MAVEN Solar Wind Electron Analyzer seeks answers at microscopic levels

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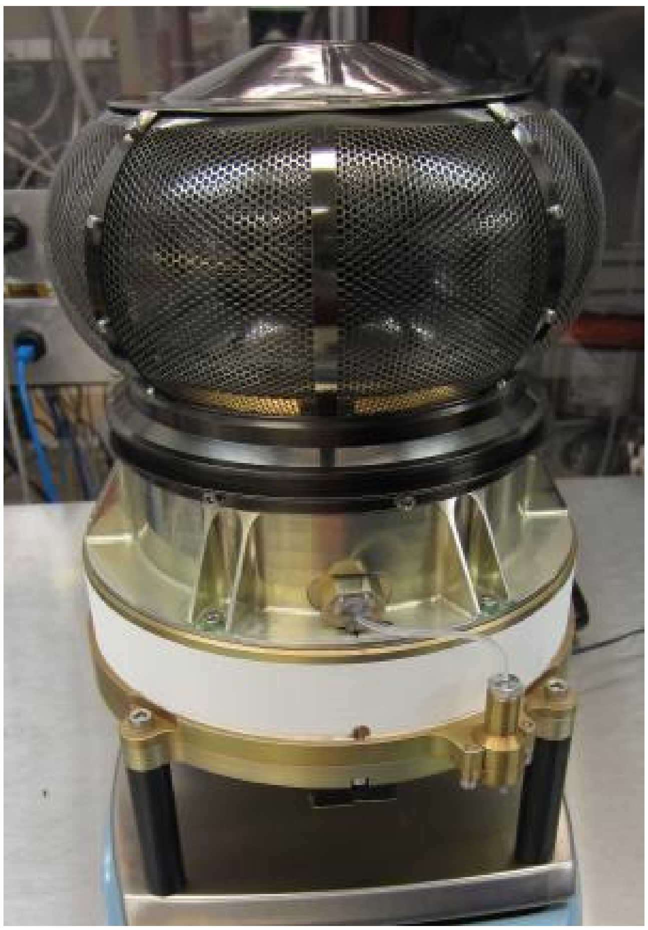

The Solar Wind Electron Analyzer is shown before being delivered to the MAVEN spacecraft. Credit: David L. Mitchell, SSL, UC Berkeley

When the Mars Atmosphere and Volatile Evolution Mission launches in

November to study why the Red Planet is losing its atmosphere, one of its instruments will look to electrically charged particles called electrons for answers.

The Solar Wind Electron Analyzer or SWEA is one of the eight instruments aboard MAVEN that will try to solve the mystery of Mars' dwindling atmosphere, a process that has reduced the planet to a frozen desert.

Produced in a collaboration between the Space Sciences Laboratory (SSL) at the University of California, Berkeley, and the Institut de Recherche en Astrophysique et Planétologie (IRAP) in France, SWEA's assignment is to analyze electrons found in two distinct regions around Mars: the solar wind passing by and a layer of Mars' upper atmosphere—the ionosphere.

Instrument lead David L. Mitchell of SSL said that SWEA would use the information on electrons to track how other charged particles, such as planetary oxygen ions, are escaping the planet's atmosphere. Solar wind, which continuously blows off the sun's surface at around a million miles per hour, is packed with charged particles and magnetic field lines that can interact with particles in Mars' upper atmosphere, providing a fraction of them with enough energy to leave the planet.

Using electric fields to bend the paths of electrons onto its detectors, SWEA can differentiate between electrons found in the solar wind and those in the Martian ionosphere by identifying their different energies. Mitchell said solar wind electrons possess a broad range of energies, while those in the planet's atmosphere are produced at specific energies.

"The instrument will tell whether the spacecraft is measuring planetary plasma or solar wind plasma," Mitchell said, referring to the mixture of electrons and other charged particles. "It determines the environment, which is important for setting the stage for interpreting other measurements."

By identifying where solar wind plasma ends and planetary plasma begins, Mitchell said SWEA would be able to zero in on the top of the planet's ionosphere.

"We're trying to understand the boundary layer between the solar wind and the planet's ionosphere because this is a key region where planetary material is being lost," Mitchell said. "We want to understand the loss processes and how the solar wind is stripping away the atmosphere."

Mitchell said neutral particles in Mars' atmosphere can become ionized, or electrically charged, by three different mechanisms. In one of these scenarios, neutral molecules absorb solar ultraviolet (UV) light. When its energy is transferred to an electron within the molecule, the electron can be ejected, leaving behind a positively charged ion. This process is known as photoionization. The molecule can also break apart into fragments.

