# Letter of interests for the Homestake Deep Underground Science and Engineering Laboratory

**1) Title of proposal:**

*The Effect of Cosmic Rays on the Soft Error Rate of Semiconductor Memory chips at Ground Level*

**2) Proposed faculty**

Dr. Li Chen, Assistant professor, Electrical and Computer Engineering;

**3) Proposal summary**

This project aims to study the soft errors caused by cosmic rays in commercial memories such as static RAM (SRAM), dynamic RAM (DRAM) and flash memory chips at ground level. Cosmic-ray-induced soft errors in electronic components have long been a problem for the designers of satellites and spacecraft, but they have not generally been considered to be an important influence on memory chip soft error rate (SER) in terrestrial environments. However, the data stored in memory cells become more and more volatile to cosmic rays as the minimum feature sizes of transistors are scaling down. Current memory chips have higher density, lower voltage, and lower capacitance, which all tend to increase the sensitivity to soft errors. Therefore it is important to analysis the error rates caused by cosmic rays at ground level. This project proposed an experiment to measure the SER of various semiconductor memory chips underground, at sea level, and at high altitude to determine the impact of cosmic rays on memory chip SER. The new information is important for characterizing how the transient pulses affect memory circuits and for determine the best to design the fault-tolerant memory and computer systems.

**4) Background information of the project**

Many years ago, anomalies observed in electronic circuits in satellites orbiting Earth were attributed to the ionization caused by cosmic rays. Later, it was calculated that the energetic-proton component of galactic cosmic rays could account for anomalous bit errors observed in MOS memory chips in satellites. It was also discovered that alpha particles emitted by the radioactive decay of impurities in chip packaging materials can cause soft errors, also called single event upsets (SEU), in commercial microelectronic memory circuits. The density of circuits on chips had far reached the point where a single subatomic particle could upset the information stored in a memory cell. Since that time, the problem of soft errors induced by alpha-particle radiation has been studied extensively, and successful computer models have been developed to predict the sensitivity of new memory chip designs to alpha particles under known experimental conditions. Also, much work has been done characterizing the effects of cosmic rays high in the atmosphere and in Earth orbit environments both in terms of measured upset rates in flight and theoretical approaches, but very little information has been published about the effects of cosmic rays on semiconductor memories at ground level. Notable exceptions to

this were theoretical treatments, where various methods were proposed for modeling the effects.

The cosmic radiation that bombards Earth from outer space includes gamma ray photons, protons, and heavier atomic nuclei. The nuclear particles, mostly protons, have many billions of electron volts of kinetic energy, and when they collide with the nuclei of oxygen and nitrogen atoms in the upper atmosphere they smash them into energetic charged fragments. The fragments in turn hit other nuclei and cascade in an avalanche of particles down through the atmosphere to the Earth's surface. At ground level, there is a shower of secondary particles that includes high-energy neutrons, protons, electrons, muons, and gamma rays. It is the nuclear component of this secondary particle flux, mostly neutrons and secondary protons, that can cause soft errors in semiconductor memories. When a neutron or a proton with kinetic energy far greater than the binding energy of a nucleus undergoes a collision with a silicon nucleus in a semiconductor, the reaction produces highly ionizing recoils and low-Z charged particles (protons and alpha particles). An ion traveling through the sensitive volume of a memory cell will interact with the electric circuit by disturbing the electrons in the lattice as it goes by. The kinetic energy of the ion is converted into electron-hole pairs along its track as it comes to a stop in the semiconductor. The resulting charge then moves according to local electric fields and by diffusion, and it can generate a transient current pulse in the circuit. If the transient pulse is large enough, it will disturb the circuit and the information stored in the memory cell will be lost.

This project describes an experiment to measure the SER (or SEU rate) of a sample of various types of memory chips underground, at sea level, and at high altitude to determine the role of cosmic rays in memory-chip SER at ground level. The project will design a SER tester which continuously cycles through all the memory addresses on the chips and compare the data at each address to the initial data pattern. When a discrepancy is detected, the tester relayed the address of the failing bit to a computer. By comparing the memory chip SER at different altitude levels, the impact of cosmic rays on semiconductor memories can be concluded at ground level. The ability to accurately project the SER of new chip designs is necessary to assure the reliability of memory chips in the field. The new information that it provides is important for characterizing the transient pulses affecting memory circuits, for determining the best way to design computers to eliminate the problem, and for correlating SER modeling projections to SER data collected in tests performed under real-life conditions.

5) **Space and equipment requirement**

The project requires a lab room which is at the deep-underground level to eliminate the effects of cosmic rays on memory chips. A SER tester and a desktop computer are planed to be placed in the room.