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Title: Los Alamos in Space: The 50 years since Vela

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Issued: 2013-10-07

Los Alamos in Space: The 50 years since Vela

LA-UR 13-?????

Morris B. Pongratz
ISR-2

October 9, 2013

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Acknowledgements

- *VELA Satellite Program*, by Mario R. Perez and Richard D. Belian, ISR-1, LAUR-08-05501
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In the Footsteps of Giants

(and apologies to those working before Bill Gates arrived on the scene)

- **LANL** (retirees all)
  - The “Pioneers”
    - Harold, Argo, Jack Asbridge, Sam Bame, Dick Belian, Don Cobb, Jerry Connor, Jim Coon, W. Doyle Evans, Bill Feldman, J. Paul Glore, Henry Horak, Herman Hoerlin, Bob Jeffries, Conrad Longmire, Ray Klebesadel, Bob Massey, H. Milton Peek, Sid Singer, Ian Strong, John Zinn
  - The “Builders”
    - Bill Aiello, Juan Baldonado, Phil Barker, Mel Duran, Don Enemark, Hal Fishbine, Irma Gonzales, Jerry Longmire, Mick Piotrowski, Steve Wallin
  - The “Data Wonks”
    - Bob Carlos, Rod Christensen, Marilyn Halbig, Ed Hones, Jack Gosling, Sandy Kedge, Evan Noveroske, Michelle Thomsen, Karla Sofaly, Earl Tech,
  - The “Modelers”
    - Joachin Birn, Joe Fitzgerald, Peter Gary, Dan Winske
  - The “$$$ Chasers”
    - Dick Burick, Mark Hodgson, David Simons,

- **Partners**
  - **Sandia**
  - **EG&G**
  - AFTAC
  - USAF Space Test Program (STP)
  - USAF 2SOPS
  - TRW
  - Lockheed
  - Boeing
  - E-Systems
  - Aerospace
  - AFGRL/AFRL
  - U of Alaska /Geophysical Institute
  - JPL
  - Canadian NRC
  - SAIC
  - SRII
  - AeroAstro, Inc.
  - Surrey Satellite Technology Ltd.

LASL/LANSL/LANL in Space through the decades

- **60's**
  - Dominic explosion diagnostics (P-4)
  - VELA satellites design, fab, launch and monitor (P-4)
  - Thermite barium release simulations of H.A.N.E. phenomenology (J-10)
- **70's**
  - Forty-seven thermite and shaped charge barium release simulations of H.A.N.E. phenomenology and field line tracing (J-10)
  - RADEC on DSP for treaty monitoring (P-4)
  - Plasma analyzers on IMP's 6, 7 and 8 and International/Sun Earth Explorer (ISEE) 1, 2 and 3 (P-4)
  - Plasma depletion releases (J-10)
- **80's**
  - BDD and BDX NUDET sensors on GPS Blocks I and II
  - Advanced RADEC II on DSP
  - Space Nuclear Power – Galileo satellite, '89
  - Beam Experiments Aboard a Rocket (BEAR) - 7/89
- **90's**
  - CRRES barium release experiments
  - BDW EMP sensors on Block IIA GPS
  - LANL-developed satellite - ALEXIS/Blackbeard on 4/25/93
  - LANL-developed satellite – FORTE on 8/29/97
  - Sensors on Cassini satellite 10/15/97
  - Upgraded EMP and X-ray and particle sensors on Block IIR GPS
  - Lunar Prospector – '98
- **00's**
  - MTI – 3/12/00
  - Mars Odyssey – 4/7/01
  - Swift GRB satellite 11/20/04
  - CFE Sat – 3/8/07
  - BDV wideband EMP sensors on Block IIF GPS
- **10's**
  - Mars Science Lab/Curiosity – 11/26/11
  - MRM

Why did LASL go into Space?

V- 2 Rocket with only 500 pound explosive – invulnerable delivery, small payload

Fat Man with B-29 delivery – vulnerable delivery, large payload

Thor missile with nuclear warhead

High Altitude Nuclear Explosion (HANE): STAR FISH: The debris fireball stretching along Earth's magnetic field with air-glow aurora as seen at 3 minutes from a KC-135 surveillance aircraft

Motivation for Space

- National Security Missions – the ultimate "high ground"
- Science: Space – the final frontier

National Security Missions – the ultimate “high ground”

