Tuning DraGNS' Interpretations to Titan's Expected Surface Environment. A.E. Engle[1,2*], P.N. Peplowski[2†], A.M. Parsons[3‡], M. Ayllon-Unzueta[3], J.T. Wilson[2], Z.W. Yokley[2], S.M. MacKenzie[2], S.L. Murchie[2], E.P. Turtle[2], R.D. Lorenz[2], D.J. Lawrence[2], R.D. Starr[3,4]. [1]Northern Arizona University (Flagstaff, AZ 86011); [2]Johns Hopkins Applied Physics Laboratory (Laurel, MD 20723); [3]Goddard Space Flight Center (Greenbelt, MD 20771), [4]Catholic University of America (Washington DC 20064). [*]Anna.Engle@jhuapl.edu, [†]Patrick.Peplowski@jhuapl.edu, [‡]Ann.Parsons@nasa.gov.

Introduction: Titan is unique among the solar system satellites. Features that set it apart include a thick N_2-rich atmosphere that supports ongoing methane photochemistry and a surface characterized by a H_2O-rich bedrock topped by a layer of organic sediment [1, 2]. Given its primary elemental constituents of C, H, N, and O, it makes for an ideal prebiotic chemistry lab.

These qualities, and more, have made this Saturnian moon a target for *in situ* exploration. The Dragonfly rotorcraft lander was selected in 2019 as NASA's next New Frontiers class mission and will be launched in 2027, with an arrival at Titan expected in the mid-2030s. A major goal of the Dragonfly mission is to characterize the chemistry and potential for habitability on the surface [3, 4]. DraGNS (Dragonfly Gamma-ray and Neutron Spectrometer) will be one of the instruments on board the rotorcraft and is intended to measure the elemental abundances of C, N, O, H, Na, Mg, P, S, Cl, and K [5].

This mission will be the first time a gamma-ray and neutron spectrometer suite will be sent to a water-dominated world. Previously, this instrumentation had only been used to study terrestrial bodies [6], where the focus was detecting heavier rock-forming elements and H—an indicator of the presence of H_2O and OH. These spectrometers have been flown on orbital spacecraft and have used galactic cosmic rays (GCRs) as the source for high energy neutrons.

Titan will be a wholly new environment with new elements in comparison to those studied on rocky bodies. Additionally, the dense atmosphere will block GCRs from reaching the surface, meaning Dragonfly will need to bring its own neutron source. This will be in the form of a pulsed neutron generator (PNG) that will act as an active neutron source. DraGNS will also have the ability to make passive measurements using neutrons produced in Dragonfly's multi-mission radioisotope thermoelectric generator (MMRTG).

Given the marked difference between rocky and icy worlds, and this being the first time that nuclear spectrometers will be sent to a water-dominated world, we have performed a series of experiments that probe Titan surface simulant samples with DraGNS-like instrumentation. The overarching goal of the study is to provide benchmarks for models of various Titan surface environments and build our intuition for the DraGNS response to the possible elemental combinations on Titan.

Experiment Campaign: Prior to starting the experiments, an extensive literature review was carried out to determine end-member compositions (H_2O, CH_4, NH_4, carbonaceous chondrite impactor, and tholin), and craft 16+ hypothetical Titan compositions composed of combinations of 15 elements—H, C, N, O, Na, Mg, Al, Si, P, Cl, K, Ca, Fe, Ni—that may be found on or ≤10 cm under Titan's surface [7]. Absorption and moderation (downscattering neutrons to lower energies) neutron parameters were derived for each composition, where is inversely proportional to the abundance of thermal neutrons and $\xi\Sigma_s$ relates to the value of the epithermal neutrons. During this process, a strong correlation was discovered between the N/H wt. ratios and neutron parameters.

Through the implementation of principal component analysis, it was determined that H, C, N, and O are the most DraGNS-relevant elements in the collection of 15, which is reasonable given their prevalence on Titan's surface. From there, we opted to create bricks using melamine ($C_3H_6N_6$), with epoxy as a binder, and high-density polyethylene (HDPE, C_nH_{2n}) to simulate organic-rich surface material (Table 1). For mimicking the bedrock composition, we chose H_2O, H_2O + 1.6 wt.% NaCl, and H_2O + 29 wt.% NH_4OH. Estimated neutron parameters of the bricks and bedrock simulants are presented alongside those of 16 hypothetical Titan compositions in Fig. 1.

The first set of experiments focused on bench-marking neutron spectrometer (NS) results. The NS is composed of two ^{3}He-based neutron detectors, one that is Cd-wrapped and another that is unwrapped, or bare. Epithermal neutrons (>0.3 eV) are detected via the Cd-wrapped sensor and the abundance of thermal neutrons (<0.3 eV) is reported by taking the difference between the bare and Cd-wrapped sensors [7]. Radioactive ^{252}Cf was used as a passive neutron source. The samples were characterized individually, i.e., no layering, and included Bricks #1 and #2, the HDPE bricks, H_2O, and

Table 1: *Composition of bricks used in experiments. Bricks #1 and #2 are two mixtures of melamine+epoxy, and the third brick is high density polyethylene.*

Element	Brick #1	Brick #2	HDPE
H	0.07	0.08	0.14
C	0.37	0.45	0.86
N	0.50	0.23	---
O	0.12	0.22	---

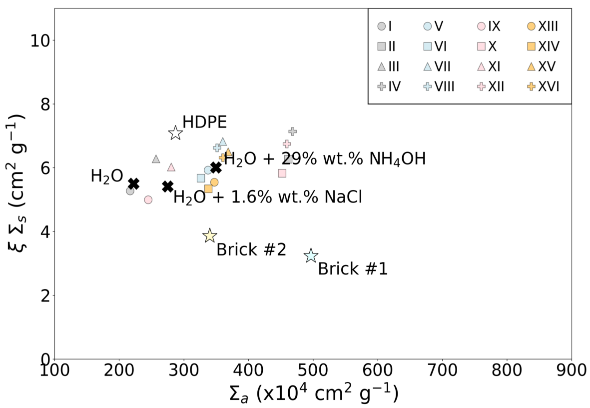

Figure 1: *Derived absorption (Σ_a) and moderation ($\xi\Sigma_s$) neutron parameters for the 16 hypothetical and 6 sample simulant Titan compositions. See [7] for descriptions of the hypothetical Titan compositions.*

H_2O + 1.6 wt.% NaCl, plus a Mars regolith simulant for comparison.

