ANTHROPOGENIC SPACE WEATHER

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What is Anthropogenic Space Weather ?

- Changes in the upper atmosphere or the near space environment produced by humans.

EXAMPLES

- Artificial Space Debris
- High Altitude Nuclear Explosions (HANE)
- Ionospheric Modification – from space
- Ionospheric Modification – from the ground
- Upper Atmospheric Chemical Releases

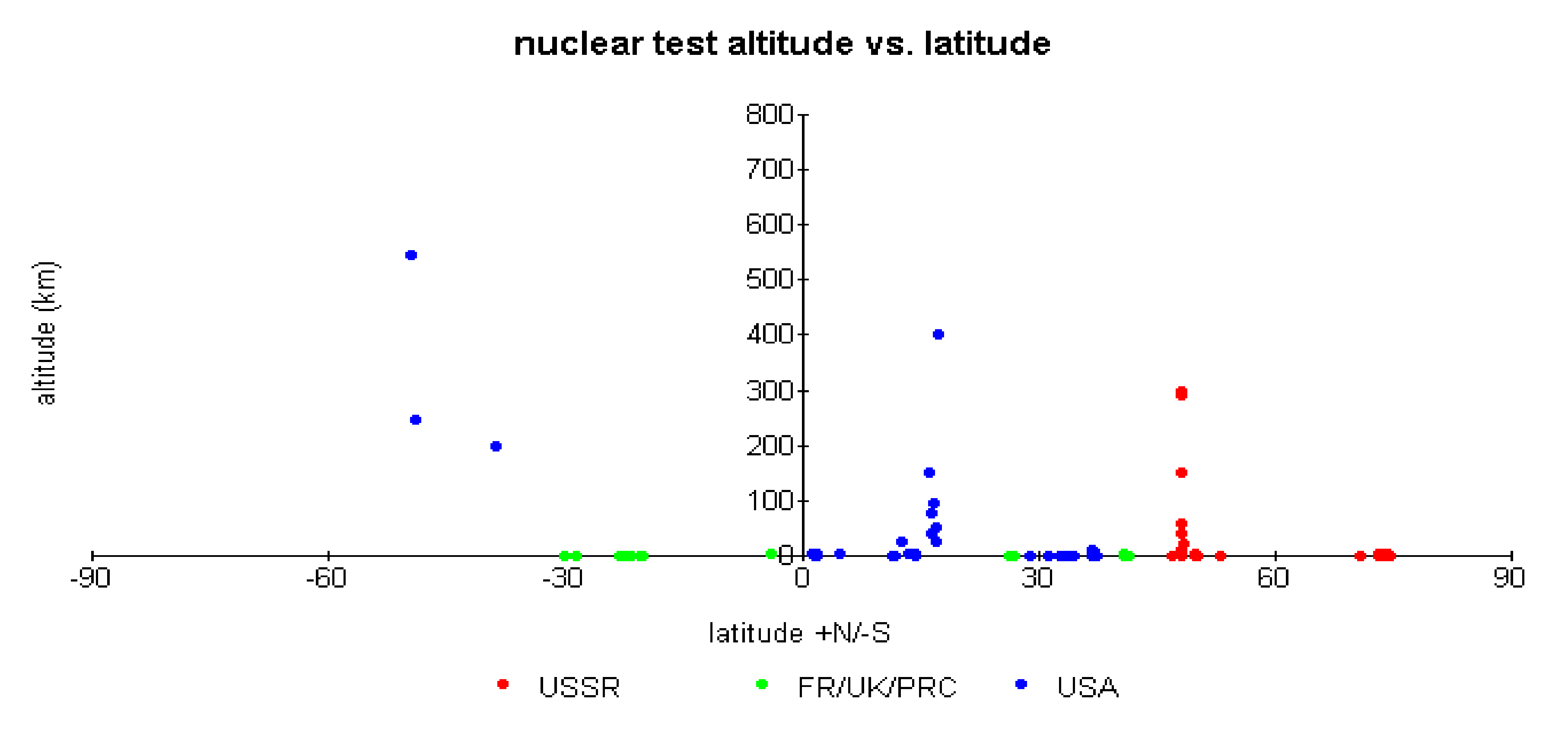
High Altitude Nuclear Explosions

A nuclear explosion above 100 km altitude and typically below 1000 km. These pose no danger to surface life but can severely damage technical systems on ground and in space, through EM and particulate radiation.

EFFECTS

- Electromagnetic Pulse (EMP)
- Ionospheric Disruption
- Global Geomagnetic Field Disturbances
- Aurora
- Immediate Nearby LEO Satellite Damage
- Increased Radiation Belts
- Delayed LEO Satellite Deterioration
- Little Effect on GEO Satellites
- Synchrotron Radio Emission

High Altitude Nuclear Explosions



Historical Atmospheric Nuclear Explosions

Exx: High Altitude Nuclear Explosion

OPERATION DOMINIC

STARFISH PRIME

Date: 9 July 1962 / 09:00:09 UT
Yield: 1.4 MT – Fusion / Fission Core
Location: Johnston Island – Mid-Pacific
Altitude: 400 Km

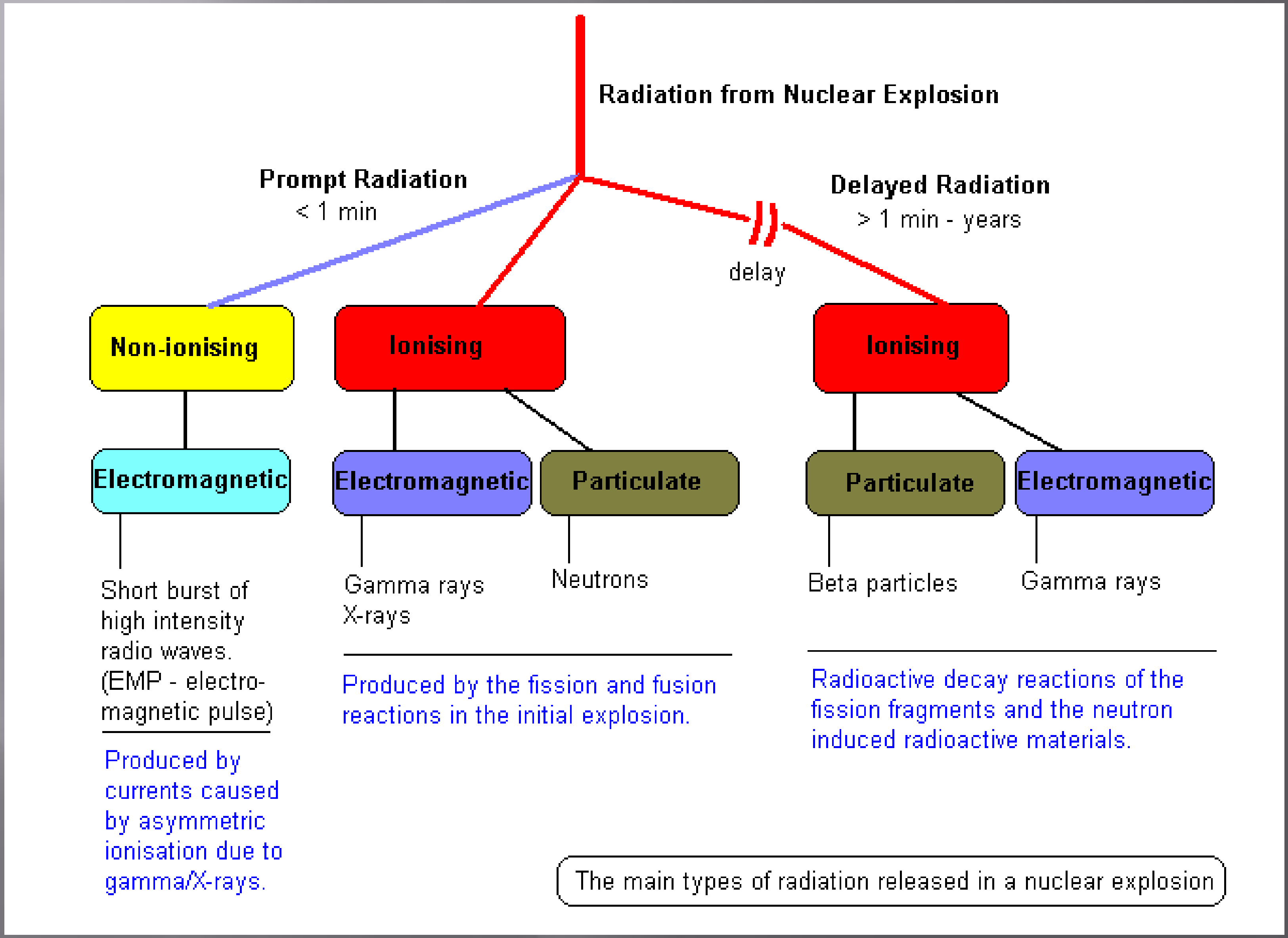
EM effects: Large electric fields (EMP) induced in long conductors on the ground. Power failures, street lighting deactivated, burglar alarms activated, telephone circuits damaged. (Hawaii)

