Van Allen Probes mark first anniversary with new discoveries and new investigations

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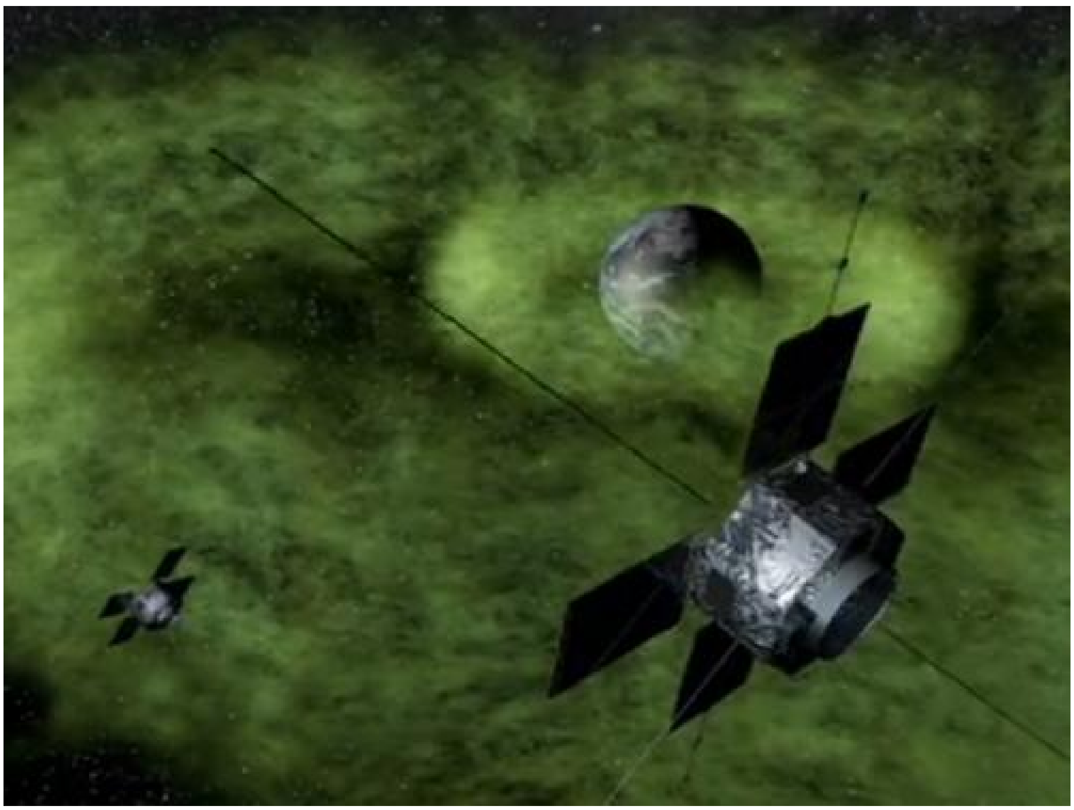

Artist's rendition of Earth's radiation belts with the twin Van Allen Probes traveling through them. Credit: NASA

One year after their launch from Cape Canaveral Air Force Station at 4:05 a.m. E DT on Thursday, Aug. 30, 2012, NASA's twin Van Allen Probes have already fundamentally changed how we understand the Van Allen radiation belts above our planet.

Data from the probes have already led to several significant discoveries, some made just days after the special twin spacecraft soared into orbit. The mission has answered one long-standing question about the nature and behavior of the belts, and revealed that the outer belt can split into two separate belts. With this first year of discovery and enhancements in operations as a cornerstone, the science teams of the Van Allen Probes (formerly named the Radiation Belt Storm Probes) are looking forward to unlocking further mysteries and advancing our knowledge of particle physics and the dynamics of space plasmas, as well as how to better protect space-based technologies like satellites.

"The science results are coming fast now," says NASA's Mona Kessel, program scientist for the Van Allen Probes. "Some of the discoveries we've made are going to rewrite the textbooks on the radiation belts. And while those discoveries are fascinating and merit more research, we're still focused on the question we asked when we designed the mission: What are the primary mechanisms of particle loss and acceleration in the belts? We're beginning to answer that now."