The second round of experiments utilized an instrument configuration analogous to the intended DraGNS layout on Dragonfly. This included the gamma-ray spectrometer (GRS), NS, PNG, and their accompanying electronics. The sample size is approximately 84” x 96” and so 144 water bricks of dimensions 9” x 6” x 18” were used to construct the bedrock simulant. To date, sample arrangements have included H_2O, H_2O + 29 wt.% NH_4OH, melamine bricks layered on H_2O, and melamine bricks layered on H_2O + 29 wt.% NH_4OH (Fig 2.).

Results: Results from the two rounds of experiments are as follows:

Neutron Spectrometer Results. Thus far, results show that thermal neutron rates of the melamine bricks are lower than those of the HDPE bricks, which is expected due to the presence of N in melamine. This is a favorable result that will boost confidence in N identification in gamma-ray spectra and may help with establishing an approximate abundance in a sample. Comparison of the H_2O and H_2O + 1.6 wt.% NaCl results suggest a smaller difference between the neutron parameters than predicted. Given this outcome, a future experiment may involve continually adding larger quantities of NaCl to H_2O until an amount is reached that shows a clear differentiation between H_2O and H_2O+NaCl.

Due to differing sample geometries between the bedrock simulants, the Mars regolith simulant and the bricks, comparison between all samples is forthcoming.

DraGNS Analog Configuration Results. Modeling indicates that N should be readily identifiable in gamma-ray spectra. While it was unclear whether N bands were present in 1-hr long collections, it quickly became evident when summing 5-8 hrs worth of spectra (Fig. 3). This is consistent with proposed N detection limits and correlates to the nominal 8-hr data collection planned for DraGNS.

Forthcoming: Interpretation of additional features in the gamma-ray spectra are ongoing. Additionally, further analysis of neutron spectra for both sets of experiments will include extracting the moderation and absorption cross sections from the neutron spectra and their comparison with the N/H wt.%.

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References: [1] Hörst (2017) *J. Geophys. Res.*, 122, 3, 432-482. [2] Griffith et al. (2019) *Nat. Astron.*, 3, 7, 642-648. [3] Barnes et al. (2021) *PSJ*, 2, 4, id. 130. [4] Lorenz, et al. 2018, *Johns Hopkins APL Technical Digest*, 34, 3, p.14. [5] Lawrence et al. (2022) *53rd LPSC*, Abstract #1939. [6] Parsons (2020) *Int. J. Mod.*, 50, 2060004. [7] Peplowski et al. (2022) *53th LPSC*, Abstract #2329.

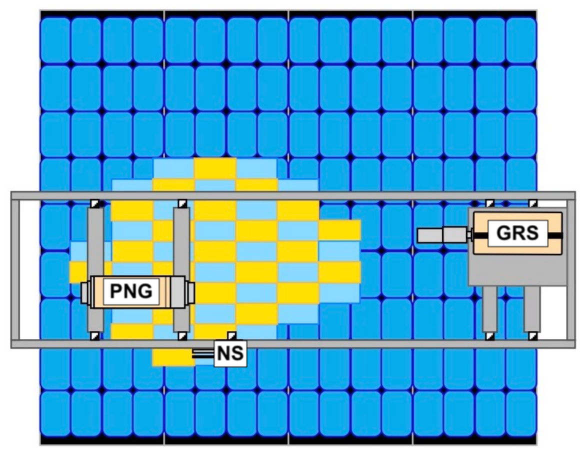

Figure 2: *Aerial view of NS, GRS, and PNG in approximate geometry to anticipated DraGNS configuration on board Dragonfly. Melamine bricks are roughly centered according to the placement of the scaffolding atop the water bricks.*

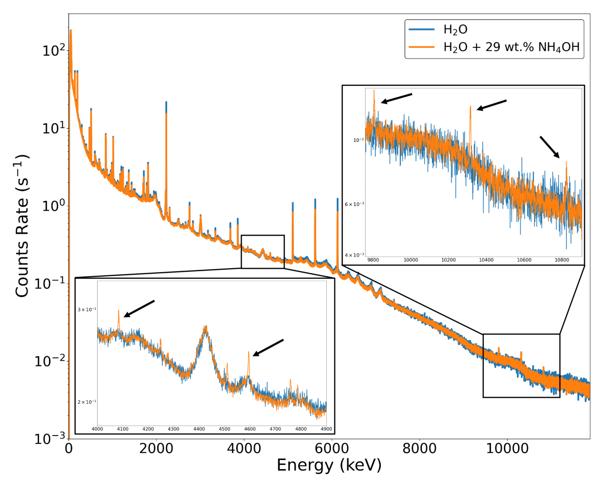

Figure 3: *Comparison of H_2O and H_2O + 29 wt.% NH_4OH gamma-ray spectra. The inset figures emphasize the placement of select N gamma-ray peaks.*