Radiation effects: Produced a large number of high energy electrons & protons which became trapped in the Earth's magnetic field creating an intense artificial radiation belt – these lasted until the early 1970's.

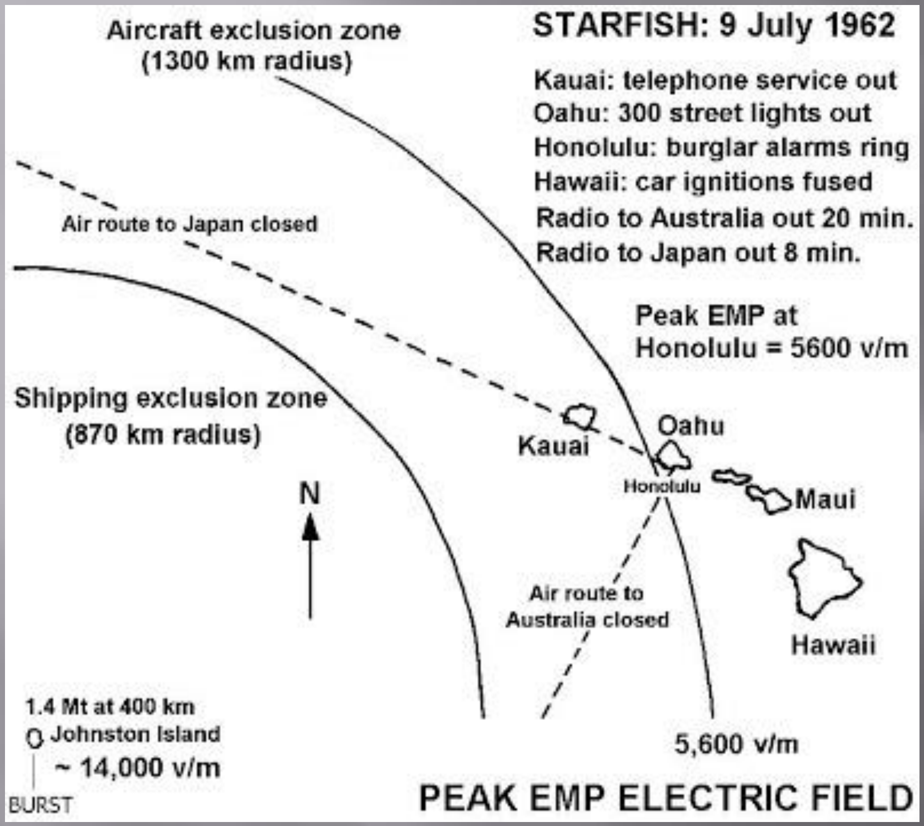
Seven satellites were destroyed within 7 months;

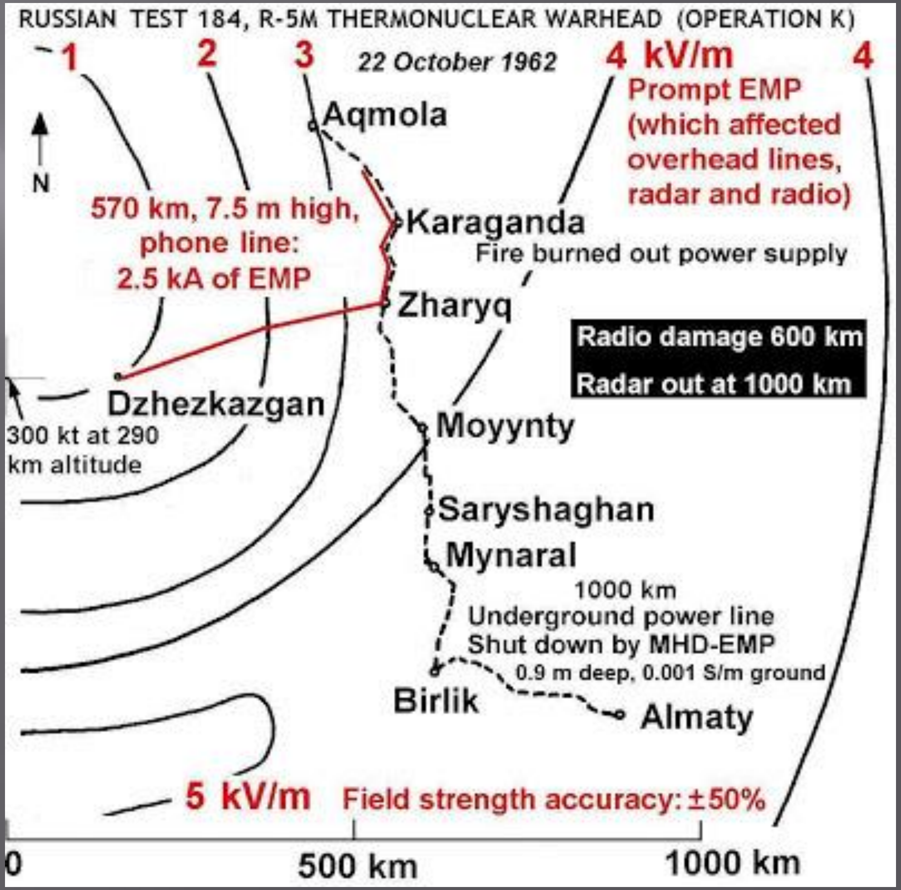
Transit 4B	Solar Cell Degradation
Traac	Solar Cell Degradation
Ariel	Solar Cell Degradation
Telstar	Command Decoder Failure

