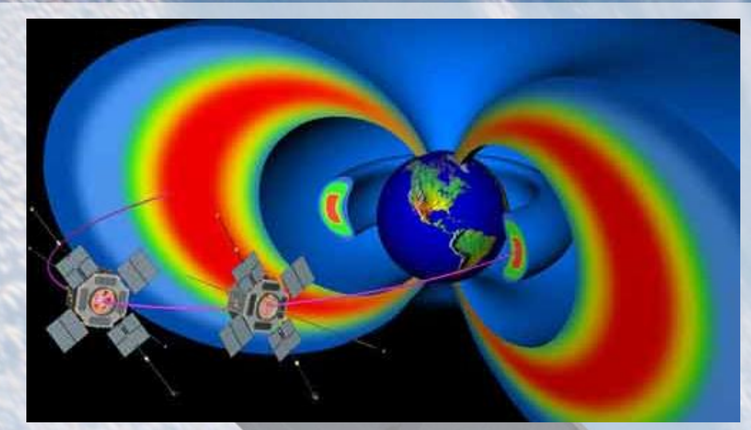
Whistler Waves in the Radiation Belt

Miles Bengtson, Sara Rosborough, Roxanna Stein

Embry-Riddle Aeronautical University, Physical Sciences Department



Van Allen Radiation Belts

The Van Allen Radiation Belts are a region in space populated by energetic particles trapped in Earth's magnetic field. These particles are a threat to spacecraft in Earth orbit, including the International Space Station the astronauts onboard. Spacecraft which frequently transit the Earth's Radiation Belts experience:

- Degradation of electronic components
- Significant surface charging
- Circuit errors

Energetic particle fluxes limit the useful lifetime of space-based systems. Under normal conditions, spacecraft can be protected from the radiation, however increases in radiation levels can shorten the lifetime of a satellite from years to months. Both natural and artificial events can increase the particle density inside the Radiation Belt significantly, endangering our assets in space.

Natural Pumping

Coronal Mass Ejections (CMEs) happen regularly on the Sun, sending large amounts of energetic particles into space. Sometimes, this dangerous radiation is directed toward the Earth. The influx of charged particles from a CME can increase the radiation levels in the Van Allen Belts by several orders of magnitude.

Artificial Pumping

Detonation of a nuclear warhead at high altitude would send many energetic (~MeV) electrons into the Earth's magnetic field , artificially pumping the Radiation Belts for many years. Radiation from the US high-altitude nuclear test Starfish Prime (1962) persisted until the 1970s and destroyed several satellites. Simulations predict that a high-altitude nuclear explosion would render many important communications, military, and intelligence satellites useless within months.

What Can Be Done?

Harden satellite

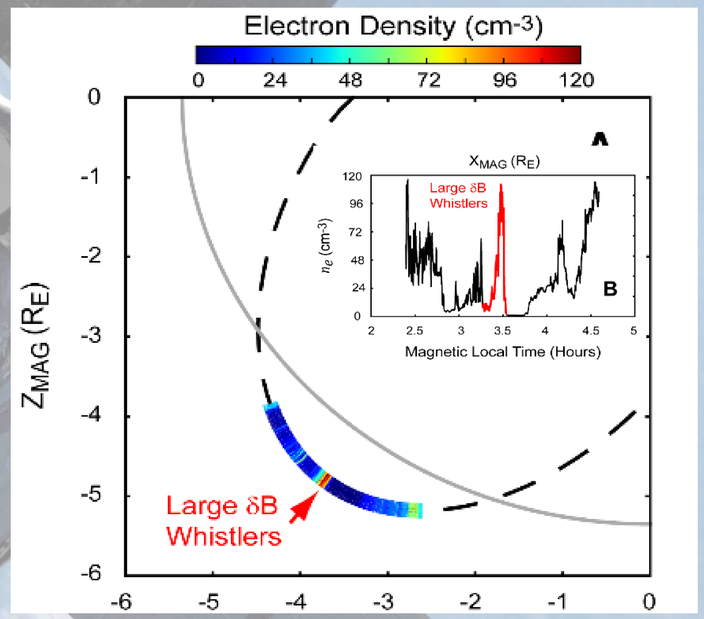
- Difficult for some functions (sun sensors, solar cells, cameras, etc)
- Significant cost and weight disadvantages

