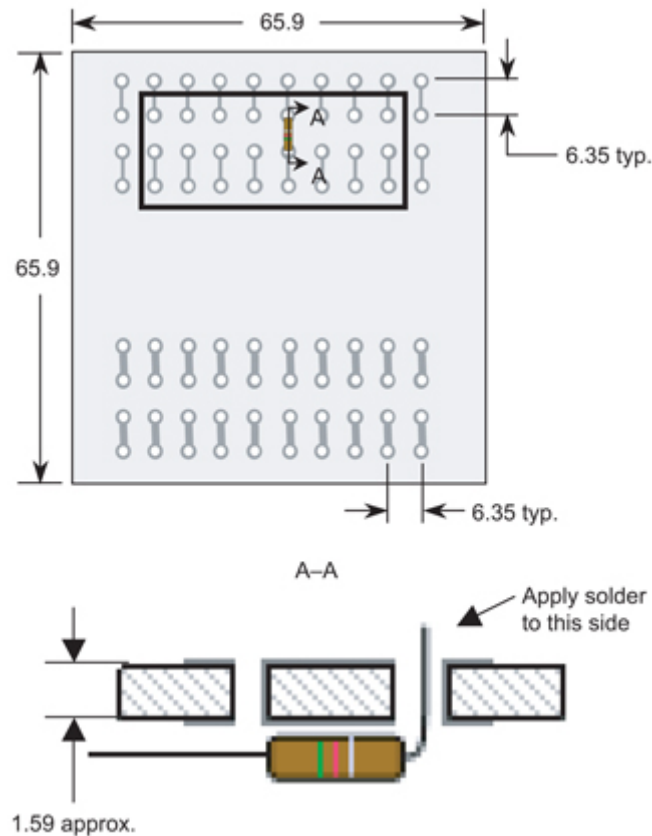


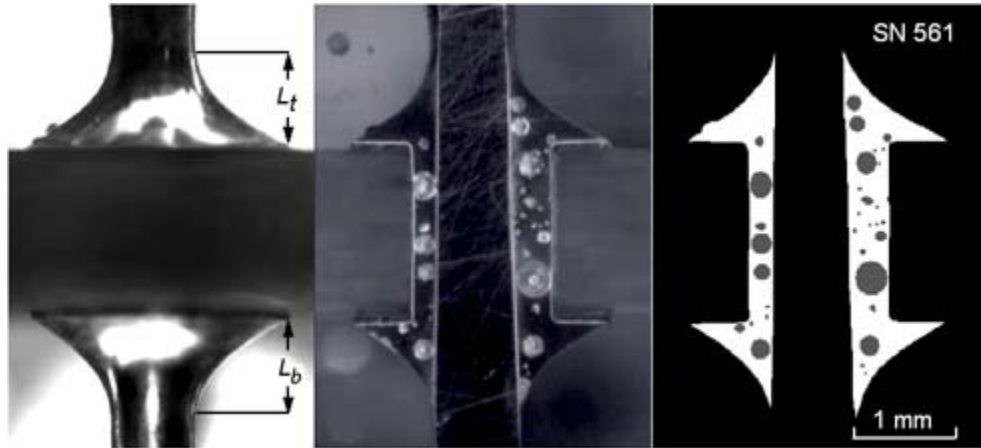
Soldering Tested in Reduced Gravity



Plated through-hole sample configuration used during reduced-gravity testing. All dimensions are given in millimeters.

Whether used occasionally for contingency repair or routinely in nominal repair operations, soldering will become increasingly important to the success of future long-duration human space missions. As a result, it will be critical to have a thorough understanding of the service characteristics of solder joints produced in reduced-gravity environments. The National Center for Space Exploration Research (via the Research for Design program), the NASA Glenn Research Center, and the NASA Johnson Space Center are conducting an experimental program to explore the influence of reduced-gravity environments on the soldering process. Solder joint characteristics that are being considered include solder fillet geometry, porosity, and microstructural features. Both through-hole (see the drawing and image on the preceding figure) and surface-mounted devices are being investigated. This effort (the low-gravity portion being conducted on NASA's KC-135 research aircraft) uses the soldering hardware currently available on the International Space Station. The experiment involves manual soldering by a contingent of test operators, including both highly skilled technicians and less skilled individuals to provide a skill mix that might be encountered in space mission crews. The experiment uses both flux-cored solder and solid-core solder with an externally applied flux. Other experimental parameters include the type of flux, gravitational level (nominally zero,

lunar, or Martian gravity), and circuit-board moisture. Postflight analysis done jointly at Glenn and Johnson consists of a visual inspection, photography, and leg-length measurements (L_t and L_b in the left image of the following figure) of the soldered joints. The cross sections of the joints are prepared and examined using standard metallographic techniques to obtain porosity measurements (see the center image). A custom computer program developed at Glenn assisted in a manual measurement of the pore area as seen in the right image. Using these data, Glenn researchers calculated the percentage of porosity exposed by dividing the voided (porous) areas by the total two-dimensional area of the joint cross section. For example, the right image has a porosity of 18.8 percent.



Images of joints after soldering in reduced gravity. Solder was applied to the top of the solder joint as oriented in the images. Left: Prior to cross sectioning. Center: After cross sectioning. Right: After computer analysis. This joint showing significant subsurface voids (18.8-percent porosity).

To date, this experiment has generated 1347 solder samples in the through-hole configuration, including 938 low-gravity samples (including some partial-gravity samples) and 409 normal-gravity samples. Testing was performed during 8 flight-weeks of the KC-135 at Glenn and used seven test operators. Findings to date (refs. 1 to 4) indicate significant increases in joint porosity and changes in joint geometry in reduced-gravity environments. These changes may reduce the joint service life. Techniques are being considered to mitigate these increases in porosity. Also, a Space-station Detailed Test Objective (SDTO) has been accepted for flight aboard the space station to verify these effects on orbit.

References

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Find out more about this research at <http://www.ncser.net/r4d/>

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Special recognition: An article featured in Welding Journal (Oct. 2003), "Gravitational Effects of Solder Joints," was based on our paper (Richard Pettegrew, Dan Haylett, Robert Downs, Peter Struk, and Kevin Watson) presented at the 2003 International Brazing and Soldering Conference. That paper was selected for one of two Outstanding Paper awards. The Welding Journal article reviews our recent effort to understand how the traditional manual soldering process is affected by reduced gravity.