Radiation from Nuclear Explosions

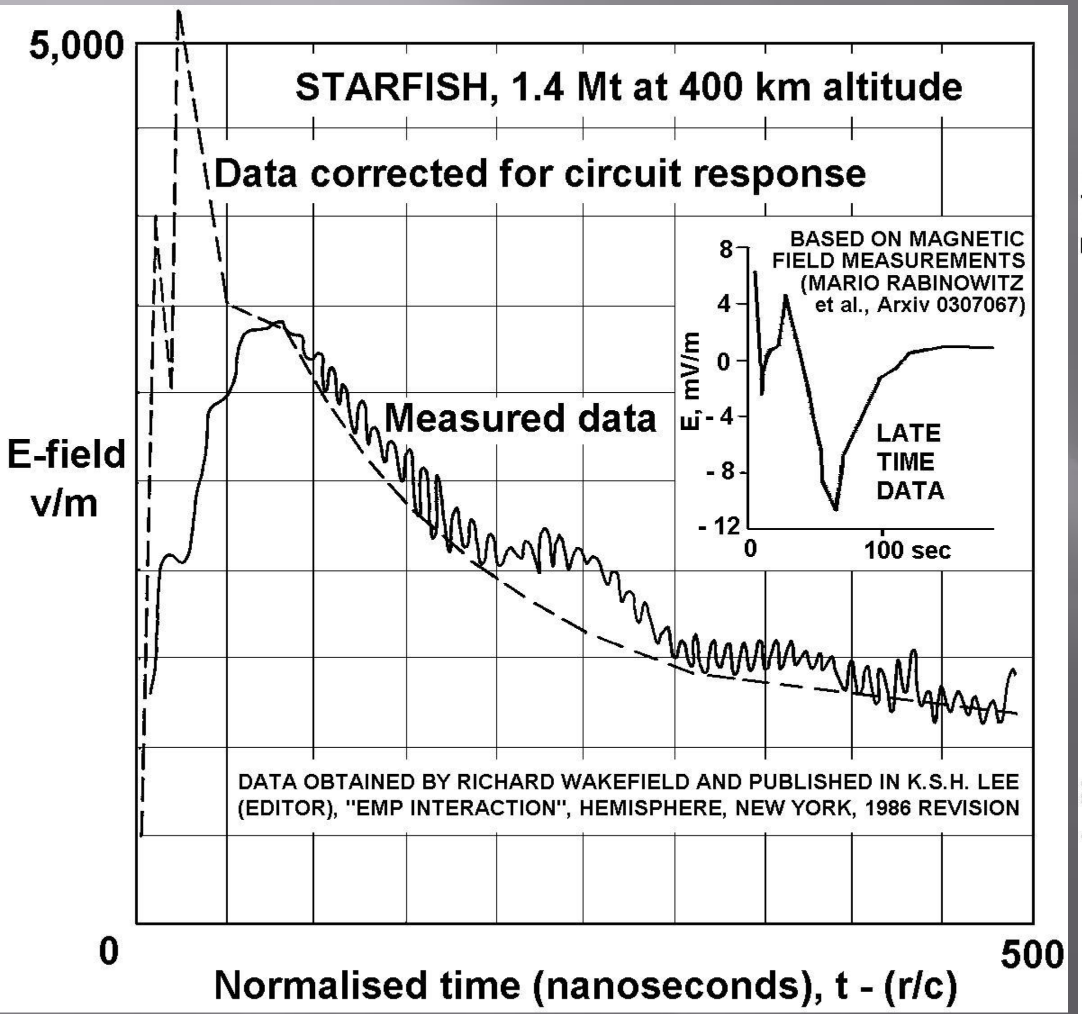


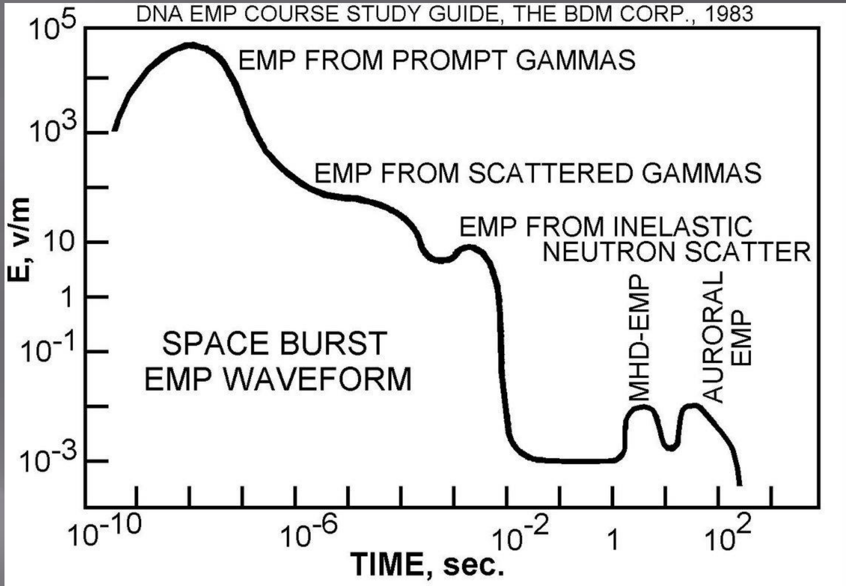
Electromagnetic Pulse

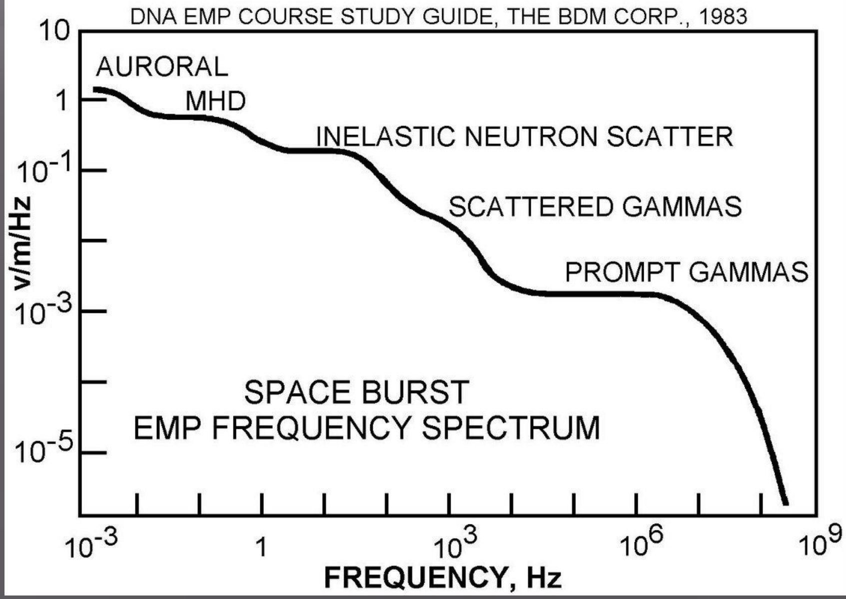




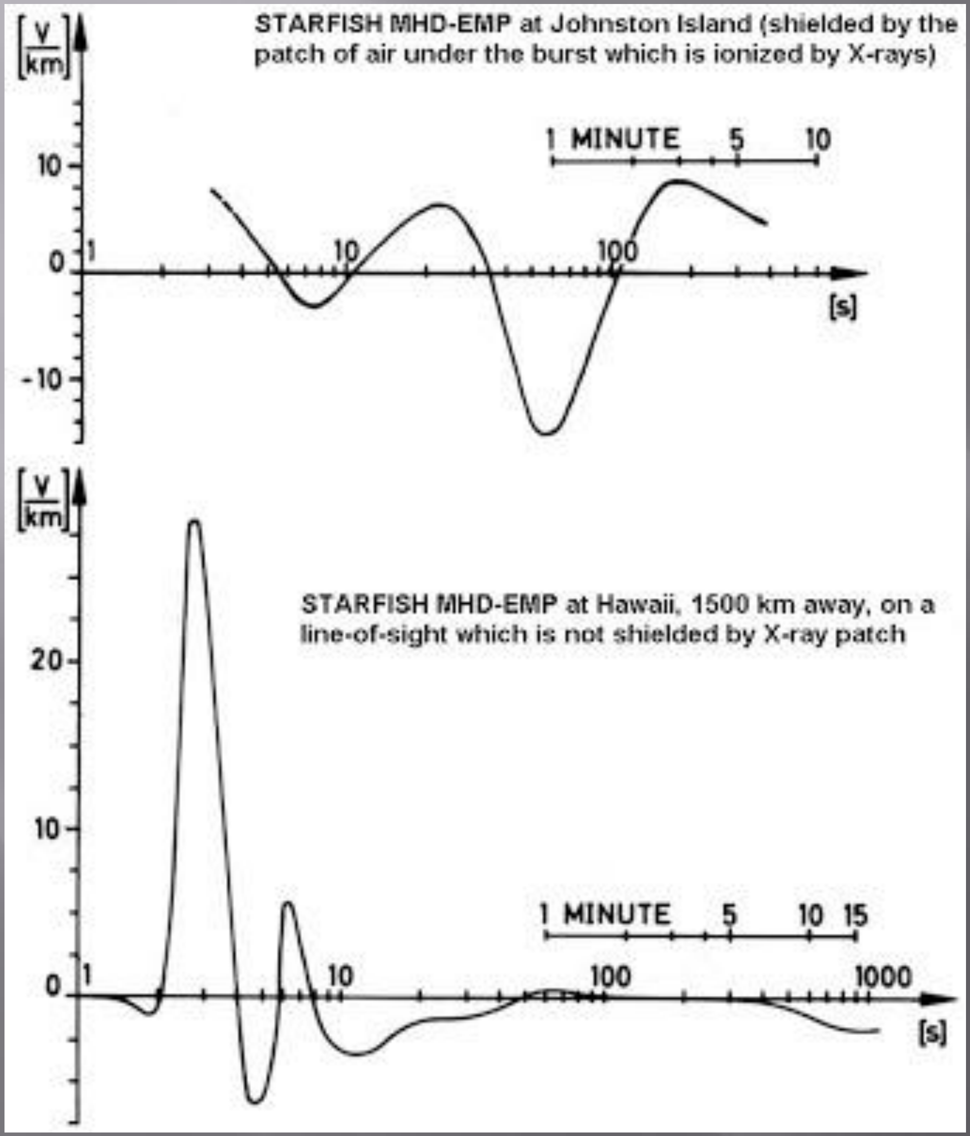
Electromagnetic Pulse





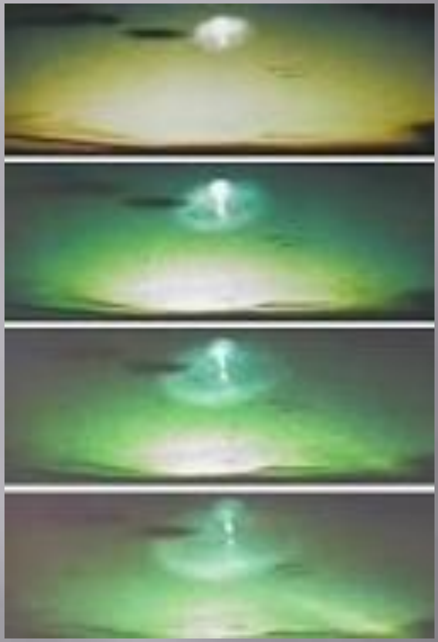


Electromagnetic Pulse



The later occurring and lower frequency EMP penetrates the ground and can cause problems in underground cables.

Ionospheric Disturbances



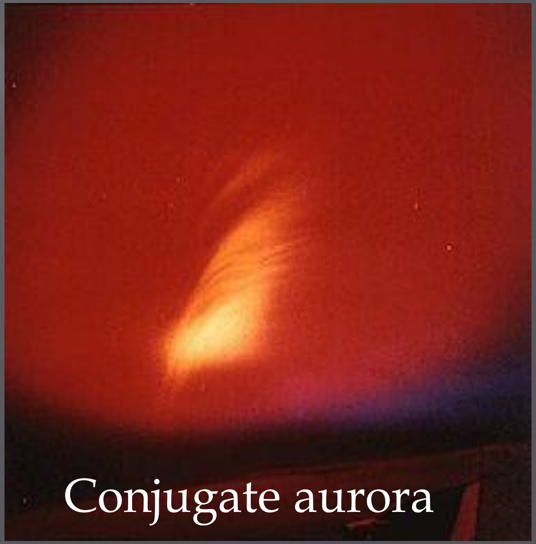