Ionization can also occur when fast moving electrons—either solar wind electrons or newly liberated electrons from the photoionization process—collide with neutral molecules. These collisions can transfer enough energy to eject an electron from the molecule.

Finally, ionization can occur when a fast moving ion from the solar wind crashes into a neutral particle in the atmosphere, stealing one of its electrons in a process known as charge exchange. Gaining an electron causes the solar wind ion to become neutral as it speeds away, leaving the original atmospheric particle ionized in a process Mitchell described as a "hit and run."

"It takes energy to break apart and ionize atmospheric gases," Mitchell said.

Once the atmosphere's neutral atoms or molecules lose an electron and become charged through one of these processes, the magnetic field in the solar wind can pick them up and carry them away as it passes over the planet. To be picked up, the ions first need to reach high altitudes, where they no longer collide with other atmospheric molecules. Mitchell said some ions are produced at a high altitude, while others may be ionized at lower altitudes and gain the energy needed to reach high altitude through different means, like getting accelerated by electric fields.

"One of the goals of MAVEN is to understand how ions get the energy required to reach high altitude," Mitchell said.

In addition to energy requirements, Mitchell said the ions must travel along magnetic field lines in order to leave the atmosphere. The electrically charged particles are subject to magnetic forces, causing them to follow magnetic field lines in a corkscrew-like pattern. Working together with the MAVEN Magnetometer, or MAG, SWEA will be able to distinguish electrons traveling in one direction along the magnetic field from those traveling in the opposite direction. By measuring the energies of electrons traveling in each direction, SWEA can determine whether a magnetic field line passes through the ionosphere, connects with the solar wind, or forms a closed loop. Over the course of many orbits around the planet, SWEA and MAG can create a "road map" of how charged particles move in the Martian environment.

While Earth actively generates a global magnetic field within its core, Mars' magnetic field is dominated by magnetized rock in its crust. Unlike the north and south magnetic poles of Earth, Mitchell said Mars features many localized magnetic fields, as if there were many bar magnets scattered all over the planet. This complex configuration of magnetic fields rotates with the planet once every 24.6 hours—a full Martian day—which makes studying the routes for charged particle escape as challenging as it is interesting.

In addition, the solar wind has its own embedded magnetic field that wraps around the planet's ionosphere. The interactions between the two fields can provide different mechanisms for particles to exit.

"These two systems of magnetic fields can connect with one another," Mitchell said. "There will be times when crustal magnetic field will open up and connect with solar wind's magnetic field lines, forming a path for solar wind plasma to travel down into the atmosphere or a path for planetary ions and electrons to travel upwards and escape."

Mitchell said the SWEA measurements would complement several other instruments aboard, including the magnetometer, to determine whether the interacting magnetic field lines are forming possible escape routes.

"This is one reason why the SWEA and MAG instruments are important," Mitchell said. "They tell us whether the magnetic field opens into the solar wind, providing a conduit for escape, or whether it forms closed loops and traps the ionosphere."

SWEA also complements the Langmuir probe, which will measure electrons that are moving too slowly for SWEA to detect.

"The entire package is going to be working together," Mitchell said.

SWEA will make measurements over a wide range of altitudes ranging from 93 miles (150 km) to 3,870 miles (6,230 km) above the planet's surface. The instrument will also make extremely fast measurements—around every two seconds—at low altitudes where rapid changes in magnetic configurations are expected.

The instrument will have to overcome a distinct challenge in order to make its measurements—the spacecraft itself. Although the instrument can observe an impressive 86 percent of the sky, the spacecraft will block some of the instrument's vision. Furthermore, the spacecraft itself can become charged and bend the trajectories of electrons as they pass nearby, increasing the fraction of the sky blocked by the spacecraft. To reduce this effect, Mitchell said SWEA will be positioned on the end of one of the spacecraft's booms, keeping it far enough away to minimize the effects of the spacecraft .

In addition to making a major scientific contribution to the MAVEN mission, SWEA lead electronics engineer Ellen Taylor of SSL said the instrument marked an important collaboration between IRAP in France—which produced the instrument's analyzer—and the SSL, which produced the instrument's electronics.

"The international collaboration is significant, and making sure you have input from all over is very useful," Taylor said. "It's always beneficial to both sides, as the science itself is the main importance and the engineering is a nice collaboration, since we're getting hardware from [IRAP] that we can fly on our spacecraft."

Although the instrument was a lot of work to develop, Mitchell said the results it's capable of producing make it worthwhile.

"It's been a tremendous amount of work," Mitchell said. "But it's all coming together, and it feels good to have the instrument on the spacecraft, and we're looking forward to launching it on its way to Mars."

MAVEN's principal investigator is based at CU/LASP. The university provided science instruments and leads science operations, as well as education and public outreach, for the mission.

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