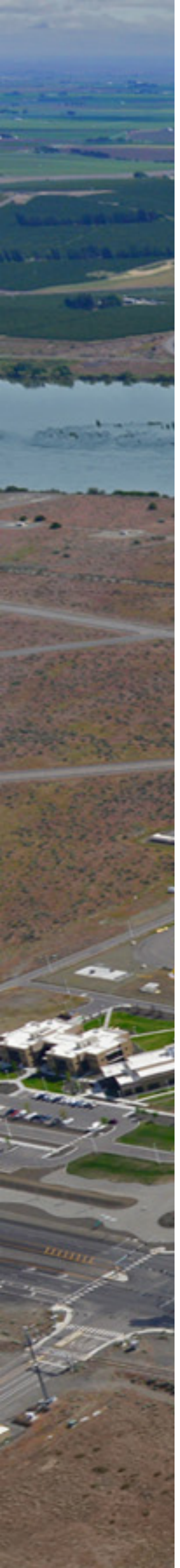

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Nuclear Explosion Monitoring: An overview of the global monitoring system

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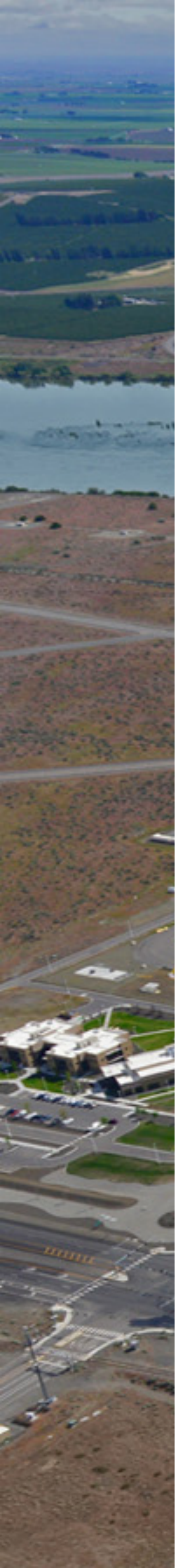
Applied Antineutrino Workshop

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy



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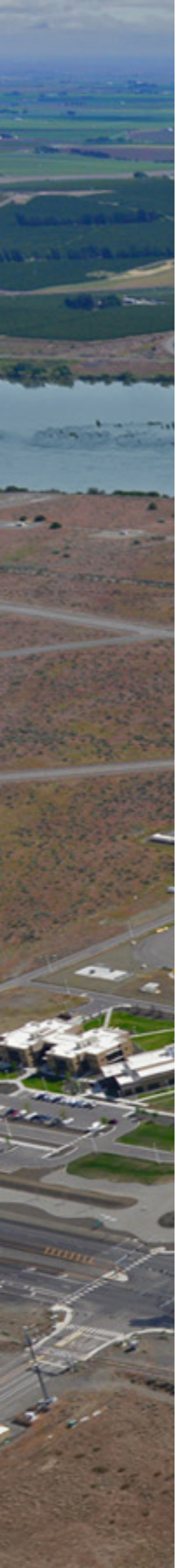
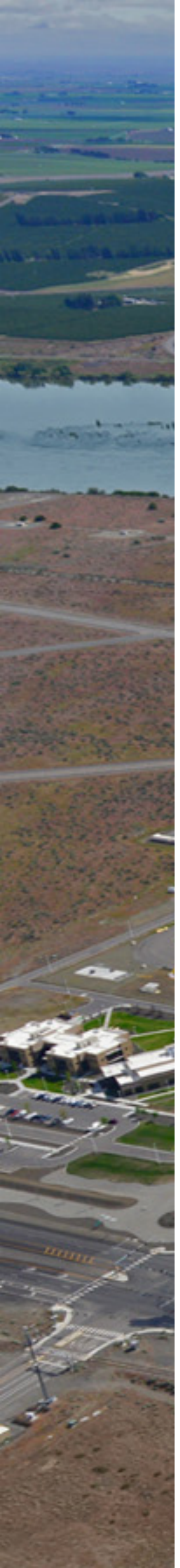


Outline

- Historical Perspective

- Nuclear explosion monitoring technologies
  - Seismic sensors (land)
  - Hydroacoustic (water)
  - Infrasound (air)
  - Radionuclide
    - ✓ Particulate
    - ✓ Noble Gas

- Monitoring Criteria



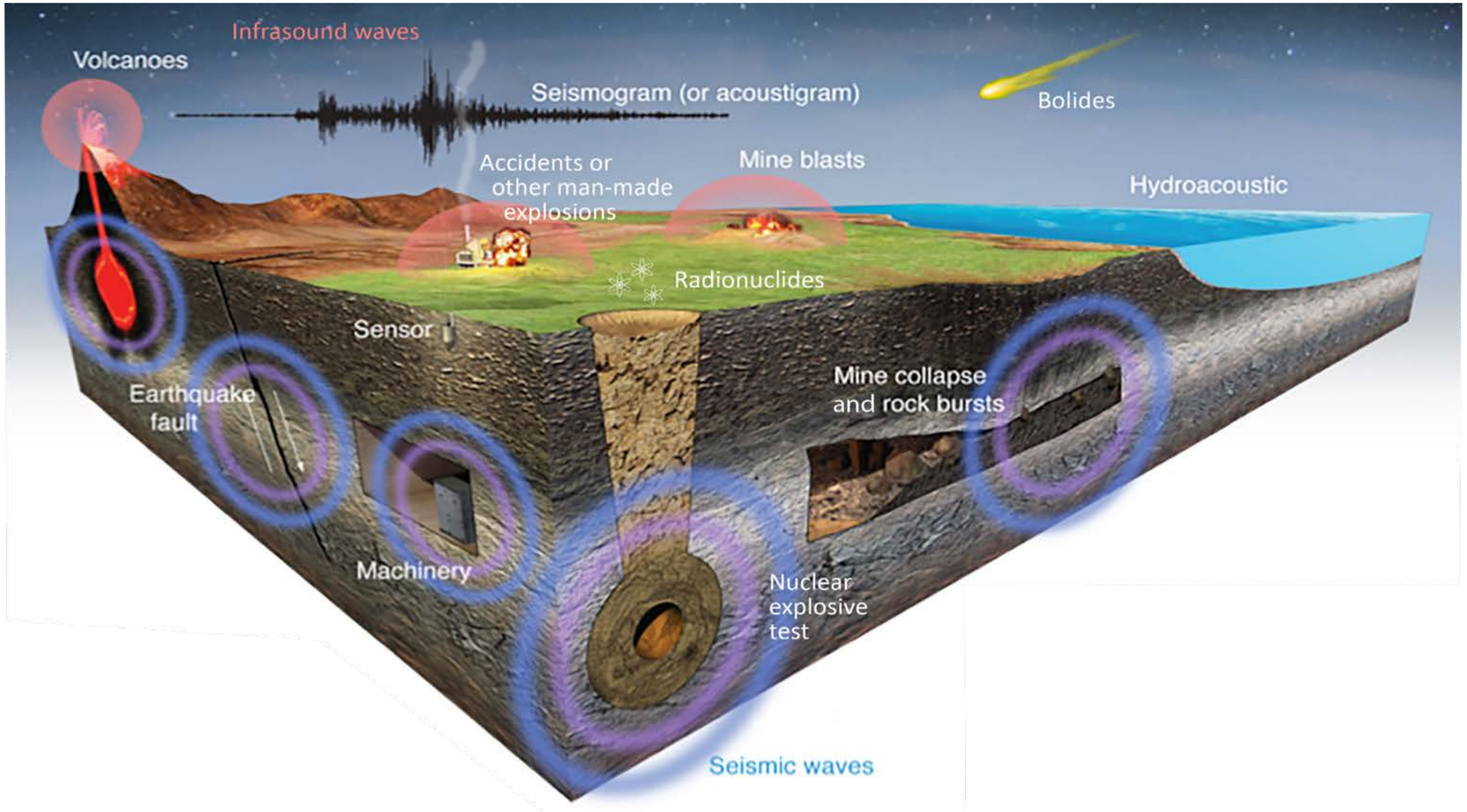
PNNL Nuclear Explosion Monitoring Program

