Los Alamos Participation in Active Experiments in Space

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Los Alamos National Laboratory Group ISR-2

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Outline

- The People
- The Money
- Catalog
- Techniques
- Diagnostics
- Objectives
- Examples

Our Many Partners

- Sandia National Laboratory
- University of Alaska Geophysical Institute
- Canadian National Research Council
- Naval Research Laboratory
- Aerospace Corporation
- Lockheed Palo Alto Research Laboratories
- Goddard Space Flight Center
- Max Planck Institute

In Memoriam

- Eugene Michael "Gene" Wescott (February 15, 1932 – February 23, 2014) was an American scientist, artist, and traditional dancer. Wescott worked at the Geophysical Institute of the University of Alaska Fairbanks from 1958 to 2009. He was appointed Professor Emeritus of Geophysics, and had an extensive background of research in solid earth geophysics and space physics. He was involved directly in auroral and magnetospheric electric field studies and plasma physics experiments using barium and calcium plasma rocket injections at Poker Flat Research Range.

In the marriage between the Geophysical Institute and the AEC, Gene had the range and the ideas and the AEC had the rockets, the aircraft, and the shaped-charges.

CRRES PIs

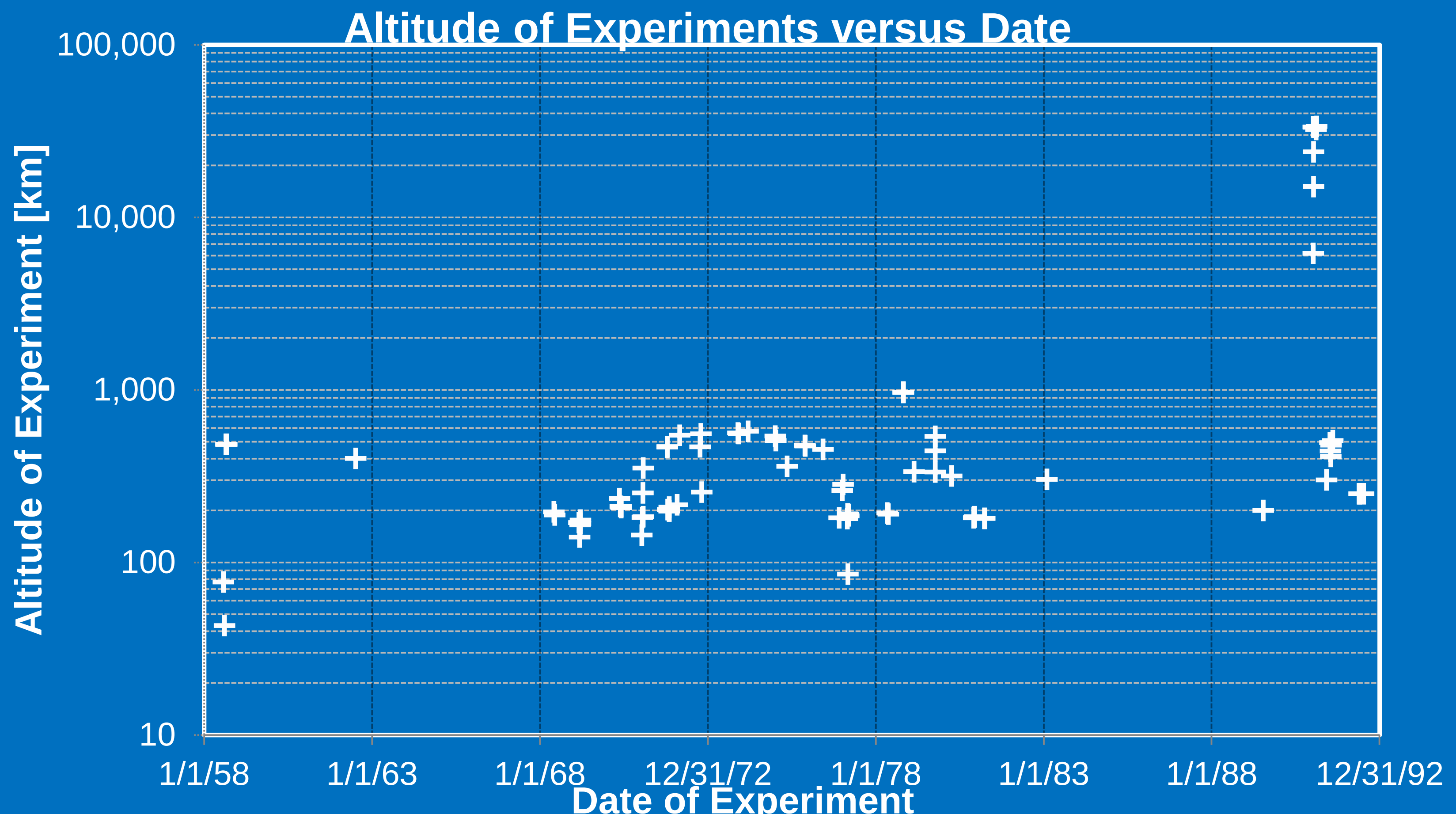
The Money

- Department of Defense and Atomic Energy Commission
- As part of Safeguard C of 1963 Limited Test ban Treaty, the AEC and its successors maintained ships, labs, rockets, aircraft, and a "dedicated staff“ to enable the Government to resume testing nuclear weapons in the atmosphere
- N.A.S.A.
- Defense Nuclear Agency
- Strategic Defense Imitative Office

