The Dragonfly Gamma-Ray and Neutron Spectrometer (DraGNS): Providing In-situ Measurements of Titan's Elemental Composition. David J. Lawrence[1], Dewey Adams[1], William F. Ames[1], Mauricio Ayllon-Unzueta[2], Bret M. Bronner[2], Morgan T. Burks[3], Frederic Gicquel[4], John O. Goldsten[1], Jacob M. Greenberg[1], Nathan R. Hines[3], Ralph D. Lorenz[1], Scott L. Murchie[1], Charles W. Parker[1], Ann M. Parsons[2], Patrick N. Peplowski[1], Colin Z. Sheldon[2], Zachary W. Yokley[1]; [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD; [2]NASA Goddard Spaceflight Center, Greenbelt, MD; [3]Lawrence Livermore National Laboratory, Livermore, CA; [4]Schlumberger Technology Corporation, Houston, TX; (David.J.Lawrence@jhuapl.edu).

Introduction: Dragonfly is a mission that was selected for flight in 2019 as part of NASA's New Frontiers program. Its primary goal is to characterize the chemistry and habitability of Saturn's largest moon Titan [1]. It will accomplish this goal by using Titan's thick atmosphere and low gravity (relative to Earth) to fly a rotorcraft across Titan's surface. The Dragonfly lander will spend two Earth years characterizing at least 20 different locations with various geological settings. At each location, the lander's instrument suite will acquire photogeology data, characterize Titan's meteorology, sample Titan's surface materials, and determine Titan's surface composition.

The Dragonfly Gamma-ray and Neutron Spectrometer (DraGNS) is one of the lander's four primary instruments, and its goal is to measure Titan's bulk elemental composition at each of the landing sites. DraGNS will measure the elemental abundances of C, N, O, H, Na, Mg, P, S, Cl, and K, if present on Titan's surface with abundances each of greater than 1 wt.%. DraGNS is currently in its preliminary development phase, and its design is being matured based on various requirements, constraints, and opportunities. Here, we present the current DraGNS design and operational strategy.

DraGNS Overview: Gamma-ray and neutron spectroscopy is a standard technique for measuring elemental composition on airless or nearly airless planetary bodies, where galactic cosmic rays (GCRs) hit planetary surfaces and generate line-emission gamma rays and broad energy neutrons from which elemental abundances are determined. Titan's thick atmosphere, however, prevents GCRs from reaching its surface. To carry out gamma-ray and neutron composition measurements on Titan, DraGNS uses a Pulsed Neutron Generator (PNG) to locally illuminate the surface with neutrons that generate the gamma rays and neutrons from which elemental abundances are determined. PNG-based nuclear spectroscopy is a standard technique for Earth-based geological applications [2-4], and is now being adapted for its first use in the outer solar system.

DraGNS contains five components distributed across the Dragonfly lander (Fig. 1). These are the Pulse Neutron Generator (PNG), the PNG control electronics, the Gamma-Ray Spectrometer (GRS), the Neutron Spectrometer (NS), and the Data Processing Unit (DPU).

PNG: The PNG is adapted from a design that has been in use by Schlumberger Technology Corporation (STC) for over 10 years in oil-well logging applications. The PNG consists of an accelerator tube that generates 14 MeV neutrons by accelerating deuterons (D) and tritons (T) into a solid target to generate neutrons using a DT fusion reaction. The standard neutron count rate for DraGNS will be 10^8 neutrons per second. The PNG includes a diamond-based fast-neutron sensor to monitor PNG output. Due to its use in oil-well applications, the mechanical design of the PNG is inherently robust. Engineering work is in process to configure the PNG to successfully operate on Titan's surface after a 6.5-year cruise and 2 years of integration and test on Earth. The PNG is being designed and built by STC and will be integrated into the Dragonfly lander by Goddard Spaceflight Center (GSFC).

PNG Control Electronics: Dedicated PNG Control Electronics (CE) are being designed and built by GSFC. The PNG CE consists of a set of four electronics boards that provide the command/telemetry interface with the DraGNS Data Processing Unit (DPU) and the state machine that operates the PNG. The PNG CE also provides bias voltages and drive currents required for PNG operation.

GRS: The GRS is a high purity Ge (HPGe) sensor that provides superior energy resolution compared to scintillator-based gamma-ray sensors. The DraGNS GRS is a 5-cm diameter by 5-cm tall Ge crystal, which is identical in size and shape to the sensors used for the MESSENGER and Psyche GRNS and MEGANE instruments [5-7]. HPGe sensors need to operate at cryogenic temperatures, and a unique feature of the DraGNS sensor is that it will be passively cooled by Titan's atmosphere, which has a stable temperature of 94±1 K. To enable this cooling, the HPGe cryostat is located on the outside of the Dragonfly lander. Engineering work is in process to ensure the GRS will successfully operate after a 6+ year cruise and while immersed in Titan's thick atmosphere.

NS: The NS consists of two 1.27 cm by 17 cm long ^{3}He gas proportional sensors. As is standard for other ^{3}He-based NS systems [5-7], count rates from the two sensors (one of which is covered in a layer of Cd) will measure thermal (<0.4 eV) and epithermal (>0.4 eV) neutrons. On Titan's surface, it is expected that the NS will be sensitive to variations of Titan's H/N ratio [9].