- History of program dates back to the Hanford Pu production mission and environment measurements associated with it
  - A nuclear explosion monitoring program was born

- The “modern” PNNL nuclear explosion monitoring program began in mid-1992
  - ✓ Operation of the U.S. Certified Radionuclide Laboratory, RL-16
  - ✓ Development of the particulate and noble gas monitoring systems
    - IMS technologies
  - ✓ Technology for radionuclide detection
  - ✓ Xenon International

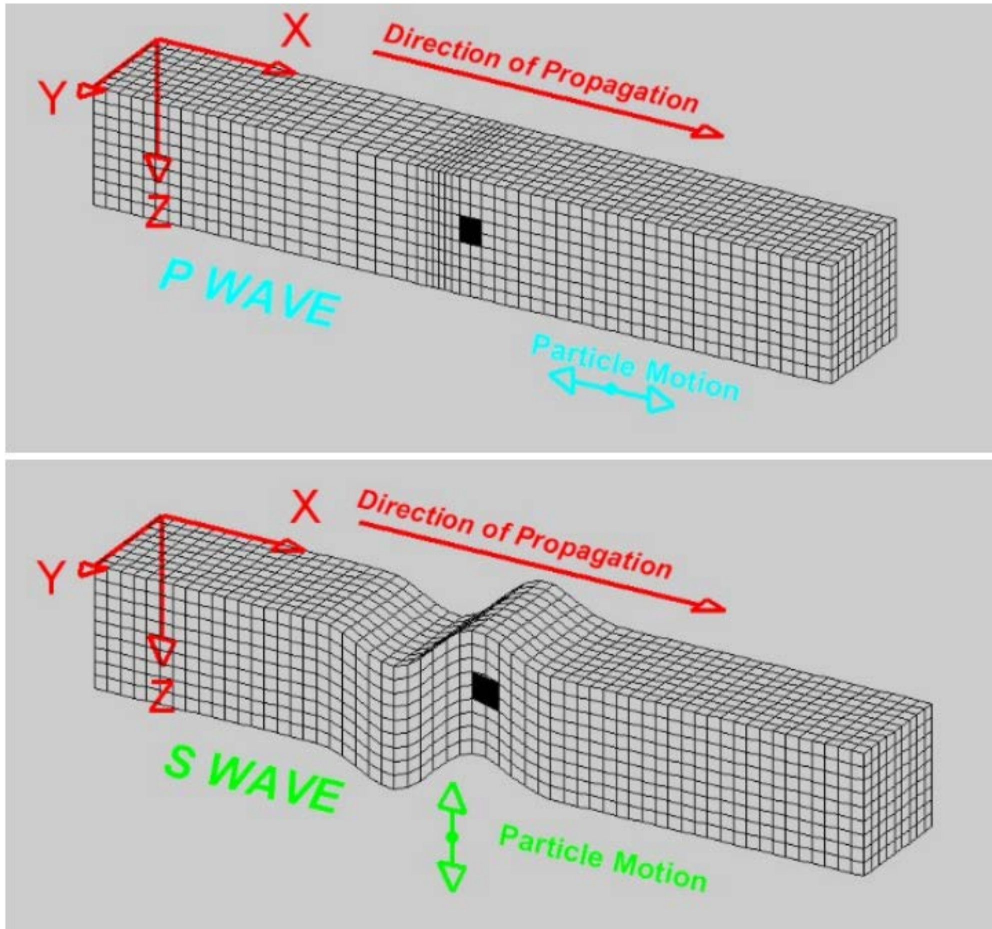
Nuclear Explosion Monitoring Overview

- Total International Monitoring System cost is ~$1B with a ~$100M operating cost per year



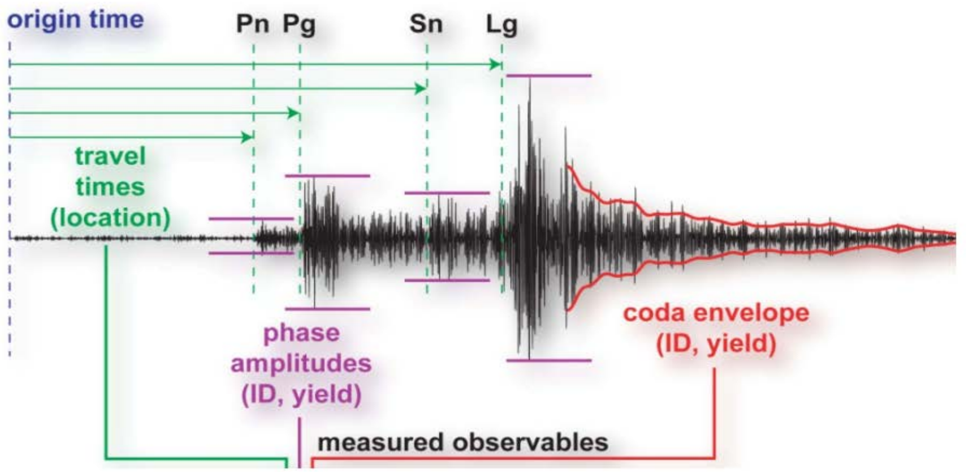
Seismic Overview

- Seismic sensors around the world detect motion geologic motion
  - Focus on P-waves and S-waves