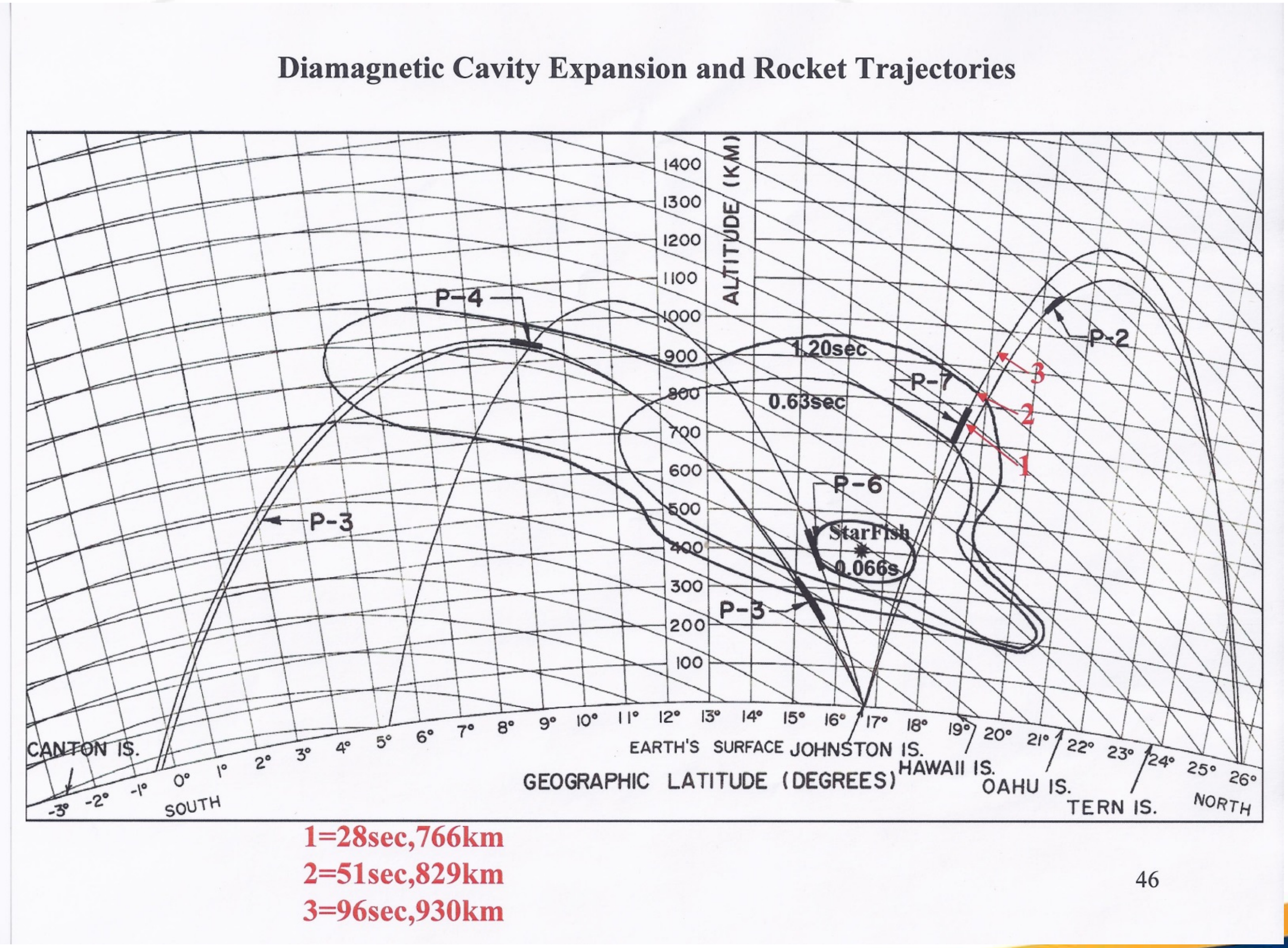
- Diagnose device outputs – measure γ-ray, neutron and X-ray emissions from “bare” device.
- Anti-ballistic missile defense – H.A.N.E. plasma causes radar and IR blackout and clutter that blinds tracking systems.
- Communications /Command /Control /Intelligence – striated H.A.N.E. plasma disrupts transionospheric communications (analogous to impact of ripples on pool surface).
- Surveillance – detection of nuclear explosion detonation (NUDET) from low yield at large distance to high yield nearby imposes wide dynamic range requirements on space borne sensors.
- Space control – space vehicle vulnerability, the “high ground” is inhospitable - NUDET and the natural space environment:
  - NUDET: Prompt gamma ray damage to space assets and delayed damage to satellites from energetic betas and fission fragments
  - Natural environment: spacecraft charging, “killer” electrons, meteorites.

