Crystal Oscillator Acceleration Sensitivity Testing (COAST) Device

Progress Report

For Society of Physics Students

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Introduction

COAST (Crystal Oscillator Acceleration Sensitivity Testing) was proposed to the Society of Physics Students for funding in 2004 as a project to develop a test bed apparatus for measuring minute frequency shifts in quartz crystal oscillators that occur due to accelerations. The investigation originated from a risk study undertaken by one of the faculty advisors for a spread spectrum transceiver. The transceiver is planned for sounding rocket use and there is a potential that high accelerations could cause sufficient reference oscillator frequency shifts to allow a loss of communications.

During the design phase, the student team realized that a modified version of the test bed could be flown in NASA's University Reduced Gravity Flight program. A second proposal was submitted and subsequently funded for 2005. The team submitted a proposal to NASA and was accepted for the 2005 flight cycle. This report summarizes progress made to date.

Milestones

The project's original time of substantial completion was set for April 2005. This date was first delayed until end of June 2005 to accommodate NASA's acceptance of a new reduced gravity aircraft. The aircraft was delivered to NASA in April of 2005 without interior modifications completed. This has resulted in another delay for the flight. The new scheduled experiment flight week is now in mid November. The delay has allowed the team the luxury of fine tuning various aspects of the apparatus resulting in a more robust experiment. The table below contains our original estimates for milestones.

Item	Completion Date
C-9 Microgravity Proposal	October 2004
Shake Table Fixture Design	November 2004
Resonance Tests of Fixture on Vibration Table	November 2004
Prototype of Environmental Board and Crystal Oscillator Board	December 2004
Fully Assembled Test Setup	February 2005
Several Test Sessions on Vibration Table	February 2005
Flight on DC-9 Microgravity Plane	March 2005
Final Testing on Vibration Table if Needed	April 2005

The current status of each item will be discussed.

C-9 Microgravity Proposal

A completed proposal was submitted to NASA in early November of 2004. This was concurrent with the submission of a follow on grant to SPS. A copy of the proposal to NASA is appended to this report.

Shake Table Fixture Design

The shake table fixture apparatus design was completed in November of 2004. This design included circuitry supporting sensors for the following environmental elements: temperature, humidity, pressure, noise, three axis vibration, three axis magnetic field, and three axis acceleration. These are all variables that can affect frequency of oscillators. Additionally, the fixture includes the ability to support the device under test in three axes.

Resonance Tests of Fixture on Vibration Table

While the original schedule for vibration testing was planned for November of 2004, the actual testing was delayed until March. Our team had learned of a delay until June for any flights and the time was used to make a substantial mounting fixture for the shake table and better coupling of the experiment to the mounting. Testing involved subjecting the basic fixture a sweep of table frequency from below 1 Hz to 20,000 Hz Calibrated three axis accelerometers recorded vibration response on the table, on the fixture and on a dummy board mounted in the test fixture. A photo taken at the test is included below.

