Test Article** underneath the F-15B airplane during flight.

NASA Dryden Flight Research Center's new Propulsion Flight Test Fixture (PFTF), designed in house, is an airborne engine-testing facility that enables engineers to gather flight data on small experimental engines. Without the PFTF, it would be necessary to obtain such data from traditional wind tunnels, ground test stands, or laboratory test rigs.

Traditionally, flight testing is reserved for the last phase of engine development. Generally, engines that embody new propulsion concepts are not put into flight environments until their designs are mature: in such cases, either vehicles are designed around the engines or else the engines are mounted in or on missiles. However, a "captive carry" capability of the PFTF makes it possible to test engines that feature air-breathing designs (for example, designs based on the rocket-based combined cycle) economically in subscale experiments.

The discovery of unknowns made evident through flight tests provides valuable information to engine designers early in development, before key design decisions are made, thereby potentially affording large benefits in the long term. This is especially true in the transonic region of flight (from mach 0.9 to around 1.2), where it can be difficult to obtain data from wind tunnels and computational fluid dynamics.

In January 2002, flight-envelope expansion to verify the design and capabilities of the PFTF was completed. The PFTF was flown on a specially equipped supersonic F-15B research testbed airplane, mounted on the airplane at a center-line attachment fixture, as shown in Figure 1.

NASA's F-15B testbed has been used for several years as a flight-research platform. Equipped with extensive research air-data, video, and other instrumentation systems, the airplane carries externally mounted test articles. Traditionally, the majority of test articles flown have been mounted at the center-line tank-attachment fixture, which is a hardpoint (essentially, a standardized weapon-mounting fixture). This hardpoint has large weight margins, and, because it is located near the center of gravity of the airplane, the weight of equipment mounted there exerts a minimal effect on the stability and controllability of the airplane.

The PFTF (see Figure 2) includes a one-piece aluminum structure that contains space for instrumentation, propellant tanks, and feed-system components. The PFTF also houses a force balance, on which is mounted the subscale engine or other experimental apparatus that is to be the subject of a flight test. The force balance measures a combination of inertial and aerodynamic forces and moments acting on the experimental apparatus.

The PFTF instrumentation system is a slave to the instrumentation system of the F-15B airplane. At present, as many as 128 parameters can be monitored by use of the PFTF; however, it is possible to expand the capabilities of the PFTF to monitor more parameters, if necessary. These monitored parameters can include, but are not limited to, pressures, temperatures, accelerations, vibrations, and strains. Sample rates are variable, generally between 10 and 400 samples per second, but much higher data-acquisition rates are possible. Parameters can be recorded aboard the F-15B airplane by use of a digital recorder or telemetered to a control room.

An experimental apparatus as heavy as 500 lb (≈227 kg) and as long as 12 ft (≈3.7 m) can be mounted on the PFTF. The PFTF can accommodate experiments in which are produced thrusts or drags as large as 2,000 lb (≈8.9 kN) and side forces up to 500 lb (≈2.2 kN). For envelope-expansion

