

RECOMMENDATIONS OF THE
NASA SUN-EARTH CONNECTION
RADIATION
WORKING GROUP
REPORT

APRIL, 2005



Executive Summary

In January, 2004, The President announced a redirecting and refocusing of NASA's strategic goals toward a "Vision for Space Exploration." This initiative seeks to dramatically expand NASA's human exploration from low-Earth orbit to the lunar surface as early as the year 2015, then push beyond to Mars and other solar system bodies. In response, the NASA Sun Solar System Connection Division (SSSC, formerly the Sun-Earth Connection (SEC)) is examining its portfolio of science missions and its other programs. The mutual interests of SSSC science and support of human exploration missions come together in space weather and climatology and their impacts on astronaut radiation exposure, spacecraft shielding, and on operational systems that support human missions.

The Director of the former Sun-Earth Connections Division convened a workshop on April 5-6, 2004, in Washington, D.C., of space weather, space radiation, space physics, solar physics scientists, and other experts. Their goal was to identify the elements of the current and planned SSSC program contributing toward enabling human exploration missions and to identify the critical exploration-enabling science areas under SSSC's purview but not addressed by the current program. Attendees represented expertise in space weather and human radiation protection science as well as operational support elements involved in planning, designing, and executing manned exploration missions.

This report discusses highlights and recommendations from the workshop including: a synopsis of the state-of-the-art of space weather elements, particularly the radiation environment as related to manned exploration missions; research needs related to understanding and forecasting galactic cosmic ray (GCR) exposures and solar particle events (SPEs); specific *in-situ* measurement requirements and the infrastructure necessary to carry-out the measurement program; and recommendations regarding roles of current and planned SSSC space missions.

A host of other issues, most notably radiobiological effects and potential mitigation techniques (which play an even more important role than physical factors in determining the risk from space radiation exposure) were not examined during this workshop. Also excluded were exposures from potential nuclear power sources and the environmental impact to electronic parts and systems, surface materials, etc.

The threat to astronauts from radiation is substantial and well-documented. Astronaut space radiation exposures during exploration-type missions, and the methods to control and reduce them, depend on many physical factors such as mission duration, the amount of shielding available during transit phases and while on the lunar or Martian surface, etc. Each of these factors has a varying degree of importance to astronauts' exposures depending on the type of mission. To help establish priorities, the workshop members considered these factors in the broad context of two mission classes: (a) those involving

multiple missions to the lunar surface over an extended period of time and (b) a (temporary) manned exploration of Mars.

Using these assumptions, astronaut radiation exposure concerns result from GCR and large (1 in 10 years) solar particle events (SPEs). The geomagnetically trapped radiation belts are not viewed as a major concern for astronaut health. Based on the Apollo program experience, the exposure to crews there is small compared to the expected total GCR and SPE exposures.

The workshop group recognized the unique position of the SSSC program to provide support towards enabling the successful return of humans to the Moon and the eventual human exploration of Mars. SSSC's research program and assets are an integral component of the toolkit NASA must use to confront the health risks from exposure to space radiation during exploration missions. SSSC's potential contributions in this regard fall into two categories:

- providing the measurements and physical understanding to enable the incorporation of prudent and efficient radiation protection strategies into the design of crew vehicles and mission plans;
- providing the physical understanding necessary for the development of operational radiation protection techniques and tools that will be used by flight support personnel during periods of high space weather activity.

Overall Recommendations

Central to supporting spacecraft/habitat design and operational mission phases is the development/completion of state-of-the-art space environment models capable of quantitatively describing the current state and future evolution of the inner heliosphere and its charged particle environment. As humans venture away from Earth orbit for the first time, it will be necessary to have models that can forecast space weather throughout the 3-D heliosphere and not just along the Earth-Sun line.

The minimum conditions necessary to generate these advanced models are simultaneous radiation environment measurements from: the first Lagrangian point (L1), from points closer to the Sun as well as lunar and Martian orbits, and supplemented by data from other heliospheric locations. Data from multiple spacecraft are needed to understand the longitudinal and radial developments of solar particle events, and measurements closer to the Sun can provide ground truth on the conditions under which solar particles are accelerated and transported. Providing these measurements will require a coherent infrastructure of instruments to be developed and put into place in the near-to-mid term. Such an infrastructure is analogous to deploying remote weather stations and new weather satellites to support the exploration and development of remote corners of the Earth. The finite lifetime of space-based monitors and the long-term nature of NASA's exploration goals mandate that this be an essentially permanent infrastructure investment. These new measurements must be supplemented by the continued analysis of the rich treasure trove of existing space environment measurements in order to gain adequate samples of extreme solar events and to understand the timescales of GCR intensity fluctuation.

Although current plans envision the first human exploration missions 10-15 years in the future, SSSC's support should begin immediately through the continuation of on-going synoptic charged particle and plasma measurements by the ACE, Ulysses, Wind, and Voyager spacecraft. For the longer-term, the SSSC program must ensure that the STEREO and SDO missions be kept on their current schedules. SSSC should also seriously consider scheduling the Solar Sentinels program so that the mission's spacecraft are operating by the next solar maximum.

In terms of enabling the new strategic vision, the most notable gap in the current SSSC program is the lack of space plasma and energetic charged particle monitors upstream of Earth in the mid-to-long term. Measurements from these monitors provide the context for understanding, comparing, and inter-relating all other (recent) past, current and future space radiation measurements. For the past seven years these data have been provided nearly continuously by the ACE spacecraft and may continue for another 5-10 years. At some point, however, ACE data collection will stop. The SSSC program should begin investigating now options to continue making these measurements beyond the ACE era.

This report was prepared and approved by the following members of the workshop panel:

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Charge to the Committee:

At the request of Dr. Richard Fisher, Director of the former Sun-Earth Connection Division, and Dr. Madhulika Guhathakurta, Living With a Star Program Scientist, a workshop was convened of scientists and other experts in space weather, space radiation, space physics, and solar physics. Its purpose was to identify which elements of the current and planned SSSC fleet contribute to the improved understanding of galactic cosmic rays and solar particle events in the context of enabling human exploration missions, as well as which critical areas are not being addressed by the current planned program.