How'd you pay for this?

- DARPA
- AEC/ERDA/DOE/NNSA
- "Readiness to test" clause in CTBT
- DNA/DTRA
- NASA
- Weapons Program
- Shh.. don't tell anyone, but a lotta folks worked nights and weekends without pay.

Device Outputs: Diagnostic Rocket Trajectories

LASL Group P-4 - STAR FISH Event July 9, 1962



Space-based Nuclear Detonation Detection: What do you measure?

Part of an integrated program involving air, space, and ground assets

Together, they answer the questions:

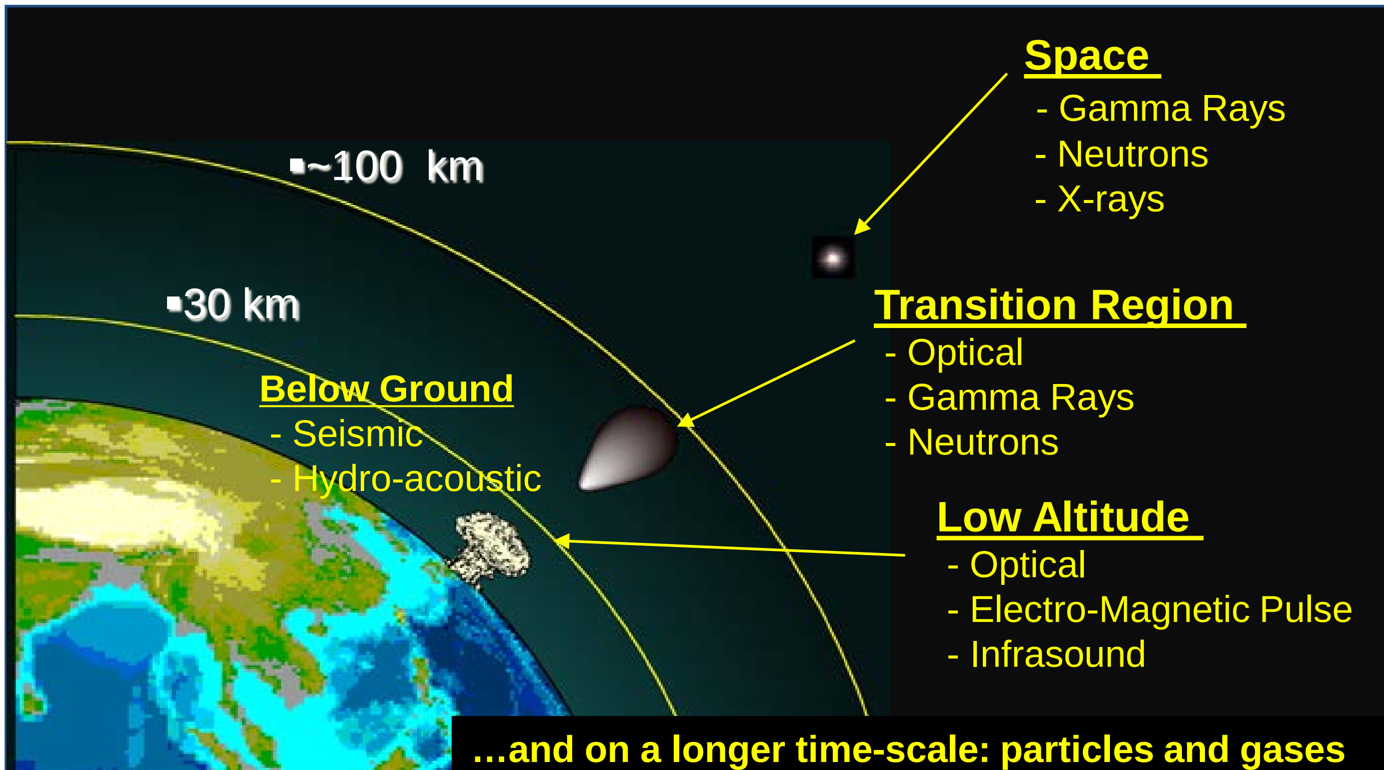
Did it happen?

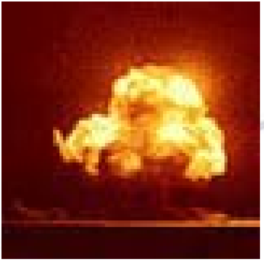
Was it nuclear?

Where was it?

How big?

Who did it?





