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About the cover
Polar dunes on Mars are shown during early spring when covered with carbon dioxide and water frost. Dark sand cascades down the lee slopes as the frost begins to warm and sublimate.

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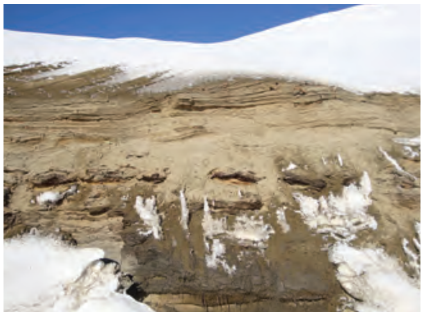

Departments

Mars On Earth

The Great Kobuk Sand Dunes in Alaska provide an Earth analog for Martian geology

By Cynthia L. Dinwiddie, Ph.D.

© Photo courtesy Seth Kantner

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On Aug. 5, 2012, at 9:32 p.m. Alaska time, the Mars Science Laboratory on NASA's Curiosity rover descended to the Martian surface in a place called Gale Crater. Between the rover and a mountainous peak in the center of the impact crater lies a field of dark sand dunes. Planetary scientists have recently discovered that sand dunes on Mars are actively moving by using a satellite remote-sensing method that was first developed at Southwest Research Institute (SwRI) by Dr. Marius Necsoiu to estimate the speed at which the Great Kobuk Sand Dunes are moving in Kobuk Valley National Park, Alaska. Because good repeat photographic images of the Martian surface are relatively few, scientists are just beginning to have enough data to compare images of a single planetary scene at multiple times. Some people talk about Mars as if it were a dead planet, but if one looks closely at the planet long enough, it becomes apparent it is alive with many physical processes. In the recent past, planetary scientists thought sand dunes on Mars were frozen in space and time, but since 2008 they've known that it isn't true. Geologically speaking, Mars is very much alive.

To help prepare humankind for exploration of other worlds and expand understanding of extraterrestrial geologic processes, planetary scientists study the extreme landscapes of Earth that are most similar to other planets or their moons. In the scientific discipline of comparative planetology, the features and processes that are observed on extraterrestrial planetary bodies in our solar system are compared to similar features and processes on Earth because our own landscapes are more easily accessible for detailed study and analysis — we call these places "planetary analogs" because they are reasonably comparable to planetary landscapes. This is why a team of SwRI researchers began conducting satellite remote-sensing investigations of the Great Kobuk Sand Dunes in 2008, and then traveled to this planetary analog site to perform geophysical, meteorological and geomorphological field research in 2010.

Sand dunes in Kobuk Valley National Park are excruciatingly slow-moving, just like dunes on Mars. Sand dunes near Earth's equator don't move slowly like this, and the smaller the dune, the faster it moves. Strangely, however,

Dr. Cynthia L. Dinwiddie is a principal engineer in the Earth, Material and Planetary Sciences Department of the Geosciences and Engineering Division. She is a hydrogeologist who develops integrated geophysical and remote-sensing characterization methodologies to investigate hydrologic processes on Earth and Mars.

Credit: NASA/JPL-Caltech/MSSS

A photographic image of the surface of Gale Crater, Mars, taken by the Curiosity rover reveals a field of dark sand in the foreground, with the foothills of Mt. Sharp in the distance.

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remote-sensing data analyses suggest that the largest dunes in Kobuk Valley may actually move faster than the smallest ones. Why do Arctic dunes behave differently than warm-climate dunes, and do any Martian dunes behave like Earth's Arctic dunes? To better understand why cold dunes move so slowly, the SwRI team used tools including shallow boreholes, ground temperature sensors and ground-penetrating radar and capacitively coupled resistivity surveys to peer inside the sand dunes in Kobuk Valley in late March 2010, when the weather was cold. During March in Alaska, "cold" means an average daily temperature of 6 degrees Fahrenheit. This is cold enough that the seasonally frozen active layer was at its maximum annual thickness, and it was assumed that the dunes likely would be frozen to their base. The annual average temperature in Kobuk Valley is 25 degrees Fahrenheit, which is cold enough for the dunes to be surrounded by widespread, discontinuous permafrost.

At the Great Kobuk Sand Dunes, lowland areas between dunes (called interdunes), small dunes, downwind lee slopes of large dunes, and most of the upwind stoss slopes of large dunes are snow-covered for approximately two-thirds of the year, and only the elevated crests of the largest dunes remain exposed to wind throughout much of the winter season. It is thought that this seasonal disconnect between the dune sand and winds may be why the large dunes in Kobuk Valley move faster than the small ones. Polar dunes on Mars experience a similar disconnection during Martian winter, when they are covered with carbon dioxide and water frost.

Electrical resistivity surveys of the sand dunes showed that the seasonally frozen active layer was approximately 13 feet thick beneath dune crests, and less than 7 feet thick beneath interdunes. The dunes are composed of fine sand, through which liquid water should permeate and drain rapidly. However, the team found groundwater in boreholes below the frozen interdunes, and no permafrost. So, despite an average annual temperature that is 7 degrees colder than water's freezing point, liquid water persists year-round beneath the dunes.

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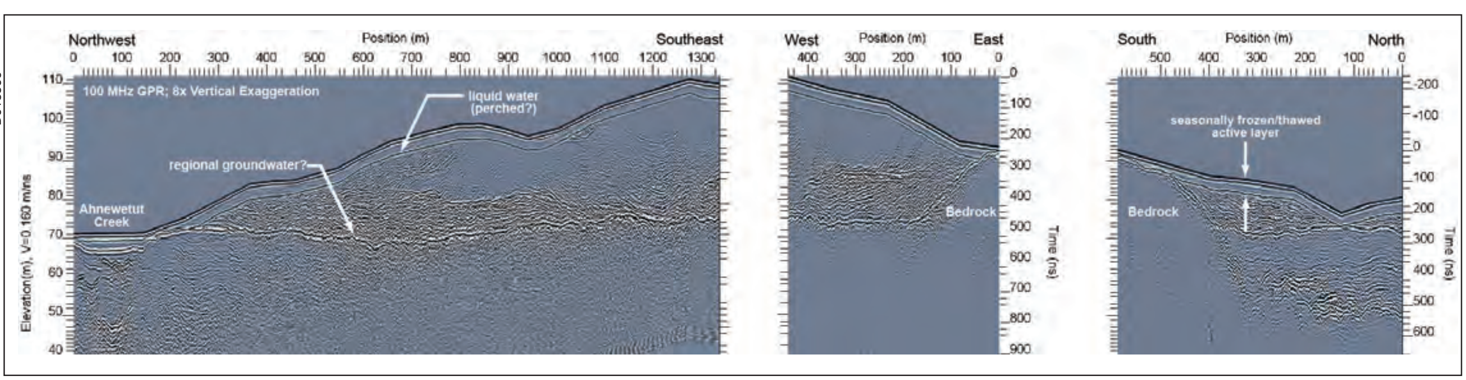
A series of 2.4-kilometer-long radargrams show regional groundwater at about 70 meter elevation above mean sea level and a layer of perched liquid water high in the dune uplands. These data were collected by 100 MHz ground-penetrating radar antennas towed on a sled by a snowmobile (photo at left).



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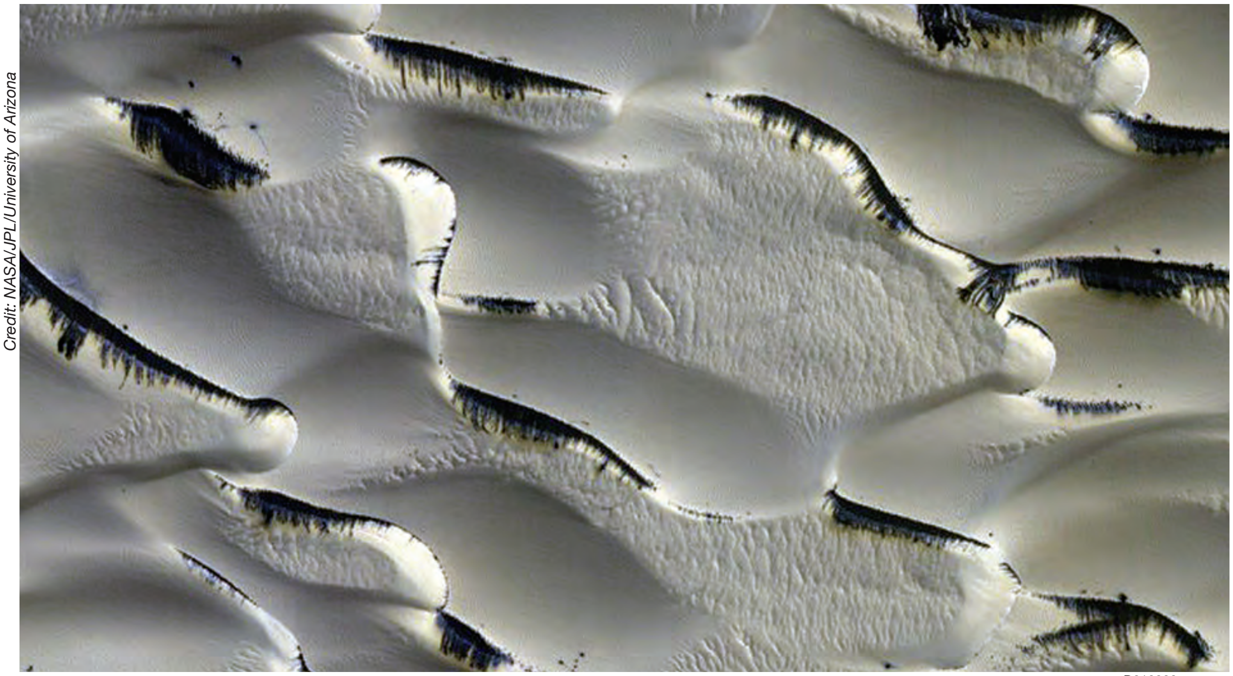

Credit: NASA/JPL/University of Arizona

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Polar dunes on Mars are shown during early spring when covered with carbon dioxide and water frost. Dark sand cascades down the lee slopes as the frost begins to warm and sublimate.

Water where ice should be

Geophysical data suggest that the regional groundwater beneath the dunes is relatively flat-lying, like a table top, and approaches the surface within the interdunes; however, the data also strongly suggest that there is a thin layer of liquid water just below the frozen active layer, which mirrors dune elevation and relief (i.e., topography). This liquid water perched high in the dune system was curious and unexpected, leading the SwRI research team to look into possible explanations. The presence and topographic mirroring behavior of the near-surface liquid water layer suggests that it is perched on a thermally controlled, low-permeability barrier to downward water flow. This barrier would have had to have developed in dynamic equilibrium with slow dune migration, and eroding remnants of it may be visible on upwind stoss slopes when not covered by snow.

The data suggest that this low-permeability barrier develops throughout the Great Kobuk Sand Dunes by freeze-drying, which can produce both ice lenses and calcium-carbonate cements, called calcrete, at the base of the active layer, where downward freezing from the land surface occurs. A cryogenic barrier could be composed of an ice-rich layer that lies perpendicular to the direction of heat flow at the base of the active layer. It also may be composed of cryogenic cement or other clay-sized particles preferentially deposited through cryogenic processes during annual freeze-up. Supporting the calcrete hypotheses, carbonate grains comprise 7 percent of the dune sand, and widespread calcrete has been observed by others when snow cover is absent.