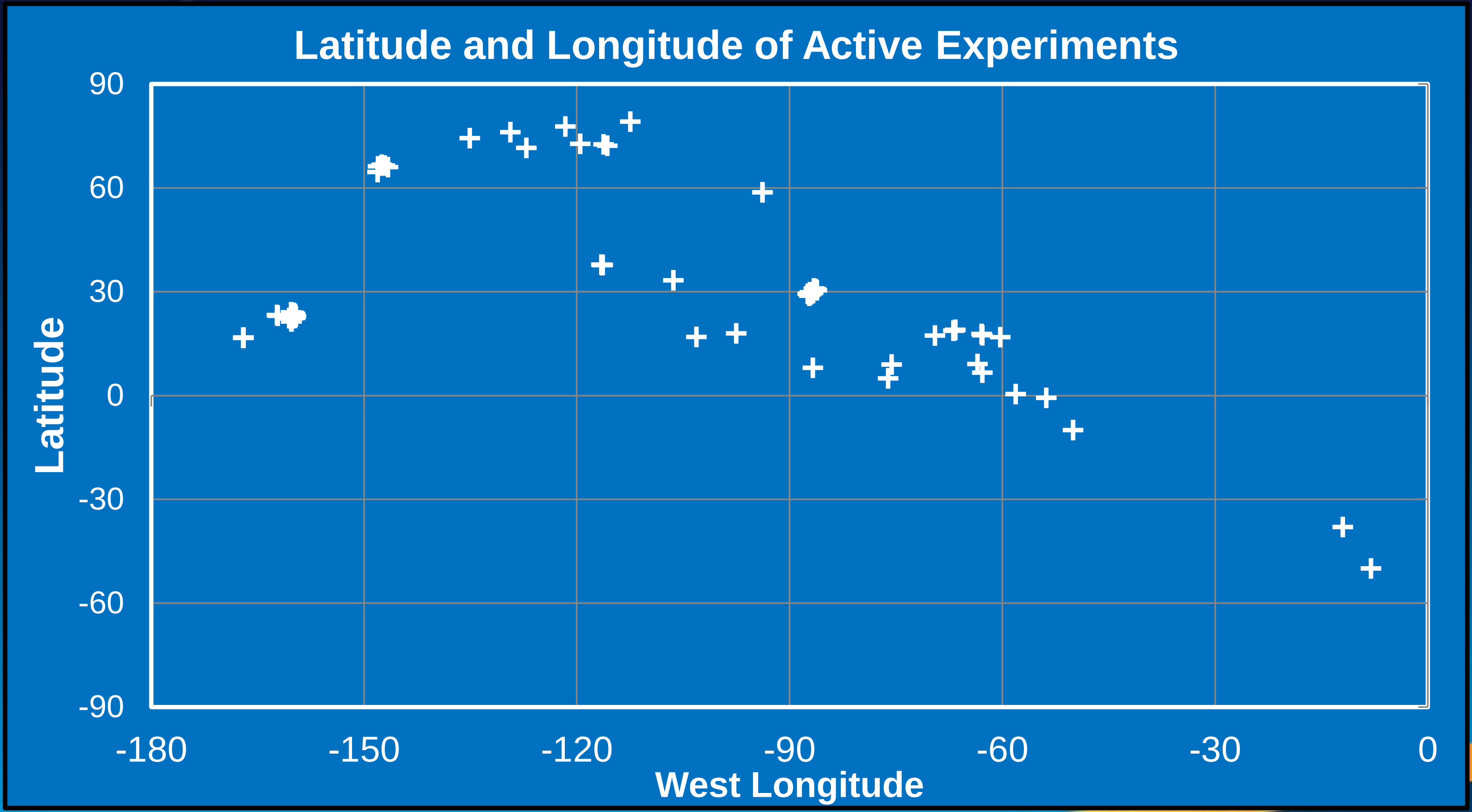
Catalog

Beginning with the Teak nuclear test in 1958 and ending with the NASA-sponsored CRRES experiments in 1992 Los Alamos has been involved with 107 active experiments in space, not including any RF modification experiments.

Los Alamos–related active experiments through the years



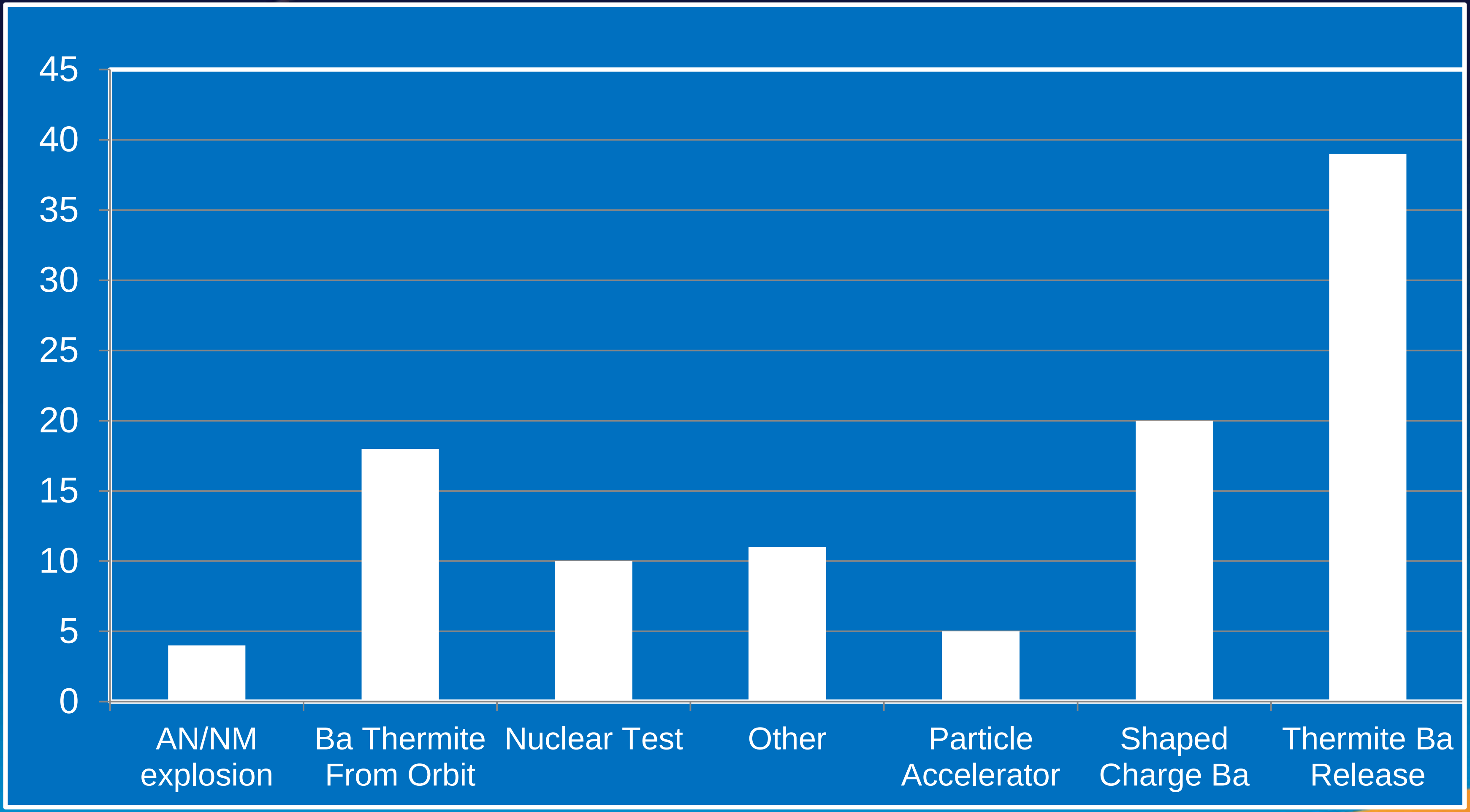
Los Alamos–related active experiments - location



