Current quartz oscillator technology is limited by quartz mechanical Q. With a possible improvement of more than \( \times 10^{4} \) Q with sapphire acoustic modes, the stability limit of current quartz oscillators may be improved tenfold, to \( 10^{-14} \) at 1 second. The electromagnetic modes of sapphire that were previously developed at JPL require cryogenic temperatures to achieve the high Q levels needed to achieve this stability level. However, sapphire’s acoustic modes, which have not been used before in a high-stability oscillator, indicate the required Q values (as high as \( Q = 10^{8} \)) may be achieved at room temperature in the kHz range. Even though sapphire is not piezoelectric, such a high Q should allow electrostatic excitation of the acoustic modes with a combination of DC and AC voltages across a small sapphire disk (~1 mm thick). The first evaluations under this task will test predictions of an estimated input impedance of 10 kilohms at Q = 10^{6}, and explore the Q values that can be realized in a smaller resonator, which has not been previously tested for acoustic modes.

This initial Q measurement and excitation demonstration can be viewed similar to a transducer converting electrical energy to mechanical energy and back. Such an electrostatic tweeter type excitation of a mechanical resonator will be tested at 5 MHz. Finite element calculation will be applied to resonator design for the desired resonator frequency and optimum configuration. The experiment consists of the sapphire resonator sandwiched between parallel electrodes. A DC-AC voltage can be applied to generate a force to act on a sapphire resonator. With the frequency of the AC voltage tuned to the sapphire resonator frequency, a resonant condition occurs and the sapphire Q can be measured with a high-frequency impedance analyzer.

To achieve high Q values, many experimental factors such as vacuum seal, gas damping effects, charge buildup on the sapphire surface, heat dissipation, sapphire anchoring, and the sapphire mounting configuration will need attention. The effects of these parameters will be calculated and folded into the resonator design. It is envisioned that the initial test configuration would allow movable electrodes to check gap spacing dependency and verify the input impedance prediction.

Quartz oscillators are key components in nearly all ground- and space-based communication, tracking, and radio science applications. They play a key role as local oscillators for atomic frequency standards and serve as flywheel oscillators or to improve phase noise in high-performance frequency and timing distribution systems. With ultra-stable performance from one to three seconds, an Earth-orbit or moon-based MSAR can enhance available performance options for spacecraft due to elimination of atmospheric path degradation.

This work was done by Rabi T. Wang and Robert L. Tjoelker of Caltech for NASA’s Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47343
in less than 80 BRAM, 52k Slices on a Virtex 5LX330T, 25% and 24% of resources, respectively. Using a 100-MHz clock, this build would perform stereo at 39 Hz.

Of particular interest to JPL is that there is a flight qualified version of the Virtex 5: this could produce stereo results even for very large image sizes at 3 orders of magnitude faster than could be computed on the PowerPC 750 flight computer. The work covered in the report allows the stereo algorithm to run on much larger images than before, and using much less BRAM. This opens up choices for a smaller flight FPGA (which saves power and space), or for other algorithms in addition to SAD5 to be run on the same FPGA.

This work was done by Carlos Y. Villalpando and Arin C. Morfopoulos of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

The software used in this innovation is available for commercial licensing. Please contact Daniel Broderick of the California Institute of Technology at danielb@caltech.edu. Refer to NPO-47245.