The SwRI team believes these cold-climate sand dunes move slowly because seasonal snow cover acts like a windshield above the sand, and seasonally frozen water in the active layer immobilizes most of the sand during the winter. Warm-season rains also play a role in minimizing the sand that is available to be lofted by wind. Finally, the regional aquifer beneath the interdunes and the perched

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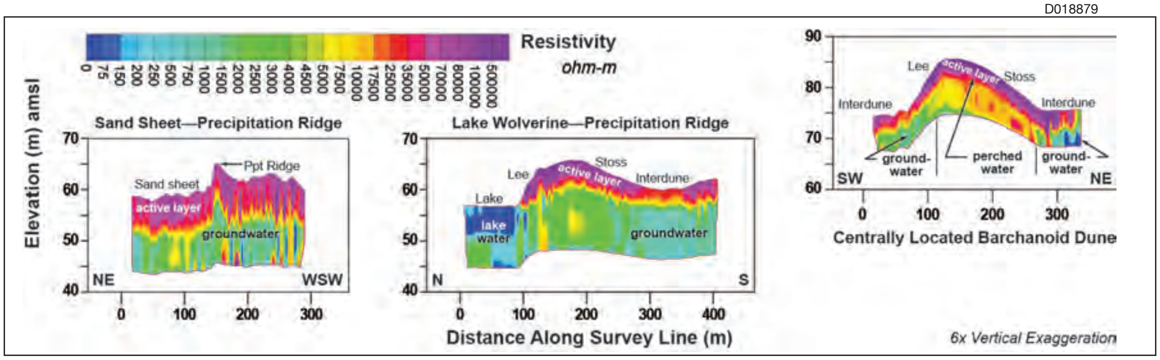

Resistivity data from three sites on the Great Kobuk Sand Dunes indicate transitions between the frozen active layer (hot colors) and the regional groundwater aquifer (cool colors). Intermediate colors beneath the elevated dune at the third site probably indicate a thick ice- and water-free vadose zone between the active layer and the regional water table aquifer. Resistivity measurement equipment and excavation of a confirmatory borehole are illustrated in the photos at right.

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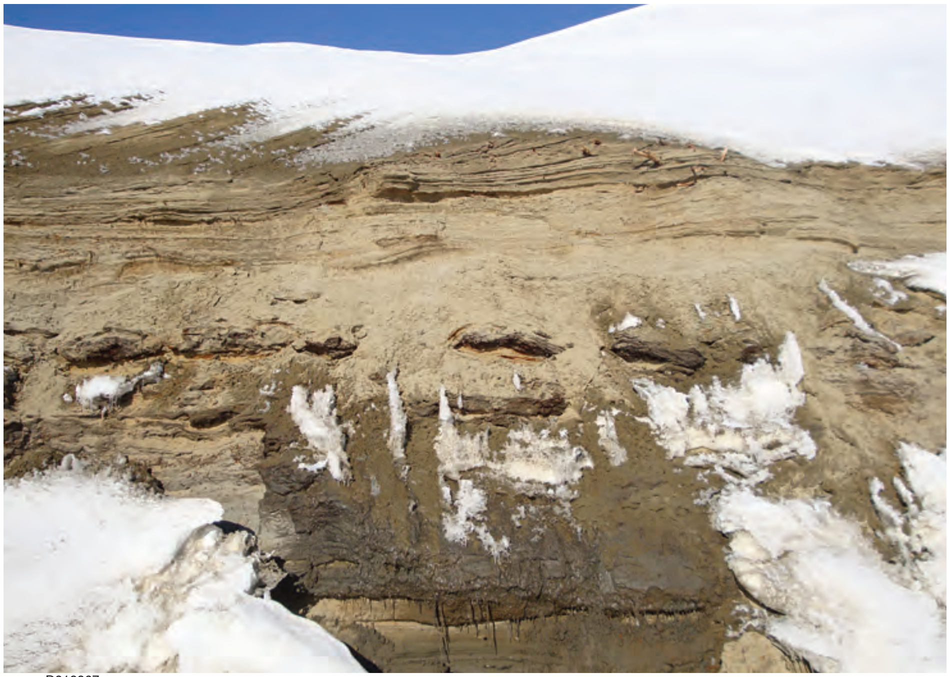

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Snow-covered sand dunes in the Kobuk Valley National Park, Alaska, provide planetary geologists with a planetary analog for similar structures observed on the surface of Mars. A surprising observation at the Great Kobuk Sand Dunes was the discovery of liquid water emerging from the dunes, despite subfreezing temperatures that correspond to some measured on Mars.

water high in the dune uplands both make the sand sticky, like wet beach sand that can be molded when one builds a sand castle. The Great Kobuk Sand Dunes are a "wet" sand dune system. Although they are influenced by a semi-arid climate, there is a lot of near-surface water trapped above the near-continuous permafrost in this region. These dunes provide an excellent planetary analog site for studying how the water cycle influences sand transport under conditions similar to those of Martian polar deserts, especially ancient Mars, which was a bit warmer and wetter, and subject to higher atmospheric pressure, than the planet is today.

Gully erosion parallels

While conducting this planetary analog study at the Great Kobuk Sand Dunes, SwRI scientist Dr. Don Hooper noticed that several meltwater debris flows were forming on some west-facing slopes of the dunes. Debris flows with gully or erosion tracks also appear on the slopes of several dune fields on Mars. This new observation was important because it indicated that yet another planetary analog process was occurring at the dunes, and only a few minutes of above-freezing temperatures are needed to melt water and mobilize sand transport down steep slopes. Small debris flows originate near dune crests, become channelized down lee slopes, and terminate with a fan-shaped deposit. New surveys will be needed to measure debris flow rates and gully morphologies, slope angle, solar radiation, subsurface temperature and moisture profiles and other variables to validate a conceptual model of the processes that control debris flow formation on the Great Kobuk Sand Dunes.

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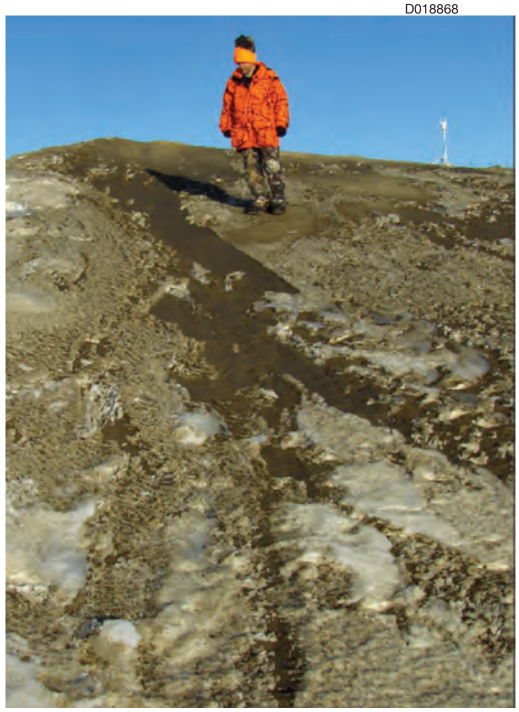

Meltwater debris flow appears on the lee slope of a sand dune at Great Kobuk. A weather station is in the distance.

Conclusion

Liquid water, solid ice and water vapor can coexist in stable equilibrium at what is called the "triple point of water." Recent measurements of air temperature and pressure in Gale Crater on Mars suggest that liquid water potentially would be stable there during the warmest portion of each day under current environmental conditions. Late-winter to early-spring conditions and processes at the Great Kobuk Sand Dunes are sufficiently similar that they can serve as an informative analog to near-equatorial processes in Gale Crater, Mars. Consequently, information from SwRI's studies at the Great Kobuk Sand Dunes can be directly applied to mission results from Curiosity. Effective use of this Earth analog can give important clues to the search for water on Mars.

Questions about this article? Contact Dinwiddie at (210) 522-6085 or cynthia.dinwiddie@swri.org.

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Measuring the Radiation Environment on Mars

An SwRI-led instrument is determining radiation hazards for future manned missions to Mars

The car-size Mars Science Laboratory spacecraft has been exploring the surface of the Red Planet since August 2012 to assess past and present habitability of Mars. Positioned near the center of the rover, the SwRI-led Radiation Assessment Detector is about the size of a coffee can and is characterizing the planet's radiation environment, a key influence on life.

By Donald M. Hassler, Ph.D.

Image courtesy of NASA/JPL

After the newest Mars rover, Curiosity, landed safely on the Red Planet's surface on Aug. 6, 2012, scientists began a new round of exploration using the car-size vehicle's 10 onboard science instruments.

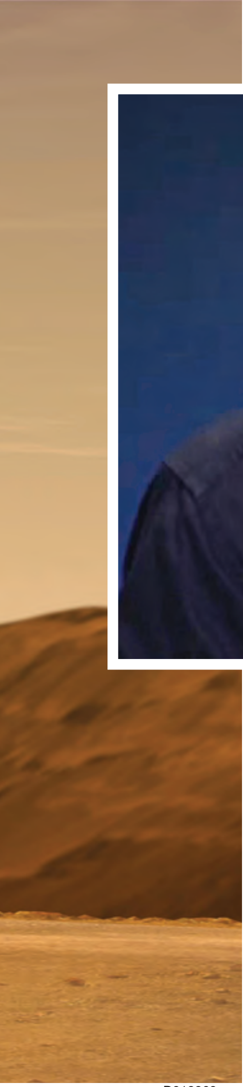
One instrument, however, had already been gathering valuable data during the nine-month journey from Earth to Mars. The Southwest Research Institute (SwRI)-led Radiation Assessment Detector (RAD) was powered up and began collecting data 10 days after the spacecraft was launched from Cape Canaveral on Nov. 26, 2011. Since then, RAD has collected roughly seven months of data during the cruise and now more than five months of data on the Martian surface. These are the first measurements of their kind taken on any other planet's surface besides Earth.

RAD is a compact but powerful energetic particle analyzer designed to characterize the radiation environment on the surface of Mars and quantify the radiation hazard that astronauts might encounter on future human missions to the Red Planet. RAD's measurements will help NASA plan future manned missions as well as help validate the radiation transport models that are being used to evaluate spacecraft and spacesuit shielding designs. The radiation environment on Mars is a complex combination of galactic cosmic rays, solar energetic particles, secondary neutrons and other particles created both in the atmosphere and at the Martian surface. One of the unique aspects of RAD is that it is capable of simultaneously measuring and identifying these different particle types, over a wide energy range, using a small (approximately three pounds) package.

Dual purpose: astronaut safety and Mars habitability

The primary, overarching scientific objective of the Mars Science Laboratory is to "assess the past and present habitability of Mars," and to search for the elements needed to support life, such as water and carbon-based materials. RAD plays an essential role in achieving MSL's prime science objective by helping to characterize and understand "life-limiting" factors, or factors detrimental to habitability, through its measurements of energetic particle fluxes at the surface of Mars. At the same time, RAD's characterization of the Martian radiation environment is a critical contribution to NASA's efforts to plan for possible future manned expeditions. By addressing both science and human exploration objectives, RAD has effectively become a "poster child" for cooperation and science exchange between NASA's Science and Human Exploration Directorates.

In addition to identifying radiation hazards for future human exploration, characterizing the radiation environment on the surface of Mars will also aid understanding the degree to which the radiation environment might put constraints on the existence of microbial life (past or present), or the preservation of signs of such life, since radiation also contributes to the breakdown of near-surface organic compounds. For example, how deep below the regolith, or Martian surface, must microbial life be (or have



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been) to survive the mutagenic influences of the observed radiation levels? Although current-day radiation levels probably make the surface of modern Mars inhospitable for microbial life as we know it, RAD's measurements will help determine the depth below the surface that a possible future robot on a life-detection mission might need to dig or drill to reach a "microbial safe zone."