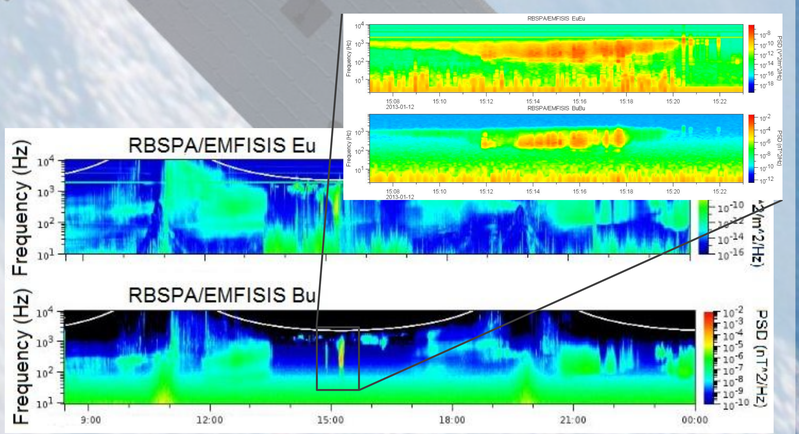
Deplete the satellite-damaging particles from the Radiation Belt

- Whistler waves can scatter particles out of the Radiation Belt
- These waves could be sent into the Radiation Belts at a reasonable cost
- Necessary science base needs formulation and definition

Whistler Waves

Whistler waves are Very-Low-Frequency electromagnetic waves (< 30 kHz) which propagate in the Radiation Belts. They can be naturally generated by lightning strikes or artificially generated by antennae, such as the HAARP array in Alaska. These waves interact with particles, causing them to precipitate into the atmosphere where they are lost. The end result is that the radiation is removed from the Radiation Belts. Whistlers waves are guided by density ducts into the magnetosphere, as seen below. Our research objective is to achieve a physical understanding of how whistler waves propagate in density ducts and how they interact efficiently with energetic particles.





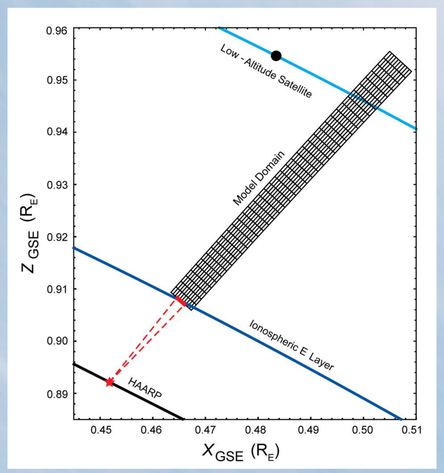
Remediation Mechanism

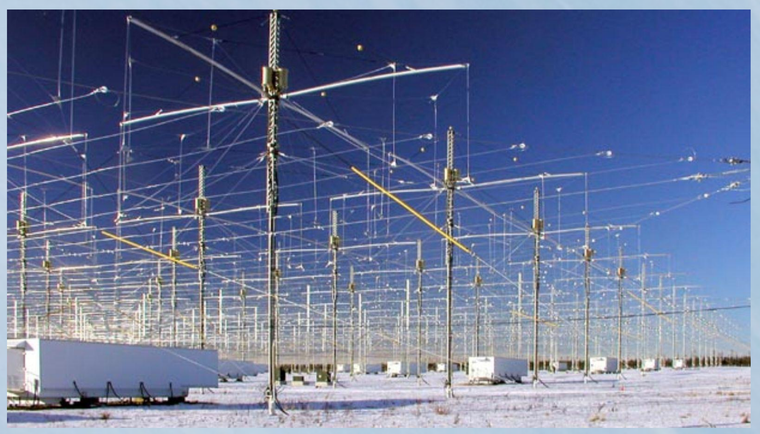
Phase 1

- Use HAARP to heat the ionospheric plasma
- This will create a density duct

Phase 2

- Use HAARP to launch whistler waves
- The waves will be guided by the duct to the region with the energetic particles
- The particles will precipitate out of the Radiation Belts





Our Research

Numerical models have been developed by Dr. Anatoly Streltsov and Dr. Jesse Woodroffe describing whistler wave physics. We need to prove that these models are accurate using actual observations from the magnetosphere. The Van Allen Probes satellites are flying in the Radiation Belts and provide lots of relevant data. Preliminary analysis shows quantitative agreement between the models and the Van Allen Probes observations.

Additional events are needed to fully validate the numerical models. Our plan is to find relevant events from the Van Allen Probes data, model them in maximum detail, and compare the results to the observations.

Our objective is to confirm that the numerical models accurately represent wave and particle physics in the magnetosphere.