Active Experiment Techniques

- Explosions
  - Nuclear
  - High Explosives (actually H_2O and CO_2)
- Injections
  - Shaped Charges
  - Particle Accelerators
- Releases
  - Thermites
  - SF_6

Los Alamos Techniques



Diagnostics

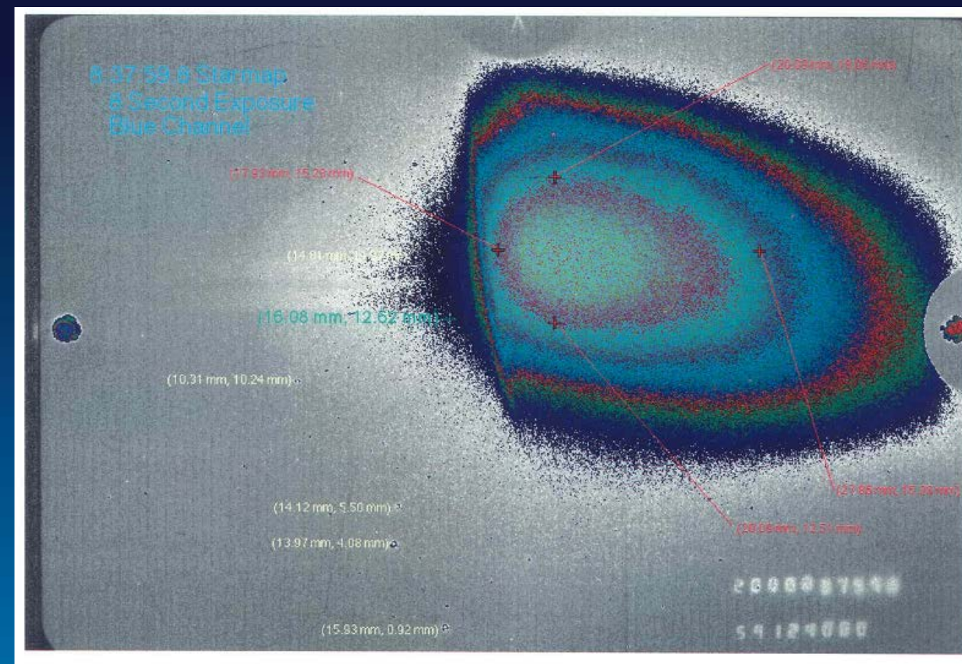
- Optical
  - Ground-based
  - Aircraft
- *In Situ*
- Satellites
- RF

Optical Diagnostics

- Cameras
  - TV
  - B&W and Color film
  - Image intensified
  - Interference filtered
- Fabry-Perot
- Spectrographs
- Photometers

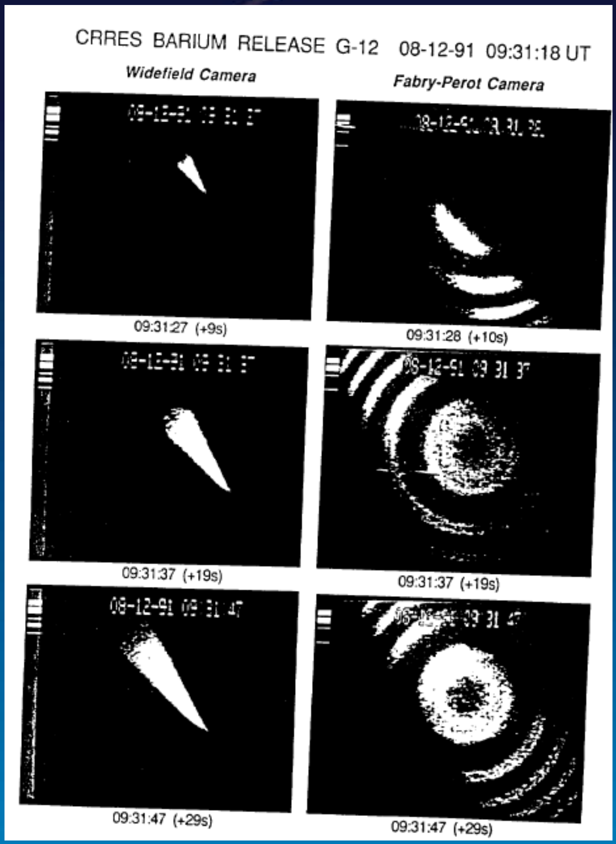
A picture is worth a thousand words (and takes Giga bits to process!)