For the purposes of human exploration, planning for a future manned mission to Mars requires understanding the possible radiation hazards over the course of the entire round-trip mission. In general, a manned mission to Mars can be separated into three phases: the cruise phase to Mars (six to nine months), the time on the Martian surface (more than six months), and the return trip to Earth (six to nine months). Therefore, estimating the total radiation dose that an astronaut will receive on a future Mars mission requires assessing the contributions from all three phases. Consequently, an important secondary objective of RAD is to characterize the radiation environment from inside the MSL spacecraft during its journey through interplanetary space on its way to Mars. Interestingly, the level of shielding provided by the MSL spacecraft is not unlike that of the International Space Station (ISS) or the Crew Exploration Vehicle (CEV) that will be used to take future astronauts into deep space. Thus, during the cruise phase to Mars, radiation levels measured by RAD served as a proxy for the radiation levels that astronauts might experience on a journey to Mars.

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Dr. Donald M. Hassler is a senior program director in the Planetary Science Directorate at Boulder, Colo., part of SwRI's Space Science and Engineering Division. He has more than 25 years of experience in space physics and the development, characterization and calibration of space instrumentation, and he is principal investigator of the Radiation Assessment Detector.

The first data packets received from RAD revealed a strong flux in space, even inside the spacecraft, with radiation doses about four times higher than the baseline levels measured on the launch pad from the spacecraft's own nuclear-powered generator. RAD was measuring the relevant energetic particle species originating from galactic cosmic rays, the Sun and other sources. Of particular interest were particles accelerated by flares and coronal mass ejections (CMEs) originating from the surface of the Sun, which spew fast-moving clouds of radiation across the solar system. Besides being scientifically interesting in terms of their physics, particles from these giant clouds could pose a potentially greater biological hazard as they hit the spacecraft and release an inward cascade of secondary particles inside the capsule. Just as an astronaut would be, RAD was tucked inside the spacecraft for the journey and thus could characterize these secondary particle showers, as well as higher-energy galactic cosmic rays and the secondary particles that they produced inside the spacecraft as well. Thus, measurements taken by RAD are providing insight into the shielding required for spacecraft to be used in future manned missions to deep space.

Weathering a solar storm

The decision to power RAD on during the journey to Mars was validated when the spacecraft was exposed to the largest solar particle event since 2003. The flood of energetic particles unleashed by a solar flare and a fast-moving CME swept over not only the spacecraft, but also Earth and Mars. Although solar storms create the Earth's aurorae and can affect Earth satellites, air travel and GPS systems, this one did no damage to the Mars Science Laboratory. However, its effects could be seen clearly in data downloaded from RAD.

The event was particularly exciting because of the alignment of Earth, the MSL and Mars at the time, and also because of the opportunity it afforded to compare data from RAD with data from other spacecraft that also observed the storm. The solar particle event was observed by the Solar Dynamics Observatory (SDO), Geostationary Operational Environment Satellites (GOES), the Advanced Composition Explorer (ACE) and the twin Solar Terrestrial

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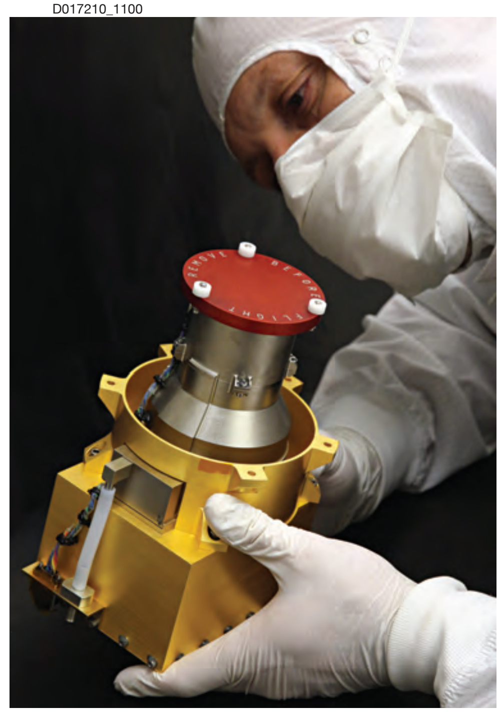
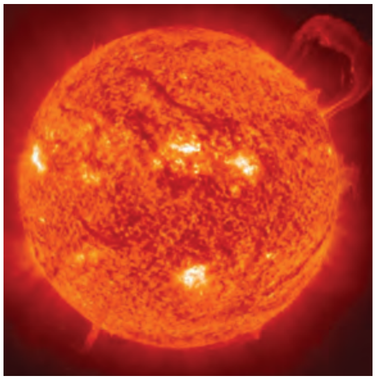


The Radiation Assessment Detector, one of 10 instruments onboard the Mars Science Laboratory, measures fluxes of solar energetic particles and galactic cosmic rays to help assess the radiation environment on Mars, as well as on the journey from Earth to Mars.

Relations Observatory (STEREO) spacecraft in Earth orbit, as well as by the Solar Heliospheric Observatory (SOHO) flying at the Lagrangian Point L1 between Earth and the Sun.



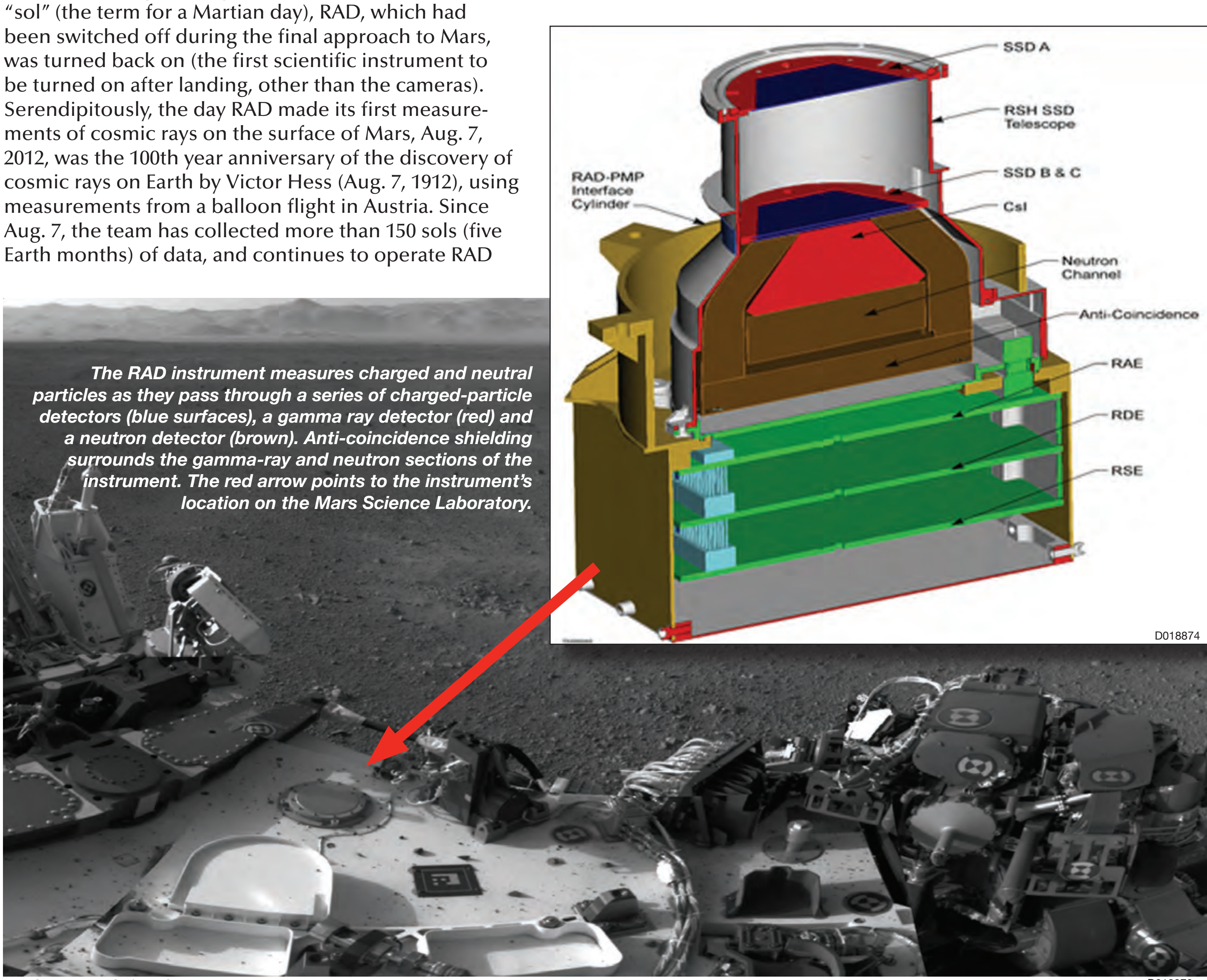
During the seven months of cruise observations, as the Sun's activity was increasing, RAD observed several large X-class and M-class solar flares. Data from RAD, taken from inside the MSL, are now being compared with data from the other satellites to better understand and predict the dose rate that future astronauts will experience.

First measurements from the surface of another planet

Curiosity landed on Mars with a flawless, "picture-perfect" landing, on Aug. 6, 2012. The next day, or "sol" (the term for a Martian day), RAD, which had been switched off during the final approach to Mars, was turned back on (the first scientific instrument to be turned on after landing, other than the cameras). Serendipitously, the day RAD made its first measurements of cosmic rays on the surface of Mars, Aug. 7, 2012, was the 100th year anniversary of the discovery of cosmic rays on Earth by Victor Hess (Aug. 7, 1912), using measurements from a balloon flight in Austria. Since Aug. 7, the team has collected more than 150 sols (five Earth months) of data, and continues to operate RAD around the clock. As Curiosity begins its traverse of the Red Planet, sampling the soil and sniffing the air, RAD quietly collects data in the background, accumulating statistics and keeping a watchful eye for any signs of the type of flares or solar storms seen during cruise. So far, the space weather on Mars has been quiet. But as the 11-year solar maximum approaches, many more large solar particle events or solar storms are expected over the course of the mission. And given that the rover and all 10 instruments are working perfectly, it is hoped that the mission will be long-lived, perhaps lasting until the next solar maximum — the period when the Sun is most active — 10 to 12 years from now.

