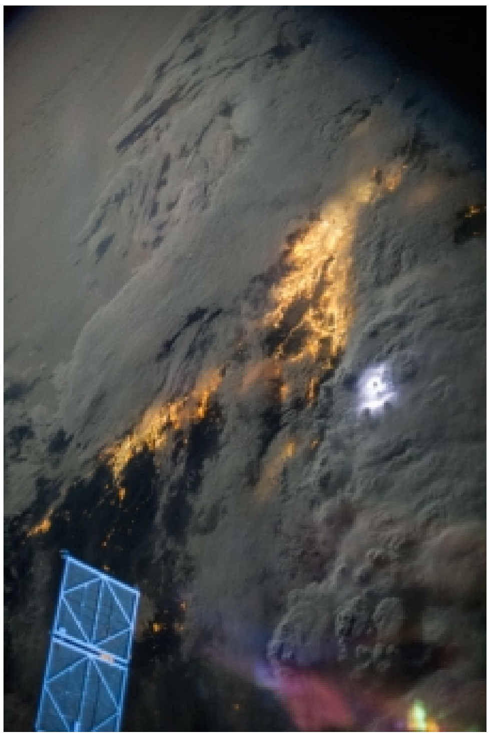
It's like a party in the atmosphere

November 7 2013, by Jessica Nimon



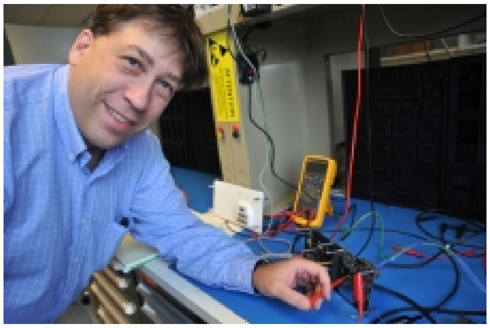
This International Space Station Crew Earth image of storm clouds over California shows lighting as a white glow to the right of center. The yellow lit areas, beneath the clouds are the night lights from the highly populated areas of Los Angeles and San Diego. Credit: NASA

Ever attend a wild party with flashing lights and loud music that snowballs into a dazzling moment worth remembering? That's something like how scientists describe the chain reactions in our atmosphere that lead to lightning. In September, researchers began using the International Space Station as a platform to study the mysterious cosmic catalyst and consequence of lightning, which may actually have origins more explosive than you might guess.

The Space Test Program-Houston 4-FireStation (STP-H4-FireStation) investigation, also simply known as FireStation, will orbit the Earth for a year attached to the outside of the space station. FireStation is sponsored by NASA and the National Science Foundation in partnership with the U.S. Department of Defense and its Space Test Program. This instrument collects data as it flies over thunderstorms, taking aim at the exciting energy exhibit to help scientists answer burning questions involving the relationship between lightning and gamma rays.

"Somewhere in the atmosphere momentarily there's just an incredible amount of energy release and what happens in that region is something of a witch's brew," said Doug Rowland, principal investigator for FireStation at NASA's Goddard Space Flight Center in Greenbelt, Md. "You get antimatter created in the Earth's atmosphere during this interaction, you get energetic neutrons that basically you never see in the quiet atmosphere, that you only associate with nuclear reactions, that are happening in our atmosphere whenever these things go off. That's one of the first fundamental science reasons [to study this phenomenon]—it's part of our planet; we don't understand it; we want to understand it."

During the "atmospheric party" of a thunderstorm, clouds charge as ice crystals rub together. This dance separates them by electrical charge and weight, leading to a sudden and dramatic release of lightning. While we know this is the source of the dazzling display, scientists still don't fully understand what initiates the process. A prevailing theory is a chain reaction called a seeded avalanche breakdown, which is where an outside energy source sets off a few energetic-free electrons within the Earth's electron field. "The idea is that you get a cosmic ray coming in that has a million electron volts of energy and it can serve to trigger another breakdown mechanism that generates gamma rays," said Rowland.



