CAPABILITIES OF GAMMA RAY AND NEUTRON SPECTROMETERS FOR STUDYING TROJAN ASTEROID SUBSURFACE ICES. A. M. Parsons[1], L. Evans[1,2], L. Lim[1],and R. Starr[1,3]. , [1]NASA Goddard Space Flight Center, Ann.M.Parsons@nasa.gov, [2]Computer Sciences Corporation, [3]Catholic University of America

Introduction: Trapped in stable orbits around Jupiter's L4 and L5 Lagrange points, the Trojan asteroids are positioned right at the boundary between the inner and the outer solar system. The history of these bodies is unknown: were they formed at the outer edges of the main asteroid belt and then migrated outwards to L4 and L5 or were they formed in the Kuiper belt and then migrated inwards before being captured at L4 and L5? Studying the compositional and physical properties of these Trojan asteroids will provide a window into the dynamical history of the early solar system as well as information about what might be some of the solar system's most primitive bodies. To date, no spacecraft mission has ever visited a Trojan asteroid, but the scientific return of such a Trojan Tour and Rendezvous mission is so great that it was specifically targeted by the 2011 Planetary Decadal Survey Committee as one of the highest priority missions for the New Frontiers program.

As the scientific community studies different Trojan asteroid mission architectures and instrument suites, it is important that a variety of high heritage instrument technologies be considered so that the mission payload utilizes the most appropriate technologies for the highest scientific return. In this presentation we will demonstrate the unique capabilities of high heritage gamma ray and neutron spectrometers for determining the surface and subsurface composition of Trojan asteroids. Specifically, we will use MCNPX computer simulations to study the ability of these instruments to characterize the composition and depth of ices that may be buried beneath a thin outer layer of chondritic material. Unlike IR or X-ray observations, the penetrating nature of gamma rays and high-energy neutrons allows scientists to probe 30-50 cm below the surface of a planetary body without making contact with it. These measurements can thus be made using remote sensing instruments from a low altitude (~50 km) orbit above the asteroid. Similar instruments have been successfully flown on previous missions such as Mars Odyssey, NEAR, and MESSENGER, so high heritage designs can be readily obtained.

Important Trojan Scientific Measurements: Because Trojan asteroids may have been formed far out in the Kuiper belt, they may consist largely of ice that was covered by a thin regolith layer as the objects moved inward into the solar system. It is thus important that a Trojan Rendezvous mission contain instruments that can determine if there are indeed stable volatile species trapped below the surface. As described in a recent review of Kuiper belt objects composition [1], for objects the size of a Trojan asteroid, the most stable species besides H_2O will be CO_2, H_2S and CH_4. NH_3 may also be found if the object was formed at a sufficiently great distances (>30 AU). To substantiate the possible Kuiper belt origin of Trojan asteroids, it is therefore important to look for indications that specific elements such as C, O, N, S and H are buried beneath the surface. Only gamma ray and neutron instruments are capable of this kind of measurement.

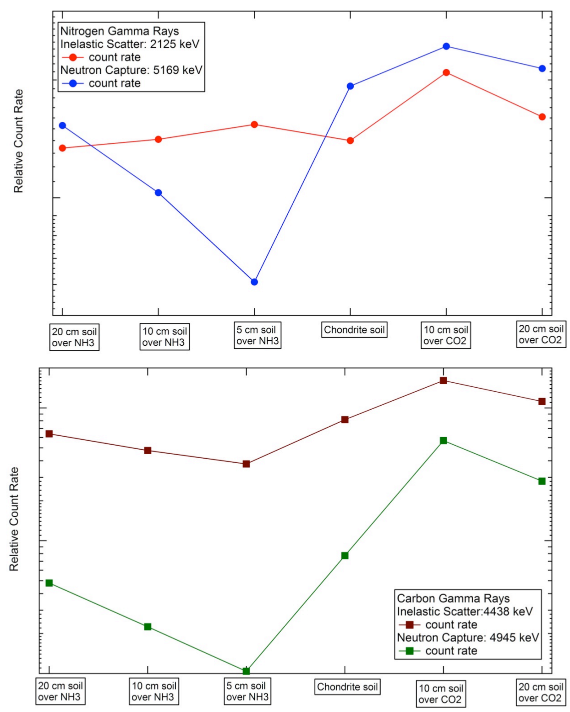

Figure 1a,b: Simulated gamma ray line count rates for the three asteroid composition models: a) two nitrogen gamma ray peaks and b) two carbon gamma ray peaks.

