Modeling the prodromal effects and performance reduction of astronauts from exposure to large solar particle events

S. Hu1, M. Y. Kim2, G. E. McLellan3, H. Nikjoo1, F. A. Cucinotta4

1Division of Space Life Sciences, USRA, Houston, TX, 77058. 2Wyle Laboratories, Houston, TX, 77058. 3Health Effects and Medical Response, Applied Research Associates, Inc., Arlington, VA 22203. 4NASA Johnson Space Center, Houston, TX, 77058

Introduction

- Radiation exposure from solar particle events (SPE) presents a health concern for astronauts, that could impair their performance and result in possibility of failure of the mission.
- Assessing the potential of early radiation effects under such adverse conditions is of prime importance.
- A biologic based mathematical model1 which describes the dose and time-dependent early human responses to ionizing radiation is presented.

Human Response Program (1981-1996)

- Radiation Induced Performance Deduction (RIPD) code
- Model calculation: performance degradation

Human response quantification

<table>
<thead>
<tr>
<th>Severity level</th>
<th>Signs and symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Vomiting/retching several times</td>
</tr>
<tr>
<td>4</td>
<td>Vomiting/retching once or twice; nauseated and vomiting may recur</td>
</tr>
<tr>
<td>3</td>
<td>Nauseated, sweating, frequent retching and swallowing to avoid vomiting</td>
</tr>
<tr>
<td>2</td>
<td>Upset stomach, clammy and sweaty; mild nausea</td>
</tr>
<tr>
<td>1</td>
<td>Normal; no noticeable effect</td>
</tr>
</tbody>
</table>

Exposure Calculation

Model system:
- Baryon transport code (BRYNTRN2)
- Spherical spacecraft in deep space
- Computerized anatomical man (CAM) model

Worst Case Study

Model Calculations

30 hours stay in spacecraft during the August 1972 SPE peak

- Early illnesses of UG and FW are manifested inside a poor shelter.
- Performance degradation is expected but risk of death is small.

Worst Historical Event

BFO dose rate during August 1972 SPE

Which dose to use: skin dose or bone marrow dose?

EVA protons are attenuated by the body tissue much more effectively than gamma-rays.

For gamma-rays, the ratio of dose rate of FIA (free-in-air) to that of MLT (midline tissue) is 1.5.

Conclusions and Future Work

- Assuming the same prodromal effects for exposures to SPE radiation as those for the gamma rays, the worst-case historical SPEs are capable of inducing early effects to crew members and impair their performance.
- Events with higher flux or frequency (2 times that of August 1972) significantly increase the ARS effects but the incidence of mortality is small (2%) even without medical treatment.
- Bench marking of the RIPD code to space radiation environment is necessary for a precise analysis of the health risk to astronauts.
- Specific organ dose (e.g., stomach, intestinal) will be used in future work.

References