Trinity, 21 kt
16 Jul 1945

Joe 1, 22 kt
29 Aug 1949

Program origins and drivers

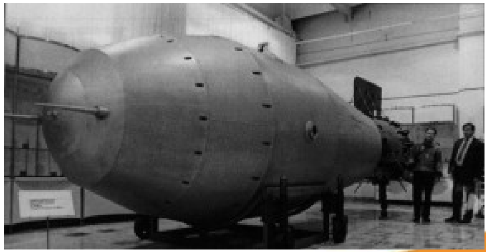
- November 1945, the US, the UK, and Canada proposed the establishment of a UN Atomic Energy Commission for the purpose of "entirely eliminating the use of atomic energy for destructive purposes."
- July 1946, President Truman signs law replacing Manhattan Engineering District with the Atomic Energy Commission (AEC)
- March 1947 Lt Gen Vandenberg, Head of the Central Intelligence Group (CIG) establishes the need for a "Long Range Detection (LRD)" capability
- Sept 1947, General Eisenhower, Chief of Staff, directs General Spaatz, Head of Army Air Forces, to develop an LRD capability to "detect nuclear explosions" anywhere in the world.
- 29 August 1949, USSR detonates Joe-1, ending US nuclear weapon monopoly and initiating the nuclear arms race
(surprise to some technical analysts)
- 1 September 1949, Committee on Atomic Energy (CAE) Boner Panel recommends canceling LRD program.
Two days later an RB-50 collects evidence of Joe-1…

Program origins and drivers

- Oct 1952, US detonates Mike (10.4 Mt) on Eniwetok Atoll – the first thermonuclear device
- August 1953, Soviets detonate a thermonuclear device
  - surprising some "experts"
- 1952 -1964, Britain, France, and China join the nuclear weapons club - support for monitoring remains high
- 1958, US and Russia each declare a trial moratorium
  - Chairman Khrushchev suggests ban without verification
  - President Eisenhower demands that the technical experts meet and agree on means of verifying before entering any treaty
- 1961, Russia breaks out of its self-declared moratorium:
  - 45 tests (atmospheric and underground) in 100 days
- US responds in kind: pressure builds for Test Ban Treaty

Mike, 10.4 Mt

Nikita Kruschev

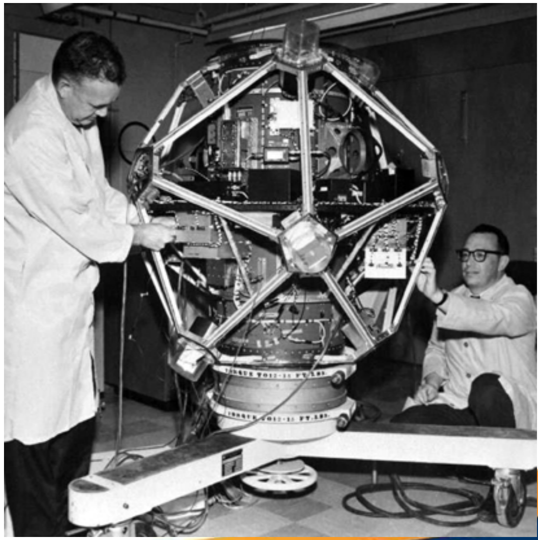


Oct 1961 CsarBomba, 50Mt

Our Heritage: Space-based Nuclear Detonation Detection ….From Vela to GPS … and beyond