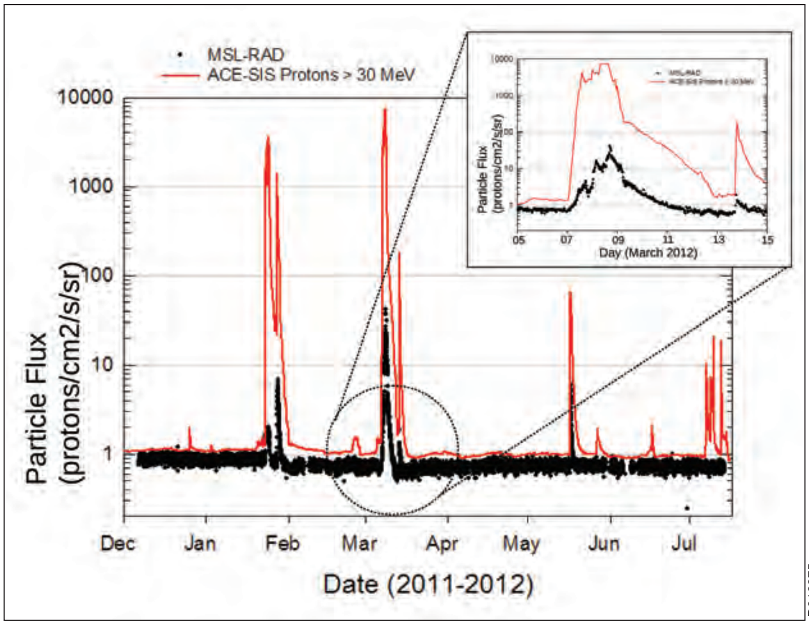
Operating on "Mars time"

Although the operation of RAD on Mars is relatively simple, the operation of the rover, with all 10 scientific instruments, is quite complex. Not only does the science operations team need to coordinate the daily observing programs of each of the 10 instruments, the team also needs to assess the results of the previous sol's activities and plan the activities for the next sol, including coordinating the daily drives or traverses, selecting, handling and processing soil samples, as well as the daily commanding and telemetry schedules. Complicating these daily activities is the fact that a "sol" is 39 minutes longer than an Earth



The RAD instrument measures charged and neutral particles as they pass through a series of charged-particle detectors (blue surfaces), a gamma ray detector (red) and a neutron detector (brown). Anti-coincidence shielding surrounds the gamma-ray and neutron sections of the instrument. The red arrow points to the instrument's location on the Mars Science Laboratory.

Courtesy NASA/JPL-CalTech



The MSL spacecraft provided some shielding from solar events during cruise, reducing significantly the particle flux observed by RAD during these events. The particle flux observed by RAD inside the MSL spacecraft is shown in the figure to be several orders of magnitude less than that observed by the unshielded SIS instrument on the ACE spacecraft.

day. So, for the past four months the entire science operations team has been operating on "Mars time," meaning that the start of each workday begins about 39 minutes later than the previous one, making it difficult to establish a daily routine. An operations day that begins at 8 a.m. one day would start at 8 p.m. two weeks later. Because the operations team includes engineers, operations specialists and scientists to perform all of the tasks associated with operating the rover and science instruments, as well as assessing the science and engineering results from each previous day's activities, more than 200 people have been adjusting to Mars time. One of the more interesting aspects of operating on Mars time was to deliver a science lecture with 200 MSL scientists in the audience, at 3 a.m. Earth time.

Radiation environment sensitive to Mars weather and climate

One of the first exciting results from RAD is that the radiation environment on Mars is very sensitive to daily changes in weather, primarily atmospheric pressure. The Martian atmosphere provides some level of shielding from the harsh galactic cosmic rays coming from space, and the RAD team is finding that the thickness of the atmosphere as a function of daily heating and cooling varies by about 10 percent, which causes a few percentage points variation in the radiation dose observed at the surface. As longer time series of data are accumulated, seasonal variations may appear as well.

Not only are there diurnal variations caused by thermal tides in the atmosphere, but also the team is observing longer-term variations associated with changes in the magnetic structure in the heliosphere or interplanetary space surrounding Mars. This heliospheric structure is magnetically tied to the Sun, and it rotates with the Sun with a 27- to 28-day period. Although many new discoveries are being made about the Mars environment with RAD, the team is still waiting for solar activity to pick up and the first large solar storm to be observed from the Martian surface.

The RAD instrument's makeup

Positioned near the left-front corner of the rover, the three-pound RAD is only about the size of a coffee can, but performs the same functions as Earth-bound devices 10 times its size. RAD consists of a charged particle telescope comprising three solid-state silicon detectors and a cesium iodide (CsI) calorimeter. An additional plastic scintillator is used together with the CsI calorimeter, surrounded by an anti-coincidence shield, to detect and characterize neutral particles, such as neutrons and gamma rays. The outputs of the various solid-state detectors, and photodiodes used with the CsI and plastic scintillators, are converted to digital signals for further processing. The digital logic includes an embedded microcontroller to bin and format the data.

The RAD instrument is mounted just below the top deck of the rover, with the charged particle telescope pointed in the zenith direction. In this way, RAD detects charged particles arriving from space as well as neutrons and gamma rays coming from Mars' atmosphere above, as well as from the surface below.

Conclusion

RAD continues to operate flawlessly on the surface of Mars, and is expected to do so throughout the nominal two-year mission, as well as for any extended mission, which it is hoped will last 10 years or more, providing an unprecedented, entire solar cycle of radiation data from the surface of another planet. The importance of characterizing the radiation environment wherever humans go in space with an instrument such as RAD has been recognized by NASA's Human Exploration and Operations Directorate. SwRI scientists are building a next-generation RAD for Johnson Space Center to go on the International Space Station in 2014.

Questions about this article? Contact Hassler at (303) 546-9670 or donald.hassler@swri.org.

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The RAD project is a team effort, with many individuals and organizations providing significant contributions. SwRI, together with Christian Albrechts University in Kiel, Germany, built RAD. The dedicated efforts of the many scientists, engineers, technicians and support staff, at both SwRI and CAU, are gratefully acknowledged. In particular, the efforts of Dr. Cary Zeitlin, John Andrews, Dr. Bent Ehresmann, Kerry Neal, Joe Peterson, Dr. Scot Rafkin, Kelly Smith, Yvette Tyler and Eddie Weigle at SwRI, Robert Wimmer-Schweingruber, Eckart Boehm, Stephan Boettcher, Soenke Burmeister, Jan Kohler, Jingnan Guo, Cesar Martin and Lars Seimetz at CAU, Guenther Reitz at Germany's national aerospace research center, Deutsches Zentrum für Luft- und Raumfahrt, Dave Brinza at Jet Propulsion Laboratory, Arik Posner at NASA HQ and Frank Cucinotta at Johnson Space Center, have been fundamental to RAD's success. RAD is supported by funding from the NASA Human Exploration and Operations Mission Directorate and DLR. Early development for RAD was supported by SwRI's internal research and development program.





Fit for Service

SwRI engineers use a variety of techniques to ensure the integrity of pressure vessels and other structures

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SwRI researchers routinely perform fit for service analyses on a variety of structures such as the hull of the next-generation Alvin manned submersible shown here.

By Joseph Crouch and Curtis Sifford

Pressure vessels are common pieces of equipment used worldwide for many applications, such as compressed air cylinders, hyperbaric test chambers, chemical reaction vessels, medical decompression chambers and submarine pressure hulls. They are designed to hold gases or liquids at pressures that are frequently much greater than atmospheric pressure, or in the case of a submarine pressure hull, to withstand the crushing external pressure of the deep ocean.

Compressed air cylinders provide a constant air supply for powering pneumatic tooling. Hyperbaric test and chemical reaction chambers create pressurized environments that simulate deep ocean pressures or geologic formation pressures, or create an environment to allow chemical reactions to occur. Decompression chambers are used for safe decompression for saturation divers who perform work in deep water, or for medical purposes to promote healing.

As with most structures, pressure vessels are designed for a finite useful life based on such parameters as the number of pressurization cycles expected, the magnitude of each pressure cycle and structural changes, such as a reduction in material thickness caused by corrosion. These "design" parameters are usually estimates and are often greater than the actual values experienced during operation. If the values used to predict the design life of the vessel are more excessive than what is actually experienced, the vessel will still possess *usable life* upon reaching the end of its *design life*.

Unless the structural integrity of a vessel can be re-assessed to determine that it can still be used safely for a longer period of time, a vessel that has reached the end of its design life should be taken out of service. Replacements can be costly, and the loss of a vessel interrupts productivity. Thus, establishing any remaining usable life is very important.

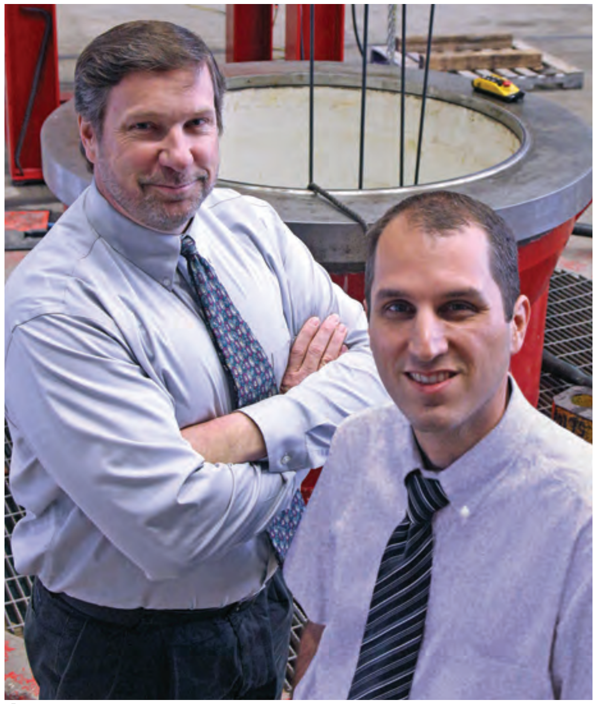
What is "fitness-for-service" analysis?

For more than 35 years, Southwest Research Institute (SwRI) engineers have performed structural integrity assessments on pressure vessels, aircraft and propulsion systems, offshore structures, and other structures in accordance with sound engineering principles and relevant industry practices. Recently, as customer demand for pressure vessels has increased, SwRI re-established a program for fabrication of pressure vessels in accordance with Section VIII, Divisions 1, 2 and 3 of the ASME (American Society of Mechanical Engineers) Boiler and Pressure Vessel Code. ASME rules enable SwRI engineers to perform detailed structural integrity assessments, or fitness-for-service (FFS) analyses, of pressure vessels in accordance with both API (American Petroleum Institute) and ASME standards.

The structural integrity of a pressure vessel is generally assessed by comparing the calculated stress with the strength of the material and then considering other potential failure mechanisms like fatigue. This type of assessment usually assumes that the vessel is free of defects such as cracks, voids, weld slag or inclusions.

However, defects that may have occurred during fabrication, or that develop during its service life also are often present. A fracture mechanics assessment is therefore required to determine if these defects will have a negative effect on the future operation of the vessel.

A pressure vessel containing a defect is considered fit-for-service if it is able to withstand the loads (such as pressure, thermal, wind and earthquake) experienced during its desired service life with a suitable safety margin to account for any uncertainty in the assumptions used for the assessment. Key elements for an FFS assessment are the loads applied to the component, the dimensions and shape of any defects, the material's mechanical properties (such as fracture toughness), and the rate of crack growth for the material.



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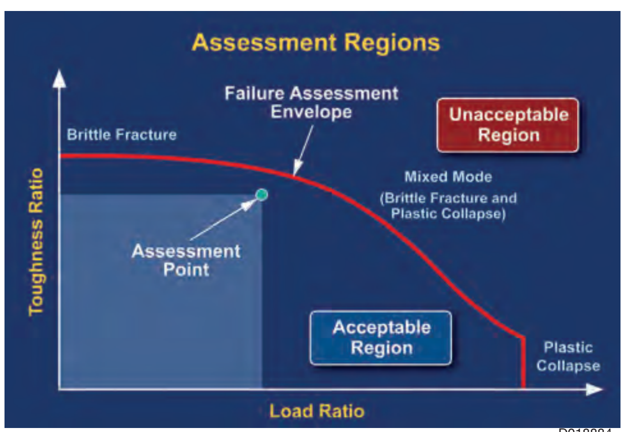
Joseph Crouch (left) is manager of the Marine Structures and Engineering Section in SwRI's Mechanical Engineering Division. Crouch has extensive experience in the design, fabrication and testing of structures for the oil and gas, offshore, marine, space and aerospace industries. Curtis Sifford is a senior research engineer in the Marine Structures and Engineering Section. He specializes in the design and analysis of pressure-containing structures.

