

***Recommendations arising from a feasibility study
of (a) Astronaut Standardized Career Dose Limits
in LEO and the outlook for BLEO; (b) the
Biological Response of Humans to Energetic
Particle Radiation under microgravity conditions***

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*This presentation is dedicated to the memory of our
distinguished colleague*

Dr. Vladislav Petrov

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An overview is provided in the draft document of the radiation hazards pertaining to deep space travel and an account is also given of how these hazards are predicted.

The overall study revealed thus far that major internationally based research and engineering projects covering a broad range of topics require to be carried out in order to develop mitigating strategies that can alleviate the risks to human health incurred beyond BLEO.

Thirteen recommendations for the implementation of such large projects are contained in the draft report and a selection of these is presented in what follows.

Implementation of the recommendations



To carry out the major projects identified to be required to implement the mounting of viable manned missions in BLEO, it is recommended that Space Agencies/Space Companies/ International and Private Entrepreneurial Organizations address the mastering of required technologies (such as fast propulsion; customized spacecraft design/shielding; habitat design, space power technologies, human and robotic partnerships, advanced space communications, advanced navigation, etc.).

Implementation of the recommendations contd.



In parallel, the International Academy of Astronautics, in a catalyst role of fostering global international co-operation, could organize studies and projects aimed at harnessing the strengths and facilities of both existing space powers and emerging nations to investigate related interdisciplinary issues.

Ongoing progress in pursuing these complementary approaches could be assessed by the Heads of Space Agencies and by the Academy's Human Space Flight Coordinating Group (HSFCG) at bi-annual summit meetings so as to maintain momentum and direction regarding global advancement toward human missions in BLEO.

Remarks on LEO and BLEO



The career dose limits presently assigned to astronauts in LEO are not standardized among the agencies. Also, much scientific work and modeling presently remains to be done in order to understand the LEO environment more fully.

No limits are as yet adopted for BLEO. Further, until the large uncertainties in estimating the risks to human health accruing to irradiation are better understood, dose limits for BLEO cannot be meaningfully assigned.

Recommendations Regarding Dose Limits



Assess the radiation standards now adopted by the space agencies for LEO in the light of the new space observations presently becoming available.

Make a preliminary definition of BLEO levels in the light of updating information concerning the risks posed to human health in micro-gravity.

Take into account the total radiation risk (including carcinogenesis, degenerative tissue and cognitive effects) when estimating health risks for space personnel on long duration excursions.

Present outlook for BLEO



At the present time the ‘outlook for BLEO’ suggests that, in the future, agencies which will individually (or co-operatively) launch human missions to the Moon, the Asteroids and Mars will probably agree within their own communities what can be an acceptable risk to onboard personnel in order to successfully achieve the objectives of the particular mission they are mounting.

This trend will be further assessed when the study is completed in 2015/16.

Recommendation to implement Fast Propulsion



It is recommended, given that the development of a propulsion system with the capability to provide a rapid transit to Mars would result in significantly reducing the onboard radiation risks to humans stimulated by heavy ion bombardment, that options for fast propulsion systems for interplanetary missions be vigorously pursued and supported by the space agencies.

Recommendation to carry out onboard particle monitoring.



Spacecraft providers should ensure that vehicles with human crews are equipped with a near-relativistic electron detector system having sufficient sensitivity to unambiguously detect 'first arriving' fast solar electrons. A near relativistic solar proton detector system with complementary sensitivity should also be installed.

In addition, individual crew members should be provided with active and passive personal dosimeters based on, well-characterized, charged particle/neutron measurements.

Recommendation to co-ordinate solar studies



New insights into the circumstances under which flares associated with Coronal Mass Ejections and hard spectrum SEPs take place are urgently required so that precursors to these events can be recognized. It is therefore recommended that co-ordination of international studies aimed at carrying out relevant solar observational programs be organized by the International Academy of Astronautics.

Recommendation Regarding SEP Prediction



There is a pressing need to establish, and suitably support, international co-operation with regard to comparing in detail the results obtained using all the interplanetary radiation models now available (from America, China, Europe, Japan and Russia) in order to arrive at globally agreed conceptions concerning them.

Data sets gathered by a plethora of past and ongoing missions (e.g. the: ISS modules, Lunar Reconnaissance Orbiter, Mars Odyssey, Mars Science Laboratory, Mercury Messenger, as well as other relevant, near Earth, spacecraft (e.g. SOHO, ACE GOES etc.) can provide validation of the predictions.

Co-ordination between groups engaged in these wide ranging studies could be organized under the aegis of the IAA.

Recommendation to provide a . Network of ground stations on Mars



The Space Agencies should in parallel take steps to establish a ground network of measurement stations on Mars using sites characterized by different soil compositions, hydration states and altitudes.

These stations could consist of dedicated phantoms designed to provide a detailed level of information (ground truth) concerning the temporally changing dose distributions at these various planetary locations.

Recommendation to make available Space Weather Alerts



To enable effective onboard risk management based on alerts of eminent hazardous particle environments at a spacecraft in BLEO, the space agencies should ensure that communications to support the telemetry of real-time space weather information to a vehicle implementing a deep space mission are set in place prior to that mission.

This would involve positioning scientific spacecraft at various solar longitudes in operationally viable positions to support the sending of real-time data to the manned vehicle at an emergency frequency.

Recommendation to make available Space Weather Alerts.



Also, since spacecraft suitably positioned to provide optimal information on activity taking place on the far side of the Sun would significantly enhance real-time forecasting capability and, thereby, ensure an improved possibility for crews to respond in time to emergency situations, the provision of such spacecraft should be considered by the space agencies to constitute part of the backup system for a deep space mission with related support funding duly taken into account.

Also, an alert system should be developed for use in a potential habitat on Mars to relieve the necessity to rely on ground based information concerning space weather.

Recommendation to develop a Human Space Awareness System



A preliminary concept for a Human Space Awareness System (HSAS) should be developed for crewed missions to provide:

- the means of prompt onboard detection of the arrival of hazardous particles;*
- a strategy for the implementation of onboard responses to hazardous radiation levels;*
- support modeling/data gathering to reliably predict the arrival of hazardous radiation at a spacecraft in BLEO;*
- guarantee the timely transmission of particle alerts to a distant crewed vehicle at an emergency frequency using suitably located support spacecraft.*

Summary of actions to be implemented next in Cosmic Study 3.19/1.10



- **Foster development of improved Models and Technologies relevant to the support of Human Space Exploration.**
- **Co-ordinate international research into the biological effects of space radiation in microgravity.**
- **Assess the radiation standards adopted by space agencies for LEO in the light of new measurements.**
- **Make a preliminary definition of BLEO levels.**
- **Develop a preliminary concept for a *Human Space Awareness System* (HSAS) that will provide for crewed missions the means of effective onboard risk management.**

The study requests manpower from the space agencies dedicated to help in carrying out these major international activities

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