

Deep Space Test Bed for Radiation Studies

James H. Adams, Mark Christl, John Watts
Marshall Space Flight Center

and

Eugene Kuznetsov and Zi-Wei Lin
University of Alabama in Huntsville

Summary

Introduction: A key factor affecting the technical feasibility and cost of missions to Mars or the Moon is the need to protect the crew from ionizing radiation in space. Some analyses indicate that large amounts of spacecraft shielding may be necessary for crew safety. The shielding requirements are driven by the need to protect the crew from Galactic cosmic rays (GCR). Recent research activities aimed at enabling manned exploration have included shielding materials studies. A major goal of this research is to develop accurate radiation transport codes to calculate the shielding effectiveness of materials and to develop effective shielding strategies for spacecraft design. Validation of these models and calculations must be addressed in a relevant radiation environment to assure their technical readiness and accuracy.

Test data obtained in the deep space radiation environment can provide definitive benchmarks and yield uncertainty estimates of the radiation transport codes. The two approaches presently used for code validation are ground based testing at particle accelerators and flight tests in high-inclination low-earth orbits provided by the shuttle, free-flyer platforms, or polar-orbiting satellites. These approaches have limitations in addressing all the radiation-shielding issues of deep space missions in both technical and practical areas. An approach based on long duration high altitude polar balloon flights provides exposure to the galactic cosmic ray composition and spectra encountered in deep space at a lower cost and with easier and more frequent access than afforded with spaceflight opportunities. This approach also results in shorter development times than spaceflight experiments, which is important for addressing changing program goals and requirements.

The Balloon-Borne Deep Space Test-Bed Concept: The present capability of the Long-Duration Balloon Flight program of NASA's Scientific Balloon Facility is sufficient to provide useful exposures in support of the Vision for Exploration. The polar program has conducted successful flights yearly during the local summer since 1981 with typical flights lasting more than 10 days for science payloads up to 1800 kgs. These circumpolar flights maintain altitudes above 120,000 feet ($\sim 3.5\text{g/cm}^2$ residual atmospheric thickness) at magnetic latitudes near 70 degrees. The test-bed facility must provide exposures in a radiation environment similar to those encountered in transit to Mars or on the lunar surface. The energetic particles that dominate interplanetary space have two principal sources: Solar Energetic Particles (SEP) and GCR. The SEP present a significant radiation hazard but only during periods of solar outbursts that are typically short in duration. The crew can often avoid these by taking refuge in storm shelters designed into crewed systems. More problematic for missions exceeding 1-year duration is the continuous GCR flux. The level of solar modulation at the Earth's orbit is nearly the same for the orbit of Mars. Because the Earth's magnetic field closely resembles a dipole, there is an access window to the GCR flux at high magnetic latitudes. The vertical geomagnetic cut-off for protons at 75° latitude is $<0.100\text{MV/c}$. This permits direct exposure to the interplanetary GCR environment.

Exposure on stratospheric balloon flight near the magnetic poles of the Earth will be similar to an exposure on a massive spacecraft in the interplanetary medium. The omni-directional GCR flux is reduced to half its free-space value because of shadowing by Earth. Since this shadowing is independent of primary composition and energy, the effect does not complicate the analysis. The GCRs that interact in the Earth's atmosphere below the test-bed will produce albedo of secondary particles (neutrons, protons, electrons) that will irradiate the test-bed from below just as would happen when cosmic rays interact with a massive spacecraft. The detailed design of the test-bed will influence the effect of this secondary particle flux, which must be characterized to interpret the shielding data correctly. There will also be GCR secondary particles produced by interactions in the residual atmosphere above the balloon. The amount of overburden for high-altitude polar flights is $\sim 4\text{g/cm}^2$ and it varies little during the flight because the balloon floats at a constant density. The presence of the test-bed itself is a source of albedo and therefore must be considered in the analysis. A detailed simulation model of the balloon-craft subsystems and structure can be used to understand the secondary particles produced by GCR interactions in the vehicle and the shielding that the vehicle provides from the albedo coming from below.

DSTB Radiation Detectors: It is important to accurately monitor the radiation environment on each flight. The data are needed to account for variations due to solar activity, the flight path and duration and the payload configuration. The onboard monitoring together with that available from operational satellites can be used to characterize the radiation environment during the flight. In addition, measurements at atmospheric depths of 18 to 20 g/cm^2 could be used to simulate Martian surface radiation environment.

A suite of radiation monitors have been developed and tested for measurements on a balloon-borne exposure platform. The basic instrument suite includes tissue equivalent proportional counters, passive and active solid-state dosimeters, charge particle spectrometers, and neutron monitors. These instruments have been adapted for measurements on the DSTB platform. Using these instruments the test-bed can acquire the data necessary to accurately define the shielding effectiveness of candidate shielding materials and test the accuracy of the models and radiation transport codes. This instrument suite would also provide the exposure data needed to conduct other radiation related investigations and to test the response of new radiation monitoring instruments in the deep space radiation environment.

POC: Mark Christl

Email: Mark.Christl@NASA.GOV

Tele: (256) 961-7739