Typically, a fracture mechanics fitness-for-service assessment is performed after a defect or crack has been found following routine inspection, maintenance or safety checks, or when the effect of an undetectable crack needs to be considered. The assessment determines whether the pressure vessel is safe to operate with the defect or to establish inspection intervals for monitoring the defect. If the defect size is unacceptable, then the user must decide whether to repair it, replace the equipment or re-rate the equipment for a safe, lower operating load. A fracture mechanics assessment may also be used as input to a quality control program to determine critical locations for future inspection, the size of a defect that must be detected with a high confidence and the necessary inspection interval.

SwRI engineers use the guidelines presented in Fitness-for-Service, API 579-1/ASME FFS-1, which is "a compendium of consensus methods for reliable assessment of the structural integrity of equipment containing identified flaws," first issued as a recommended practice document in January 2000. These methods require that the state of the vessel be determined using nondestructive evaluation (NDE) methodologies. This can be done specifically for an FFS effort as part of a safety program, or the FFS assessment can result from the identification of flaws found during routine inspection.



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A failure assessment diagram approach is one method SwRI researchers use to determine if a structure is fit for service.

The FFS process begins with an NDE evaluation of the structure. This provides details such as depth, length and location of any defects or cracks that have been detected. Based on the probability of detection, assumptions must be made about other defects that might exist but may not have been detected. Once the defect state of the vessel has been characterized, *linear elastic fracture mechanics* analysis is used to calculate the stress intensity factor, K, a measure of the "driving force" available in the structure that can cause a crack to propagate unstably. SwRI has a great deal of expertise in NDE methodologies, probabilistic assessment and uncertainty characterization, as well as fracture mechanics and finite element analyses, all of which are important to an FFS assessment.

SwRI engineers use finite element analysis to determine the stresses in the structure that result from the applied loads. When a structure is loaded to a level that is less than the yield strength of its material, it behaves *elastically*, meaning it returns to its original shape like a spring, when the load is removed. If the structure is loaded to a stress level that is greater than its material yield strength, it may experience a change in shape resulting from permanent *plastic* deformation, the extent of which could be local (barely noticeable) or global (large deformations) approaching plastic collapse, depending on the magnitude of the applied loads. In the presence of plasticity, the driving force that would continue to propagate a crack may be underestimated using *linear elastic fracture mechanics*. Thus, to account for the interaction between failure by fracture (crack instability) and failure by plastic collapse under limit load, SwRI uses the failure assessment diagram (FAD) approach. The FAD is a two-parameter graphical representation of the failure envelope of a cracked structure expressed in terms of the ratio of the applied stress intensity factor to the material fracture toughness (the toughness ratio, $K_r = K_{app}/K_{mat}$) and the ratio of the applied load to the plastic limit load of the structure (the load ratio, $L_r = P/P_L$).

To use the FAD approach, assessment points with coordinates (L_r , K_r) calculated based on the applicable loads, crack type and crack size(s), and material properties are compared with the failure envelope line. Assessment points that lie inside the envelope indicate non-failure, while assessment points outside the envelope indicate failure. For many fatigue crack growth analyses, the assessment points will initially be far inside the failure assessment line envelope and will gradually grow toward the envelope as the crack grows sub-critically. When the load ratio is low, the FAD predicts failure based on fracture instability; however, as the load ratio increases, the interaction of the presence of plasticity decreases the allowable stress intensity factor. If the assessment point is on, or inside, the FAD envelope, which indicates that there is remaining service life, then the pressure vessel is deemed safe, and therefore fit for service. A fatigue crack growth analysis must then be performed to determine how long the pressure vessel will remain fit for service.

FFS examples

Recently, SwRI engineers have performed FFS assessments on an in-service section of a gas pipeline, a submarine hull and a decompression chamber for a large tunnel boring machine. During inspection, the gas pipeline was found to have a defect and required FFS assessment to determine if the defect had to be addressed immediately or if it was still usable for a specified period of time. Because the submarine was newly built, researchers had to assume that a defect existed, but was too small to be detectable. The FFS assessment on the submarine was performed to determine if the possible defect would jeopardize the safety of the occupants between scheduled inspection intervals.

The tunnel boring machine was an earth pressure-balanced type, which provides continuous support to the tunnel face by balancing the earth and water pressure against the thrust pressure of the machine. Under normal operating conditions, workers operate the machine in an enclosed environment behind the cutting head, which is maintained at atmospheric pressure. However, if cutting head maintenance is required, workers must travel through the decompression chamber, which exposes them to elevated pressures. Once they complete their activity under pressure, they then have to re-enter the decompression chamber and stay inside while the pressure is slowly brought back down to ambient conditions, much as a diver must decompress in a chamber after spending time deep below the surface. This decompression prevents the maintenance personnel from getting sick from "the bends," which is caused by gas bubbles forming in their blood.

The problem arose when the tunnel boring machine was required to dig deeper into soil conditions that demanded a higher internal pressure rating. The decompression chamber was re-analyzed for the higher pressure and then subjected to a hydrostatic pressure test in accordance with the ASME Boiler and Pressure Vessel Code to prove the structural integrity of the system. The ASME code also requires an inspection of the welded joints following the pressure test. During this inspection, multiple defects were found in some welds. SwRI engineers were therefore asked to perform an FFS assessment to determine if the weld defects had to be repaired or if the decompression chamber was fit-for-service with the defects in place.

For the decompression chamber, the principal loading was a result of internal pressure. Residual thermal stresses from welding were also considered. Engineers determined a residual stress distribution using a solution from FFS that provided a conservative upper bound for the residual weld stresses based on numerical analysis and a literature survey of published results.

How residual stresses affect the stress intensity factor depends on the level of material plasticity. For elastic conditions, the residual stress can significantly weaken a structure containing cracks. On the other hand, when there is high plasticity, the effect of these stresses can be small. The API/ASME FFS methodology applies a plasticity interaction factor to the stress intensity factor to account for this effect.

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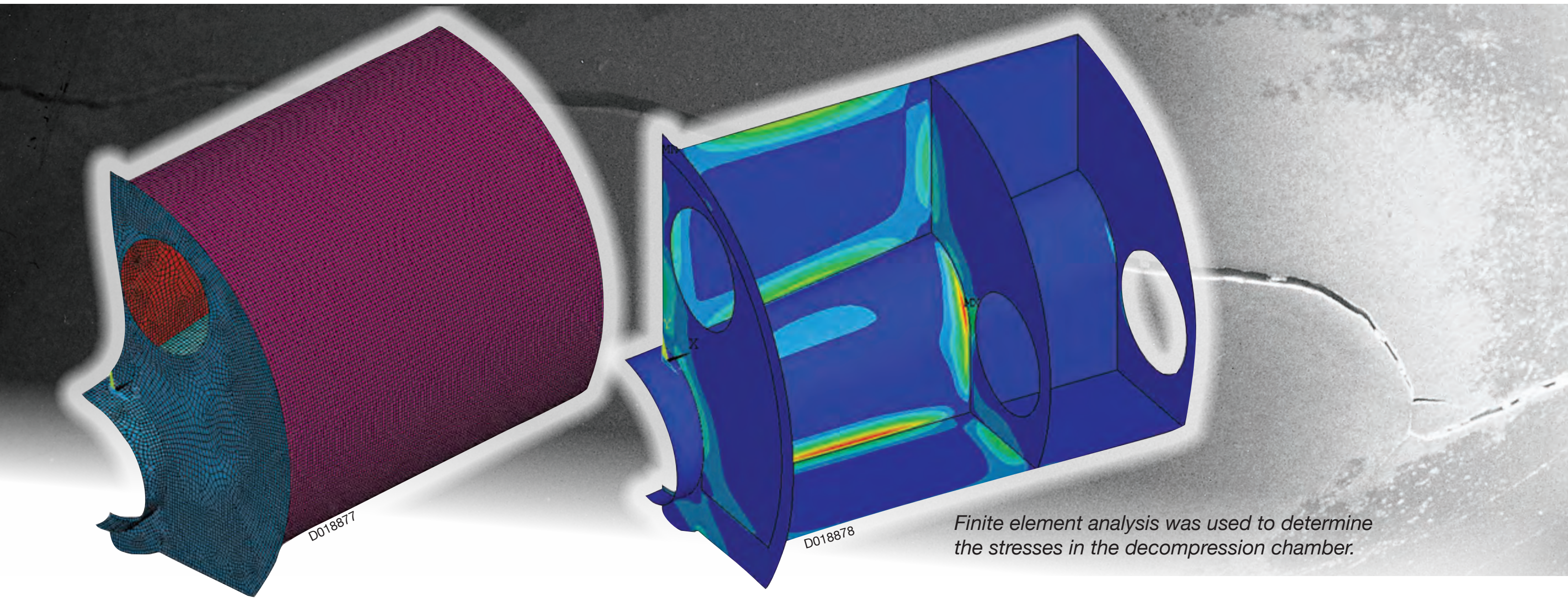
Senior Research Engineer Curtis Sifford went onsite and examined the decompression chamber of the tunnel boring machine.

The crack dimensions and shape were determined using phased array ultrasonic inspection. With this type of NDE inspection, multiple ultrasonic elements are used and their timing is varied so it is possible to steer, focus and scan the beam, providing a visual image of the defect or crack. Nearly all of the defects found on the decompression chamber were embedded and classified as weld slag or porosity. Although classified as "inclusions," the defects were considered to be cracks for the FFS assessment. Researchers also determined the defect depth, length and distance from the surface.

The crack-growth rate and fracture toughness are well documented for SA516 Grade 70 steel, the base metal used in the chamber. However, this was not the case for the weld metal. There were additional concerns regarding the welds' toughness since they were not stress-relieved. For these reasons, SwRI researchers performed fracture toughness testing on the welded plate. They tested the fracture toughness in the weld metal, at the fusion line and in the heat-affected zone. Results were used to establish a fracture toughness value that could be used for the FFS assessment.

Stress intensity factors for the weld defects that were assumed to be cracks were calculated using the SwRI-developed computer code NASGRO®. NASGRO, which earned an R&D 100 Award in 2003, was initially developed and released in the 1980s for fracture control analysis of NASA space hardware and has been continuously improved since 2000 by the NASGRO

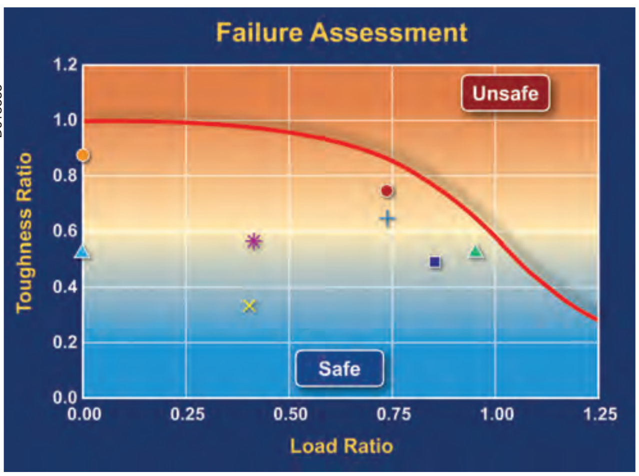


Finite element analysis was used to determine the stresses in the decompression chamber.

