would be increased gradually from zero and, after a time to be determined by trial and error, translation along the weld seam would be increased gradually from zero to a steady weld speed. The weld would be ended by running the mechanism off the workpiece or, if the lower shoulder were detachable, by detaching the lower shoulder from the spindle and pulling the pin tool out.

This work was done by Arthur C. Nunes, Jr., of Marshall Space Flight Center. Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31648-1.

Strain Gauges Indicate Differential-CTE-Induced Failures

Failures are indicated by changes in slopes of strain versus temperature.

Goddard Space Flight Center, Greenbelt, Maryland

A method of detecting mechanical failure induced by variation in temperature at an adhesive bond between two materials that have different coefficients of thermal expansion (CTEs) involves monitoring of strain-gauge readings. This method can be regarded as an exploitation of the prior observation that the readings of strain gauges commonly used in tensile and compressive testing of material specimens include features indicative of incremental failures in the specimens. In this method, one or more strain gauges are bonded to either or both of the two materials near the bond between the materials. (The adhesive used to bond the strain gauges would not ordinarily be the same as the one used to bond the two materials). Then strain-gauge readings are recorded as the temperature of the materials is varied through a range of interest. Any significant discontinuity in the slope of the resulting strain-versus-temperature curve(s) is taken to be a qualitative indication of a failure of the bond between the two materials and/or a failure within one of the materials in the vicinity of the bond.

The method has been demonstrated in experiments on specimens consisting of polyacrylonitrile-fiber/epoxy-matrix laminated composite plates bonded by epoxy to smaller plates made, variously, of aluminum, titanium, and a low-CTE nickel/iron alloy. In preparation for each experiment, strain gauges were bonded, by use of cryogenic-rated adhesives, to the composite plate near the corners of the metal plate (see Figure 1). In each experiment, strain-gauge and temperature readings were taken as the specimen was cooled from room temperature to 20 K. The specimens were then returned to room temperature and ultrasonically inspected for damage in the bond region.

No failure events were detectable in the strain-gauge readings from the composite/titanium and composite/low-thermal-expansion-alloy specimens, and ultrasonic inspection of these specimens revealed no damage. However, failure events were seen in the strain-gauge readings from the composite/aluminum specimens (see Figure 2), and ultrasonic inspection confirmed that there was damage in the bond regions of these specimens.

This work was done by Brian Harris of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-14984-1

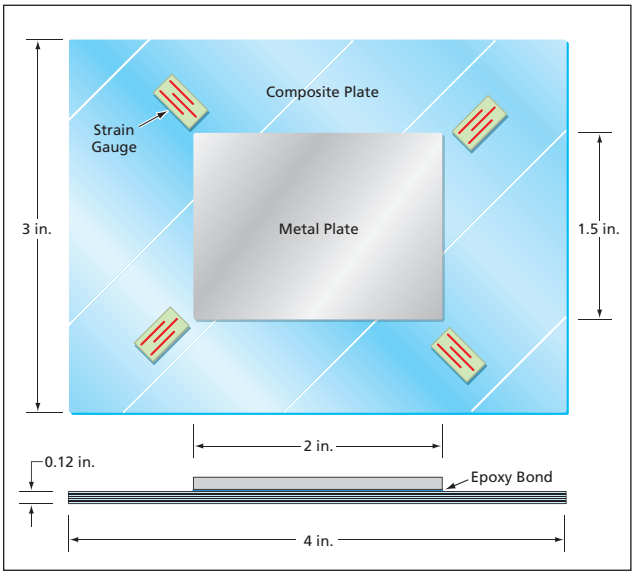

Figure 1. **Strain Gauges Were Bonded** to the composite plate near the corners of the metal plate because differential-thermal-expansion-induced stresses were expected to be large at these locations.

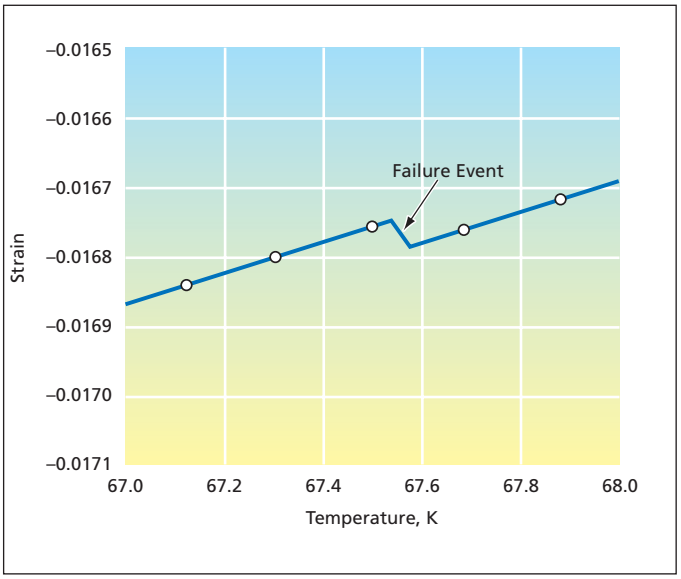

Figure 2. **Part of the Strain-Versus Temperature Curve** from one specimen includes a slope discontinuity indicative of a failure in the metal/composite bond region.