Project Synopsis

Long Range High Explosives Detection

In order to effectively manage hazardous environments, one requires a detailed knowledge of those materials that pose a threat to valued assets. In battlefield and force-protection environments, high explosives (HE) that remain hidden from conventional interrogation methods pose a particular threat, as recognized by our adversaries. If a HE package is buried or otherwise secreted from optical sensing methods, then a penetrating interrogation tool is required.

Neutral particles, such as photons and neutrons, can pass relatively unmolested through the charge clouds from which materials are composed, and are therefore viable tools for interrogating the surrounding environment. Furthermore, the discrete nature of the gamma-ray products that follow inelastic neutron interactions allows one to examine the isotope composition of various target materials. One can therefore develop relatively non-intrusive inspection methods using continuous or pulsed fast neutron sources coupled with sensitive gamma-ray detectors. The viability of this method has been proven for proximate objects, and for HE in particular. However, scanning a wide field of view and sensing objects at long range is much more challenging because of the increased competition between counts returned from the target of interest, which greatly diminish in number, and unwanted interactions that occur in the surrounding environment, which, on a relative basis, increase.

Regardless of the detector technology employed, the rapid diminution in the target material's count rate at long-ranges can best be countered by increasing the effective area of the detector. Thus, we are developing an instrument with a relatively large detection volume. During the Phase I research, we determined that one doesn't need an inordinately large volume- a cubic meter for instance- but rather, if one uses scintillation materials of good stopping power, such as BaF_2, $LaCl_3(Ce)$, or NaI(Tl), then a decimeter thick detector with 10 dm^2 cross-sectional area can image the environment in the seconds required to allow the rapid mobile transit of the imaging platform. That volume must however be segmented in order to minimize the probability of pulse pile-up and to enable the depth and angular imaging of the environment. Isolating the HE from noisy sources can be accomplished by imaging the environment such that concentrations of explosives, as measured via their isotropic ratios, can be discriminated from extraneous objects. Successful imaging requires the localization of the interaction locations, which implies a detector that must sense both the depth of interaction and its angular position. Existing technology, in the form of gamma-scatter cameras (or Compton cameras), can be used to extract the angular information, but usually at the cost of instrument complexity. In Phase I, we proposed a Compton camera solution that was built on previous developments in the field, but which simplified the angular reconstruction and did so in much larger detection volumes that those usually deployed. Our experimental and analytical results gathered during the previous work period confirmed the viability of such a design.

In particular, we are using fast inorganic scintillation crystals, such as BaF_2 or $LaCl_3$(Ce), and multiple photon sensors to localize the interaction location of the Compton electron and the scattered gamma-ray in order to extract the angular position of the target. Neutron time-of-flight methods, enabled by a pulsed 14 MeV neutron source, are to be used to gauge the depth of interaction, which when coupled with the angular information, will provide an element-sensitive map of the surrounding environment.

During Phase I, we assessed both pixellated planar detectors and bar detector designs and concluded that for pixellated configurations, the shallow depths permitted by the mechanical properties of scintillation crystals will result in resolution loss when high energy gamma-rays are incident, because of the considerable range of the recoil electron will result in information loss. The results indicate that longer detector elements will be needed, configured in a bar-detector arrangement, the exact arrangement of which will be determined during Year 1 of Phase II, when the detectors are tested at the gamma-ray energies of interest, in the 4 – 6 MeV range.

The Phase I modeling results indicated that the proposed detector allows considerable source flexibility because it can handle either a single high intensity source pulse to interrogate the environment, or repeated pulses of lower neutron emission strength. Furthermore, the results show that a standard accelerator-based DT source is not a viable neutron source for the HE imaging problem. The HE imaging application, the successful realization of which would certainly enhance the military's defensive capabilities, does therefore provide justification for the continued refinement of the plasma-based neutron source. The Phase II effort is designed to optimize the detector design during Year 1 and to confirm its feasibility by testing a scaled prototype by the end of Year 2.

The development of such at tool would greatly benefit the Dept. of Defense, other Federal Agencies such as the Homeland Security Agency, as well as private users. If one can remove the uncertainty regarding the materials in the surrounding environment, then the transport of hazardous materials and other contraband can be greatly hampered. Furthermore, if the instrument can be commercialized at relatively low cost- as is the goal- then true border-control can be implemented by deploying an array of scanning instruments.

There are various competing technologies that can potentially solve the problem of non-intrusively interrogating the environment at intermediate to long ranges. As determined during Phase I, neutron interrogation and return-gamma sensing provides one feasible method of accomplishing that goal. The research during Phase II is designed to realize that capability in an imaging instrument.