How do killer electrons affect you?

You won't personally run into these little powerhouses unless you become an astronaut, but you probably have experienced their effects. Many satellites that carry signals for phone service, pagers, remote and educational TV broadcasts, as well as scientific, military and business data, must reside in and at the outer fringes of the outer belt.

Because there are backup systems to deal with the outer belt effects from strong solar activity, such as alternate satellites or signal routes, you rarely know about problems. Service providers do the scrambling, though your credit card approval might take longer. The costs of dealing with such problems are passed along to the users of these technologies - and you are probably one of them!

About NASA's "Living With a Star" Program

The goal of NASA's multi-mission "Living With a Star" program is to gain understanding of aspects of the Sun-Earth system that affect life and society. The highest priority of the geospace (near-Earth space) portion of the program is to understand the acceleration, global distribution, and variability of energetic electrons and ions in the inner magnetosphere.

http://lws.gsfc.nasa.gov/

for more information:

Web sources

Exploration of the Earth's Magnetosphere
http://www.phy6.org/Education

Radiation Effects & Analysis Home Page
http://radhome.gsfc.nasa.gov/

Solar Wind Makes Waves; Killer Electrons Go Surfing?
http://www.nasa.gov/centers/goddard/news/topstory/2003/0904magwaves.html

Radiation Belt Storm Probes
http://lws.gsfc.nasa.gov/missions/geospace/geospace.htm

Print sources

How to Cope with Space Weather, Daniel N. Baker, Science, 297, 1486-1487, 2002.

Introduction to Geomagnetically Trapped Radiation, M. Walt, Cambridge University Press, 1994.

Storms from the Sun, M. Carlowicz and R. Lopez, Washington, DC: The Joseph Henry Press, 2002.

National Aeronautics and Space Administration

Do Killer Electrons Affect You?

high energy particles in space

What are killer electrons?

You probably know that **electrons** are negatively-charged particles that orbit the nucleus of an atom. You might not know that swarms of electrons, free of their atomic nuclei, zip around above us all the time at nearly light speed. They are trapped in Earth's magnetic field well above our atmosphere.

Carrying up to 1000 times more energy than dental x-rays, they can penetrate deeply into satellites they encounter. So you shouldn't be surprised that in large numbers they can disrupt satellite operations - and in extreme cases "kill" (cause the failure of) satellites.

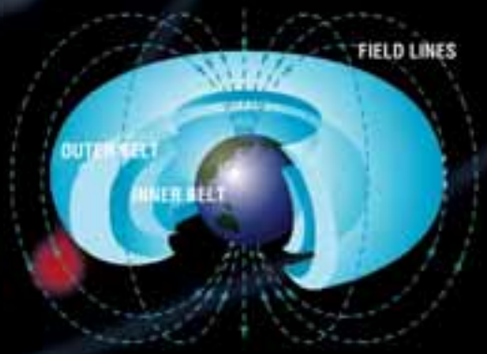
How do we know killer electrons exist?

NASA

Using data from the very first U.S. satellites in 1958, Explorers I and III, James Van Allen discovered them *(right, model of Explorer I held by Pickering, Van Allen, and von Braun)*. Since then many satellites have flown through the radiation belts and taken measurements of them.

Where do we find killer electrons?

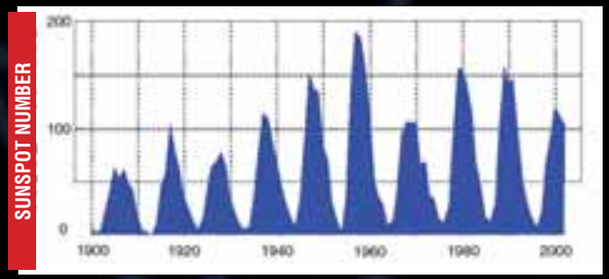
Killer electrons lurk in the outer of two **radiation belts** *(below)* surrounding Earth. (Damaging *ions* collect in the inner belt, but that belt is better understood and more predictable.) The Earth's magnetic field restricts the motions of the electrons, shaping the regions where they are. They are part of our planet's **magnetosphere**, the region in space where Earth's magnetic field is the dominant force on electrically-charged particles. (In images, magnetic fields are shown as lines of magnetic force, or **field lines**.)



The outer belt is at its highest over the equator, usually 13,000 to 32,000 km (8,000 to 20,000 miles) up. It dips down to low altitudes near the poles. Most of the orbit of the International Space Station is below the outer belt. But solar activity can drastically change the numbers of electrons in the belt and move it much closer to Earth.

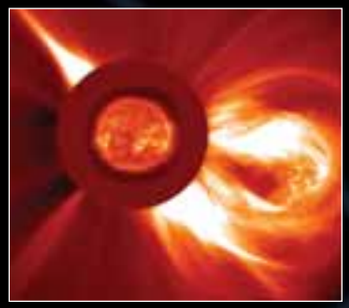
When do we find killer electrons?

The two types of solar activity that seem to most greatly affect the number of electrons are related to the **sunspot cycle**. This cycle is a measure of the number of sunspots over time, and it rises to a maximum and falls to a minimum during each eleven year cycle *(below)*.



NOAA/NGDC

Coronal mass ejections, which are primarily solar maximum events, are blasts of energetic particles from the Sun *(bright bubble on side of the Sun, in extreme ultraviolet image below)*. When a CME approaches Earth it transfers energy to the magnetosphere and produces a **magnetic storm** (world-wide magnetic disturbance). We find up to 1,000 times more killer electrons near the peak of a magnetic storm and in the following days! But the outer belt has a puzzling and unpredictable response to these storms: the number of electrons may increase, decrease, or not change at all.



SOHO, NASA/ESA

High-speed streams of particles escaping through **coronal holes** *(below, dark regions in x-ray image)* seem to be even more effective at increasing the electron intensities. Although usually near the Sun's poles, the holes often expand toward its equator around solar minimum, which can point the streams in the direction of Earth. They produce magnetic activity that somehow boosts the number of outer belt electrons.

SOHO, NASA/ESA

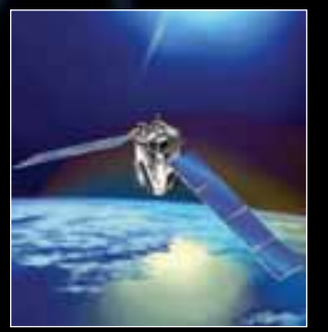
How are killer electrons created?

Both Earth's upper atmosphere and the Sun continuously supply low-energy electrons to the outer belt. Scientists think that some of these particles are accelerated to high speeds right there in the belt, using the energy from solar activity. But they don't yet know what causes that acceleration.

What kind of damage can be caused?

Killer electrons easily penetrate satellite shielding and burrow into insulation around electronic components. An electrical charge from accumulating electrons can build up, and an internal electrical discharge, like a miniature lightning strike, can damage these components. The damage can cause satellites to lose - or produce errors in - data or even shut down their electronic systems. Experts don't agree on how many satellites have been damaged by killer electrons, but the number of reported problems doubles during years with the greatest solar activity.

Spacecraft systems can't be completely shielded from the electrons, so they have to be designed to survive an *"Attack of the Killer Electrons"*. Scientists need to collect data from specially designed satellites passing through the belts to better understand the killers, predict their intensities, and give engineers the data they need to improve spacecraft defenses.



TIMED, NASA/JHU/APL