The Naval Research Laboratory has long history of developing gamma- and X-ray radiation detector technology and applications. This investment in technology has produced a rich variety of scientific and technical advances. Much of our work over the last several decades has focused on detectors which function in a high radiation environment as is typical in Earth orbit. This investment has led to the successful completion of astrophysics instrumentation on major NASA missions such as the Compton Gamma Ray Observatory and the Solar Maximum Mission, as well as opportunities provided by the military Space Test Program such as the recent Unconventional Stellar Aspect experiment.

A natural direction that our detector technology and expertise is applied is in the area of environmental remediation, homeland security, nuclear medicine, and nuclear nonproliferation. Another current area of interest is in cosmic dust, man made orbital debris, and atmospheric science. A requirement in many of these applications is the need for a variety of detector systems that are sensitive to the radioactive signature (i.e. spectra) exhibited by extremely small quantities of radioactive isotopes. An equally rich area of interest is in the development ultra-low background counting technology itself. Much of this technology has been developed and advanced for studies in neutrino physics, and for the detection of dark matter. Measurements are typically performed deep underground where detectors are shielded from cosmic rays and the secondary particles that they create. This technology provides a new capability: the ability to detect trace amounts of radioactivity contained in small samples of material. These counting techniques are already being applied to screen materials that will be used in order to construct ultra-low background detection systems.

In a broader sense, the ultra-low background counting technology is also useful in the field of trace nuclear characterization. This includes such things as nuclear fingerprinting, and the unraveling the history of a sample based on detection of trace radioactivity. A niche for these detector systems in the detection of extremely small quantities of radioactive material, where they can be significantly more sensitive than conventional mass spectroscopy. This niche is bounded by those isotopes with half-lives between a few hours and about 100 years. This boundary is depends on details such as sample size, sample impurities, decay signature, as well as the sample preparation. Under the right conditions, detection thresholds on the order of a few decays over a period of weeks can be achieved. Another application is for larger samples with an extremely dilute isotope of interest. Large samples do not lend themselves to mass spectroscopy, but in some instances may be well suited for low background counting.

Key applications of interest to which this detection capability can be applied include improved radio-dating capabilities, the study of the radiation environment of cosmic dust and atmospheric samples, and environmental monitoring. Dust samples may be collected in space for return to Earth, or directly from the atmosphere. Analysis of
these samples provides direct measurements of transport and mixing phenomena in the atmosphere. Alternately, $^7$Be and other isotopes produced by cosmic ray interactions in the atmosphere may be used to study transport phenomena in the exo-atmospheric region above the Earth. Short lived isotopes are expected to provide an indication of whether the dust originates from outside or inside the Earth’s magnetosphere.

We are also interested in developing applications in the field of nuclear non-proliferation. The ability to detect underground testing of small-yield nuclear weapons is particularly important in the world today. Inevitably, small quantities of gasses and radioactive dust are produced in any nuclear test. Atmospheric samples and dust collected from these test sites can provide important evidence as to the nature of the test.

This spring marks the completion of two new detector systems that we have invested in. One system is an ultra-low background germanium detector, modeled after the GEMPI-I detector, and the other a low background gas detector modeled after the GNO/GALLEX detectors, both developed by the Max Planck Institut für Kernphysik, Germany. Both systems are now located at Laboratori Nazionali del Gran Sasso (LNGS), Italy. We are also constructing a new low background counting facility closer to home in the Kimballton mine, called the Kimballton Low Background Facility (KLBF). This new facility will begin operations this year with a germanium detector provided by the National Institute of Standards, Maryland, and provide a local capability to make measurements and screen materials.

Studies are currently in progress to collect cosmic dust with sounding rockets and return the samples to Earth for rapid analysis. The first of these sounding rockets was launched in January, 2005, and the second is scheduled for March, 2005. These samples are immediately sent to LNGS for analysis.

NRL is working with Virginia Tech to construct the KLBF. This is a pre-DUSEL laboratory located away from active mining activity. It serves as both a path-finder laboratory, but also contributes directly to science. It will also provide essential services that will be fundamental to the DUSEL facility and many of the principle experiments. The key services include:

- Measurement of low background materials used for building experiments.
- Screening of materials brought into the laboratory.
- Study of background sources.
- Development of low background detectors and systems.

In addition, the KLBF will support science and applications:

- Measurements of samples, e.g. space, sedimentation, ocean, biologic.
- Host for visiting scientists and experiments
- National security.
- Nuclear nonproliferation.

The KLBF will establish an underground facility in an unused drift, known as XC-4 on the 14th level of the mine. XC-4 is far from the active mining activity at a depth of 1400 mwe. It will be operational in July 2005 (projected). It will serve two functions: (1) provide useful high-quality low-background laboratory space, and (2) provide an engineering model for the development of the primary DUSEL low background facility.
KLBF will be a building measuring 32’ wide and 60’ long, with a minimum clear ceiling height of 12’. It will be kept at a positive pressure over the ambient environment with filtered air to minimize contamination from mine dust, diesel fumes, or other particulates. The air quality shall be sufficient to maximize the efficiency of secondary air filtration that may be required around the various experimental stations. The environment will maintained warmer and dryer than the external environment, thus there will be no condensation either inside or outside the structure.

The building will be erected upon a concrete pad designed with fluid containment capacity. Concrete comes from local sources consisting primarily of local limestone sand, and aggregate, and screened for radioactivity. The preliminary design provides for containment of a minimum of 300 cubic feet liquid, consistent with a worst-case spill of the full volume of liquid scintillator in a LENS prototype module and a large safety margin (>2). Containment is achieved by a small concrete berm around the experiment area. The berm will have a gentle slope in critical access areas, enabling vehicles and carts to easily pass over it. The concrete pad for the building is designed to both contain fluids from inside the building, and exclude water from outside the building.

The building will be provided with 50 kW electrical service. Power is drawn from a 480 V line provided by the Chemical Lime Company. Sub-panels will distribute power to the various experimental areas. The building and immediate surroundings will be protected from falling rock by a steel mesh anchored to the mine ceiling. Interior and exterior lighting will provide a comfortable work-environment. Emergency lighting will be provided. Fire suppression will be developed to support the use of flammable materials, such as liquid scintillators.

The site plan is shown in figure L.1. The KLBF will provide infrastructure necessary to host laboratories NRL, VT, and others. Experimenters will initially be required to provide their own enclosures if they require secondary air filtration. Access is provided by a 14’x14’ roll-up door on the end face of the building, and a loading dock on a platform to the side of the building.
Figure L.1 – KLBF concrete pad, building placement and site plan.