

Space Radiation Effects on Inflatable Habitat Materials Project

Center Innovation Fund: JSC CIF (Also Includes JSC IRAD) Program | Space Technology Mission Directorate (STMD)



ABSTRACT

The Space Radiation Effects on Inflatable Habitat Materials project provides much needed risk reduction data to assess space radiation damage of existing and emerging materials used in manned low-earth orbit, lunar, interplanetary, and Martian surface missions. More specifically, long duration (up to 50 years) space radiation damage will be quantified for materials used in inflatable structures (1st priority), as well as for habitable composite structures and space suits materials (2nd priority). The data acquired will have relevance for nonmetallic materials (polymers and composites) used in NASA missions where long duration reliability is needed in continuous or intermittent radiation fluxes. This project also will help to determine the service lifetimes for habitable inflatable, composite, and space suit materials.



One example of an inflatable habitat, the proposed Bigelow Aerospace BA-330. Image credit: AP

ANTICIPATED BENEFITS

To NASA funded missions:

When humankind lands on Mars in the 2030s, the Orion Multi-Purpose Crew Vehicle will serve as the crew delivery vehicle, potentially in combination with an inflatable activity module, which will provide additional living space for the crew on the 16 month long journey from Earth to Mars and back. This study will look at how the inflatable materials in inflatable modules perform in long-term radiation environments by developing methods of testing and certifying materials for deep space radiation environments. Specifically, these test methods provide NASA with a pathway for future material tests and service life certifications, including inflatable habitats (1st priority), spacesuit materials (2nd priority), and composites.

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To NASA unfunded & planned missions:

Beyond those benefits previously described for funded missions, these test methods provide an avenue for the determination of service life for materials that may be used in an inflatable activity module for the Orion Multi-Purpose Crew Vehicle and notional inflatable lunar habitat.

To other government agencies:

Service life test methods developed will serve the global community well for the planning and development of sustained operations in space, on the Moon, and Mars.

To the commercial space industry:

One inflatable habitat, the Bigelow Expandable Activity Module (BEAM), is scheduled to launch aboard the eighth SpaceX cargo resupply mission to the International Space Station in 2015. These irradiated material test results provide NASA and inflatable habitat manufacturers critical data needed to determine radiation survivability in any long-term space radiation environment. It is worth noting that these inhabitable structures may be used by NASA accompanying Orion during humankind's Martian missions in the 2030s and could serve as habitats during future lunar and/or Martian expeditions.

To the nation:

Test methodology certifying materials for extended use in space radiation environments provide a tactical advantage in the utilization of space-based reconnaissance, geolocation, and communications satellites. Further, the service life test methods developed will serve the nation well for the planning and development of sustained operations on the moon and Mars.

Management Team

Program Executive:

- John Falker

Program Manager:

- Ronald G Clayton

Project Manager:

- Charles Nichols

Principal Investigator:

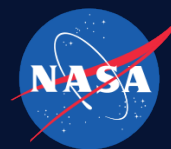
- Jess Waller

Co-Investigator:

- Kristina Rojdev

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DETAILED DESCRIPTION

Introduction:

A manned expedition to Mars is the culminating goal of U.S. human spaceflight, with missions anticipated in the next 15 to 20 years (by the mid-2030s). But more than a half-century after the dawn of the Space Age, shielding and sheltering measures to protect crews from space radiation still need to be developed, requiring breakthroughs in lightweight materials needed to make long duration space missions possible. Space travel has always sought lighter, more cost efficient vehicles. As missions get longer during man's journey into deep space, lighter mass/volume efficient structures are needed to allow these spacecraft to carry more fuel. During the long journey to the Moon and Mars, inflatable habitable structures provide a viable solution. One option NASA is investigating is the Bigelow Expandable Activity Module (BEAM). This inflatable habitat is scheduled to arrive at the International Space Station (ISS) in 2015 for a two-year technology demonstration.

To send an expedition to Mars today, NASA would have to knowingly expose astronauts and vehicles to high levels of space radiation due to the long-durations required for Mars missions. During a Mars round-trip, the vehicle would spend a majority of its time in deep space, or on the Martian surface, facing exposure to the following types of space radiation.

- Solar particle events (SPE) generated by solar flares or coronal mass ejections from the sun. Such events consist primarily of directional protons with energies ranging from tens to hundreds of MeV.
- Galactic cosmic rays (GCR) from outside the solar system but generally from within our Milky Way galaxy. GCRs consist of omnidirectional protons mostly, but also silicon, iron and other nucleons (nuclei stripped of electrons) are present with particle energies on the order of 1 GeV.
- Secondary radiation as a result of primary radiation interacting with the surface of a planetary body (i.e. the lunar regolith).