NASA's CRRES G-9 release – amateur's photograph



NASA's CRRES G-9 release – BaII in false color contours

Examples of specialized optical diagnostics



G-12 barium release filtered image sequence. Fringes from the 2-mm Fabry-Perot etalon…reveal the double-peaked nature of the ion radial velocity distribution [Rairden et a., 1994)].

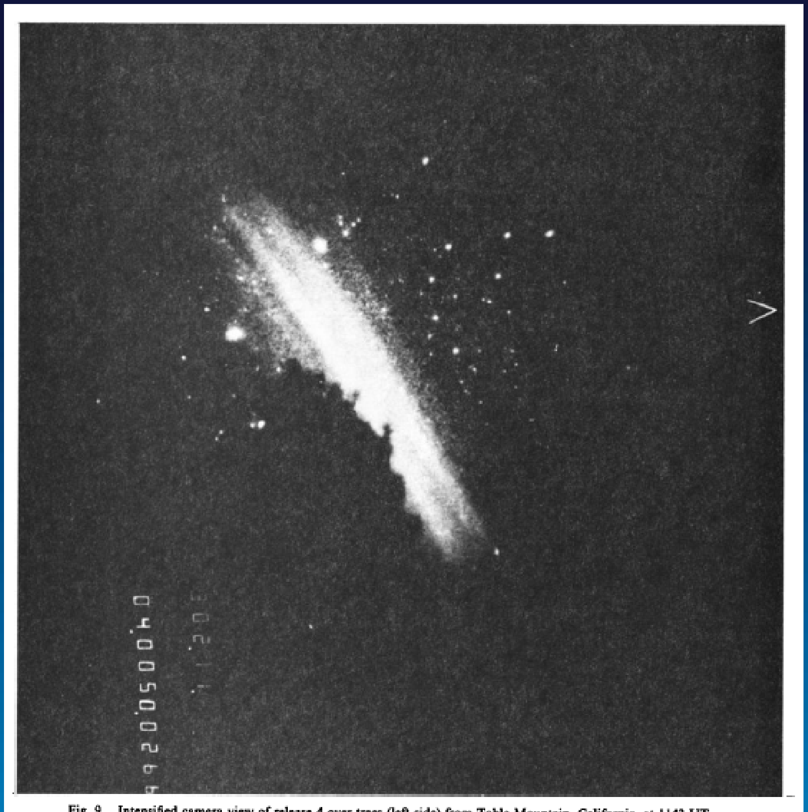


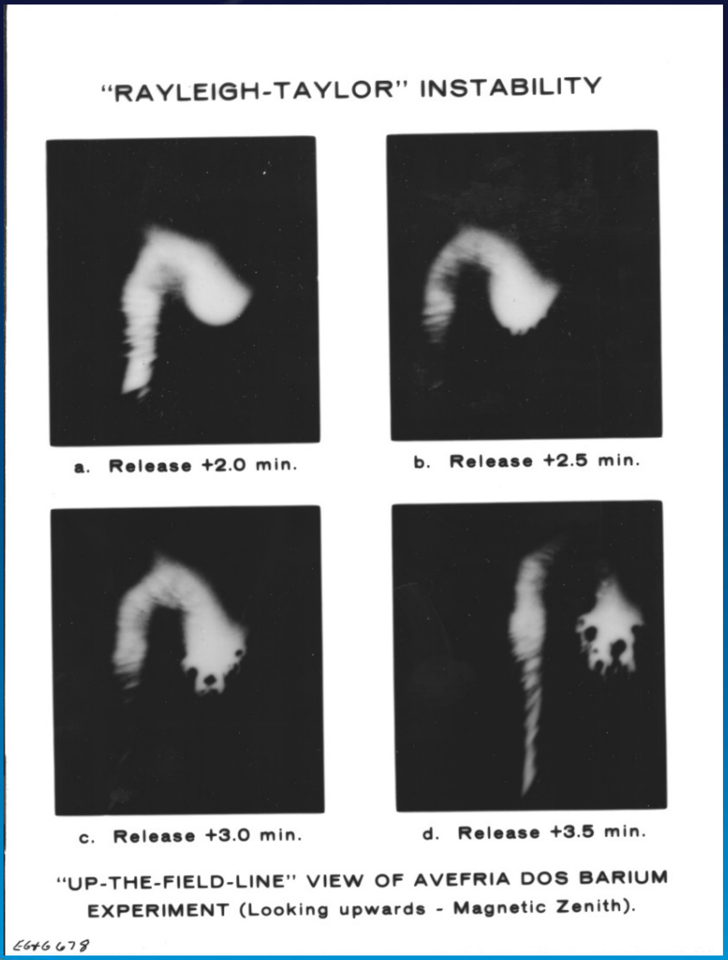
Fig. 9. Intensified camera view of release 4 over trees (left side) from Table Mountain, California, at 1142 UT.