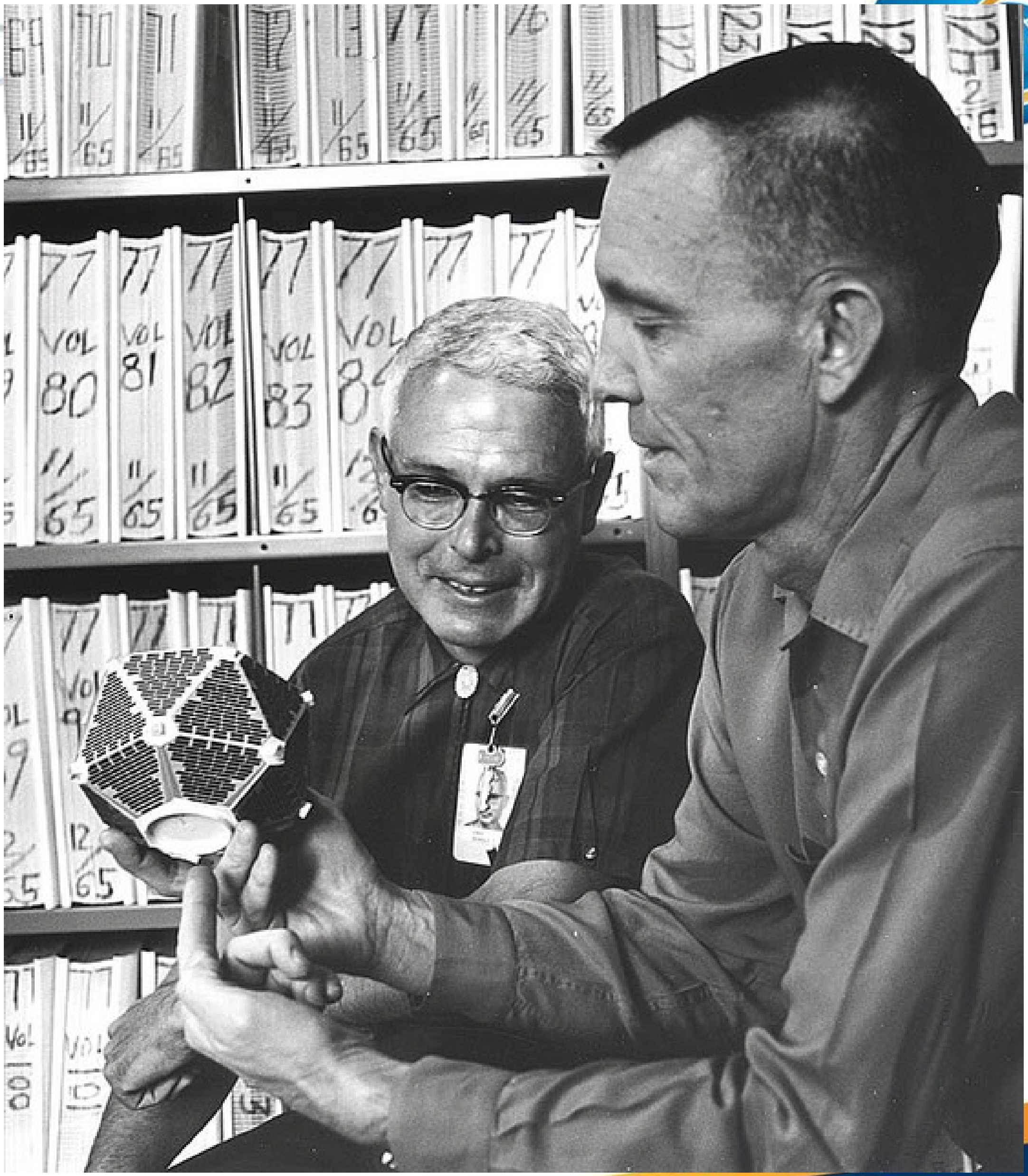
- 1959, the Advanced Research Projects Agency (ARPA) was established, immediately proposed the Vela, or “watchman” project in three parts:
  - Vela-Uniform for underground detonation detection
  - Vela-Sierra for ground-based detection of high altitude and space nuclear detonations
  - **Vela-Hotel for satellite-based detection of nuclear detonations**

- 1958 -1959, AEC supported scientists began considering the new satellite technology as a means of monitoring nuclear explosions anywhere above the surface of the earth.
  - 10 June 1959, Los Alamos and Sandia initiate work on Vela-Hotel sensors
  - ARPA supports development of the required satellite and missile
- The first Vela Hotel pair was launched on October 17, 1963



Managers were allowed to touch…

- Jim Koon (P-4 Group Leader) and
- Harold Argo (P-4 Deputy Group Leader) with Vela model.