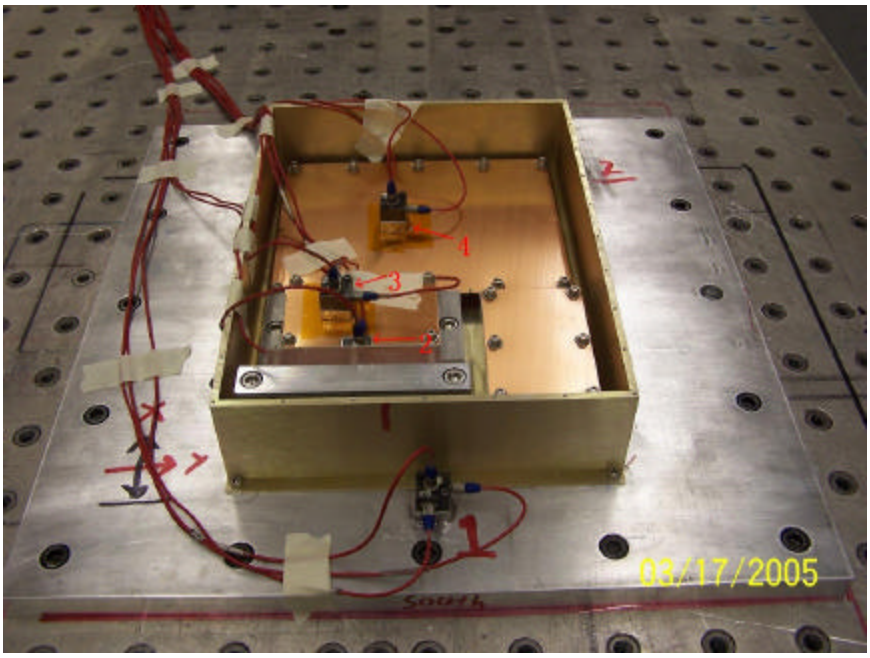

Figure 1 – Photo of COAST test fixture undergoing vibration tests

The vibration tests have identified no major resonance problems below 500 Hz. Additionally, the data will allow selecting calibration test frequencies that induce minimal cross axis responses in the fixture. This will allow calibration data to be taken and handled as single dimension effects improving the quality of our gamma (acceleration sensitivity) measurements. This work was done at Eagle Picher Industries in Joplin, MO. Eagle Picher is an advanced aerospace battery manufacturer with extensive environmental testing facilities.

Prototype of Environmental Board and Crystal Oscillator Board

Prototypes of these boards were completed by January 2005. As each circuit was verified, the schematic was submitted to printed circuit board software. A final design was submitted to PC Boards of Chanute, KS for production of both the environment circuit boards and the crystal test boards. This occurred in April of 2005.

Fully Assembled Test Setup

Upon delivery of the circuit boards, our team began assembly of the finished test setup boards. Three environment boards were prepared and tested. These were major operations involving testing of all sensors and implementing a small number of field corrections. All three boards are fully functional allowing for a flight test fixture, a ground test fixture, and a functioning spare. This was completed in mid May and occurred at the time we were being notified to expect a major delay into the fall.

Several Test Sessions on Vibration Table

This has not been completed. We anticipate calibration measurements to occur in August or September following the return of our students from their summer assignments.

Flight on C-9 Microgravity Plane

The flight week for COAST on the C9 aircraft is now scheduled for mid-November of 2005. However, we have conducted a flight test in a single engine aircraft of only the crystals with no environmental data recorded. A Cherokee 180 flew the reduced apparatus containing two counter-aligned Piezo Technologies XO3080 crystal oscillators and two of our students to an altitude of 4500 feet. The plane was then banked at 60 degrees and held in level flight for approximately 90 seconds. This condition subjected the plane to a net 2 g acceleration aligned with the gamma vector direction for the oscillators. With the two oscillator signals injected into an rf mixer, the low frequency difference signal was displayed on a handheld digital scope. During the banked turn, the students reported an approximately 0.06 Hz shift as measured on the oscilloscope screen. Our expected frequency shift value was 0.02 to 0.06 Hz. More local flight tests are anticipated prior to the C-9 flight with NASA. The choice of crystal oscillators is especially significant as we were able to acquire four oscillators from the same production batch NASA Wallops is using for their transceiver tests.

Final Testing on Vibration Table if Needed

These are not anticipated and would not occur before early December 2005. They would most likely happen if the flight test data did not match shake table calibration data predictions.

Budget

The Society of Physics Students granted $2000 for this project work. Of these funds, $190.50 remains. The funds were used to purchase electronic and mechanical hardware for the apparatus. Details of expenditure will be given in the final report in December.

Notably, the student teams have matched the SPS funds with a $2000 grant from the NASA Kansas Space Grant Consortium. These funds will be used to offset travel costs to Houston in November. Additionally, local lab and travel funds of $3500 have resulted in an over 3:1 leveraging of SPS funding.

Concluding Notes

The support provided by SPS has enabled not only the creation of the flight hardware for the COAST tests, but funds leveraging, high profile summer activities for the Physics students involved and design, test protocol, lab and shop experiences for participants of demanding nature. Sensor calibration, additional operational tests, the flight test, and data analysis are all that remain to conclude this activity. Three documents are appended to this report. These are copies of the original proposal to NASA and a copy of the Technical Experiment Description Package (TEDP) submitted in February to describe the apparatus and its safety concerns. The final document is the data sheets for the crystal oscillators chosen for testing.