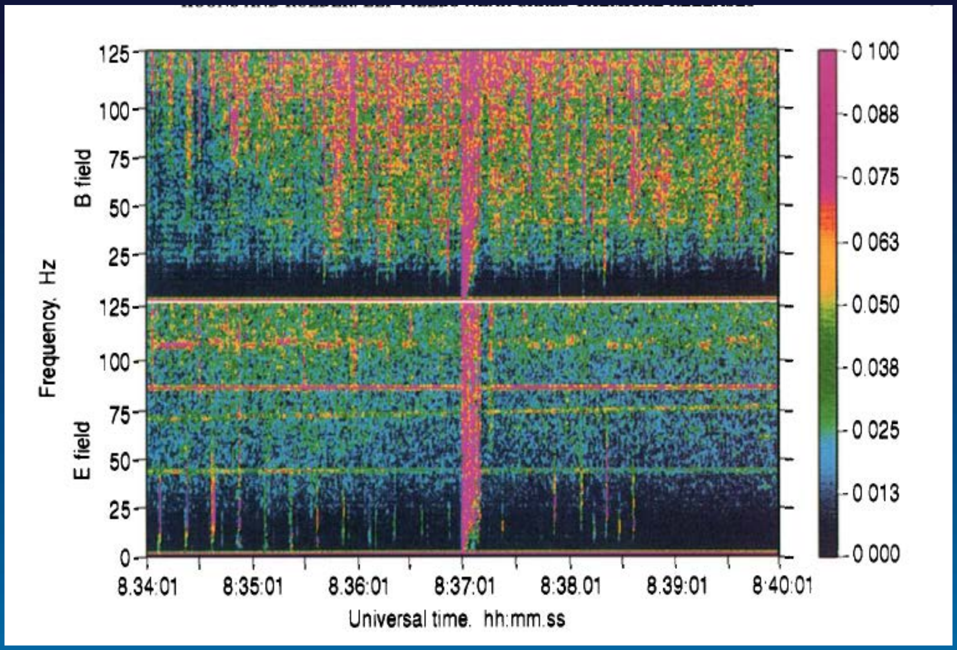
Table Mountain Observatory filtered, intensified camera image of the CAMEO polar cap barium release showing star field and obstruction by tree [Heppner et al, 1981)]

Active Experiment Objectives

- Magnetic field line tracing
- Fluid Plasma Instabilities
- Kinetic Plasma Instabilities
- RF Propagation
- Enhanced electron precipitation
- Diamagnetic cavities
- Polarization fields
- EMP
- ICBM Defense
- Ionospheric Chemistry
- Winds
- H.A.N.E. simulation

Fluid and Kinetic Plasma Instabilities





Spectrogram of the field intensities for the G-9 chemical release on July 19, 1991. (top) Magnetic field; (bottom) electric field. [Koons and Roeder, 1995]

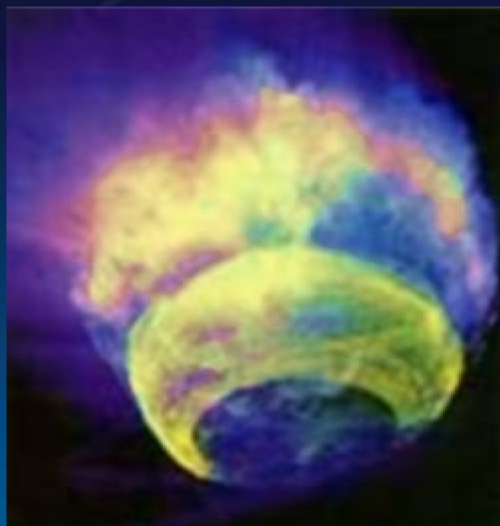
Examples

- Orange - Nuclear Test
- Tordo/Periquito - field line tracing
- Waterhole – ionospheric depletion
- Hope event – RF propagation
- CRRES G-9 – kinetic plasma instabilities
- B.E.A.R. – particle beam

Orange - Nuclear Weapons Effects Test

8/12/58 - 3.8 Mt @ 43 km above Johnston Island

Los Alamos NATIONAL LABORATORY EST. 1943



Orange Event: toroidal yellow or orange colored fireball and white-blue-green-purple air radiation induced glow photographed from the deck of a U.S. aircraft carrier at 1 minute after burst, 12 August 1958.

[Hoerlin, 1976]

- Orange-like explosions could be used to “dump” anomalous levels of satellite killing radiation.
- Low altitude, high yield explosion would “heave” massive quantity of neutrals into the upper atmosphere causing energetic particles to scatter and precipitate.
- Detonation at location conjugate to South American Anomaly would result in the killing radiation being quickly dumped .

NNSA National Nuclear Security Administration

Field Line Tracing:

1975 shaped charge injections from Cape Parry Canada - Tordo and Periquito

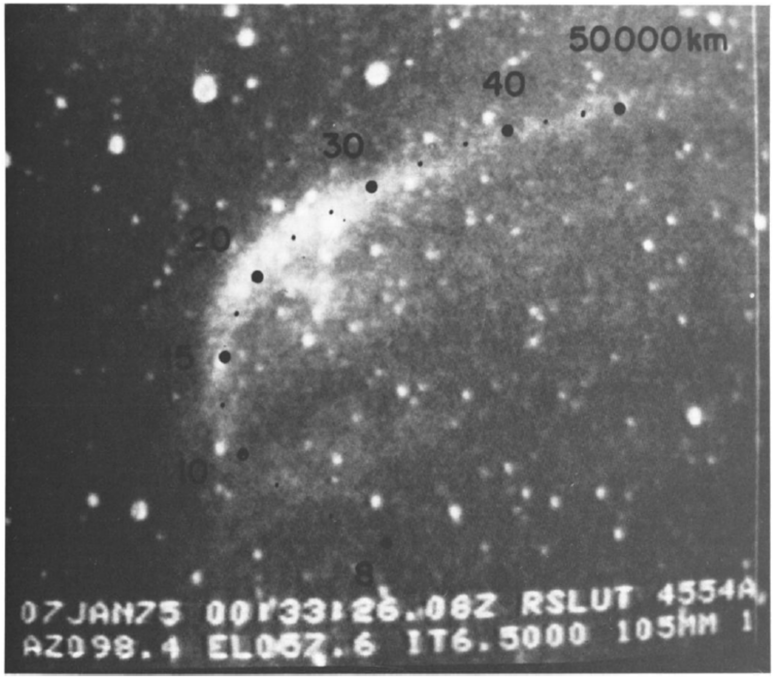


Fig. 8. TV frame and theoretical field line from Resolute Bay, Northwest Territories, at 0033:26 UT. The normal termination at the upper end of the streak (lower right) would be near 27,000 km. Note that the apparent end is near 50,000 km.