FireStation principal investigator Doug Rowland of NASA's Goddard Space Flight Center poses with the engineering unit of FireStation's interface board. Credit: NASA/Debora McCallum

Seen as terrestrial gamma ray flashes (TGFs), these events are short—on the line of milliseconds, like a lightning flash—bursts of gamma rays (ionizing radiation) from the Earth's atmosphere. With a typical energy level of 1/40th of an electron volt, it is not intuitive to think of the planet as the origin of these quick flashes that have as much as 100 million electron volts. "I always thought this was a really weird idea," said Rowland, "that your local weather, that your lightning depends on a cosmic ray that's traveled for 150 thousand light years or a million light years from some exploding star that just set off your lightning stroke over your head."

FireStation is capable of measuring these lightning and gamma ray flash events simultaneously to determine if TGFs are indeed generated by the electric fields during thunderstorms. The goal is to better understand the fundamental connection between the two natural phenomena. Researchers want to know what kinds of lighting produce gamma ray flashes and delve into the mechanisms of how this process takes place.

Putting FireStation on the space station allows for simultaneous readings and higher data collection than possible with the related CubeSat mission, called Firefly. Hitching a ride aboard station enables ground telemetry communications of 500 kilobits per second—faster than most mobile phones connect to the Internet—vs. the 300 bits per second possible with Firefly, which is a constraint similar to a slow modem from the 1980s. This means FireStation will be able to collect and transmit complete datasets for analysis. "On FireStation we get every single event, every single gamma ray that hits our detector, and we can sort them out on the ground using ground-based computers, so that's a huge help," said Rowland.

Without the specific instrument and the platform of the space station, this could have been a "chicken or the egg" type scenario. "We are measuring lightning flashes—which has been done before—and we are measuring gamma ray flashes—which has been done before—but we are doing it on the same platform, so that we can see for the same event the lighting and the gamma rays it produces," said Rowland. "You can imagine a case where if you don't know exactly where the events and the signals were traveling at different speeds, you might reverse the cause and effect. So having it in the same platform is new and very helpful."

As the space station orbits the Earth and encounters a thunderstorm, FireStation collects data. This starts with the radio signals from a distance as the station approaches a storm that is still thousands of miles away. As the instrument gets closer to the storm, a gamma ray detector will capture evidence of TGFs. "We'll start to pick up individual lightning flashes," said Rowland, "and then maybe once in awhile we'll see one of these TGF events lined up with a radio emission and an optical emission all close together within milliseconds of each other. We'll say that's a gamma ray flash event and study those."

The FireStation instrument is made up of three components: a set of two radio wave antennas, a collection of nine photo detectors and a gamma ray detector. The two antennas—a rabbit ear antenna and a magnetic loop antenna—measure lightning by picking up the specific audio frequencies produced by the electromagnetic fields vibrating. This can sound something like bacon frying or similar to a whistle, depending on the type of lightning, which falls within a few kilohertz range. The gamma ray detector uses a special transparent crystal that illuminates when in contact with gamma rays. The photo detectors pick up the generated light signals as evidence of possible TGFs for researchers.

"We really want to be able to say that lightning happens 60 times a second all over the world and yet the gamma ray flashes are observed at a space of something like a few times an hour, if you globally integrate the known measurements and extrapolate the known measurement," said Rowland. "So what is it about those lightning flashes that is unusual or special?"

With a bass system of thunder and a radiant show of lightning, an atmospheric party is the ultimate "see and be seen" event to study. While FireStation is a fundamental science mission, lightning research as a whole stands to help people on the ground in more ways than one. "There's lots of interest in lightning research in general," said Rowland. "If you can predict under what conditions lightning is more common or more frequent or more hazardous, you can better design your lighting protection systems and you can better design your power grid to handle lighting."

Provided by NASA/Johnson Space Center

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