Trojan Asteroid Simulations. The discussion that follows is based on the results of Monte Carlo N-Particle extended (MCNPX)[2] computer simulations of neutron flux ratios and gamma ray count rates measured by a 6.7 cm tall, 6.7 cm dia. HPGe gamma ray spectrometer (the same size as the Mars Odyssey GRS [3]) at a 50 km altitude above a 120 km diameter spherical Trojan asteroid. While the true excitation source is the Galactic Cosmic Ray (GCR) flux out at 5 AU, for these preliminary simulations we used a 1 particle/cm^2/s GCR flux, which is closer to the average GCR flux at 1 AU. Since these simulation results scale linearly with the input GCR rate, the results for measurements at 5 AU can be easily calculated once the 5 AU GCR flux is estimated. Our final presentation will be based on simulation results scaled to a more accurate 5 AU GCR flux. Since these preliminary qualitative results are used to illustrate the best methods for the detection of subsurface CO_2 and NH_3, our use of a less accurate GCR input flux causes no problems.

Computer simulations were run for three elemental composition configurations for this asteroid: 1) a basic CI chondritic composition; 2) a two-layer model with NH_3 buried under 5, 10 and 20 cm thick layers of chondritic soil; and 3) another two-layer model with CO_2 buried under 10 and 20 cm thick layers of chondritic soil.

Gamma Ray Spectrometer Results: Measurement of the count rates for gamma ray lines at energies characteristic of specific isotopes provides the bulk elemental composition of the asteroid material. Thus our simulation results reflect the composition of the asteroid. We also ran computer simulations to study how nitrogen and carbon gamma ray count rates would vary for CO_2 and NH_3 buried at different depths below the asteroid's surface. Figure 1 provides plots of simulated gamma ray count rates for two nitrogen (1a) and two carbon (1b) gamma ray peaks for each of the layering models. While the gamma ray count rates from the inelastic scattering process are not very sensitive to burial depth for either element, the thermal neutron capture line count rates seem quite sensitive to depth for both nitrogen and carbon.

Neutron Measurements: If Trojan asteroids have a significant icy component below the surface, neutron measurements may also be an excellent way to identify ice type and burial depth. The ratio of fast neutrons (E>0.1 MeV) to thermal neutrons (E<0.04 eV) may be especially diagnostic. Figure 2 shows how this ratio may vary depending on the burial depth and the type of ice below the surface. Thermal neutrons are depressed in the presence of nitrogen because of a large resonance in the $^{14}N(n,p)^{14}C$ reaction near 3 eV. CO_2, on the other hand, is excellent at thermalizing neutrons, but has a low capture cross section resulting in an enhanced thermal neutron flux. The ratios in Figure 2 reflect these differences. The fast/thermal neutron ratio, especially when used in conjunction with the gamma ray data, may prove to be a very useful means for detecting these trapped subsurface volatiles.

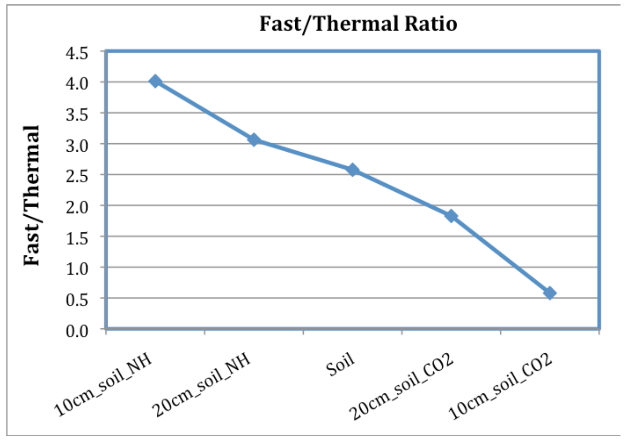

Figure 2. Fast/Thermal neutron ratio for two different ice cores, ammonia (NH_3) and carbon dioxide (CO_2), and for two different burial depths, 10 and 20 cm, compared to a pure soil composition.

Conclusions: Preliminary simulation results indicate that there may be effective methods for detecting subsurface CO_2 and NH_3 on Trojan asteroids using gamma ray and neutron instruments. We will continue to study the use of these methods as we refine our simulations. The results of these refined simulations will be presented, providing quantitative estimates of expected gamma ray and neutron fluxes from a Trojan asteroid so that the required observation times can be determined for the detection of specific elements. It is crucial to know the expected element sensitivities at specific altitudes and observation times to provide a trade space between cost/engineering feasibility and scientific return. These simulations permit an informed evaluation of this trade space to produce the optimal mission concept for the highest scientific return given the resource constraints.

The potential contributions of these high energy instrument technologies to the study of Trojan asteroids is thus quite compelling and is worthy of greater study as the scientific community continues to develop their Trojan Tour and Rendezvous Mission concepts.

References: [1] M. Brown (2011) *Annual Review of Earth and* Planetary Sciences, arXiv:1112.2764v1 [astro-ph.EP]. [2] D. B. Pelowitz et al. (2005) *MNCPX User's Manual, Version 2.5.0*, LANL, LA-UR05-0369. [3] W. V. Boynton, et al. (2004) *Space Science Reviews,* 110: 37–83.