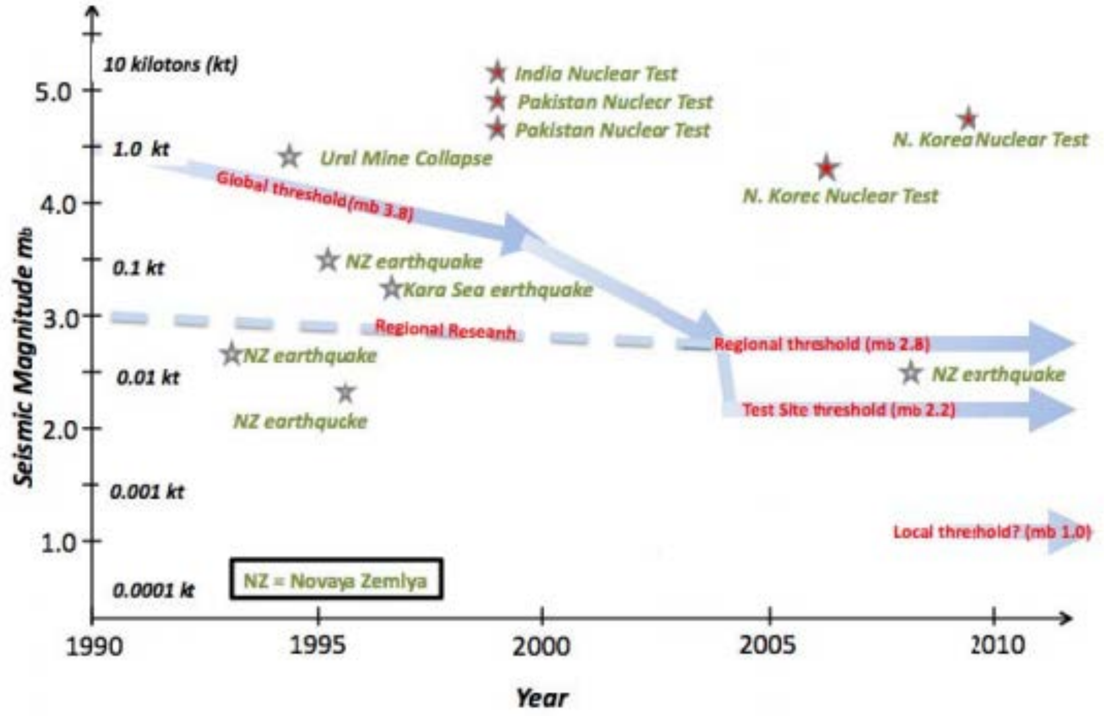


Seismic Capabilities

- The large network of 170 seismic sensors allows for:
  - Event identification
  - Characterization (earthquake versus explosion)
  - Additional sensors are operated throughout the world to monitor for earthquakes (USGS)

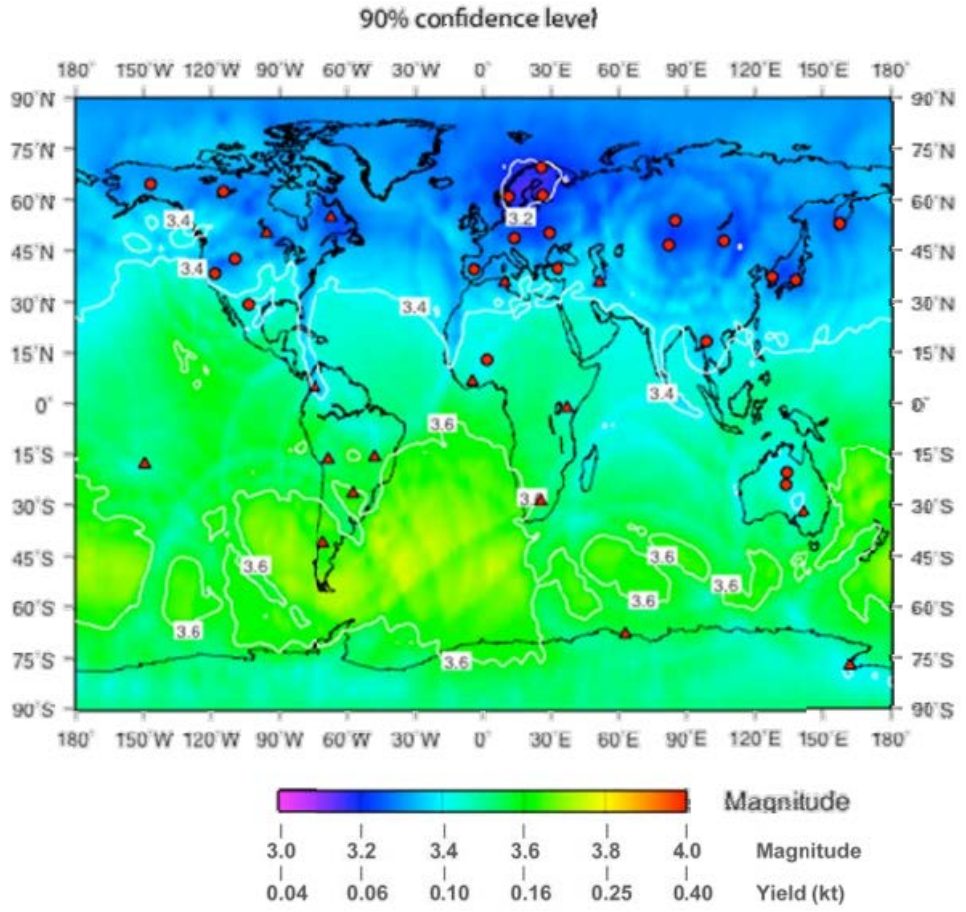


$$mb = 3.92 + 0.81 \log W \text{ (NTS)}$$
$$mb = 4.45 + 0.75 \log W \text{ (Semi)}$$

