VOICE-OVER: Space weather is something that our planets experiences every day. It happens when storms from the Sun affect Earth’s magnetosphere and ionosphere.

A world-wide network of observatories and institutions studies the effects of space weather.

Out in the countryside near Boston, Massachusetts, scientists at MIT’s Haystack Observatory use a variety of instruments, including radars and GPS systems to understand just what happens when the Sun stirs up a little space weather.

PHIL: Here at Haystack, we are primarily interested in measuring the space environment that is closest to Earth. We want to discover how our planet’s upper atmosphere reacts to solar wind changes and solar storms.

Our facility is an atmospheric observatory. We use radio waves to probe our planet's magnetospher, atmosphere, and ionosphere.

Cut to sequence with police officer using lidar to pull over oncoming cars.
You may have seen police officers aiming handheld ranging devices, which are either radars or lidars, at oncoming traffic. What they’re doing is bouncing off of cars --- radio waves for the case of a radar – or a laser light beam in the case of a lidar -- to see how fast those cars are moving.

At Haystack, we use our radars in a very similar way to study the ionosphere.

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Crossfade to Phil in front of Millstone Hill system.

Behind me is the Millstone Hill radar system, in operation since 1960. It’s one of several radars funded by the U.S. National Science Foundation. Millstone Hill is also part of international chain of radars built to track changes in Earth’s ionosphere.

There are two large antennas here. The first is the Millstone Hill steerable antenna. It collects radio waves, much as a telescope collects light waves. It is 46 meters across — about the length of a soccer field.

Crossfade from Phil and Millstone Hill to graphic of Earth with animated map showing range of radars.

We study the upper atmosphere over a wide range of sky by moving our antenna in the direction we want. Our range extends into northern Canada, south to Florida, east to the middle of the Atlantic Ocean, and west to Iowa.
Our other antenna is used as a zenith radar which does not move and points upwards. We use it for experiments where we want to sense the upper atmosphere, between 90 and 1,000 kilometers altitude. What we study depends on a number of factors, including time of day, season, and solar cycle.

Crossfade to radar data of atmosphere

By combining data from these two systems, we can put together a three-dimensional view of the upper atmosphere.

Crossfade to animations of how signals reach atmosphere and bounce back.

To do our experimental studies, we use a transmitter to send a radar signal up to the sky. When the signal reaches Earth’s upper atmosphere (called the ionosphere), it gets scattered by electrons. These electrons, along with ions, make up the ionosphere. Because electrons are very small, the scattered signals are very weak. So, we need large antennas to detect them.

Crossfade to data plot of signal information.

The return signals tell us about the ions and electrons in the upper atmosphere — how hot they are, how many there are, how fast they are moving, and even their chemical composition — what gases they come from. We can also tell how all these qualities change when a solar wind burst slams into our atmosphere.
The data we get provides information about conditions in the upper atmosphere.

*Crossfade sequence of data plots from upper atmosphere and models.*

Data from our observations goes into sophisticated computer models of Earth’s atmosphere. These allow us to study space weather, similar to the way that meteorologists use conventional weather radars and models.

*Crossfade to Phil in front of MISR for summary.*

Haystack Observatory has done more than 40 years of observations that are helping us understand the short- and long-term changes our planet goes through when space weather happens.

What we learn using our radars is an important part of understanding space weather.

*Closing title and credit sequence.*