The radiation belts are two donut-shaped regions of highly energetic particles trapped in the Earth's magnetic field – the inner, located just above our atmosphere and extending 4,000 miles into space; and the outer, from 8,000 to 26,000 miles out – and are named for their discoverer (as are the probes), the late James A. Van Allen of the University of Iowa. The belts' makeup and properties have affected both spaceflight and physics research for the past 50 years, and the Van Allen Probes were designed to answer a number of fundamental questions about these harsh regions of space.

First light, first discoveries

The scientific successes for the Van Allen Probes began almost immediately after launch, starting with a discovery made when scientists turned on the Relativistic Electron Proton Telescope (REPT) instrument on Sept. 1: a new third radiation belt, formed at the interior of the outer belt. According to Dan Baker, REPT instrument lead at the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado in Boulder, "a powerful electron acceleration event was already in progress, and we clearly saw the new belt and new slot between it and the outer belt." The new belt was destroyed four weeks later by another solar storm – another new observation previously unavailable until the Van Allen Probes mission. The REPT instrument is part of the Energetic Particle, Composition, and Thermal Plasma Suite (ECT).

Just a few days later, on Sept. 5, members of the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) team made an audio recording of radio waves in the belts, at a frequency audible to humans, known as "chorus." While scientists have known about chorus since the 1950s, these new high-quality recordings became known as "the sounds of space" and drew a great deal of interest around the world. Chorus is caused by plasma waves in the belts, and is suspected to be related to the process that accelerates electrons to speeds which can harm spacecraft and astronauts.

One fundamental question the mission hopes to answer is how the particles in the belts are being accelerated to nearly relativistic speeds: Is it an external force, or is it happening within the belts themselves? On July 25, researchers published data from an early 2012 event that showed there is definitely an internal particle accelerator. "We have real evidence that the changes originate from within the belts themselves." says Geoff Reeves, the first author on the paper and a radiation belt scientist at Los Alamos National Laboratory in Los Alamos, N.M. In fact, Reeves and other researchers are looking at the chorus waves studied by EMFISIS principal investigator Craig Kletzing (University of Iowa) and the EMFISIS team to see if and how chorus (or another type of electromagnetic wave) is behind the acceleration. "The Van Allen

Probes are equipped with instruments that should help us figure that out as well," Reeves says.

Solar powered science, made faster

The driving force behind the events in the radiation belts is the sun, which is in the midst of solar max – the peak of solar activity, which rises and falls over a roughly 11-year cycle. While this current solar max has been relatively sedate, the mission has still made a number of important observations, and all the teams report that they are looking forward to more events like coronal mass ejections and solar storms that can affect the trapped particles. "Some of the largest historic events have occurred near solar maximum and during the declining phase following solar max," says Harlan Spence, principal investigator for ECT (which includes Baker's REPT and is the basis for Reeves' work), from the University of New Hampshire. "We're still anticipating some big events, and we've had a year to deeply understand the probes and how our instruments behave in space, and so we're prepared for what the sun may soon throw our way. This next year is full of opportunity."

Back on Earth, the mission operations team at the Johns Hopkins University Applied Physics Laboratory (which built the spacecraft and operates the mission for NASA) along with the Flight Software (FSW) and Radio Frequency (RF) Teams, have recently made some improvements in getting the science teams more data. By adding data compression algorithms to the FSW and expanding the allowable downlink range with the APL station, the team recently produced a "huge leap in the amount of data we can download," explains APL's Ray Harvey, Van Allen Probes mission operations manager. "We're targeted to download an average of 5.9 gigabits of science data a day, but now we're getting seven to eight gigabits, and last week we achieved nine gigabits on one day's worth of contacts. I suspect we'll get even more in the future."

In the meantime, the instrument teams are examining the data already collected and preparing to publish papers and findings, as well as releasing some fascinating new products. "We have made the cleanest, most high-fidelity stereo recording of the same chorus wave recorded from different spacecraft," says EMFISIS's Kletzing. "We're working on finalizing it now. It will certainly tell us about the spatial extent and evolution of the chorus wave, which along with particle data from other instruments should tell us some things about electron energies."

Kletzing, like the other team leads, is seeing not just new and great data, but better and wider uses of it. "All the teams have access to each other's data to put that information into the story they are telling about the belts," he says. "We are seeing data from two, three, and four instruments in the team's papers, and it really makes a difference. The tools to gather data, and the tools to share it, are much better than just a few years ago. It really is working."