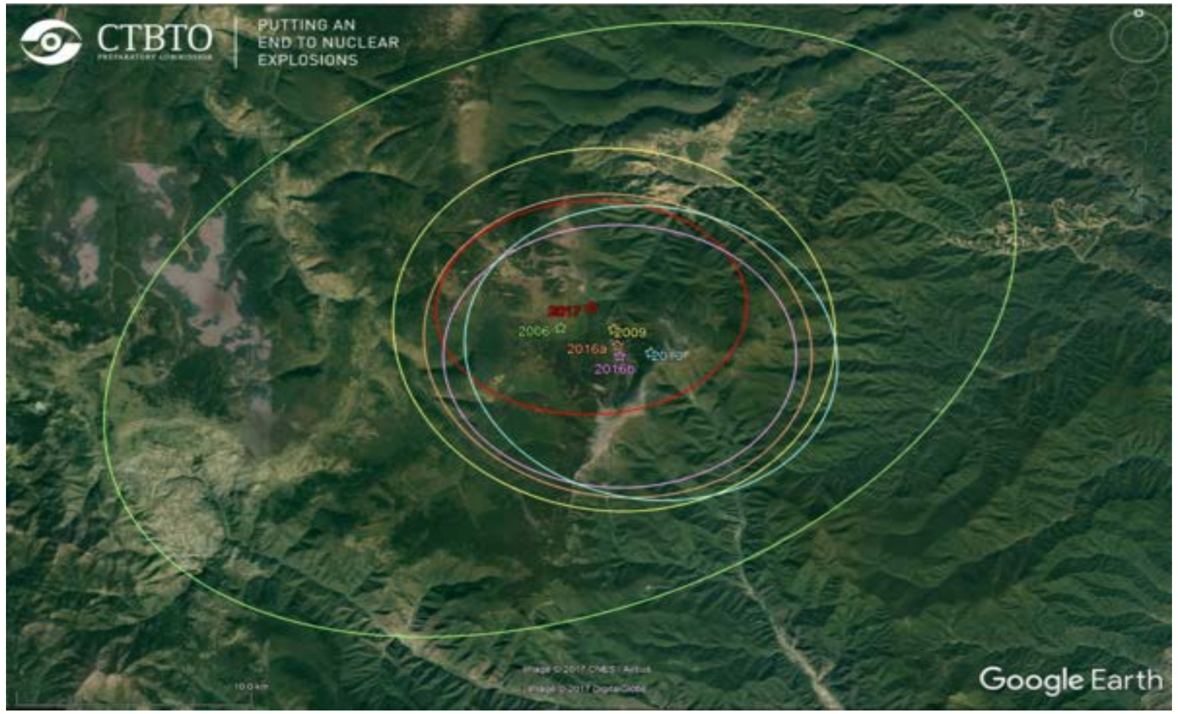


Seismic Capabilities

- The use of multiple seismic sensors for event characterization also allows for a location determination



