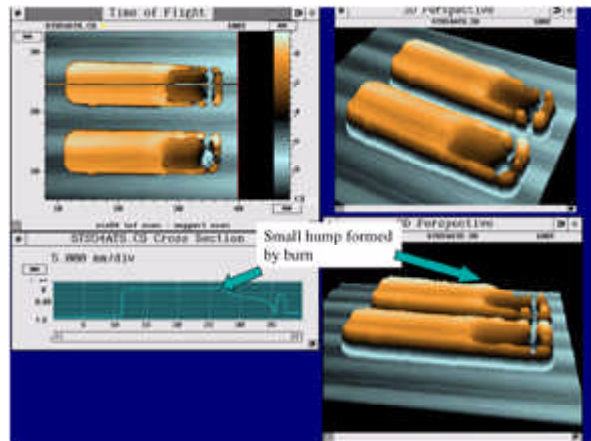


# New Technology—Large-Area Three-Dimensional Surface Profiling Using Only Focused Air-Coupled Ultrasound—Given 1999 R&D 100 Award

Surface topography, which significantly affects the performance of many industrial components, is normally measured with diamond-tip profilometry over small areas or with optical scattering methods over larger areas. To develop air-coupled surface profilometry, the NASA Glenn Research Center at Lewis Field initiated a Space Act Agreement with Sonix, Inc., through two Glenn programs, the Advanced High Temperature Engine Materials Program (HITEMP) and COMMTECH. The work resulted in quantitative surface topography profiles obtained using only high-frequency, focused ultrasonic pulses in air. The method is nondestructive, noninvasive, and noncontact, and it does not require light-reflective surfaces. Air surface profiling may be desirable when diamond-tip or laser-based methods are impractical, such as over large areas, when a significant depth range is required, or for curved surfaces. When the configuration is optimized, the method is reasonably rapid and all the quantitative analysis facilities are online, including two- and three-dimensional visualization, extreme value filtering (for faulty data), and leveling.

The method is simple and reproducible because it relies mainly on the knowledge of and the constancy of the velocity of sound through air. When the air transducer is scanned across the surface, it sends pulses to the sample surface, where they are reflected back along the same path as the incident wave. (We recommend an air transducer with a ~1-MHz nominal center frequency to generate the air pulses.) Time-of-flight images of the sample surface are acquired and converted to depth and surface profile images using the simple relation  $d = V(t/2)$ , where  $d$  is the distance,  $t$  is the time of flight, and  $V$  is the velocity of sound in air.



*Air surface profiles for Burned Space Experiment samples. Left: Two-dimensional view*

*and line profile across one scan line of top sample. Right: Three-dimensional views.*

The system can resolve surface depression variations as small as 25  $\mu\text{m}$  with 400- $\mu\text{m}$  lateral resolution, is useable over a 1.4-mm vertical depth range, and can profile large areas limited only by the scan limits of the particular ultrasonic system. (The best-case depth resolution is 0.25- $\mu\text{m}$ , which may be achievable with improved isolation from air currents and vibrations—both external vibrations and those due to motor or bridge assembly movement.) Results are shown for several proof-of-concept samples: plastic samples burned in microgravity on the STS-54 space shuttle mission and a partially coated, cylindrical ceramic composite sample. When compared with diamond-tip profiles and measurements from micrometers, the topographical representations for all the samples are impressive. Funding for this work came from the NASA HITEMP and COMMTECH programs and from Sonix, Inc.

## **Bibliography**

Roth, D.J., et al.: 3-D Surface Depression Profiling Using High-Frequency Focused Air-Coupled Ultrasonic Pulses. NASA/TM—1999-209053, 1999.

**Glenn contact:** Dr. Don J. Roth, (216) 433-6017, Don.J.Roth@grc.nasa.gov

**Authors:** Dr. Don J. Roth, Harold E. Kautz, Dr. Phillip B. Abel, Mike F. Whalen, J. Lynne Hendricks, and James R. Bodis

**Headquarters program office:** OAST

**Programs/Projects:** HITEMP, COMMTECH, Space Act Agreement

**Special recognition:** 1999 R&D 100 Award