Radiation degradation of spacecraft materials may pose a serious threat to crew who depend on a habitat during Martian expeditions to keep them safe. If material properties change significantly while exposed to large levels of radiation, the structure could fail unexpectedly resulting in loss of life or mission.

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Objective:

To establish conservative service lifetimes for inflatable and habitable composite materials, the primary goal of this project will be to simulate a cumulative 50-year (maximum) dose due to SPE and GCR radiation in inflatable materials NASA may use. The layers of most concern within an inflatable are the restraint and bladder layers. HZETRN, a one-dimensional transport code used to calculate absorbed dose in materials, has already been used to calculate anticipated deep space and Mars habitat doses for inflatable habitats. Results show that GCR doses in the vicinity of 700 cGy (700 rad) can be reached in these layers for an inflatable over a 50-year duty cycle.

While this dose may seem small, it must be realized that GCR nucleons have energies on the order of 1 GeV and greater, and damage due to nonionizing energy loss (NIEL) is not accounted for when assessing damage. The SPE exposure is much greater with absorbed doses up to 15,900 Gy (1.59 Mrad) in the outer deployment system, 117 Gy (11,700 rad) in the restraint layer, and 103 Gy (10,300 rad) in the bladder layer of an inflatable habitat over a 50-year deep space mission. Hence, investigating nonionizing energy loss (NIEL) displacement damage by FLUKA will also be considered. The radiation transport code FLUKA (FLUKtuierende KAskade) is used to determine the changes in total ionizing dose (TID) and singleevent effect (SEE) environments behind shielding masses when the assumed form of the SPE kinetic energy spectra is changed. FLUKA simulations have three spatial dimensions with an isotropic particle flux incident on a concentric spherical shell shielding mass and detector structure. At a minimum, other mission or service lifetime durations less than 50 years may be considered, as appropriate, for the material under investigation.

The experimental portion of the project involves exposing inflatable test specimens to a terrestrial radiation source that approximates GCR and SPE space radiation at a ground-based test facility (either Brookhaven National Laboratory or Los Alamos National Laboratory). Preliminary investigations are planned in the summer of 2015 at the Brookhaven National Laboratory NASA Space Radiation Laboratory (BNL NSRL). The facilities at BNL NSRL allow both separate and combined SPE and GCR effects to be investigated. Once results are acquired on inflatable materials (1st priority), irradiation of habitable composite structures and space suits materials (2nd priority) will be considered.

The Martian atmosphere and breathable cabin air will also inhibit or accelerate property change in irradiated parts. If deemed significant, these effects will be considered. Controls can be implemented, or the experimental design altered, such that these artifacts can be controlled or

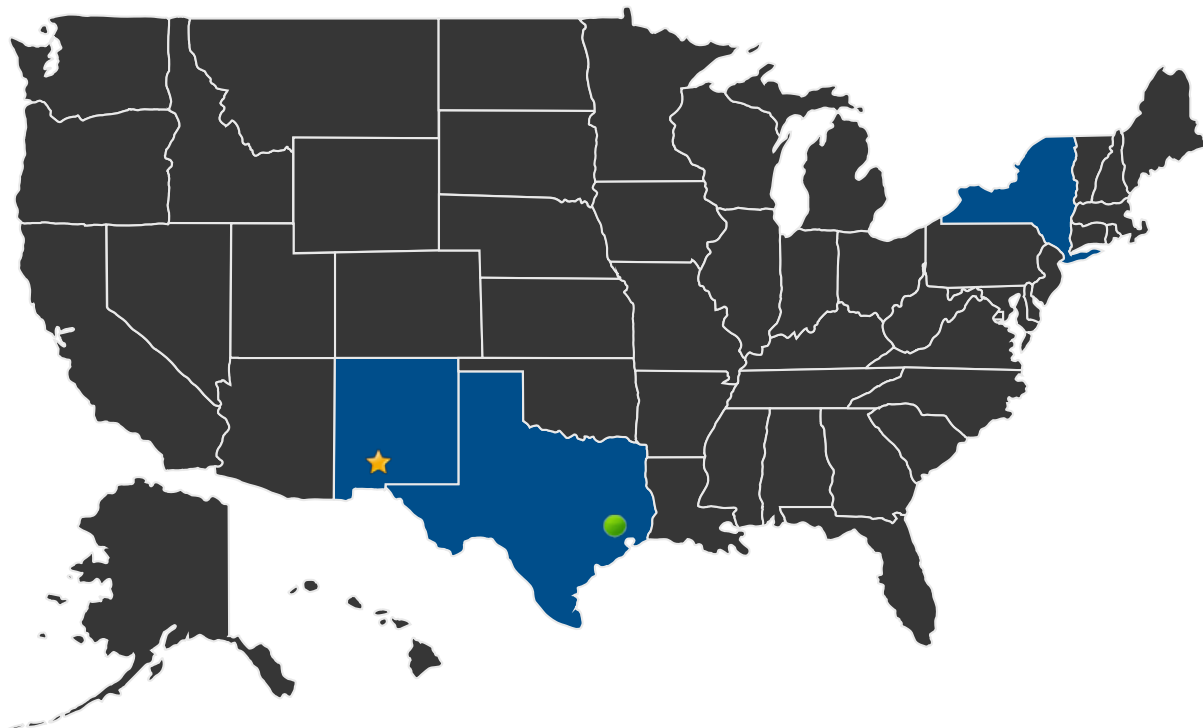
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eliminated. For example, test specimens can be conditioned, irradiated and stored in the anticipated atmosphere (air or CO₂), or conditioned, irradiated and stored in an inert atmosphere (N₂) to simulate exposure to vacuum. Last, this project will investigate time-dependent radiation damage effects through thermal aging of specimens. Dose rate effects will also be considered, and if possible, investigated.