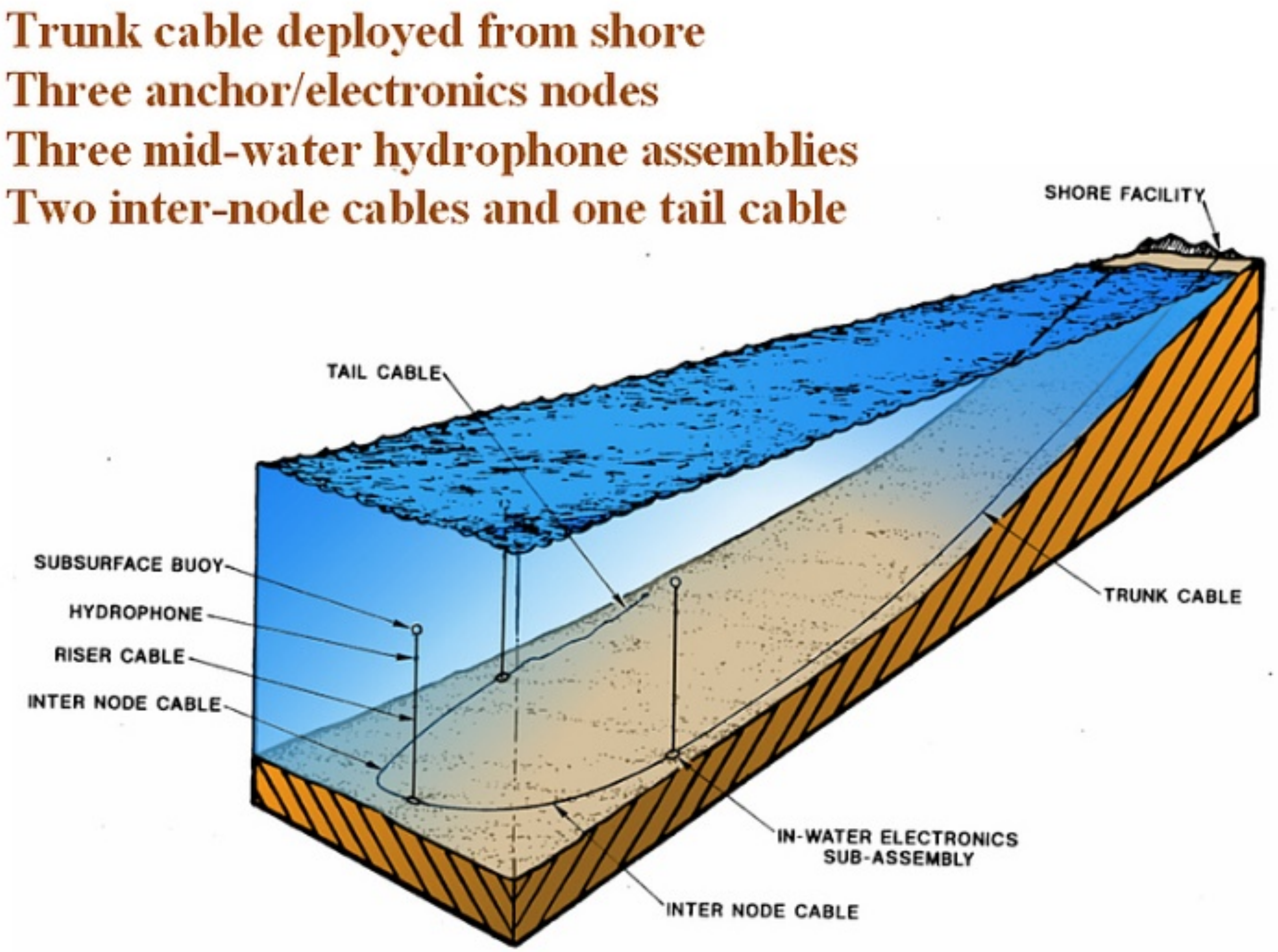
Global detection threshold of ~0.5 kT



The error ellipse (red) has shrunken to +/- 6.7 km or 109 km^2

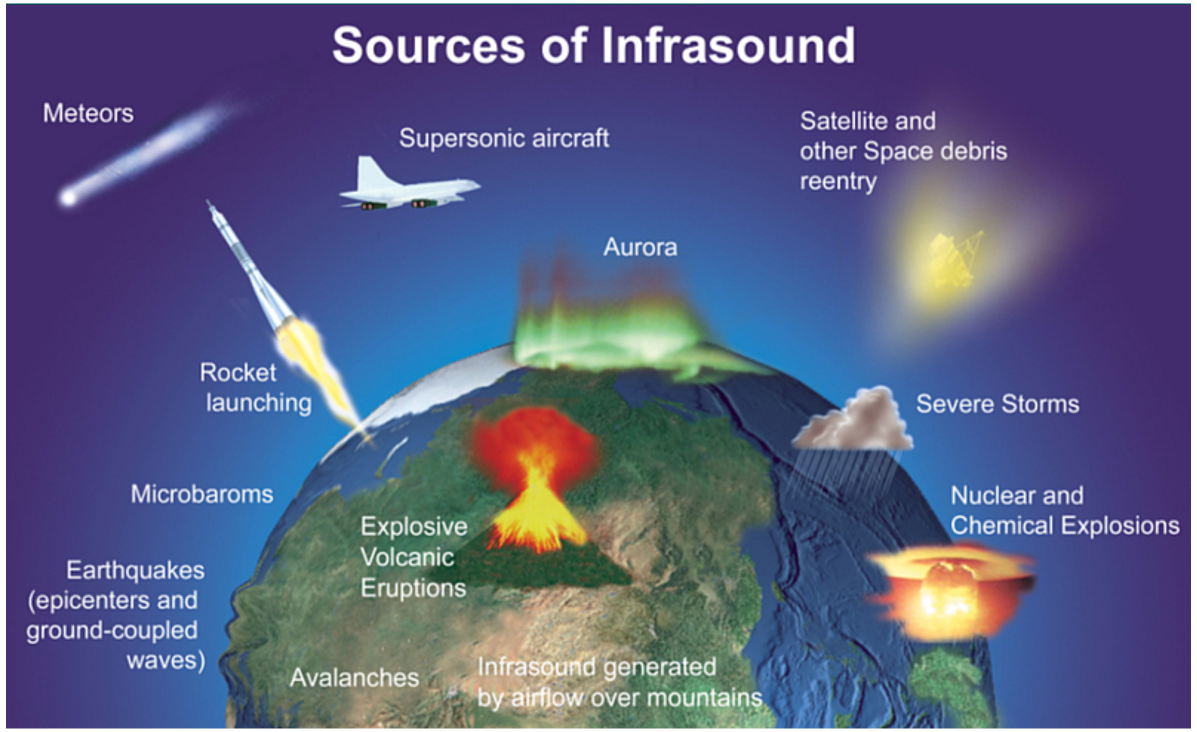
Hydroacoustic Overview

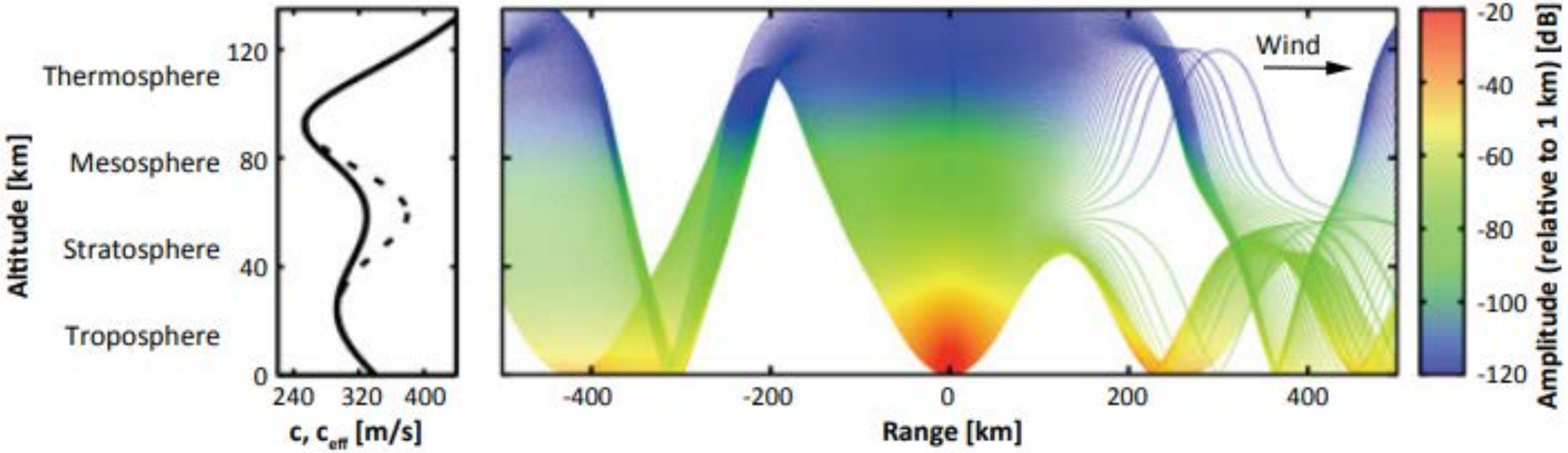
- Only 11 stations are required to monitor around the world
  - Sound waves propagate efficiently through the water