The D-region of the ionosphere suffers an immediate increase in ionisation due to prompt gamma rays and X-rays. The gamma rays penetrate to lower altitudes.

This increase in ionisation causes a “short wave fade” to frequencies up to at least 30 MHz.

At the same time there is a general increase in ionisation in the E and F layers, and OTH communication becomes possible at low VHF.

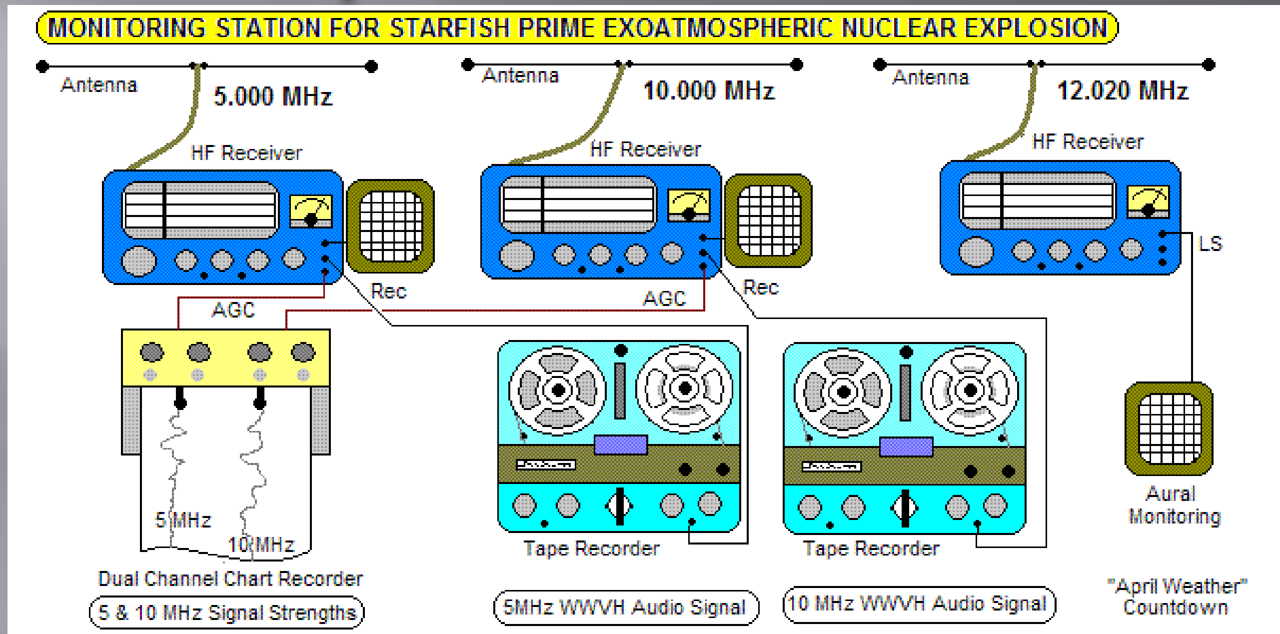
Electrons will cause later ionisation at D-region heights and below.   This recurrs at periods of an hour or so as the radiation particles move around the Earth.