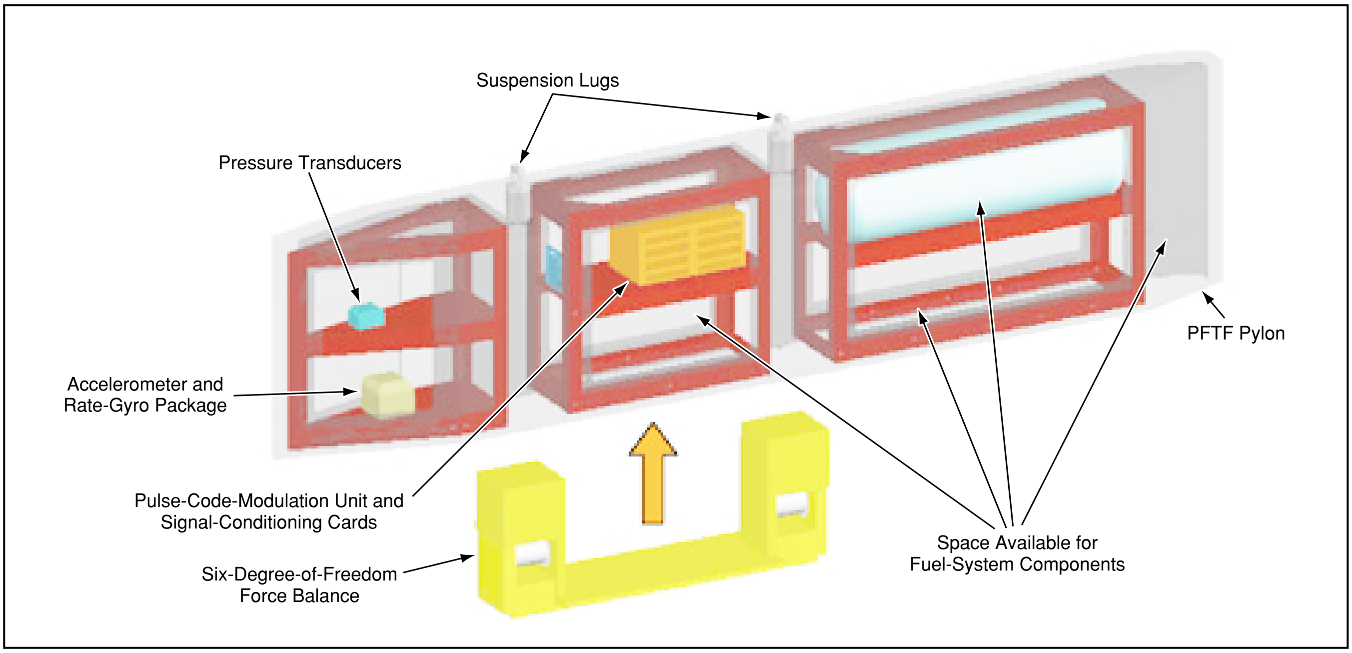


Figure 2. The **Interior of the PFTF** accommodates instrumentation and fuel-system hardware needed for an experiment.

flights, a surrogate engine-shape body denoted the cone drag experiment was flown attached to the force balance. The cone drag experiment inertially and spatially approximated a large engine test article. This cone drag experiment produced drag forces of up to 1,400 lb (≈6.2 kN) at high speeds. A top speed of mach 2.0 and a dynamic pressure of 1,100 psf (≈53 kPa) were attained in this configuration.

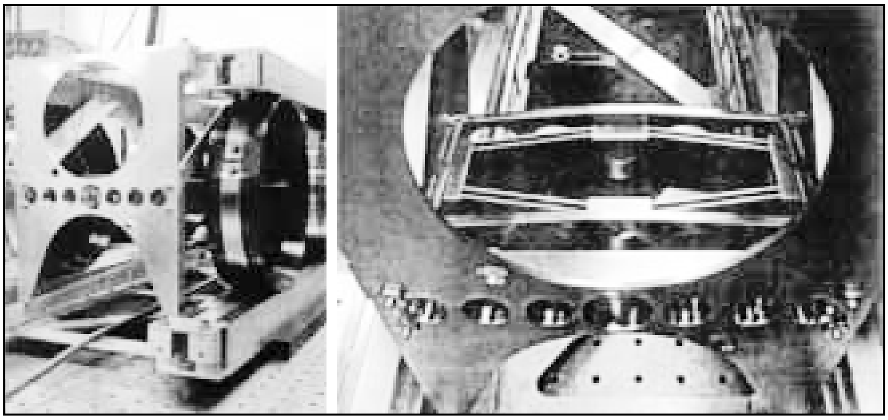
This work was done by Nate Palumbo, M. Jake Vachon, Dave Richwine, and Tim Moes of **Dryden Flight Research Center** *and Gray Creech of AS&M. Further information is contained in a TSP [see page 1].*
DRC-02-23

Mechanical Amplifier for a Piezoelectric Transducer

In addition to multiplication of stroke, the design affords momentum compensation.

NASA'S Jet Propulsion Laboratory, Pasadena, California

A mechanical amplifier has been devised to multiply the stroke of a piezoelectric transducer (PZT) intended for use at liquid helium temperatures. Interferometry holds the key to high angular resolution imaging and astrometry in space. Future space missions that will detect planets around other solar systems and perform detailed studies of the evolution of stars and galaxies will use new interferometers that observe at mid- and far-infrared wavelengths. Phase-measurement interferometry is key to many aspects of astronomical interferometry, and PZTs are ideal modulators for most methods of phase measurement, but primarily at visible wavelengths. At far infrared wavelengths of 150 to 300 μm, background noise is a severe problem and all optics must be cooled to about 4 K. Under these conditions, piezos are ill-suited as modulators, because their throw is reduced by as much as a factor of 2, and even a wavelength or two of modulation is beyond their capability. The largest commercially available piezo stacks are about 5 in. (12.7 cm) long and have a throw of about 180 μm at room temperature and only 90 μm at 4 K. It would seem difficult or impossible to use PZTs for phase measurements in the far infrared were it not for the new mechanical amplifier that was designed and built.



A **Four-Bar Linkage** provides stroke amplification and momentum compensation for the PZT mounted inside it.

To compensate for the loss of travel at cryogenic temperatures, the PZT is mounted in a novel mechanical amplifier that supports one of the mirrors of the interferometer. The mechanical amplifier, shown in the figure, was designed based on an original concept at JPL dating from 1993. The mechanical amplifier resembles an elongated parallelogram with pairs of parallel flexures along each side. The PZT