Barium illuminated field line extending to 8 R_e altitude [Wescott, et. al., 1978]

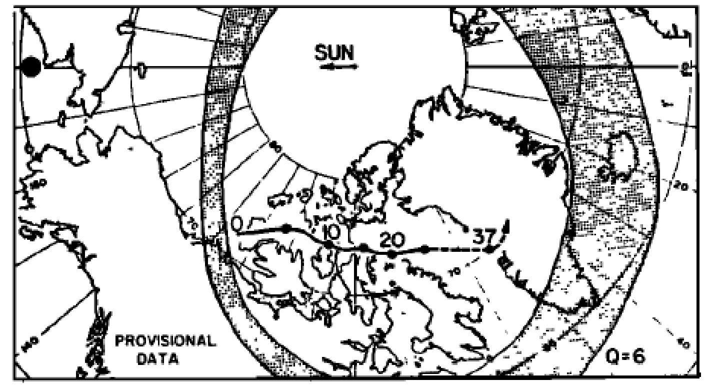


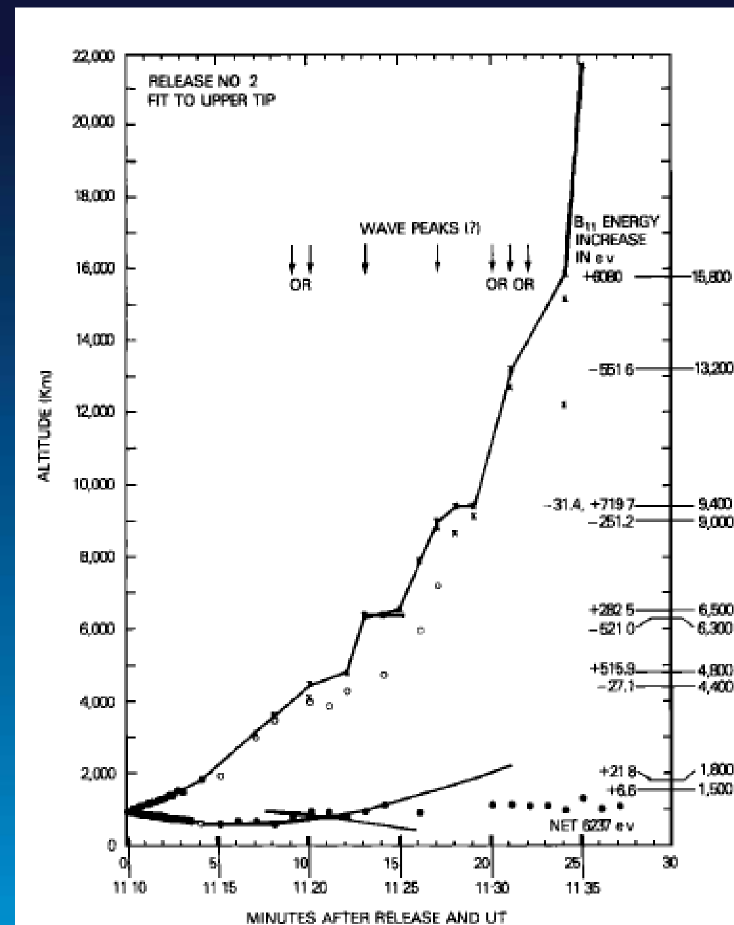
Fig. 2. Track of leading tip of ionized barium streak for Tordo I, projected down along magnetic field lines to 100 km altitude. Numbers along track are minutes after injection; circles are at 5-min intervals except for 37-min location. Dashed line after 25 min reflects present uncertainties requiring additional analysis. The statistical auroral oval for a disturbed Q=6 magnetic index is shown as the shaded area.

Anti-sunward convection over the polar cap [Jeffries, et. al, 1975]

Field Line Tracing
CAMEO

- Altitude versus time plot of CAMEO release No. 2
- Trajectory indicates up to 6 keV $E_{||}$ acceleration <u>and</u> deceleration.

[Heppner, et. al, 1981]



Waterhole I and III

- Ammonium Nitrate/Nitro Methane explosions in auroral F-region
- Charge-exchange/dissociative recombination chemistry removes ions and electrons forming a 50-km diameter “hole” in the ionosphere
- Hypothesis: field-aligned currents connected to auroral arcs are important to the mechanism producing the arc and removing the thermal plasma will perturb the currents and modify the acceleration mechanism.

[Atkinson, G, 1970]