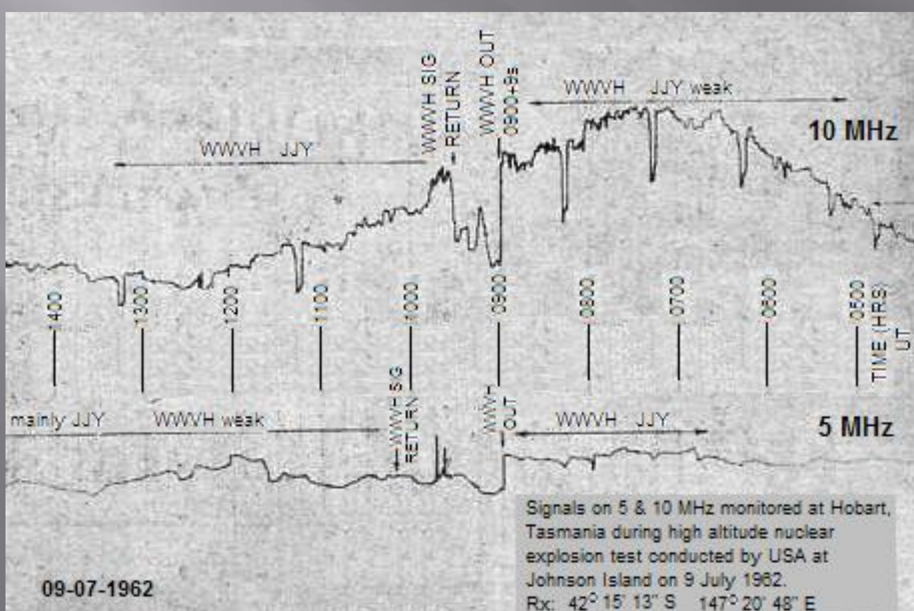
Systems affected will include HF comms and low VHF comms, OTHR, VLF comms and position errors in satellite navigation systems.



Conjugate aurora

Ionospheric Disturbances





Monitoring station set up near Hobart by Len Evans and chart record showing immediate cessation of WWVH high frequency signals due to increased D-region absorption from Starfish Prime explosion.

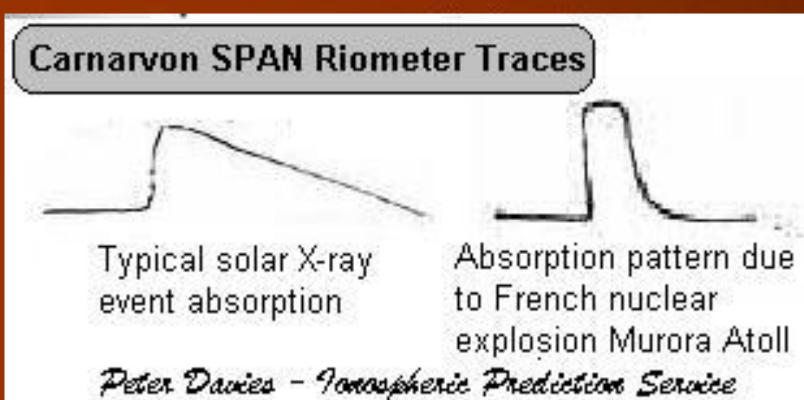
The SPAN RIOMETER

Carnarvon September 1968

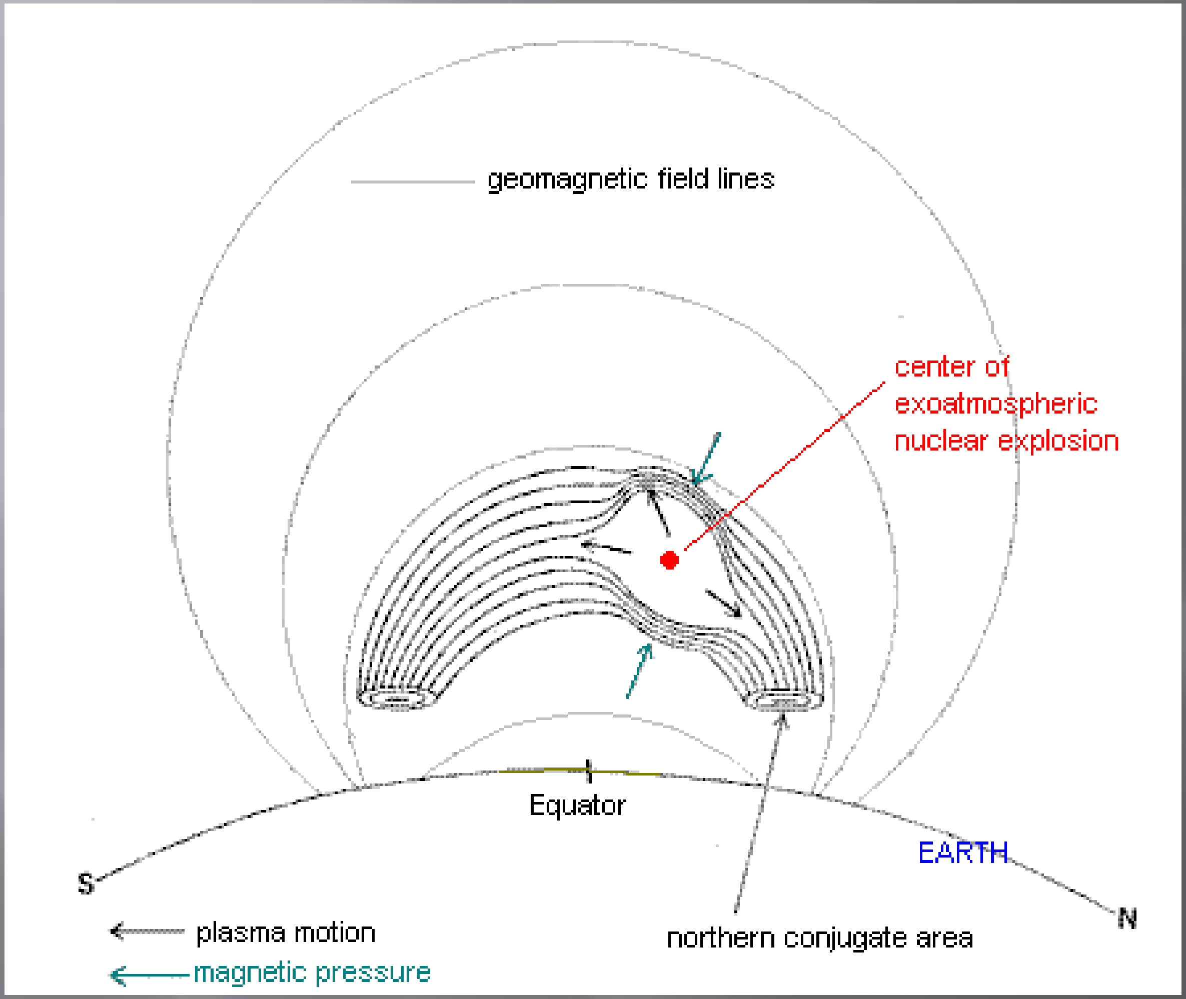
A riometer is a Relative Ionospheric Opacity Meter Using Extra-Terrestrial Electromagnetic Radiation. It is used to monitor particle precipation into the upper atmosphere.

It was included as part of SPAN to monitor radiation due to atmospheric nuclear explosions – manmade not solar radiation.

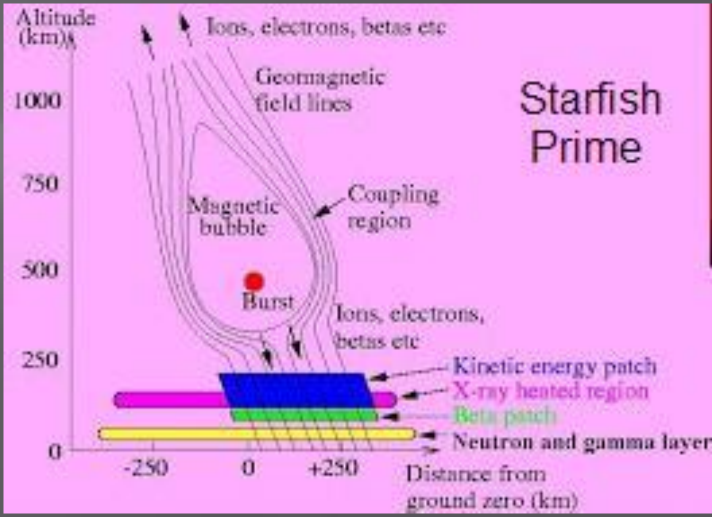
"We saw absorption on one of our riometer receivers from the French H-bomb test between 1907 and 1909 Z."



