PACKMAN-Net: A Distributed, Open-Access and Scalable, Network of User-Friendly Space Weather Stations. M.-P. Zorzano[1,2], J. Martín-Torres [1,3], T. Mathanlal[1], A. Vakkada Ramachandran[1] and J.-A. Ramirez-Luque[1]. [1]Atmospheric Science Group, Department of Computer Sciences, Electrical and Space Engineering, Luleå University of Technology, 971 87 Luleå, Sweden, [2] Centro de Astrobiología (INTA-CSIC), Torrejón de Ardoz, Madrid, Spain. [3] Instituto Andaluz de Ciencias de la Tierra (CSIC-UGR), Armilla, Granada, Spain.

Introduction: The Earth's atmosphere is continuously bombarded by energetic charged particles from space. To date, there is a missing gap of information regarding the amount, energy, time variability, and type of space radiation that reaches the lower layers of the atmosphere, as well as on its geographic and altitude distribution. This information has implications for space weather, and potential impact on infrastructures and climate. To generate a long-time record of space radiation on Earth we designed an open source, autonomous instrument, called PACKMAN (PArticle Counter k-index Magnetic ANomaly), with Commercial Off The Shelf (COTS) components, that can monitor continuously a set of critical variables at multiple latitudes and heights in the atmosphere (in balloons) [1]. After an initial deployment and testing phase, PACKMAN has demonstrated its operability at different latitudes and atmospheric heights (see *Initial deployment* section below). The purpose of the PACKMAN-Net phase of the project is twofold: 1) to design an architecture that allows for scalability with multiple instrumental nodes of equivalent format that adhere to the PDS4 standard; and 2) to ensure an efficient management (discovery, access, retrieval and analysis) of the information provided by a network of PACKMAN instruments distributed over the world by merging information and preparing data mining tools both for science, education and outreach, and space-weather alert warning systems. It aims to allow global electronic access and to provide global monitorization of space weather on community-based ground observatories as well as in other atmospheric platforms such as balloons.

This is an example of instrumentation data in our planet which needs a dedicated scalable data archiving and processing architecture that adheres to the PDS4 standard. Furthermore, this project may be used to benchmark the design of archiving, scalable, networks of future planetary instrumentation observations of the Moon or Mars.

Instrument network specifications: The purpose of this work is to demonstrate the operability utility of a network of small-sized detectors of the PACKMAN instrument, operated simultaneously to provide real time cosmic ray and solar activity monitoring, covering ground based observations over the entire planet. A critical and complementary observation is the one from atmospheric vertical soundings, using the same hardware, and measuring simultaneously ideally in a long duration (several days) circumpolar campaign, but also on shorter stratospheric and tropospheric sounding balloons campaigns.

PACKMAN is an autonomous instrument that can be deployed at any location and send the data automatically through wireless communications. The PACKMAN-G (ground) is adapted for surface monitoring, including outdoors remote operation, to provide simultaneous records at multiple latitudes (and longitudes) with different geomagnetic fields and at different heights with different total air column (pressure) and weather phenomena. The PACKMAN-B (balloon) is a TRL8 qualified flight Instrument used in balloon campaigns for tropospheric and stratospheric sounding. PACKMAN-B has been flown in two stratospheric balloons from Córdoba, Spain with Zero2Infinity and from Esrange Space Center, Kiruna, Sweden in collaboration with Swedish Space Corporation (SSC).

Initial deployment:

Through the initial deployment and testing phase, PACKMAN has demonstrated its operability at multiple latitudes and atmospheric heights:

1. Space campus LTU, Kiruna, Sweden (67.84°N, 20.41°E, 390 m)
2. LTU Main campus, Luleå, Sweden (65.62°N, 22.14°E, 15 m)
3. Boulby Mine, Cleaveland, United Kingdom (54.56°N, 0.82°W, 93 m and -1.1 km)
4. University of Edinburgh, United Kingdom (55.94°N, 3.19°W, 98 m)
5. Cordoba airport, Córdoba, Spain (37.84°N, 4.84°W, 90 m to 27 km)
6. Esrange Space Center, Kiruna, Sweden (67.88°N, 21.12°E, 328 m to 27 km)

PACKMAN is a small, robust, light and scalable instrument that monitors with two Geiger counters gamma, beta, alpha radiation and muons. This instrument includes environmental sensors to monitor pressure, temperature, relative humidity, and magnetic perturbations (with three fluxgate magnetometers in

three perpendicular axes) and includes data archiving, GPS and communication capabilities.

We illustrate through this initial network, that PACKMAN can unequivocally detect the onset of a solar storm and can provide meaningful records of particle counts, synchronous high energy particle detections, pressure and/or density anti-correlations, dependence on local geomagnetic field and elevation. We demonstrate the successful operation of the flight-model of PACKMAN instrument from the surface to the stratosphere, in a space operational environment. Through these testing campaigns, the technology has been proven to work in its final form, both for ground and space operation, and under nominal operation conditions.

Data archiving and access specifications: At present date there are 4 PACKMAN nodes operating continuously at different latitudes, and 2 extra PACKMAN nodes will be installed in Granada, Spain, and Misasa, Japan durint the spring of 2018. Besides the natural expansion of the network through collaborations with research institutions, in the future, when the instructions for construction are released, it is expected that more users may adhere to the network by building their own instrument and uploading the data. This will allow to make a scalable network and also bridge the gap between society and research, adding new stake holders such as teaching institutions (high schools, universities), or industry and infrastructures representatives. PACKMAN data will be formatted in PDS4 standard, in such a way that every instrument will be an instrument node with their own structure. New instruments can be integrated in the server creating new nodes and uploading the data over time to the same server. To be able to upload data, credentials will be required and anyone with a PACKMAN instrument can request them in PACKMAN dedicated website that will be available in a near future.

To have consistency in the products that we create, we will provide a software to save the data in the same format (for instance using the same time stamp label format and same order of variables, and file size or cadence sequence) and to upload the data to the system. Alternatively, and for users who only want to format their data, we will provide the necessary software to save the data in the correct format, this can be used for testing the instrument or to have a PACKMAN unit working as a standalone product.

The website will contain PACKMAN general information, documentation, software and registration procedure to access / upload the data. Furthermore a set of online tools and data mining codes will alow to analyse the data from PACKMAN units distributed over the world by comparing the instrument observations and providing new products for science, education and outreach, and space-weather alert warning systems. The present design considers the possibility to merge the data with other instruments (including space weather observations from orbit) and to increase the scope of research of the PACKMAN network by including extra sensors.

The observations acquired by PACKMAN will be used to provide open access, real time information, for: 1) education and public awareness of space weather phenomena; 2) to compare with Earth climate observations; 3) to provide real-time information of space weather variability for potential damage to infrastructures (telecommunications, power generation facilities, aviation, transport, etc.); 4) to monitor natural radiation sources at multiple environments; 5) to monitor the variability of the Pfotzer maximum height during different stages of solar activity and seasons and 6) finally, this project may serve as a reference for future scalable networks where multiple instruments are deployed at different sites or conditions and with different initiation times, and where the informational value increases by adhering to a common PDS4 format and analysing the data in a concurrent way.

References:

[1] Zorzano M.-P. et al (2017). *The PACKMAN radiation and environmental instrument for space weather studies.* PAC Proceedings ESA. 23rd ESA Symposium on European Balloon and Rocket Programmes and related Research – 11th -15th June 2017, Visby, Sweden.