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Waterhole I Data

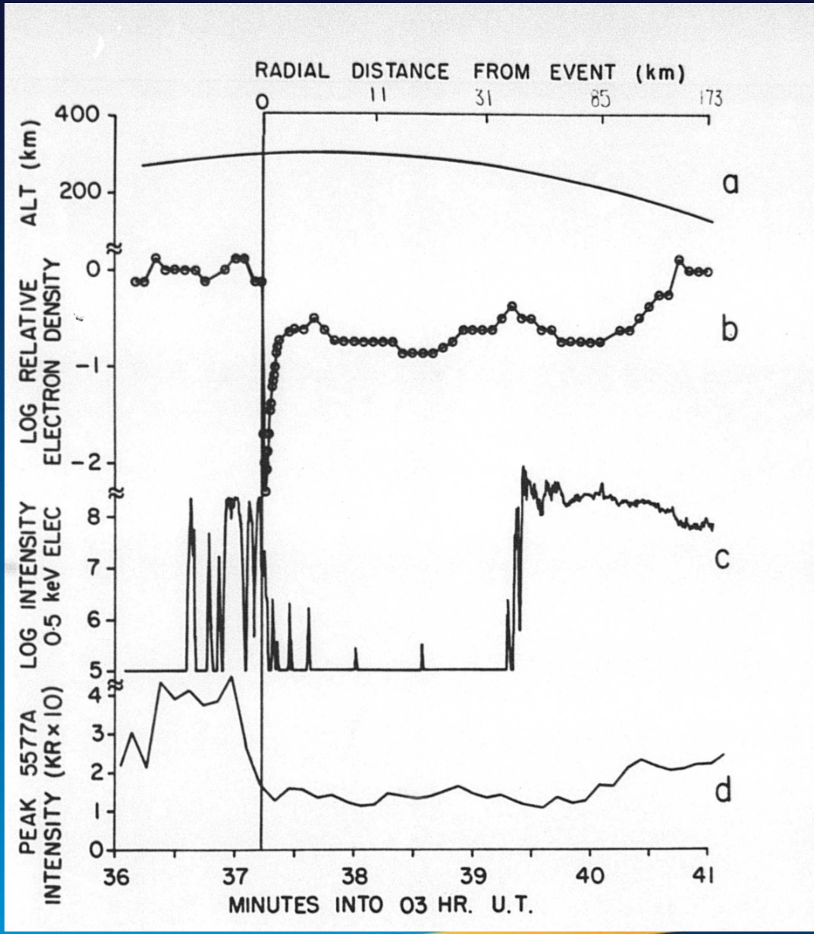
(a) Rocket altitude and distance from event,

(b) relative local electron density,

(c) precipitating electron intensity at 0.5 keV,

(d) peak column emission intensities of auroral green line.

[Whalen, et. al., 1985]]



Waterhole Results

- Waterhole I (88 kg AN/NM) was released on the poleward side of an auroral arc.
- Waterhole III (180 kg AN/NM) was released on field line connected to the arc.
- Electron flux at 1.5 keV enhanced at small pitch angles.
- “The rapid response…and spectrum changes...in energetic electron precipitation indicates…induced electric field must have been large enough to accelerate electrons up to several keV”
- “Although the two results appear to be contradictory, simple models…of the structure of auroral arcs seem to be in agreement with both experiments.”

Thermite Barium Releases in the Ionosphere

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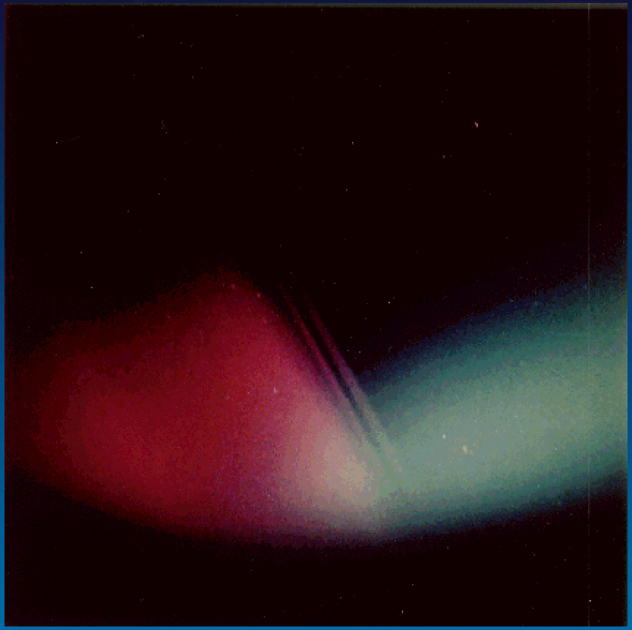

Hope Barium release at T + 20 minutes

Objective:

Create a structured plasma in the RF propagation path to test models of RF propagation for the Defense Nuclear Agency.

Diagnostics:

Optical: Measurements of the time evolution of the power spectral density (PSD) of striations for the electron column density perpendicular to the magnetic field is derived for the two clouds.

RF: Measurements of the time-of-arrival spread of energy (channel impulse response) on a phase coded spread spectrum signal emanating from a rocket launched behind the barium cloud and received at specially constructed ground receiving site in northern Florida (Beacon experiment).

Results:

The data are shown to be in good agreement with the DNA propagation channel model and a geometric optics interpretation of the observed propagation effects.

[Simons, et. al., 1984]

NNSA National Nuclear Security Administration

Thermite Releases at Orbital Velocity
CRRES

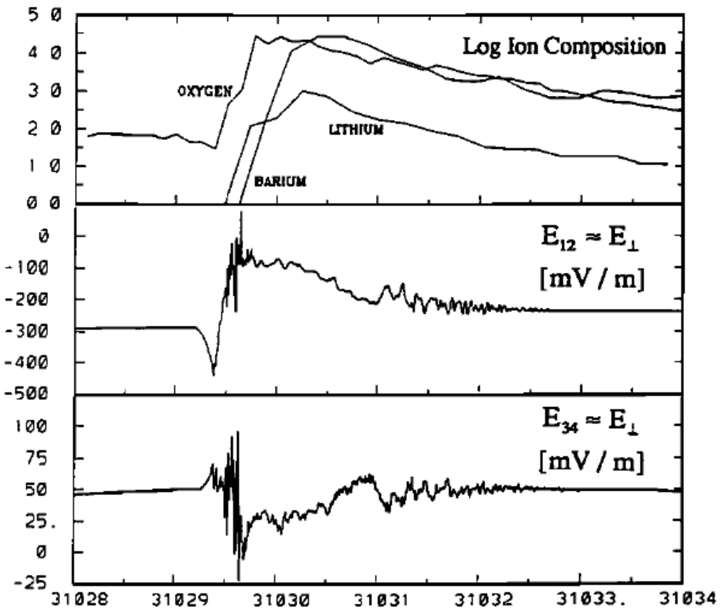

Fig. 2. Top Panel: QIMS ion composition data showing O^+, Li^+, Ba^+. Middle and bottom panels: Near-perpendicular (E_{12}) and near-parallel-to-$\bar{B}$ (E_{34}) components of the measured electric fields. GMT = 31027 sec is the approximate time of the release.

