ANNEX B. STUDY DESCRIPTION

Ariadna Call for Ideas: Innovative Radiation Shielding Approaches (14/920X)

Type of activity: Standard study (25 k€)

Background and motivation

Space radiation is considered one of the major health problems and thus potentially limiting factors for long-duration human spaceflight together with isolation and microgravity-induced physiological changes [15], [16]. Among the various health risks, carcinogenesis caused by exposure to space radiation is now generally considered the main hindrance to interplanetary travel [1], [13], [15]. Current manned missions to low Earth orbits are partially protected by the Earths' magnetosphere [12].

Astronauts are exposed to protons, electrons and heavy ions, along with secondary radiation including neutrons and recoil nuclei that are produced by nuclear reactions in spacecraft or tissue [12]. MeV electrons are encountered mainly in Earth orbit but can be hazardous for EVA and transfer phases of missions. Beyond Earth orbit, the main hazards are high energy protons and ions. While the energies of concern range from tens of MeV upwards, the lower energy portion, including particles from solar particle events can easily be shielded against. The remaining environment of concern is galactic cosmic rays (GCRs) - protons and ions of energies from 100 MeV upwards, and in particular particles of energy around a GeV. These particles are difficult to shield against and interact with matter to produce significant amounts of secondary radiation. The atomic number of GCRs extends from hydrogen to uranium; however, nuclei heavier than iron (Z=26) are infrequent [1], [12], [13], [14]. Ionizing radiation is a well-known carcinogen. The risks of cancer are generally established at relatively high doses (>100 mSv). Large uncertainties remain about cancer risk at lower doses and at low dose rates (<50 mSv/h) [1], [13], [16].

An ambitious human exploration program would thus require substantial advances in radiation shielding concepts and counter measures.

Therefore, this call for Ideas focuses on novel innovative space radiation shielding technologies or major advancements in currently proposed concepts.

Current Radiation Shielding Concepts

Recent measurements made by the Mars Science Laboratory (MSL) mission showed that the radiation experienced behind conventional shielding (approximating the shielding of current human space-flight missions) during a trip to Mars was at the high end of previous estimates [11]. Astronauts on a round trip to Mars under these conditions would receive 0.66 Sieverts [11]. One sievert is considered to give a 5% increase in a fatal cancer [11].

Researchers and engineers devised many concepts for radiation shielding. Many of the concepts found in the literature are however lacking technological readiness. For instance, some are still at the stage of the initial idea that needs to be nurtured to more promising and feasible concepts.

Currently radiation protection is mainly done by operational measures and by adding material layers (physical shield, e.g. Aluminium [2], [13], Polyethylene [2], Gold foil [2], [13]).

Ideas and concepts for radiation protection can be classified into the following categories:

- Passive radiation shielding, e.g.
  - Polyethylene boron [2], [13], [14]
  - Nano-material hydrogen storage [2], [6]
  - ISRU [2], [24]
  - Large sail/shield [2]
  - Hydrogen gas shield [2], [13], [14]

- Active deflecting shielding , e.g.
  - Magnetic field, [2], [25], [20], [26]
  - Electrostatic field [5], [2], [23], [25], [26]
  - Plasma shielding/artificial magnetospheres [2], [4], [22], [25]

- Protective clothing; e.g.
  - Space suit [7]

- Physiological protection, e.g.
  - Radiation sickness control [8], [9]
  - Skin protection [9], [17], [18]
  - DNA repairs [9], [17], [18]
  - Gas mixtures [10]

Some of these concepts are scientifically flawed and many are impractical. For example, limitations include Bremsstrahlung and plasma interactions at extreme high voltages in electrostatic shielding [23], inability to demonstrate effective deflection of GeV ions in plasma shielding [22] and high mass and complexity in magnetic shielding [20], [21]. Proposals shall demonstrate how to overcome the shortcomings identified in the references if opting for already established concepts. However, radically new ideas on radiation shielding are favoured.

Research and Study Objectives

The main aim of this Call for Ideas is to perform research on *new* and *innovative* scientific and technical concepts and techniques for innovative radiation shield technologies.

For the selected concepts or techniques, the first most important research step shall be performed during the study.

In principle, all scientific fields of potential relevance are encouraged to propose solutions.

Study Proposals

Study proposals should contain

1. the description of the general idea, including at least its
   a. scientific foundation
   b. mass and material properties (densities, volumes)
   c. energy requirements / constraints
   d. shielding capacities (for typical radiation types experienced in space beyond low Earth orbits, with emphasis on GCRs) (theoretical/practical)
   e. life-time or other limitations (theoretical/practical)

2. how the concept/idea can either substantially improve the state of the art or is substantially different to already described ones
3. the research step to be carried out that addresses and matures a key aspect of the concepts
4. Identification of possible demonstration opportunities for the proposed concepts

While new ideas will be given preference, proposals which constitute a *major* improvement of an existing concept will also be considered.
The proposed research scope needs to be feasible within the Ariadna study framework (www.esa.int/ariadna) and constitute an important step towards reaching the goals of Radiation protection.

Proposers are should underline their reasoning with references to published papers and research results and, where relevant, include an evaluation of the reference material attached to this Call.

For the selected concepts or techniques, the first proposed research steps will be performed during the study in the frame of Ariadna studies.

References

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