U.S. LOCATIONS WORKING ON THIS PROJECT



■ U.S. States With Work

★ **Lead Center:**
White Sands Test Facility

● **Supporting Centers:**

- Johnson Space Center

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Other Organizations Performing Work:

- Brookhaven National Laboratory
- Los Alamos National Laboratory

Contributing Partners:

- Texas A&M University
- University of Texas El Paso

PROJECT LIBRARY

News Stories

- NASA to Test Bigelow Expandable Module on Space Station
 - (http://www.nasa.gov/mission_pages/station/news/beam_feature.html)
- The orbital balloon: NASA tests inflatable space-craft
 - (<http://www.dailymail.co.uk/sciencetech/article-2263833/The-inflatable-module-set-International-Space-Station-extra-bedroom-32million-stay-space-hotel-follow.html>)

Publications

- Mars Educational Tools
 - (<http://mars.jpl.nasa.gov/participate/marsforeducators/>)

Videos

- Bigelow Expandable Activity Module Installation Animation
 - (<https://www.youtube.com/watch?v=F78fucCz2Jk&x-yt-ts=1421828030>)
- Bigelow Lunar Habitat
 - (<https://www.youtube.com/watch?v=lmvcgcD9N2c>)
- Transhab concept animation aboard ISS
 - (<https://www.youtube.com/watch?v=uj-RPmgiE28>)
- Video featuring the Bigelow Expandable Activity Module
 - (<https://www.youtube.com/watch?v=gFZXI45N0m8>)

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IMAGE GALLERY



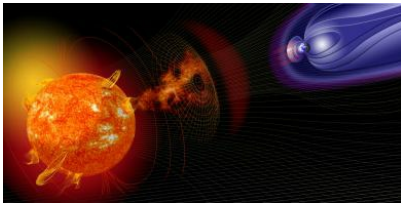
Inflatable structures may also be used as lunar or Martian habitats. Image Credit: AP



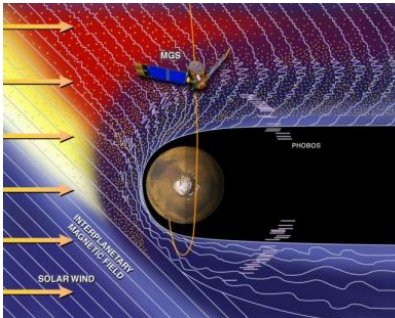
This project answers the question: What will it take for inflatable habitats to survive extreme cosmic radiation enroute to, and on, Mars?



Humankind's manned exploration of Mars will require the development of new technology and scientific advancements.



The magnetosphere protects Earth from the worst solar disturbances while redistributing energy and mass throughout. Astronauts working outside of the magnetosphere will need more robust shielding than what was used aboard Shuttle.



Unlike Earth, Mars lacks a thick atmosphere and a magnetic field. This leaves the planet totally vulnerable to radiation from space. The Mars radiation comes from many sources: the Sun's solar wind, cosmic rays from the Sun, and other stars.



Humans could become an interplanetary species in the 2030s.