Geomagnetic Disturbances

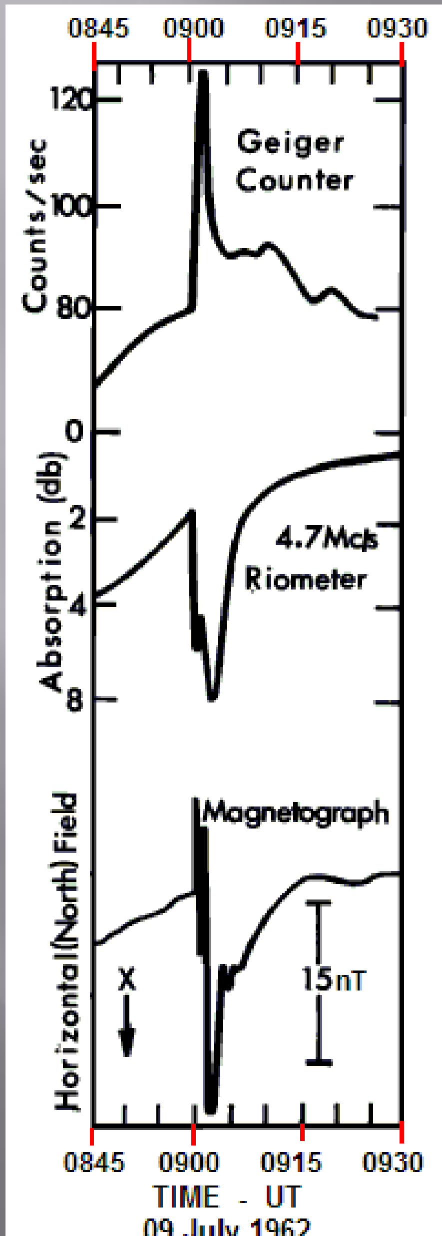


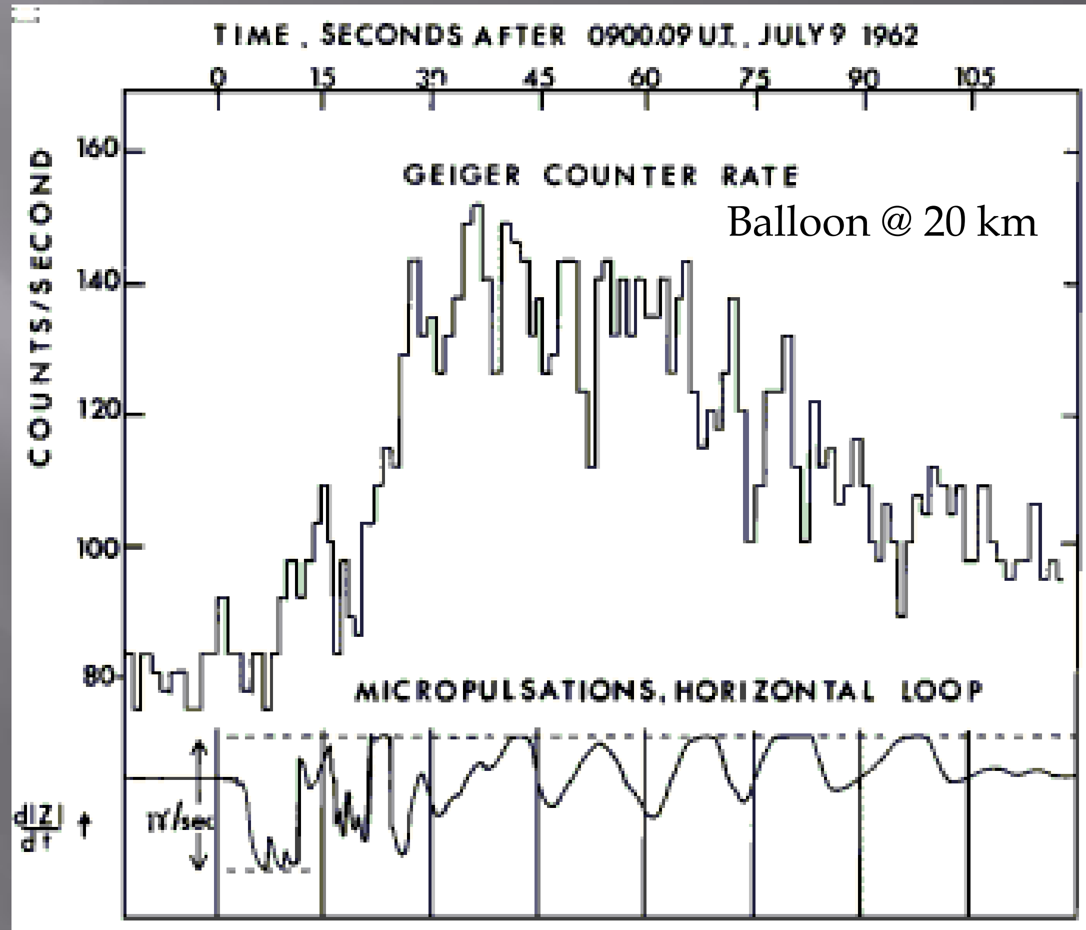
Global geomagnetic disturbances were recorded from the Starfish Prime explosion. A large volume around the explosion excludes the geomagnetic field.



The most intense field changes occur at the footprints of the magnetic field lines associated with the explosion, but significant changes are recorded at antipodal points.