Consortium under the management of SwRI. It contains a large library of advanced stress intensity factor solutions and material property data combined with extensive analysis capabilities.

SwRI engineers calculated a *toughness ratio* by dividing the stress intensity factor by the fracture toughness of the material. Given the load and toughness ratios, the assessment points were plotted on the failure assessment diagram to determine if the weld defects were acceptable. Because all of the assessment points were inside the failure assessment diagram envelope, engineers determined that the decompression chamber was fit-for-service for the expected static loads, with the weld defects found during inspection.

It is also possible for a crack to grow under cyclic loading. For this reason, a crack-growth analysis was also required. NASGRO was again used. While the tunnel boring machine is in use, the decompression chamber is kept sealed and is only used for maintenance of the cutting head. Therefore, it was expected that relatively few pressurization cycles would occur, so no significant crack growth was expected. The fatigue crack-growth analysis demonstrated that the pressure load could be cycled to the maximum operating pressure more than 9,000 times before the first assessment point on the failure assessment diagram reached the envelope. This remaining life greatly exceeded the service life of the decompression chamber for the tunneling project. Thus, the remaining life was sufficient and engineers determined the decompression chamber was fit-for-service for the remainder of the project, saving the client considerable cost and time.



Data from the analyses plotted on the failure assessment diagram show the values at which weld defects are acceptable.

Requisite tools and experience

As illustrated by the decompression chamber project, API-579-1/ASME FFS-1 FFS provides a preferred means for assessing equipment that no longer meets its original design specification or code of construction. Other assessment techniques are available for dealing with a variety of flaws or damage mechanisms, such as metal loss, pitting, corrosion, lamination, dents, gouges, weld misalignment, shell distortions, creep, fire damage and crack-like flaws. These assessment techniques can sometimes prevent costly repairs or replacement of equipment while still allowing safe operation.

A fitness-for-service assessment depends in large part on how well the defects are understood or how well the uncertainty of the information is characterized. It requires a solid understanding of fracture mechanics and crack growth phenomena. Fitness-for-service uses partial safety factors, which are factors applied to the stress, crack size and material toughness to account for uncertainty in the input parameters used for the assessment and to ensure a minimal probability of failure. Also, probabilistic analysis can be used. For this, SwRI engineers use NESSUS, a 2005 R&D 100 award-winning technology developed for NASA by SwRI.

SwRI develops and uses nondestructive evaluation techniques to characterize flaws in metallic structures. Expertise in these areas, coupled with experience in design, analysis, fabrication and use of various pressure vessels (both manned and unmanned), enables SwRI to work efficiently and effectively to assess fitness-for-service for industry and government, ensuring safe, useful life of a wide range of equipment.

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Within ARMS Reach

An SwRI-developed technique enhances the capability of portable gamma ray imaging devices

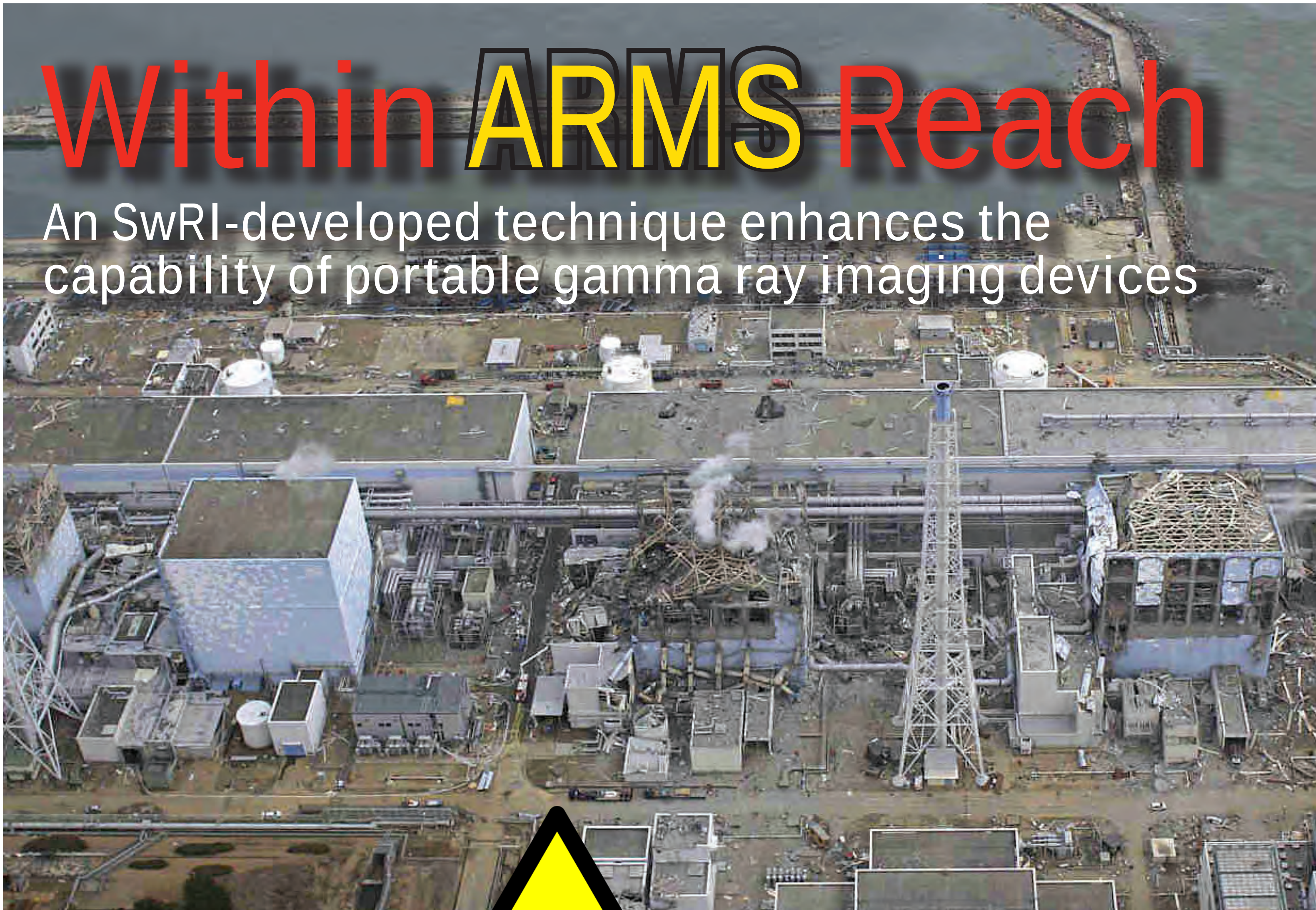

Photo courtesy of Air Photo Services Co. Ltd., Japan.

By Roland Benke, Ph.D.

Hand-held radiation survey instruments provide important, real-time information about radiation fields and nearby radioactive materials. Detection instruments can be simple or complex, depending on the specific application and data requirements. Simple survey meters, which respond to ionizing radiation without distinguishing the radiation type or its energy, are common. Gamma-ray spectrometers yield a spectrum of count rates over numerous channels that correspond to specific gamma-ray energies, or photon wavelengths. Their spectroscopic capability allows for differentiation of characteristic emissions, which is critical to identifying and quantifying contributions from multiple radioactive materials.

The Advanced Radiation Method for Surveys (ARMS), an emerging technology developed under internal research funding at Southwest Research Institute (SwRI), adds a third level of capability by generating radiation source images from existing hand-held detection instruments, without need for shielding or collimation. ARMS data requirements are minimal: only instrument position and detector output are needed. The resulting images provide a visual indication of the energy-dependent angular flux, or direction, of gamma rays, a quantity that is rarely measured for a solid angle of 4π steradians. (A steradian is the three-dimensional angle created by the sides of a cone whose apex is at the center of a sphere and whose curved base covers a certain area on the sphere's surface.)

Laboratory demonstration

Using a commercially available gamma-ray spectrometer in a laboratory demonstration, SwRI engineers positioned naturally occurring radioactive material and low-intensity radioactive sources at different locations in a room to create a crisscrossing field of gamma rays with low, medium and high energies. Because radiation measurements are more challenging with weak sources in the presence of natural background, the experiments were intentionally performed at background levels to test the robustness of the approach. In fact, at the central location where the survey measurement was performed, the dose rate attributed to all added sources of radiation was less than the background dose rate. Potassium chloride (salt), available from hardware stores, is a naturally occurring source of radioactive material due to the presence of the radioactive isotope ^{40}K at about one-hundredth of 1 percent in natural potassium.

A Japanese unmanned aerial vehicle (UAV) was able to take detailed photos of damage to the Fukushima Dai-ichi nuclear power plant on March 20, 2011 (from left: partial view of Unit 1 and view of Unit 2, Unit 3 and Unit 4). Similarly, UAVs equipped with radiation detectors rapidly assess the distribution of radioactive contamination on the ground surrounding damaged facilities. By providing finer spatial resolution compared to existing technologies, ARMS technology can generate tomographic maps of radionuclide concentrations at the surface and improve the detection of radioactive hot spots.

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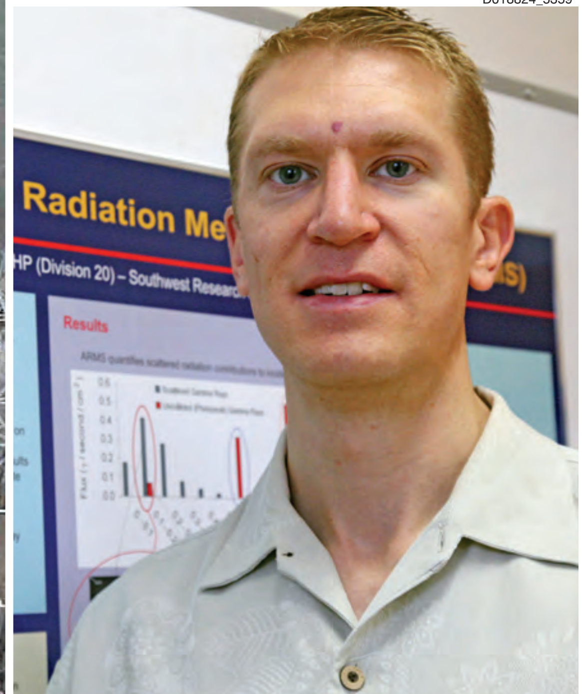

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Dr. Roland Benke is a principal engineer and certified health physicist at the Center for Nuclear Waste Regulatory Analyses in SwRI's Geosciences and Engineering Division. He has more than 15 years of experience in radiological dose assessment, radiation detection and measurement, radiation transport modeling and risk analysis.

