Alamos: An International Collaboration to provide a Space Based Environmental Monitoring solution for the Deep Space Network. S. O. Kennedy Jr.[1] (stanley.kennedy@oak-aero.com), A. Dunn[1] (alex.dunn@oak-aero.com), J. Lecomte[2] (Johanne.lecomte@us.thalesaleniaspace.com), K. Buchheim[2] (klaus.buchheim@thalesaleniaspace.com), E. Johansson[3] (edgar.johansson@lasp.colorado.edu), and T. Berger[3] (thomas.berger@lasp.colorado.edu). [1]Oakman Aerospace, Inc., [2]Thales Alenia Space Switzerland, and [3]Laboratory for Atmospheric and Space Physics

Introduction: The Alamos team is pleased to submit our response to the Call for Abstracts for the Deep Space Gateway Workshop to be held in Denver, CO this coming spring. This abstract proposes the advantages of an externally mounted instrument in support of the human physiology, space biology, and human health and performance key science area defined in the Call.

Providing the capability for rapid and responsive Space-Based Environmental Monitoring (SBEM) is critical to support space weather monitoring. Understanding the surrounding space environment is significant for human safety and technology hardening for deep space exploration.

The Alamos team is a dedicated, international group of subject matter experts (SME) and space-qualified component vendors that bring many decades of experience to support the Alamos sensor.

Alamos Team: The Alamos team is comprised of four major corporate entities, both domestic and international. Oakman Aerospace, Inc. (OAI), located in Littleton, Colorado, is the team lead responsible for systems engineering, integration, and the common interface unit development. Thales Alenia Space in Switzerland (TAS-CH), based in Zurich, Switzerland, is the provider of the Next Generation Radiation Monitor (NGRM) sub-system of the Alamos Sensor Suite. The Laboratory for Atmospheric and Space Physics (LASP), a University Affiliated Research Center (UARC) at the University of Colorado in Boulder, Colorado, serves as the subject matter expert (SME) on space weather, associated science, and components. Plasma Controlls, LLC is co-located and closely associated with the Center for Electric Propulsion and Plasma Engineering (CEPPE) at Colorado State University in Fort Collins, Colorado. Plasma Controls provides the Electro-static Analyzer Sensor (EAS) for the Alamos sensor suite. This team and its hardware is uniquely situated to support NASA's Human Exploration and Operations (HEOMD) and Science Mission Directorate (SMD) goals for the utilization of the Deep Space Gateway. Alamos also acts as a successful case study for international partnerships and collaborations and can help enable future opportunities through international collaboration.

Alamos Suite: The Alamos sensor suite is a Modular, Open-System Architecture (MOSA), rapidly reconfigurable Energized Charged Particle Sensor Suite. It is low-cost, -size, -mass, and -power, with high performance. It is also very robust in accommodating multiple satellite bus standard interfaces and reconfigurable for specific missions. For the Deep Space Gateway, it will be externally mounted and require minimum power. The system consists of a baselined, compact unit seen in Figure 1. The Alamos Sensor consists of three major sub-subsystems which include: a Common Interface Unit (CIU) for interfacing to the host spacecraft (s/c); NGRM Suite for in-situ measurement of internal charging (IC), single event effects (SEE), and event total dose (ETD); and, an Electro-static Analyzer Sensor (EAS) for measurement and reporting of surface charging (SC) effects on the Deep Space Gateway or other s/c.

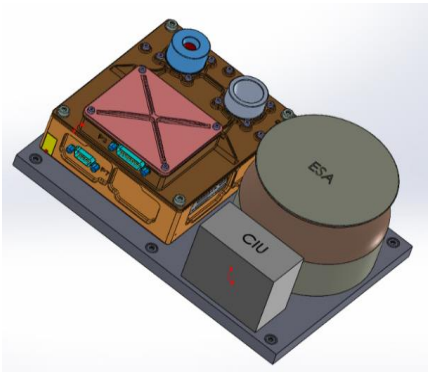

Figure-1 Alamos Sensor suite conceptual image

Integrating these three components into a common integrated ECP, Alamos leverages previous spending/development/flight heritage invested by the European Space Agency and TAS-CH without requiring a redesign or any significant non-recurring effort from the NGRM perspective. It also will bring in the Space Weather and Radiation expertise resident within the LASP space weather science team. Additionally, the CIU will allow the entire system to be modular and compatible with open standard interfaces, allowing for reduction in redesign, recurring cost savings and flexibility for future missions.