Infrasound Overview

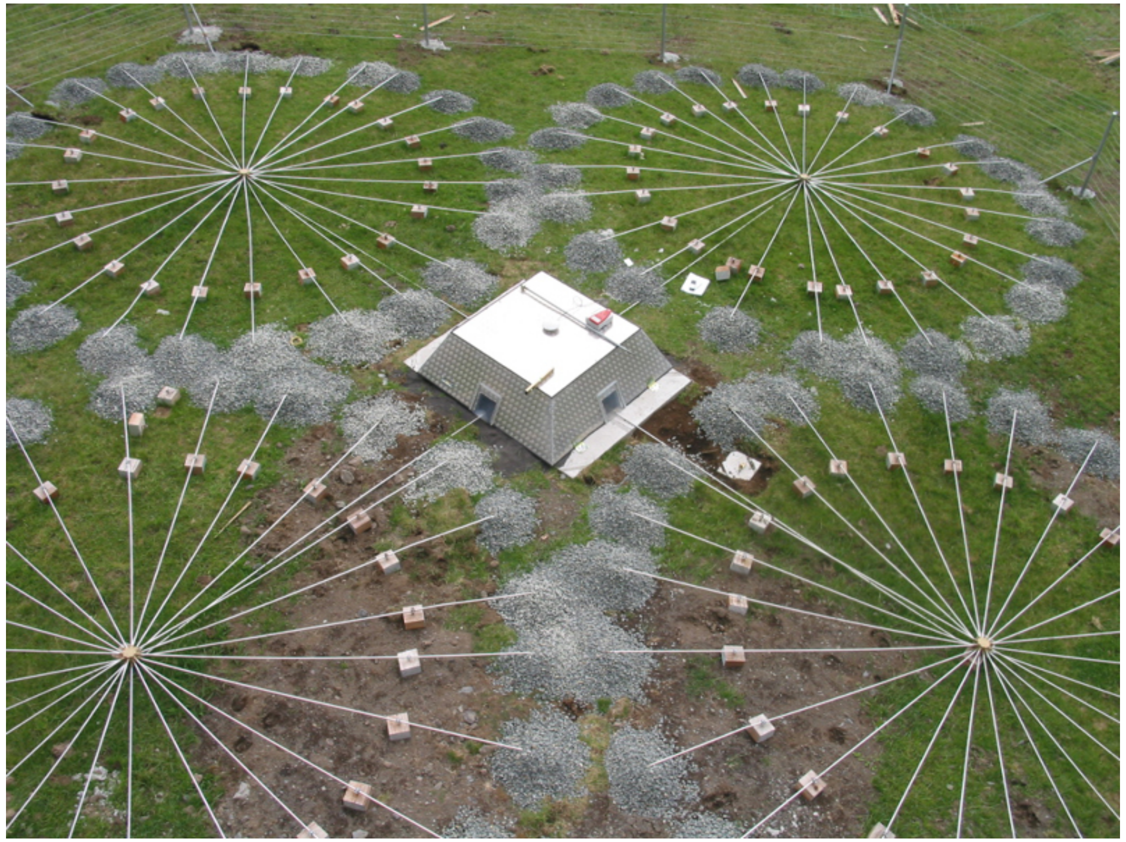
- Monitoring for the (small)pressure waves that travel throughout the atmosphere from an explosion
- 60 stations around the world

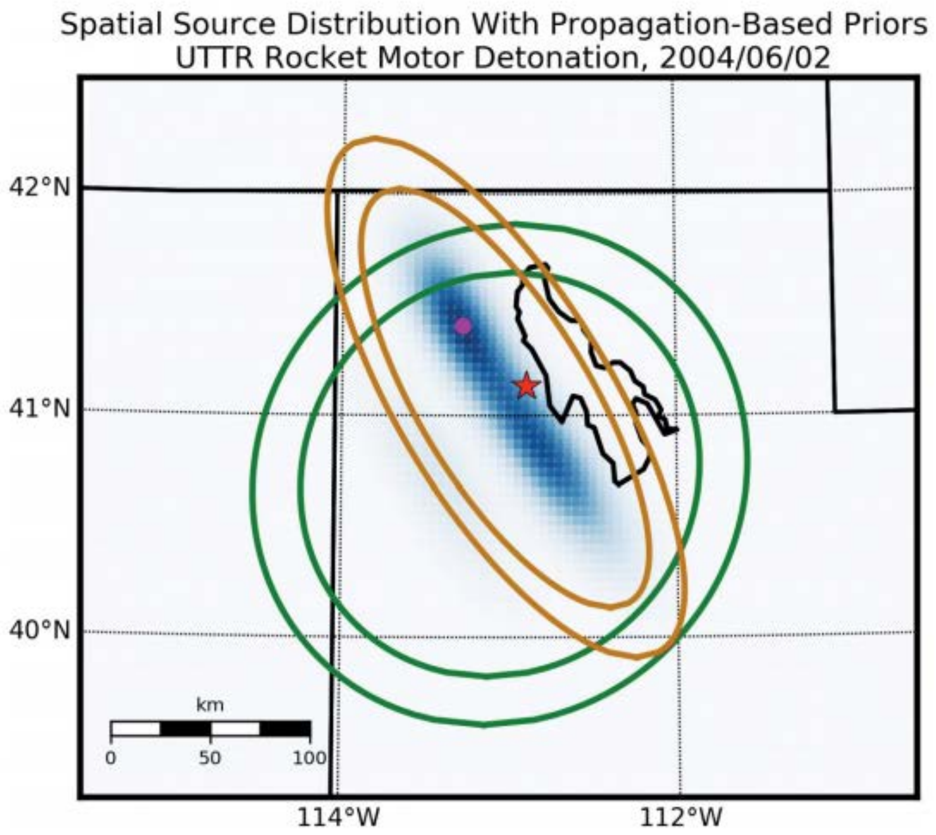




Infrasound Capabilities

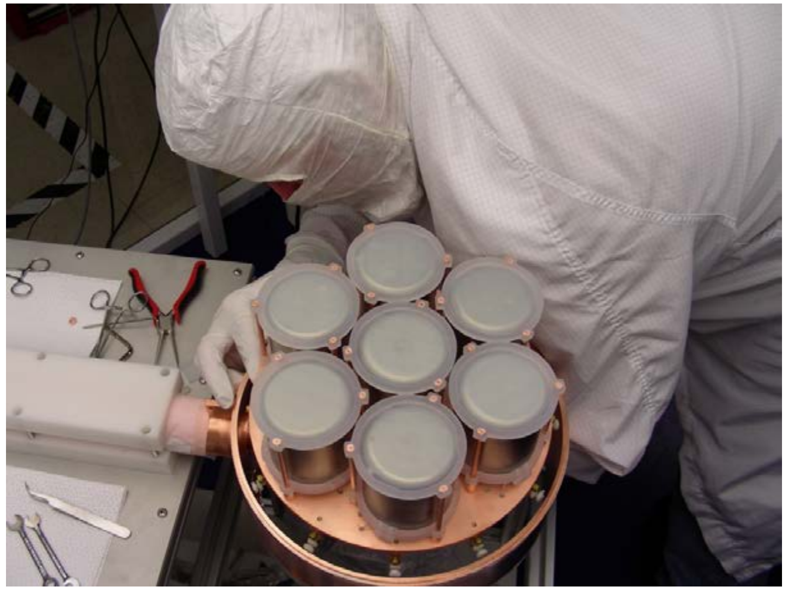
- Infrasound can be used for location of the explosion event
  - Generally seismic does a better job, but the combination of infrasound and seismic could further improve the localization