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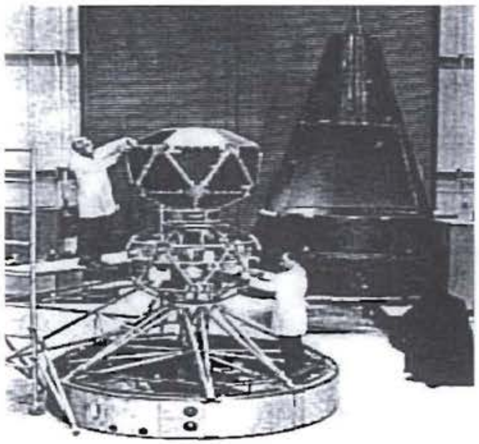
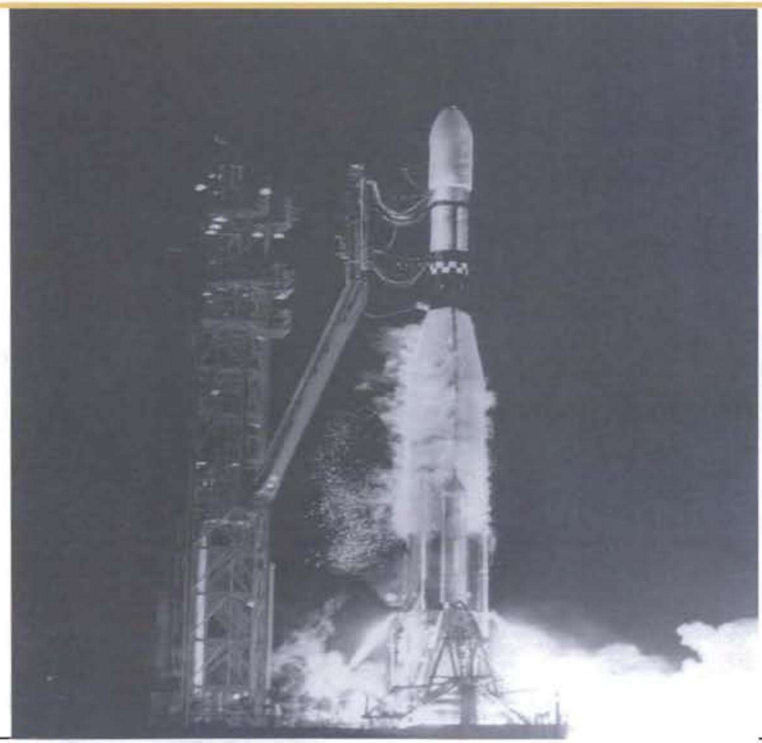
In the beginning…

The Beginning of an Era





Atlas launch of VELA 1 & 2 on October 17, 1963 (10 days after signing of the Limited Test Ban Treaty)

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NNSA

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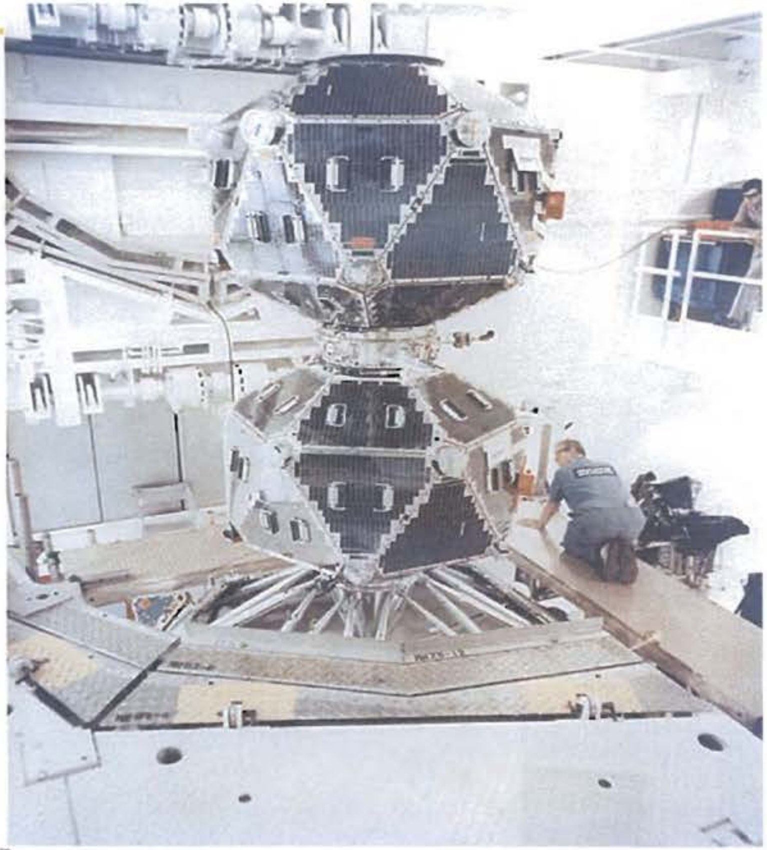
VELA Program and Spacecraft

- Started as an original Defense Advanced Research Projects Agency (DARPA) project in 1958 in response to the launch of Sputnik.

