**AUTONOMOUS MONITORING OF RADIATION ENVIRONMENT AND PERSONAL SYSTEMS FOR CREW ENHANCED SPE PROTECTION (AMORE and PSYCHE).** L. Narici[1,5] , G. Baiocco[2], F. Berrilli[1], M. Giraudo[3], C. Lobascio[3], A. Ottolenghi[2], A. Rizzo[1,5], G. Salina[4], [1]Department of Physics University of Rome Tor Vergata, Via della Ricerca Scientifica 1, 00133 Rome, Italy, narici@roma2.infn.it, [2]Department of Physics University of Pavia, Pavia, Italy, [4]Thales Alenia Space Italia SpA, Turin, Italy, [5]INFN, Sect. Roma Tor Vergata.).

## Idea Description

*Background*

Proper mitigation of radiation risks below acceptable thresholds is a must to enable deep space exploration. Solar Particle Events (SPEs) would require, for example, a combination of i) solar physics based forecasting in addition with now-casting provided by real time analysis of the SPE precursors (as measured outside the space vessel), to issue proper "warnings", ii) mitigation procedures to be activated following the warning, including multifunctional and personal radiation shielding systems on board. Understanding the risk level of an SPE from the combination of fore- and now-casting is needed to optimize the SPE mitigation procedure and validate the radiation shielding approach.

For the first time, after Apollo 17, the DSG would allow to experimentally study this issue in the actual deep space radiation environment, providing also grounds for model validations. A combination of external radiation monitoring (for precursors), area & personal monitoring would be needed for the warnings generation and for studying the correlation between warnings and actual risks due to the SPE radiation as measured by the area and personal internal monitors, as well as for validating shielding radiation transport models.

*Objectives*

*Understand the relationship between SPE precursors (as measured outside of a space vessel), the related SPE radiation in the habitat and the associated risk levels, also validating existing models.*

*Use such understanding to provide best countermeaures suggestions to the crew, with a real time, autonomous intelligent system.*

*Deepen our understanding of the effectiveness and actual ease of use of innovative personal SPE protection systems for humans in deep space.*

*Implement this strategy in flight for a demonstration test.*

In detail:

1) Study, for the first time in a human habitat in deep space, the detailed relationship between externally measured SPE precursors and the related internally measured radiation field and consequent risk increase. SPE forecasting, from Solar physics results (see for example [1]), and a preliminary study on SPEs databases will permit the selection of the best precursor(s) to be measured suggesting also risk prediction matrices (see, for example, [2]). The project will provide data to validate these strategies and estimate the accuracy of SPE nowcasting. The same data will allow for detailed studies and validations of transport codes through the habitat hull and shielding systems, including personal systems such as PERSEO [3].

2) Intelligent tools will be provided to use at best the information coming from the "nowcasting" in (1) to mitigate SPE impact on the crew, using the detailed knowledge of the shielding capabilities also of all massive items in the vessel, with no intervention of Mission Control, and minimal intervention of the crew.

In order to optimally manage the available shielding of the spacecraft for best SPE protection (attitude variations, internal disposition of the items, shelter preparation etc.) an ad hoc smart system will be developed. This would require the precise knowledge of position and shielding efficiency of all massive items in the vessel, including the movable ones: proper wireless tagging sensors will therefore be developed. The time between the SPE precursors and the arrival of the dangerous part of the SPE may be shorter than the time needed to perform the countermeasure procedures. Starting from the acquired data, the project will estimate the residual risk the crew will face in these conditions through ad hoc designed simulations and models.

During an emergency (such as following an SPE warning), the above procedures will have to be performed in the shortest possible time, and eventually (when in interplanetary missions) with no support from Mission Control due to the large comm – delay. DSG is the best platform to master these procedures in view of these voyages. This project will develop a first set of intelligent systems to collect all the sensors data and the needed knowledge information, including, for example, the health history of each astronaut, providing real time suggestions to the crew.

The system will be mostly automatic, and data will be directly downlinked on Earth whenever possible. Crew activity would be restricted to the mounting and set up of the detectors and eventually the rearrangement of items in the vessel, and would be minimal.

*Equipment to be developed / deployed:*

i) a set of small light novel and performing radiation detectors - minimum of 2: one external for SPE precursors (probably: X gamma and e-. Nice to have: ions, for an internal-external validation of transport codes), one internal (area detector, nice to have: personal detector)

ii) operating platform – smart system, wirelessly collecting all the outputs of the detectors, could also be implemented on existing systems such as tablets (eg ARAMIS [4]) or smartphones

iii) personal shielding items, such as PERSEO or elements thereof such as flexible water bags, which should be available on board DSG

iv) novel tagging system for the movable items of relevant dimensions associated with the knowledge of the shielding distribution of each item (such as a detailed CAD)

v) models and simulations to estimate the residual risk due to the fastest SPEs, that will not allow for full exploitation of the countermeasures in due time.

*Expected impacts*

The research described here will provide several key advances aimed at enabling human space exploration:

a) the study and test of the procedures to nowcast incoming SPEs from the precursors that can be measured outside the vessel will i) provide an estimate of the possible minima for warning times, ii) support the minimization of the SPEs radiation risks using the items and shielding available on board, and iii) permit to estimate the residual risk through ad hoc developed models.

b) it will provide a first seed toward a fully automated radiation management system, demonstrating also the ability of migrating the radiation-related decision processes from Mission Control to space. This “smart system” would be open to collect, correlate and analyse inputs from all the radiation and environmental detectors, as well as other relevant information, such as the health history of each astronaut, towards an integrated smart system for the autonomous managing of all operations linked to environmental conditions.

| Estimated experiment properties | Description |
|---|---|
| Mass of hardware | < 1 Kg (including 2 detectors, tagging system and hardware; shielding assumed available on board DSG) |
| Volume of hardware | < 2 lit |
| Accommodation (e.g. internal/external) | 1 detector external<br>1 detector, tagging elements, hardware internal |
| Power required | < 10 W (possibly partly battery powered) |
| Data generated | < 1 GB / day |
| Pointing/viewing/line of sight needs | Yes for the external detector. |
| Communications needed | Nice to have |
| Duration of experiment | Long (looking for SPEs) |
| Crew tasks (if needed) | Minimal: mounting, set up, eventually rearrangements of items |
| Need for retrieval and return to Earth | Nice to have |
| Specific orbit needs (if any) | No (TBC) |
| Operations without crew (if any) | Most of the time |

**References:**

[1] Anastasiadis et al. Sol Phys (2017) 292: 134. https://doi.org/10.1007/s11207-017-1163-7

[2] Posner, Space Weather, 5, S05001, doi:10.1029/2006SW000268, 2007

[3] M. Vuolo et al, LSSR (2017), http://dx.doi.org/10.1016/j.lssr.2017.08.003

[4] Augmented Reality Application for Maintenance, Inventory and Stowage (ARAMIS), www.asi.it/it/news/abitare-lo-spazio