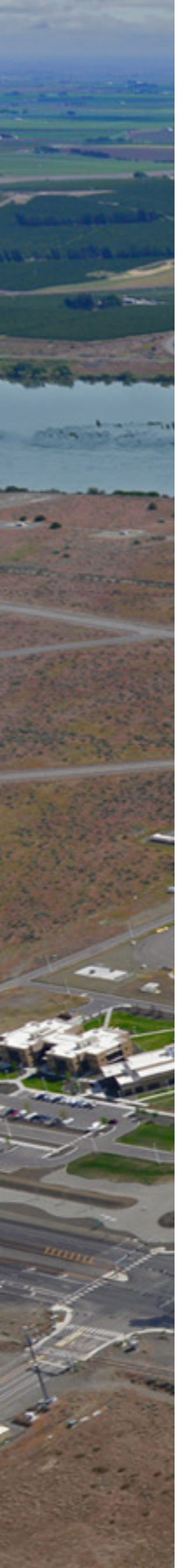




Radionuclide Particulate Overview

- 80 Stations around the world that collect particulate with air filters
- Minimum Detectable Concentrations of order $\mu Bq/m^3$ levels
- Samples are routinely reanalyzed in the laboratory environment





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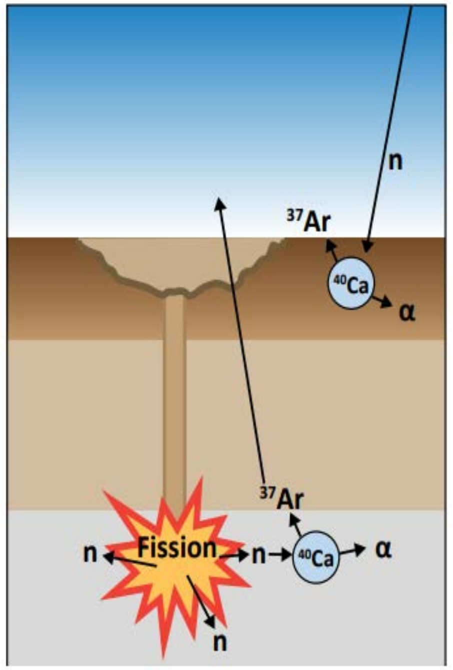
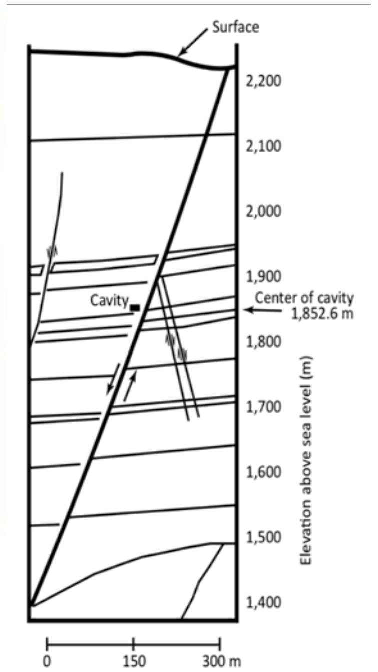
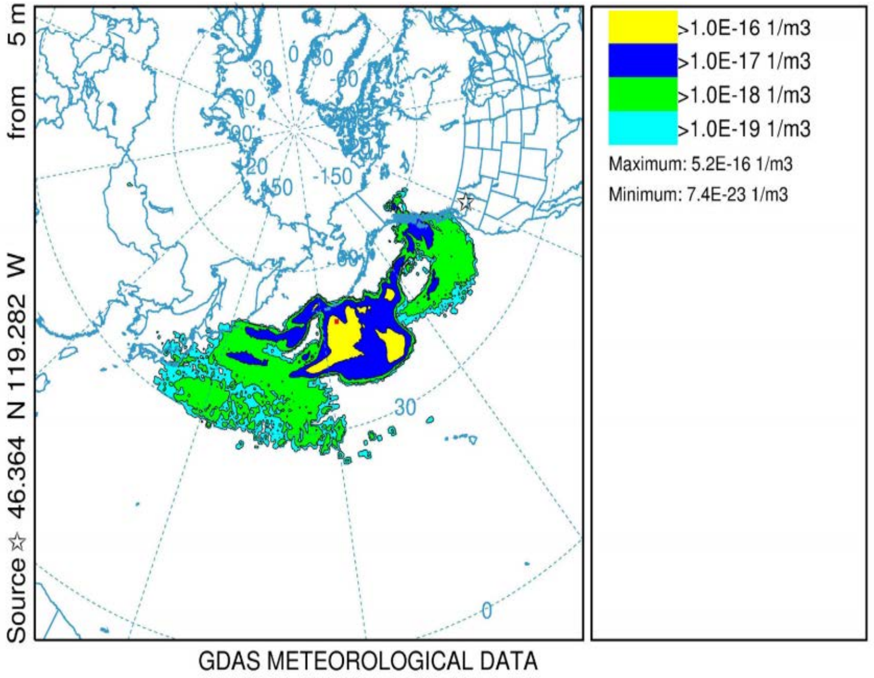
Radionuclide Noble Gas Overview

- Radioxenon is produced during the fission process
  - Escapes the underground explosion via fractures
  - Transported through the atmosphere
  - Detected via automated detection systems
  - Can be re-measured by a network of laboratory systems
- Radioargon would be looked for during a site inspection