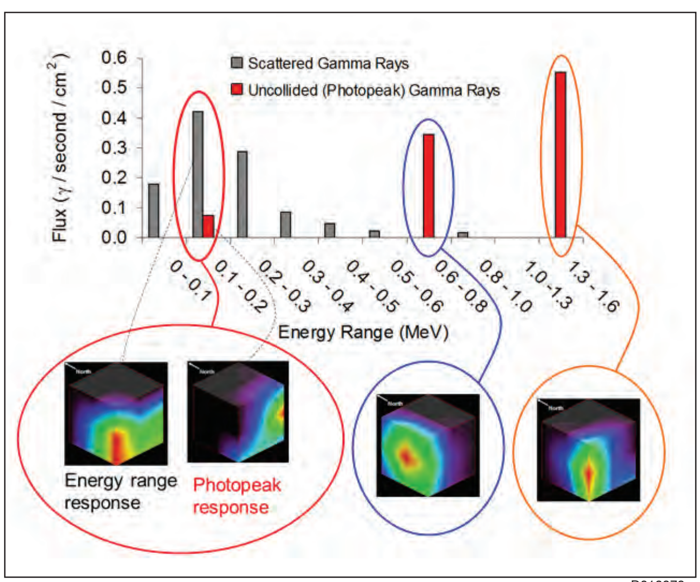
Several bags of potassium chloride were grouped together in the laboratory to create weak volume sources of high-energy gamma rays. Given that the same radionuclide, ^{40}K, also provides a significant component of the natural gamma-ray background, there was a potential for natural background interference, not only at the high-energy photopeak, but also throughout the remainder of the lower energy portions of the spectrum. The ARMS approach overcame these challenges easily. Based on a set of measurements acquired at arm's length from one central location in the room, ARMS produced a suite of three-dimensional images over the gamma-ray energy spectrum.

Although determining the three-dimensional angular flux was highlighted as an essential intermediate step, SwRI researchers initially had not foreseen or sought to generate images of the radiation source from those data. Had they not embarked on research toward the end-point, they would not have discovered something potentially more important along the way.

Other gamma-ray imaging approaches rely on detection arrays (multiple discrete detector modules or position-sensitive detectors and signal processing) and/or collimation (a process that uses shielding material to block, or significantly attenuate, incoming radiation except for that within a proscribed field of view). Because collimation and coded apertures reduce the instrument's detection efficiency and add significant weight, longer measurement times are required and portability is limited, especially for hand-held systems. ARMS is an attractive option because it does not require gamma-ray shielding or specialized detectors.

Additional potential benefit

In the mid-1990s, the International Commission on Radiological Protection and the International Commission on Radiation Units and Measurements adopted updated human models for converting ionizing radiation to radiological dose. These external dose conversion coefficients are based on radiation type, radiation energy and direction of the incoming radiation relative to the forward-facing direction of the individual. Radiological dose is determined by accounting for the dose (the energy absorbed per unit mass) received by individual organs within the body. Certain organs are more radiosensitive than others, so organ weighting factors are applied to determine the effective dose for the whole body. Because deleterious health effects can vary for the same absorbed dose from different kinds of ionizing radiation, radiation weighting factors are applied to represent the whole-body dose that is equivalent to the radiological risk of health effects from exposure. Organs more sensitive to radiation can be shielded by less sensitive organs and tissues. An inherent aspect of updated external dosimetric modeling, this intrabody shielding effect is responsible for the published sensitivity of external dose conversion coefficients to the incoming direction of radiation.



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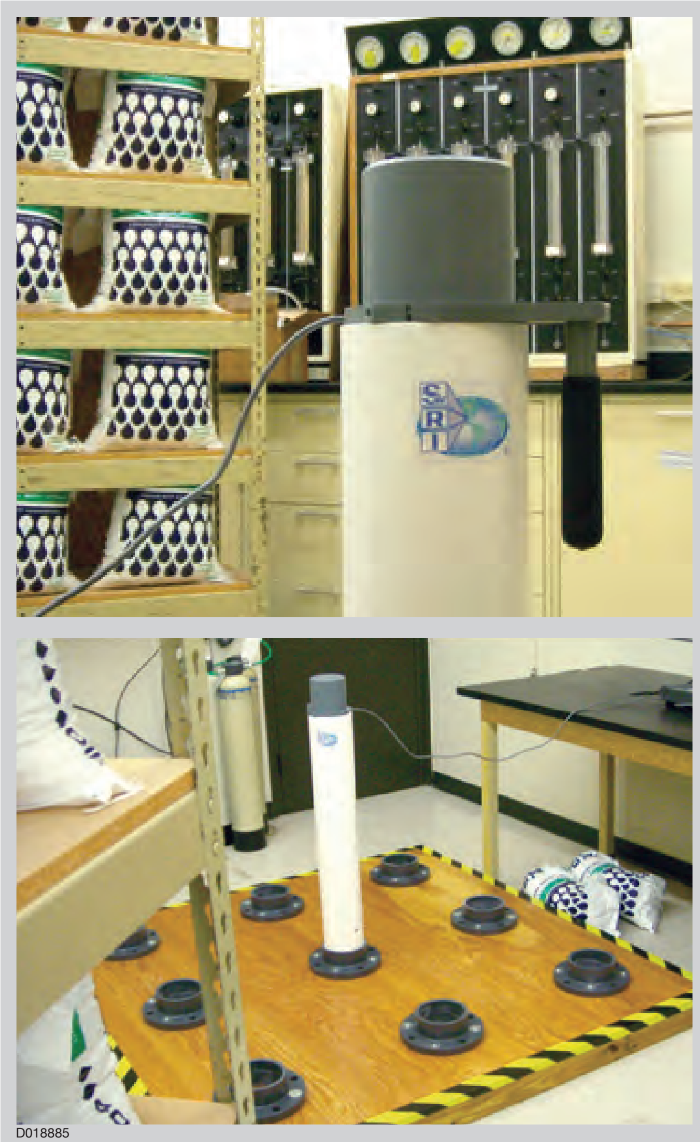
ARMS determines energy-dependent angular flux of gamma rays, which indicates their direction of origin. Red shading corresponds to the maximum fractional responses and incident directions. Black shading corresponds to negligible contributions.



The ARMS instrument is shown atop a platform in a laboratory test while exposed to low-level radiation emitted from bags of potassium chloride salt and other sources placed at several locations around the instrument.

Therefore, the ability to measure the angular flux, or directionality, of gamma rays or X-rays with a portable instrument can improve survey measurements of radiological dose rates. Using ARMS, effective dose rate at a location can be reported based on the direction an individual is facing in the radiation field, which is a new provision for radiological surveys.

Advancing the state of the art

Although it advances the state of the radiation detection art, ARMS faces a number of practical barriers to widespread adoption. Many facilities and institutions rely on simpler and less expensive instruments without spectroscopic capability for routine survey measurements. Also, for many ionizing radiation fields the effective dose is not greatly sensitive to the direction from which the radiation originates. For X-rays and gamma rays at energy levels at or below 100 keV (kiloelectron volts), the effective dose varies by less than a factor of three from different irradiation directions. At higher energies, the radiation is more penetrating, which produces a more homogeneous irradiation within the body and diminishes the organ shielding effect. For neutron radiation over a broad energy range, different irradiation directions can change the effective dose by a factor of three, and irradiation of the front of the body (anterior-to-posterior directed radiation) results in the highest effective doses compared to other irradiation directions.

As a long-standing practice, radiation workers customarily wear their personal radiation dosimeters on the front of their body, and institutions simply use the most conservative, anterior-to-posterior dose factors for all irradiation scenarios rather than accounting for different radiation directions. For situations in which such overestimates of radiological dose are acceptable, simplified approaches may continue to be the preferred option. Higher-fidelity dose rate information is enticing in situations requiring more realism in radiological dose estimation. Even though ARMS probably has a niche role in dose estimation, its abilities for improving gamma-ray imaging and radioactive material characterization hold even more promise.

Potential future applications

ARMS is a general technique, suitable to many mobile radiation detection measurements, including environmental monitoring, cargo screening and in-plant measurements where radiation readings are collected from different positions. Although demonstration measurements acquired with a spectrometer allowed for full implementation of the method, benefits also exist for ARMS applications using instruments that yield gross-count rate data instead of energy-dependent information. Medical applications, where source-to-detector distances are much shorter, also may be feasible. For beta particle detecting probes used in surgical procedures with radiopharmaceuticals to intraoperatively identify cancerous nodes and confirm their complete removal, improvements in spatial resolution and differentiation of nearby radionuclide foci can be expected with ARMS compared to current methods.

SwRI was awarded U.S. Patent No. 8,183,523, "System and Method for Acquiring Radiation Spectral Data in a Radiation Field and Determining Effective Dose Rate and Identifying Sources of Localized Radiation," on May 22, 2012. ARMS technology can be commercialized and readily applied to various existing systems for portable detection measurements, including hand-held, mobile vehicle and remotely operated unmanned systems. Other potentially promising applications include homeland security and radiological protection. Recent interest has related to aerial measurement of environmental radioactive contamination released from damaged nuclear power plants.

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TECHNICS

Brief notes about the world of science and technology at Southwest Research Institute

SwRI sets low-cost ROS-I consortium membership entry fees

With input from the industrial robotics and automation community, Southwest Research Institute (SwRI) has set a low-cost membership model for the ROS-Industrial Consortium (RIC). This model encourages a broad base of membership and gives participants more control over how development funds are used. In conjunction with the launch of the consortium, SwRI has funded a special internal research program to accelerate ROS-Industrial development and benefit the technical needs of the consortium.

"As an early adapter of ROS, SwRI has been successfully leveraging it for industrial robotics applications," explained Shaun Edwards, a senior research engineer in SwRI's Automation and Data Systems Division. ROS (Robot Operating System) is an open-source project providing a common framework of libraries and tools for a wide range of applications, particularly in service and research robotics. In January, SwRI established the ROS-Industrial repository, an open-source resource providing a common industrial control platform to facilitate technology transfer from research labs to industry.

"Following other successful open-source projects as models, SwRI is initiating a precompetitive commercial collaborative research consortium, exclusively focused on the needs of industrial robot users," said Paul Evans, director of SwRI's Manufacturing Systems Department. RIC full membership is set at $10,000, with lesser levels of membership available.

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SwRI engineers investigate "cognitive fingerprints" for bolstering computer passwords

It won't make passwords passé, but a team led by Southwest Research Institute (SwRI) intends to use "cognitive fingerprints" to make sure you are you, and not an imposter.

Even the strongest password can be used freely once it has been compromised by a computer hacker. However, a novel software-based authentication tool called covert-conditioned biometrics will attempt to use a unique sequence of problem-solving moves to distinguish between a legitimate user and an identity thief. Research in support of the system is sponsored by the U.S. Defense Advanced Research Projects Agency (DARPA).

Covert-conditioned biometrics will incorporate principles of adaptive learning, behavior modification and game theory to capture and discriminate aspects of the cognitive fingerprint that authenticate a user's identity.

"It will deploy covert games, mimicking ordinary human computer interactions. Authenticated users are likely to unknowingly develop strategies for playing the games, even if the games are imperceptible," said Jenifer Wheeler, a senior instructional specialist in the Learning Sciences and Systems Department of SwRI's Aerospace Electronics, Systems Engineering and Training Division.

SwRI has teamed with Sentier Strategic Resources LLC to combine SwRI's experience in behavioral modeling, educational software development and learning science with Sentier's experience in cognitive psychology and human-subjects testing.

Contact Wheeler at (210) 522-6052 or jenifer.wheeler@swri.org.