Polarization E-field
[Szuszczewicz et. al., 1993]

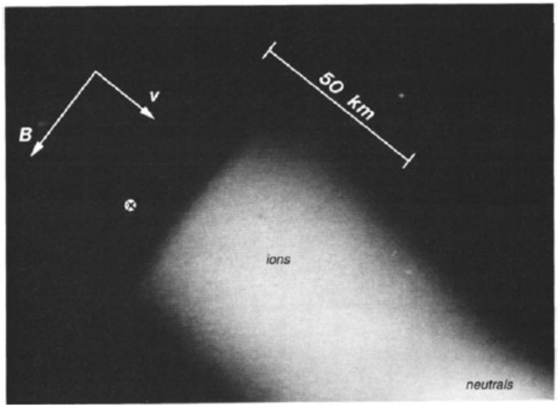

Figure 1. Intensified unfiltered CCD TV image of the G9 release 20 s after the release (aircraft 127). The edge of the ion cloud is not at the release point (marked with cross) but has "skidded" 18 km along the orbit track.

[Delamere et. al, 1996]

Phenomena

- **Polarization "skid"**
- **Magnetization**
- **Ring-distribution relaxation**

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B.E.A.R.

10-mA (equivalent), 1-MeV, neutral hydrogen beam

- **Experiment conducted for SDIO in July 1989. Most energetic particle beam ever flown.**
- **Beam Experiments Aboard a Rocket (BEAR) program launched a sounding rocket containing a neutral particle beam (NPB) accelerator.**
- **The experiment successfully demonstrated that a particle beam would operate and propagate as predicted outside the atmosphere and that there are no unexpected side-effects when firing the beam in space.**

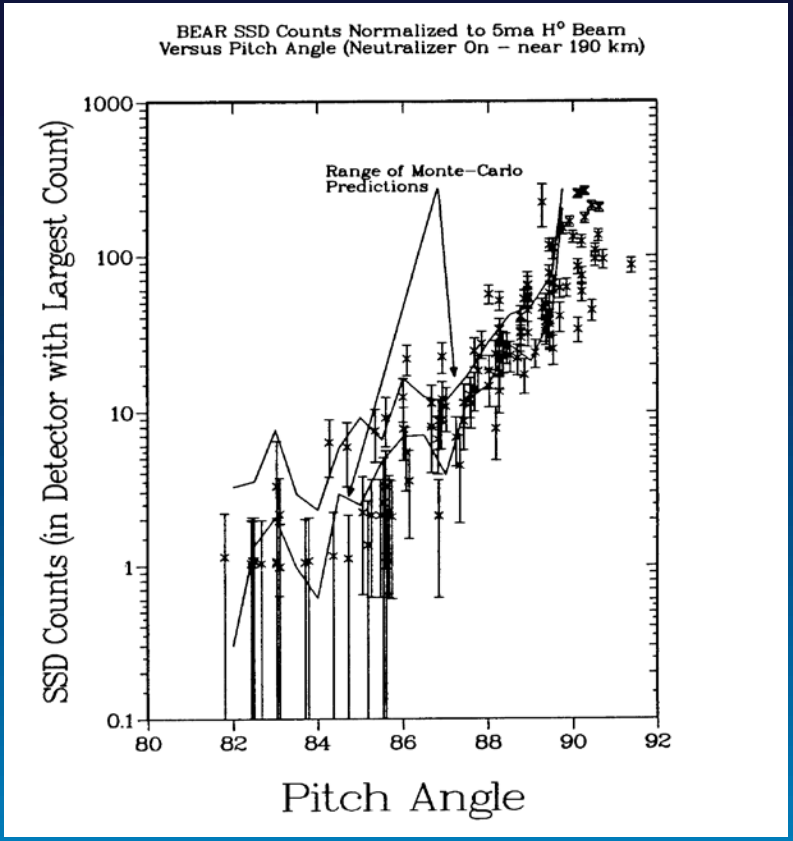
[Burick, et. al. , 1991]

Diagnostics

- Beam energy, current, divergence
- Beam composition
- Beam pointing
- Beam propagation before stripping
- Spacecraft charging

Using gradient and curvature drifts to measure H° stripping

- Use rocket ACS to fire H° beam down and east.
- Stripping produces protons that mirror and drift up and west back to the rocket.
- There is a one-to-one relationship between the pitch angle of an observed proton and the distance it traveled as a hydrogen atom before stripping.
- Solid-state particle detector (SSD) measurements of the fluence of returning protons can be used to estimate the NPB stripping cross section.



SSD flight data and range of Monte Carlo predictions

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Abstract

Beginning with the Teak nuclear test in 1958, Los Alamos has a long history of participation in active experiments in space. The last nuclear tests were the five explosions as part of the Dominic series in 1962. The Partial Test Ban Treaty signed in August 1963 prohibited all test detonations of nuclear weapons except for those conducted underground.

Beginning with the “Apple” thermite barium release in June 1968 Los Alamos has participated in nearly 100 non-nuclear experiments in space, the last being the NASA-sponsored “AA-2” strontium and europium doped barium thermite releases in the Arecibo beam in July of 1992.

The rationale for these experiments ranged from studying basic plasma processes such as gradient-driven structuring and velocity-space instabilities to illuminating the convection of plasmas in the ionosphere and polar cap to ionospheric depletion experiments to the B.E.A.R. 1-MeV neutral particle beam test in 1989.

This talk will review the objectives, techniques and diagnostics of Los Alamos participation in active experiments in space.