DPU: The DPU is a set of electronics boards that carries out DraGNS operational command and control functions as well as data acquisition and delivery to the lander. The DPU will use standard APL DPU architecture [5,7] with separate functions for sensor and PNG operation, low- and high-voltage supply, and front-end data processing.

DraGNS Operations: While the PNG will operate in a pulsed mode, it will use a large pulse-on duty fraction (>50%) for a nominal 1-ms-long pulse period. The primary reason is to provide a relatively low instantaneous count rate (<10s of kHz) in the HPGe GRS, which has a long shaping time (5–15 μs) compared to typical scintillators (<1 μs). A consequence of this type of operation is that standard time-resolved PNG spectroscopy that separates inelastic and capture gamma-ray peaks [10], and which typically employs short duty fraction (<10%) PNG pulsing, will not be used for baseline DraGNS operation. The superior energy resolution of the HPGe sensor compared to the best scintillators (0.3% versus 3% @ 1333 keV, respectively), however, enables energy discrimination, rather than time discrimination, of key gamma-ray lines.

DraGNS data collection on Titan will proceed using the following baseline plan. Active PNG measurements will occur two or three times per 2-3 Titan days (Tsols) at each landing site, where each Tsol lasts 16 Earth days. The first measurement consists of approximately 80 min of active PNG measurements, and 50 min each of pre- and post-PNG background measurements. This first measurement will provide an initial site characterization to enable comparison with prior landing sites, as well as provide information for mission operational decisions regarding drilling and sampling. The second measurement will take place later at the same site, and will consist of one or two 6-hour sessions of active PNG measurements, bracketed by pre- and post-PNG background collections. These additional PNG measurements will provide the full sensitivity and statistical precision to meet DraGNS measurement requirements at each landing site.

References: [1] E. P. Turtle et al., *50th LPSC*, #2888, 2019; [2] Grau J. & J. S. Schweitzer, *Nuc. Geophys*., 1(#2), 157, 1987; [3] Grau J. & J. S. Schweitzer, *Nuc. Geophys*., 3(#1), 1, 1989; [4] R. J. Radtke et al., *SPWLA 53rd Ann. Logging Sym*., 2012; [5] J. O. Goldsten et al., *Space Sci. Rev*., 131, 339, 2007; [6] D. J. Lawrence et al., *50th LPSC*, #1544, 2019; [7] D. J. Lawrence et al., *Earth & Space Sci*., 6, 2605, 2019; [8] W. C. Feldman et al., *J. Geophys. Res*., 109, E07S06, 2004; [9] P. N. Peplowski et al., this LPSC, 2022; [10] J. G. Bodnarik et al., *Nuc. Inst. Meth*., 707, 135, 2013.

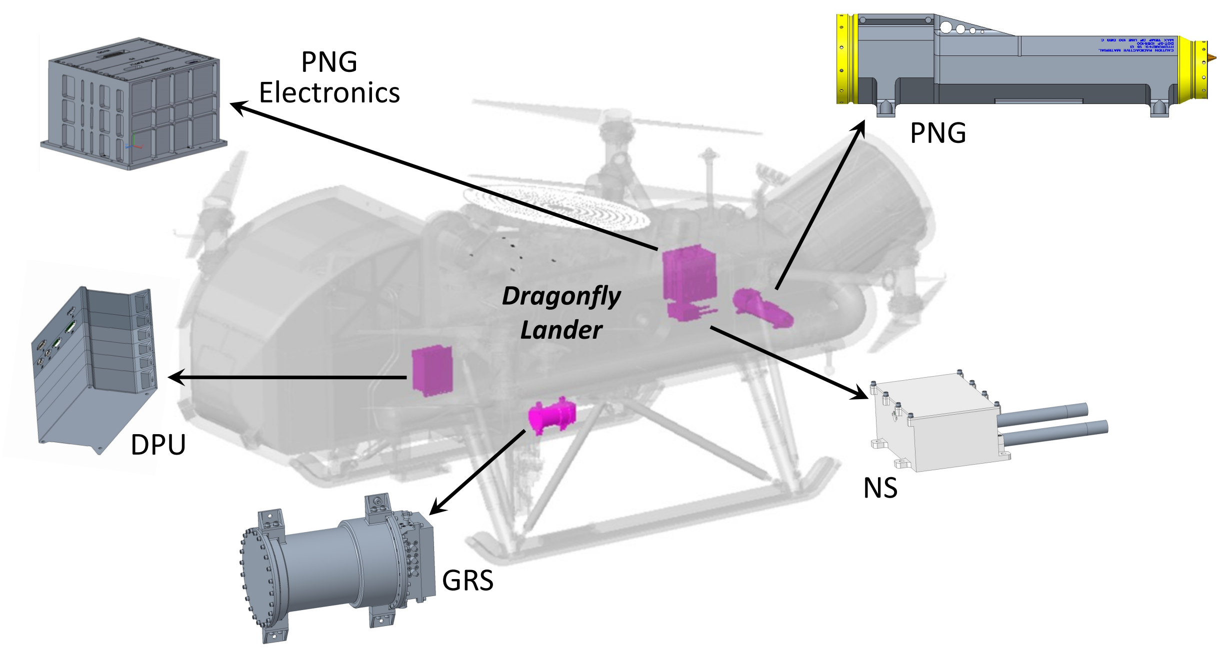

Fig. 1. Dragonfly lander illustrating the locations of all five DraGNS components.