Next Generation Radiation Monitor: The NGRM instrument is highly-mature, fully integrated suite of sensors that perform all measurements related to IC, SEE, and ETD environments. *Table-1* outlines the measurement characteristics provided by NGRM. It provides a proven and low-risk solution to gain better understanding of the radiation environments surrounding the Deep Space Network. Not only will it detect

burst anomalies for catastrophic prevention, it provides a longterm measurement and long exposure profile of the ambient environment. This data, analyzed by the space weather SMEs at LASP, is crucial to understanding the safety requirements for extra-vehicle human activities as well as the consequences of long-exposure, both from a human safety aspect and an electronics lifespan.

Table-1 NGRM Measurement Ranges

Electrons	
Minimum Energy	100 keV
Maximum Energy	7 MeV
Log Energy bins	8
Maximum Flux	$10^9 cm^{-2}s^{-1}$ (at 100 keV)
Protons	
Minimum Energy	2 MeV
Maximum Energy	200 MeV
Log Energy bins	8
Maximum Flux	$10^8 cm^{-2}s^{-1}$ (at 2 MeV)
Heavy Ions (Cosmic Rays and Solar Events Ions)	
Minimum LET	.1 MeV cm^2/mg
Maximum LET	10.0 MeV cm^2/mg
Log energy Bins	8
Identification	Particle discrimination between electrons, protons and heavy ions
Total Dose	Up to 100 krad (Si)
Non Ionizing Dose	Derive from particle spectra

Electro-static Analyzer Sensor: EAS designs are based on simple electrical physics concepts. Plasma Controls will scale the design of their terrestrial electro-static analyzer sensor in order to tune the design to meet any Deep Space Gateway or deep space orbit specific requirements. This sensor has a narrow field of view and high resolution detector ranges which will be aligned with the sources of electrons spacecraft typically experience in the GEO and polar LEO environments and will be adjusted for expected Lunar and deep-space orbit environments. Because of the low mass and volume, a number of these sensors could be deployed for multiple survey decks.

Another option provided by the Alamos team is an electro-static analyzer with an omnidirectional field of view. This sensor design, also developed by Plasma Controls, will inherently have a larger volume but will still allow the Alamos Sensor suite to remain a low mass, volume, and power option.

OAI will develop the EAS electronics and data interfaces into its CIU. This will eliminate redundancy of hardware but retain risk assurance through its modularity and easily replaceable instrumentation.

Common Interface Unit: The CIU functions include power services (switching, monitoring, and control) to the Alamos Sensor suite (NGRM, EAS(s)), data messaging services between the Deep Space Gateway and the Alamos Sensor suite, and communications. The CIU will receive power and send data to the ss/cc via any common military standard interface (MIL-STD 1553, RS422, CAN, Spacewire, etc.). The CIU will route power to the NGRM and EAS and receive data from the two sensors. The data will then be reconciled and distributed to the s/c via the common, selectable interface. The system is low Size, Weight and Power (SWaP) and modular, allowing for easy implementation and external sensor change/addition, increasing mission flexibility.

The CIU is an important function to the Alamos Sensor suite because it allows the flexibility to insert other scientific payloads, at users discretion, with minimal engineering and interface development. This is an important aspect as technological advancements are made and as Deep Space Gateway needs evolve.

Deep Space Gateway Impact: Alamos will have minimal impact on Deep Space Gateway resources while providing important knowledge on the surrounding cislunar environment. With a mass of less than 5kg, power consumption less than 10W, and a modular software and interface design, Alamos can be placed on any external surface of the Deep Space Gateway, or on multiple surfaces for additional space weather mapping, with minimal impact. Either a pre-launch configuration or a one time installation by an astronaut or external robotic arm is all that is needed for implementation. Should a unit need to be removed or replaced, on board support will be minimal.

In addition, these instruments can be stored on board for any amount of time, awaiting installation on spacecraft which may be deployed into lunar orbit from a Deep Space Gateway portal. This would allow a cost effective and low SWaP impact method to mapping lunar space weather.

Conclusions: The Alamos team proposed in this aspect will provide the Deep Space Gateway crucial data needed for space weather mapping and monitoring. Continuous monitoring of the space based environment will alert NASA of immediate anomalies that may disrupt operations or be dangerous to exposed humans, as well as evolve the understanding of long exposure for systems in new deep space environments. Also, the success of the Deep Space Gateway and beyond is dependent on successful, efficient international collaborations. The Alamos team is a leading example of such collaboration and will help to enable future opportunities of international teamwork.