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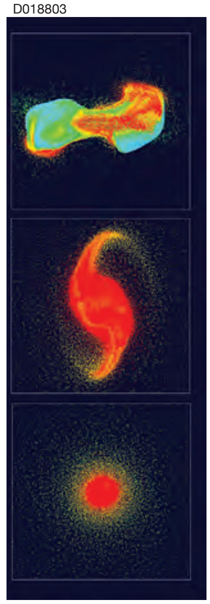


New model reconciles the Moon's Earth-like composition with the giant impact theory of formation

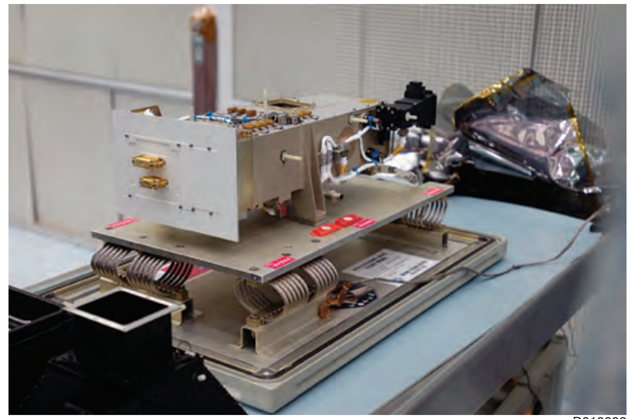
The giant impact believed to have formed the Earth-Moon system has long been accepted as canon. However, a major challenge to the theory has been that the Earth and Moon have identical oxygen isotope compositions, even though earlier impact models indicated they should differ substantially. In a paper published Oct. 16 in the journal *Science* online, a new model by Southwest Research Institute (SwRI), motivated by accompanying work by others on the early dynamical history of the Moon, accounts for this similarity in composition while also yielding an appropriate mass for Earth and Moon.

In the giant impact scenario, the Moon forms from debris ejected into an Earth-orbiting disk by the collision of a smaller proto-planet with the early Earth. Earlier models found that most or much of the disk material would have originated from the Mars-sized impacting body, whose composition likely would have differed substantially from that of Earth.

The new models developed by Dr. Robin M. Canup, an associate vice president in the SwRI Space Science and Engineering Division, and funded by the NASA Lunar Science Institute, involve much larger impactors than were previously considered. In the new simulations, both the impactor and the target are of comparable mass, with each containing about four to five times the mass of Mars. The near symmetry of the collision causes the disk's composition to be extremely similar to that of the final planet's mantle over a relatively broad range of impact angles and speeds, consistent with the Earth-Moon compositional similarities.

Contact Canup at (303) 546-9670 or robin.canup@swri.org.

Lunar Reconnaissance Orbiter's LAMP spectrometer detects helium in Moon's atmosphere



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Scientists using the Lyman Alpha Mapping Project (LAMP) aboard NASA's Lunar Reconnaissance Orbiter have made the first spectroscopic observations of the noble gas helium in the tenuous atmosphere surrounding the Moon. These remote-sensing observations complement *in-situ* measurements taken in 1972 by the Lunar Atmosphere Composition Experiment (LACE) deployed by Apollo 17.

Although LAMP was designed to map the lunar surface, the team expanded its science investigation to examine the far ultraviolet emissions visible in the tenuous atmosphere above the lunar surface, detecting helium over a campaign spanning more than 50 orbits. Because helium also resides in the interplanetary background, several techniques were applied to remove signal contributions from the background helium and determine the amount of helium native to the Moon. Geophysical Research Letters published a paper on this research in 2012.

"The question now becomes, does the helium originate from inside the Moon, for example, due to radioactive decay in rocks, or from an exterior source, such as the solar wind?" said Dr. Alan Stern, LAMP principal investigator and associate vice president of the Space Science and Engineering Division at Southwest Research Institute.

The paper, "Lunar Atmospheric Helium Detections by the LAMP UV Spectrograph on the Lunar Reconnaissance Orbiter," by Stern, K.D. Retherford, C.C.C. Tsang, P.D. Feldman, W. Pryor and G.R. Gladstone, was published in *Geophysical Research Letters*, Vol. 39, doi:10.1029/2012GL051797, 2012.

NASA Goddard Space Flight Center in Greenbelt, Md., developed and manages the LRO mission. LRO's current Science Mission is implemented for NASA's Science Mission Directorate. NASA's Exploration Systems Mission Directorate sponsored LRO's initial one-year Exploration Mission, which concluded in September 2010.

Contact Stern at (303) 546-9670 or alan.stern@swri.org.

DARPA selects SwRI's K-band space crosslink radio as communications system for a cluster of small, wirelessly connected spacecraft

The U.S. Defense Advanced Research Projects Agency (DARPA) has selected Southwest Research Institute (SwRI) to provide the flight low-rate crosslink wireless communications platform for the System F6 Program.

The System F6 Program, which is envisioned to culminate in an on-orbit demonstration in 2015–2016, is designed to validate a new space mission concept in which a cluster of smaller, wirelessly connected spacecraft replaces the typical single spacecraft carrying numerous instruments and payloads. This "fractionated" architecture enhances survivability, responsiveness and adaptability compared to the traditional monolithic spacecraft. The SwRI K-band radio is a core element of the open source F6 Developers Kit (FDK), which allows any spacecraft to participate in an F6-enabled cluster.

"As a nonprofit organization, Southwest Research Institute is ideally suited to support the DARPA System F6 FDK through the development of the K-band crosslink solution," said Dr. Mark Tapley, a staff engineer in the SwRI Space Science and Engineering Division and principal investigator for the wireless system.

Contact Tapley at (210) 522-6025 or mark.tapley@swri.org.

NRC renews contract for SwRI to continue operating CNWRA

The U.S. Nuclear Regulatory Commission (NRC) has renewed its contract with Southwest Research Institute (SwRI) for the fifth time to operate the Center for Nuclear Waste Regulatory Analyses (CNWRA®). The five-year contract, valued at almost $76 million, assures continuing technical assistance and research support to NRC activities related to storage, transportation, possible reprocessing and ultimate geological disposal of spent nuclear fuel and high-level radioactive wastes through September 2017. The CNWRA has been located at and operated by SwRI since it was created in 1987.

Established as a federally funded research and development center, the CNWRA provides independent technical assessment to the NRC, the U.S. regulatory agency responsible for evaluating safety and environmental aspects of storage, transportation and disposal of radioactive wastes. In particular, NRC was charged by Congress to evaluate and, if appropriate, license a potential high-level radioactive waste repository.

"For the past 25 years, CNWRA has been a central part of the Commission's efforts to evaluate engineering, environmental and scientific factors affecting management of radioactive wastes," said Dr. Wesley C. Patrick, vice president of SwRI's Geosciences and Engineering Division, which oversees the CNWRA.

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Technical Staff Activities

Publications

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Freitas, C.J. "WPS — A Wellbore Performance Simulator." Paper presented at the Baker Hughes Modeling and Simulations Technology Symposium, Houston, October 2012.

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Gatewood, J.T., J.J. Moore, M.G. Nored, K. Brun and V. Iyengar. "The Texas Cryogenic Oxy-Fuel Cycle (TCO): A Novel Approach to Power Generation with CO_2 Options." Paper presented at the 2012 ASME Turbo Expo, Copenhagen, June 2012.

Goguen, J.D.., B.J. Buratti, R.H. Brown, R.N. Clark, P.D. Nicholson, M.M. Hedman, C. Sotin, D.P. Cruikshank, K.H. Baines, K.J. Lawrence, J.R. Spencer and D. Blackburn. "Cassini VIMS Observations of Thermal Emission from The Warmest 'Tiger Stripes' Near the South Pole on Enceladus." Paper presented at the Division for Planetary Sciences Meeting of the AAS, Reno, Nev., October 2012.

Green, R.T. "Water Considerations in Hydraulic Fracturing." Paper presented at the Texas Alliance of Groundwater Districts Texas Groundwater Summit, Austin, Texas, August 2012.

Grosch, D.J. "Armored Vehicle Fuel Tank Study." Paper presented at the 63rd Meeting of the Aeroballistics Range Association, Brussels, Belgium, October 2012.

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Trevino, G. and C. Fronda. "High-fidelity PV Data Acquisition for Forecasting Solar Power Production." Paper presented at the 2012 National Instruments Week Conference, Austin, Texas, August 2012.

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Technical Staff Activities

Internal Research

Funded October 1, 2012

Allegrini, F., K. Coulter and M.A. Dayeh. "Carbon Foil Properties for Space Plasma Instrumentation: Carbex-2."

Anderson, S. "Capability Demonstration of Laser Desorption Resonance Ionization Mass Spectrometry for Domestic Nuclear Detection Office and NASA."

Bauta, W. "HI-6 Process Development and Parametric Studies."

Bayless, A. and P. Roming. "Capability Development of Type II Supernova Models."

Chadwell, C. "D-EGR Engine and Vehicle Demonstration Project."

Cobb, A. "Development of the MsSR4040SF Magnetostrictive Sensor Technology—Electronics Hardware."

Darnell, M. and W. Toczynski. "Feasibility of an Inter-satellite Transceiver for Small Spacecraft."

Edwards, S. "ROS-Industrial Strategic Technology Development."

Furman, B. "Photoresponsive Polymeric Composites Utilizing UV Light Harvesting from Upconverting Nanoplatelets."

Holladay, K. "Unsupervised Learning Using Minimizing Minimum Message Length Fitness."

Miles, P., S. Livi, E. Patrick and K. Ogasawara. "Capability Development for Impact Ionization Cross-section of Molecules."

Moore, A. "Non-homogeneous, Non-static Aggregate Test Bed."

Music, W. "Semi-Blind Multi-user Detector Based on LTE Uplink Control Channel Structure."

Owston, R., S. Svedeman, S. Green, S. Siebenaler and R. Wei. "Development and Demonstration of Erosion Prediction Capabilities for Oil and Gas Industry Applications."

Oxley, J. "Novel Emulsion-based Encapsulation Process."

Perry, W. "Tactical Aerobotic Launch System (TALS) Evaluation and Demonstration."

Polendo, J. and B. Nance. "Parallel Channel Direction Finding and Beamforming from Airborne Platforms Structure."

Wall, C., P. Lee, T. Reinhart and M. Treuhaft. "Detecting Piston Ring Instability with Engine Vibration Analysis."

Wellinghoff, S. and V. Lee. "Local Application, Controlled Release Formulation Strategy for the Amelioration of Oral Mucositis."

Wyrick, D. and K. Smart. "Workflow Development: Oil Industry 3D Surfaces and Geometries to 3D CAD Formats to 3D Solid Models."

Patents

Benke, R. "System and Method for Acquiring Radiation Spectral Data in a Radiation Field and Determining Effective Dose Rate and Identifying Sources of Localized Radiation." U.S. Patent No. 8,183,523. May 2012.

Chan, K., N. Cheruvu and W. Liang. "Corrosion Resistant Coatings Suitable for Elevated Temperature Application." U.S. Patent No. 8,230,797. July 2012.

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Gordon, C., C. Harbold and H. Hanson. "Method of Insertion of an Expandable Intervertebral Implant." U.S. Patent No. 8,257,440. September 2012.

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Siemsen, P. and R. King. "Portable Pop-up Direction Finding Antenna." U.S. Patent No. 8,253,638. August 2012.

Wei, R. and E. Langa. "Method and Apparatus for High Rate, Uniform Plasma Processing of Three-dimensional Objects." U.S. Patent No. 8,252,388. August 2012.

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- **29th National Space Symposium**, Colorado Springs, Colo.; April 8-11, 2013
- **Advanced Biofuels Leadership Conference**, Washington; April 14-19, 2013
- **ITS America Annual Meeting and Expo**, Nashville, Tenn.; April 22-24, 2013
- **AIChE Spring Meeting**, San Antonio; April 28-May 2, 2013
- **Offshore Technology Conference**, Houston; May 6-9, 2013
- **AAPG 2013 Annual Convention & Exhibition**, Pittsburgh; May 19-22, 2013
- **Space Tech Expo**, Long Beach, Calif.; May 21-23, 2013
- **ASME Turbo Expo**, San Antonio; June 3-7, 2013

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