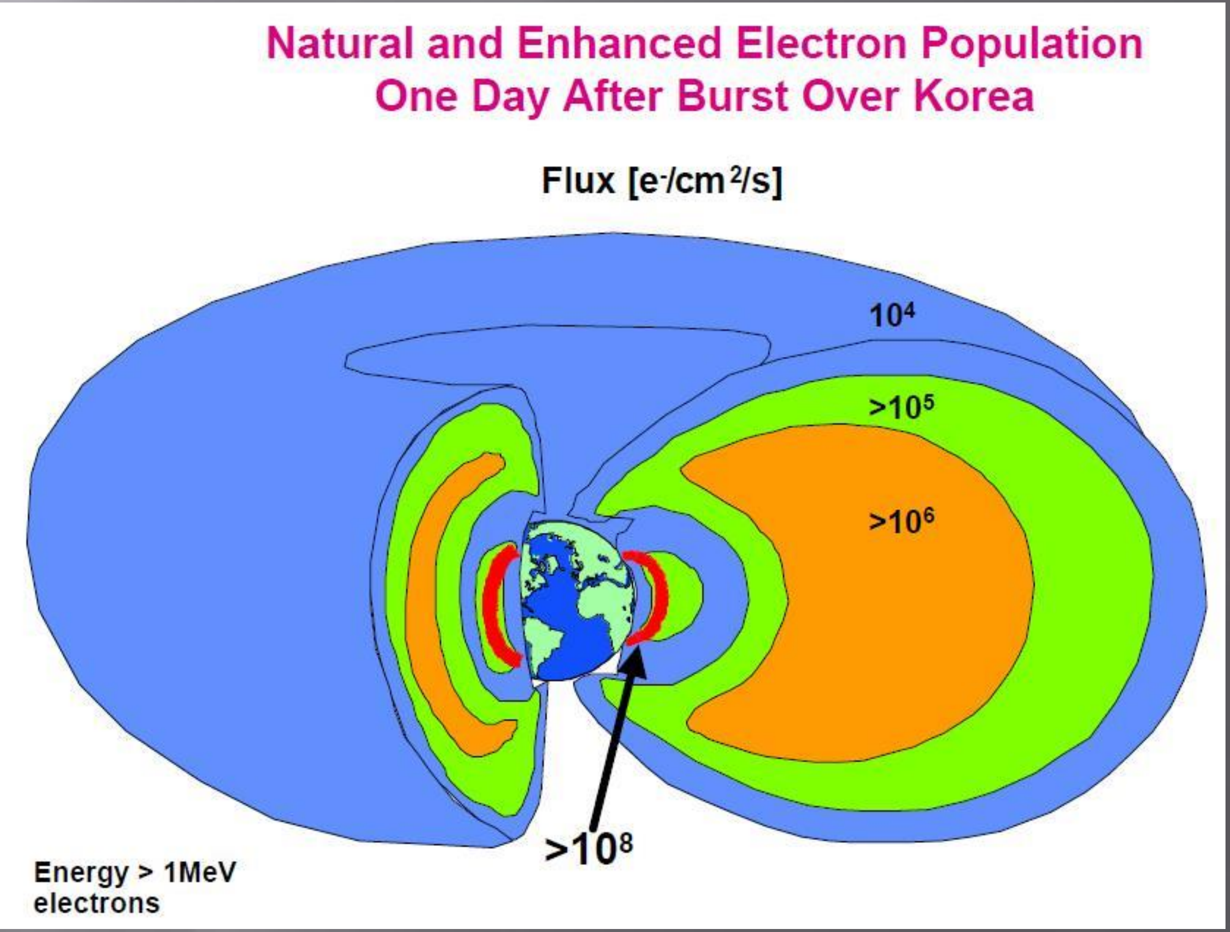
Geomagnetic Disturbances





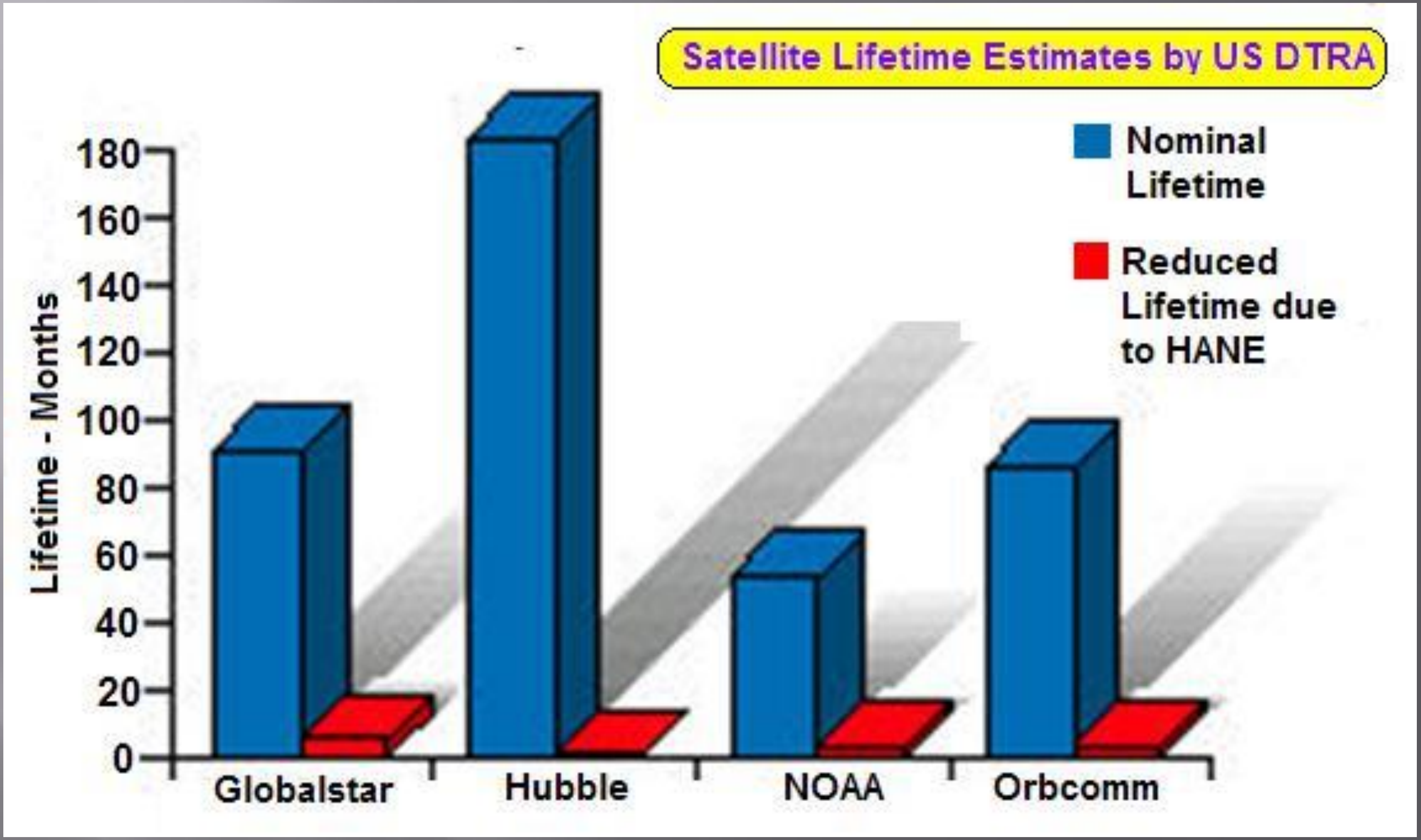
Geophysical parameters measured at Hobart following the Starfish Prime explosion. A 'mini' geomagnetic storm is apparent in the fluxgate record together with micropulsations (loop).

Radiation Belt Enhancement



Increased radiation mostly comes from decay of neutrons and fission fragments producing both high energy electrons and protons. Buildup continues for several days and poses a hazard to satellite solar panels and electronics for months