- <u>Vela Hotel (6 S/C; 1963-1965) – Atlas-Agena</u>
  - 1963 October 17 – Vela 1 & 2
  - 1964 July 17 - Vela 3 & 4
  - 1965 July 20 - Vela 5 & 6
- <u>Advanced Vela (6 S/C, 1967-1970) – Titan III-C</u>
  - 1967 April 28 - Vela 7 & 8
  - 1969 May 23 - Vela 9 & 10
  - 1970 April 8 - Vela 11 & 12 (V-B, backup S/C)
- γ-ray, x-ray, neutron, EMP, space environment
- Hotel series: 300 lbs, 90 W
- Advanced series: 698 lbs, 120 W
- Bhangmeter on Advanced Vela



Operated by Los Alamos National Security, LLC for the U.S. Department of Energy's NNSA

Vela Satellites

- Basics
  - Date: May 1969 to June 1979
  - Agency/Country: Department of Defense (DOD)
  - Instruments/Detectors: Scintillation counters (3 -40 keV)
  - Highlights: Discovery of gamma ray bursts, X-ray bursters
- The Vela-5A nuclear test detection satellite was part of a program run jointly by the Advanced Research Projects of the U.S. Department of Defense and the U.S. Atomic Energy Commission, managed by the U.S. Air Force.
- It and its twin, Vela-5B, were placed -180 degrees apart in nearly circular orbits at a geocentric distance of ~118,000 km on 23 May 1969. The orbital period was ~ 112 hours. The satellite rotated about its spin axis with a ~ 64- sec period.
- The X-ray detector was located -90 degrees from the spin axis, and so covered the celestial sphere twice per satellite orbit. Data were telemetered in 1-sec count accumulations. The X-ray detectors on Vela 5A failed on 24 July 1970.

Instrumentation

- The scintillation X-ray detector (XC) aboard Vela 5A consisted of two 1-mm- thick Nai(TI) crystals mounted on photomultiplier tubes and covered by a 5-mil-thick beryllium window. Electronic thresholds provided two energy channels, 3-12 keV and 6-12 keV. In front of each crystal was a slat collimator providing a FWHM aperture of ~ 6.1x6.1 degrees. The effective detector area was ~ 26 cm^2. Sensitivity to celestial sources was severely limited by the high intrinsic detector background.
- Both Vela 5A and 5B also carried 6 gamma-ray detectors. They had a total volume of ~ 60 cm^3 of CsI and could detect photons in the 150-750 keV energy range. It was in 1969-70 that the Vela spacecraft first discovered gamma-ray bursts. The gamma-ray detectors continued to function until at least 1979.

"We're watching"

PROCEEDINGS OF THE IEEE VOL. 53, NO. 12 DECEMBER, 1965

The Vela Satellite Program for Detection of High-Altitude Nuclear Detonations

SIDNEY SINGER

Abstract—The Vela satellite high-altitude test detection system contains X-ray, gamma-ray, and neutron detectors which sense the radiations generated by a detonation in space. The satellites also contain background radiation monitors which are useful in assessing the effect of natural background radiations on the operation of the detection system. This paper contains a review of some of the problems involved in the design of the system, and a description of the instruments. Three pairs of spacecraft are currently in orbit and the detection systems are operating essentially as expected. A survey of the characteristics of the far magnetosphere and its environs, as determined from the background radiation monitors, will also be presented.

I. Introduction

THE PRIMARY objective of the Vela Satellite Program is to carry out research and development on methods of detecting nuclear explosions in space by means of satellite-borne instrumentation. The design of a detection system depends strongly on two factors: the nature of the radiation from the nuclear explosion and the nature of the background radiation in the environment encountered by the satellite. Many features of the radiation background are still unknown, some of the problems associated with the design of the detection system, a description of the instruments, and a summary of the results of nearly two years of in-orbit operation.

II. Radiation Emitted by a Nuclear Explosion in Space

When a nuclear device is detonated in a vacuum, most of the energy is released in the form of thermal radiation from its surface and in the form of kinetic energy of the expanding reaction debris. Since the energy release is rapid and large compared to the mass of the reaction products, the surface reaches temperatures of several kilovolts (several tens of millions of degrees K). If the radiating device is assumed to emit black-body-like radiation, it follows that most of the thermal radiation corresponds to soft X-rays in the region of approximately 0.1 to 100 keV.

The nuclear detonation is also accompanied by the immediate emission of gamma rays and neutrons from the reacting mass (the "prompt" components) and de-

More treaties that constrain nuclear weapons tests / deployment

- 1963: Limited Test Ban Treaty prohibits nuclear weapons tests "or any other nuclear explosion" in the atmosphere, outer space, or under water. Signed by 130 countries, ratified by 113.
- 1967: Outer Space Treaty ("…undertake not to place in orbit around the Earth any objects carrying nuclear weapons…install such weapons on celestial bodies, or station such weapons in outer space... Signed by 125 countries, ratified by 98.
- 1968: Nuclear Nonproliferation Treaty. Signed by 189 countries
- 1974: Threshold Test Ban Treaty (UK, US, USSR, limits to <150 kt)
- 1990: Peaceful Nuclear Explosions Treaty (signed 1976) enters into Force.
- 1996: Comprehensive Test Ban Treaty: "Each State Party undertakes not to carry out any nuclear weapon test explosion or any other nuclear explosion, and to prohibit and prevent any such nuclear explosion at any place under its jurisdiction or control."
  - Signed by 178 states, ratified by 144 (incl. 35 of 44 "specified" countries)
  - 13 Oct 1999: US Senate rejected ratification of the CTBT.