"I'm still as excited about the mission today as I was at launch"

One instrument, the Relativistic Proton Spectrometer (RPS), has been providing previously unavailable particle measurements of high accuracy within the heart of the inner radiation belts. "It's hard research to do, and we've spent the past year exploring the inner belt and refining our understanding of the instrument response, because we've never had something like RPS in orbit before," says The Aerospace Corporation's Joseph Mazur, principal investigator for RPS (RPS is the primary instrument for the Proton Spectrometer Belt Research, or PSBR, investigation, under principal investigator David Byers, National Reconnaissance Office).

Findings from RPS have provided new insights into spatial gradients (the physical distribution of energetic particles) in the inner belt, as well as a look at how protons from outside the solar system gain entry to the Earth's magnetosphere. The data will also play a role in the development of the next generation of standards and models used by the satellite community for building and shielding their spacecraft.

"I'm still as excited about the mission today as I was at launch," says Mazur. "Every day we look at the data from RPS is a great joy."

Spence echoes that sentiment. "There's a continued sense of excitement because the science outcomes are absolutely stunning," he says. "And this is not a trivial accomplishment. It's very, very difficult to quantify these particle intensities in the harsh environment of the radiation belts, but we are doing just that. As a result, we are starting to knock off the big questions we had posed when we designed the mission, and we are also discovering new mysteries."

Louis Lanzerotti of the New Jersey Institute of Technology is principal investigator for the RBSPICE (Radiation Belt Ion Composition Experiment) instrument, and one of the pioneers of radiation belt physics research. He says that one of the more fascinating observations that RBSPICE has provided his team involves the injections of ions and electrons from the Earth's geomagnetic tail into the ring current, which is the large electrical current that surrounds the Earth. "We can really see these sporadic, frequent and episodic injections," Lanzerotti says. "It has really surprised us, and this data is important for understanding the energy density of the ring current and the effects on the higher energy particles."

Looking forward to year two

For the second year of the Van Allen Probes mission, the teams are eager to expand both their queries and the reach of their instruments.

"Every instrument has a personality," Spence says. "Ours are revealing riches we didn't anticipate, and showing us opportunities beyond what we had base lined. The increase in data download rates, and the knowledge we now have of the ECT instruments, gives us the opportunity to think about how best to use the capabilities and technologies to address new questions in better ways. It's like designing a better mousetrap on the fly – 'Let's see what we can catch!'"

"We are going to see a lot of different opportunities in the coming year for even more great science," says Barry Mauk, Van Allen Probes project scientist, at APL. "Because we're going to be operating on the dusk-to-dawn side of Earth, we're going to see different physical processes, and combined with the period we are in with solar max, we're hopeful for a lot of interesting events."

"We still haven't sampled one-half of the dusk to daytime orbits," Kletzing says. "There's a whole different region there, with different properties, and we're interested to see what the sun throws at us this year."

"Every week I learn something new," NASA's Kessel says. "We are now going into what historically has been the most energetic part of the solar cycle for the radiation belts. So we might see brand new things this year, and we are in an excellent position to be ready for what the sun throws at us."

From a hardware perspective, the Van Allen Probes' most significant challenge was to operate and perform measurements in the severe charged particle environment of the radiation belts, a region of space most spacecraft avoid. "The teams at NASA, APL, and the other institutions did a great job building the spacecraft and instruments," says APL's Harvey. "The probes and instruments are doing exactly what we tell them to. The Van Allen Probes are a great mission, and part of that credit goes to the late Gene Heyler [who passed away in March 2013], who designed the orbits so that the satellites lap each other several times per year, which has been a key to the science results the mission can achieve. When Gene was on a mission, you just knew what he worked on was going to work, and that's proven true again here."

For team members like Lanzerotti, who began their careers as humankind's exploration of space started, the progress and insights from the Van Allen Probes are particularly meaningful. "I started in radiation belt physics more than 45 years ago," he says. "We had no understanding of space plasma physics back then, no clue, such as when we were designing Telstar [and other early satellites]. Now, we have these impeccably designed instruments on twin spacecraft, helping us get at really fundamental understanding of space plasma physics. That has been really exciting for me to see develop over my career. This pair of spacecraft is absolutely unique."

"We're hopeful for lots of interesting events at solar max," adds APL's Nicky Fox, deputy project scientist. "We're going to be in the right place at the right time – with the right pair of spacecraft."

Provided by NASA

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