Enhanced Radiation Belt Effects

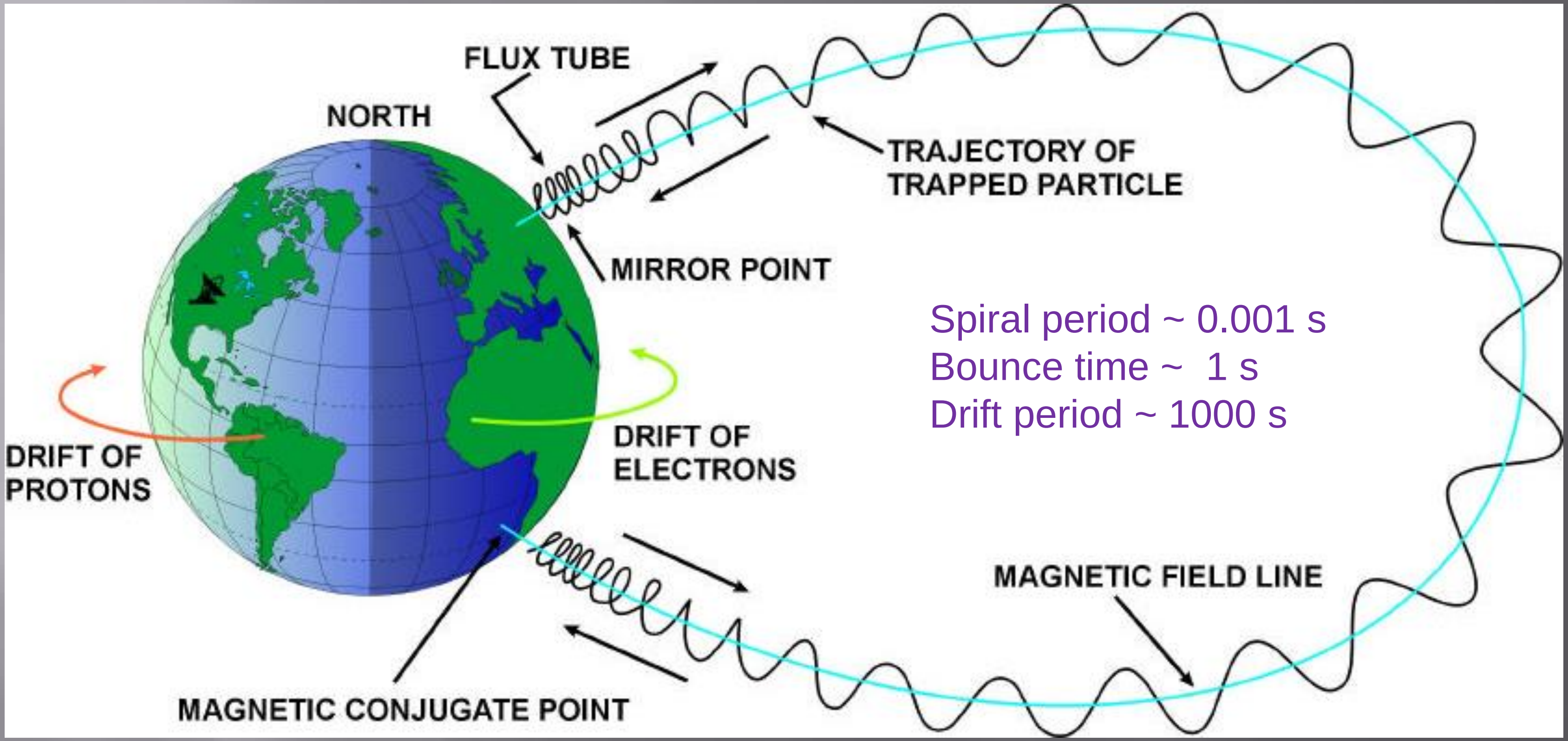


US Defence Threat Reduction Agency (DTRA) estimates that a 10-20 kT HANE would incapacitate 90% of all LEO satellites within a few months.

HANE Preparation & Mitigation

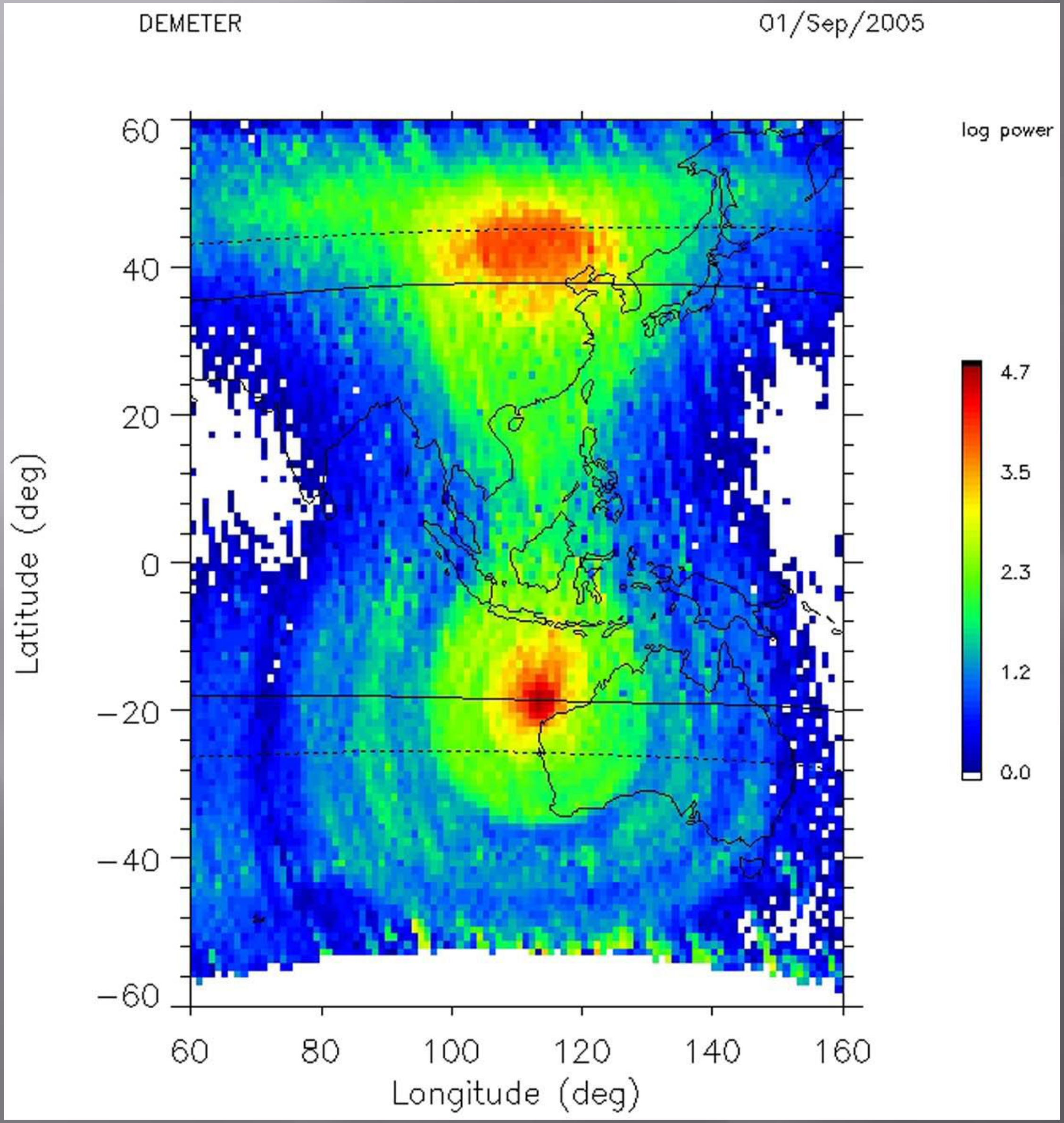
- ✓ Reinstall mid-latitude riometers and possibly SWF monitors
- ✓ Ensure forecasters know the different effects of natural and anthropogenic space weather
- ✓ EMP protection is very similar to protection against close lightning strikes
- ✓ Frequency agility is important (HF comms and OTHR)
- ✓ Do not rely solely on GNSS
- ✓ Radiation Belt Remediation (see following slides)
- ✓ Near immediate evacuation capability for any humans in orbit

Radiation Belt Remediation



The trapped particles are mostly protons and electrons. These spiral around the Earth's magnetic field lines, bounce back and forth along field lines and drift around the Earth. As the particles approach the Earth the magnetic field increases. This decreases their spiral radius, and eventually turns them around (like a magnetic mirror) and sends them back out into space. The altitude at which this occurs depends on their 'pitch' angle at the equator.

Radiation Belt Remediation



The motion of particles in radiation belts can be affected by VLF radio waves. The principal effect is to change the pitch angle of the particles and thus their reflection altitude. If this can be lowered below 100 km, the atmosphere will absorb the particles .

The right frequency and modulation causes the particles to absorb energy and move lower into the Earth’s atmosphere as they bounce between the poles. At low enough altitudes they will collide with molecules in the upper atmosphere and be removed harmlessly.

References

GENERAL

- *Glasstone*, “The Effects of Nuclear Weapons”, USGPO, 1977
- *Daniel G Dupont,* “Nuclear Explosions in Orbit”, Scientific American, June 2004

TECHNICAL

- *Herman Hoerlin,* “United States High Altitude Test Experiences”, LASL Monograph LA-6405, 1976
- *Tamas Gombosi et al,* “Anthropogenic Space Weather”, Space Science Reviews, 2017 [arXiv: 1611.03390v3]

FICTION

- *Buzz Aldrin & John Barnes, “*The Return”