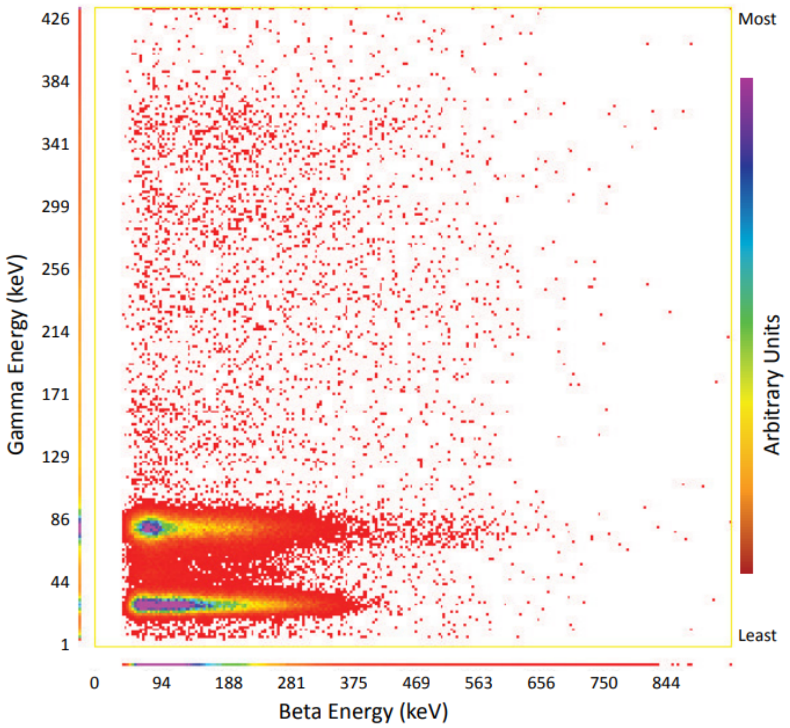


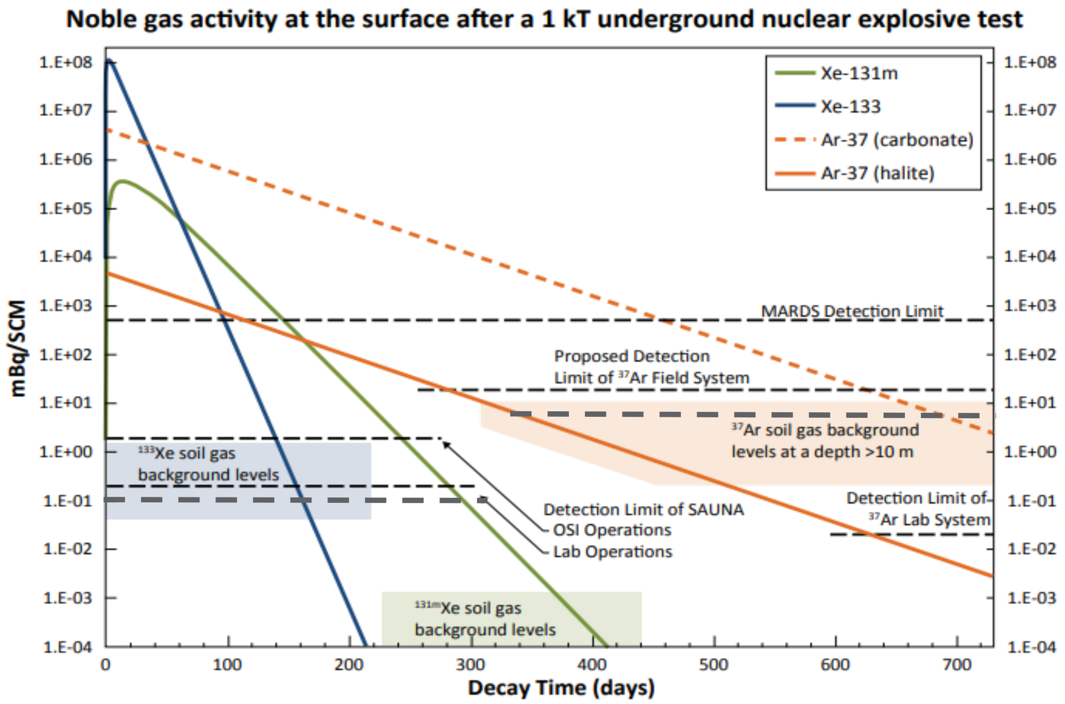


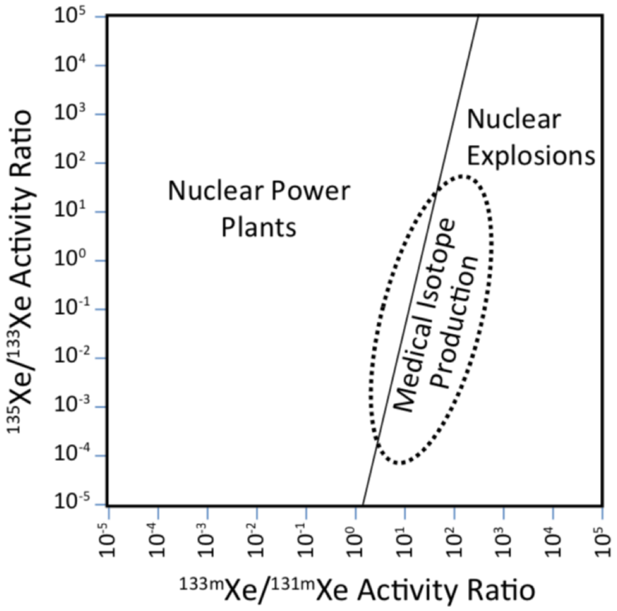


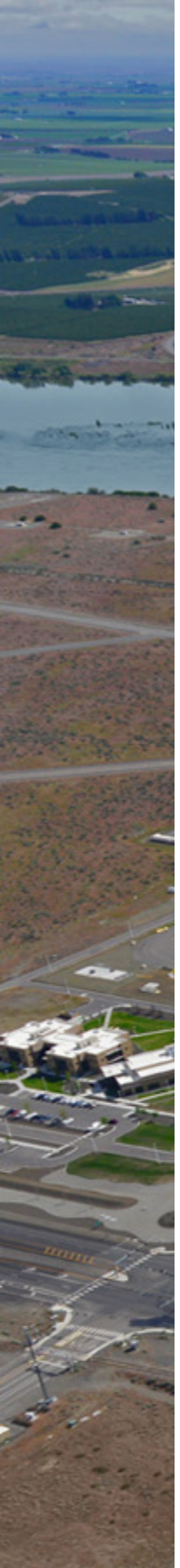
Radionuclide Noble Gas Capabilities

- 40 Stations around the world that collect gas and extract the xenon (87 ppb)
- Minimum Detectable Concentrations of order mBq/m^3 levels (1000 atoms)









Monitoring Requirements

- Monitor for nuclear explosions around the world

- Improved confidence through replicate measurements
  - Multiple seismic stations
  - Particulate and Radioxenon at RN stations
  - Secondary RN measurement in the laboratory environment

- In order for technologies to add to the monitoring network:
  - A detection threshold of order 1 kT is required (see Seismic capabilities)
  - Potential stand-off of ~1000 km is required (see RN spacing)

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References

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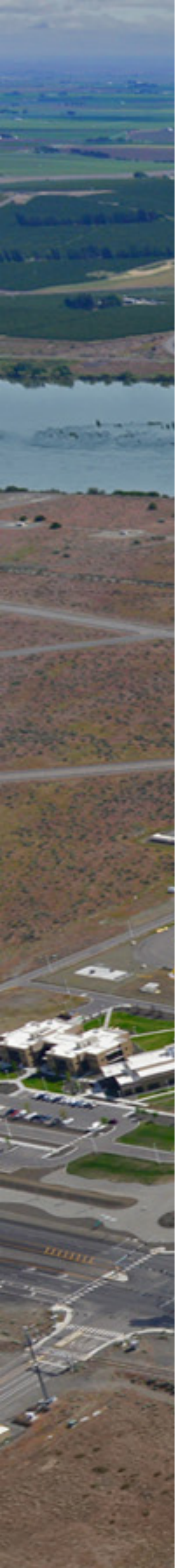

Thank you