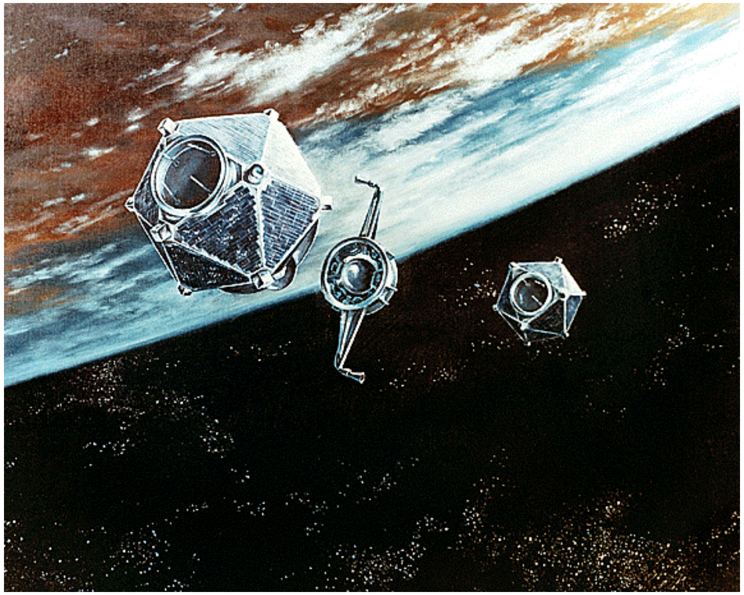
Recent US law validates the enduring treaty verification missions

2008 US Defense Authorization Bill:

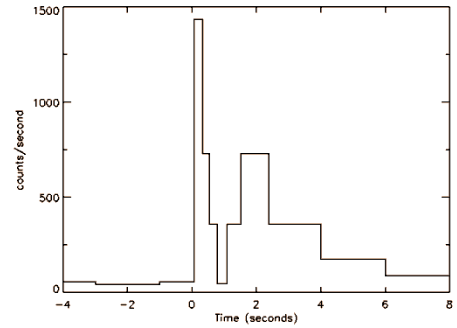
- SEC. 1065. MAINTENANCE OF CAPABILITY FOR SPACE-BASED NUCLEAR DETECTION.
  - The Secretary of Defense shall maintain the capability for space-based nuclear detection at a level that meets or exceeds the level of capability as of the date of the enactment of this Act.
- SEC. 911. SPACE PROTECTION STRATEGY.
  - (a) Sense of Congress – It is the Sense of Congress that the United States should place greater priority on the protection of national security space systems.
  - (b) Strategy – The Secretary of Defense, in conjunction with the Director of National Intelligence, shall develop a strategy, to be known as the Space Protection Strategy, for the development and fielding by the United States of the capabilities that are necessary to ensure freedom of action in space for the United States.

Science from Vela
(science plus a recruiting magnet)

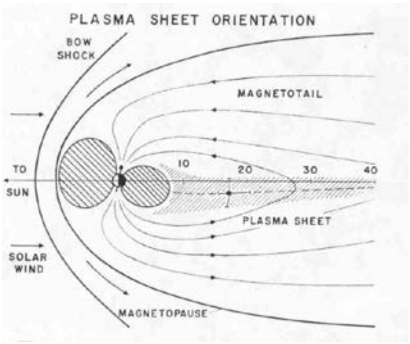
The Vela Program, 1963-1984:
Monitoring the 1963 Limited Nuclear Test Ban Treaty



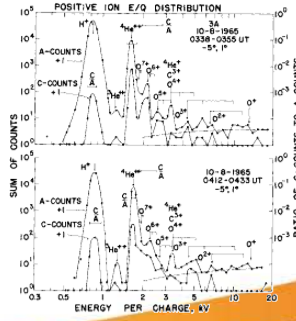
- **Discovery of Gamma Ray Bursts (***Klebesadel et al., 1973)*



- **Discovery of the Earth's Plasma Sheet**
(Bame et al., 1967)



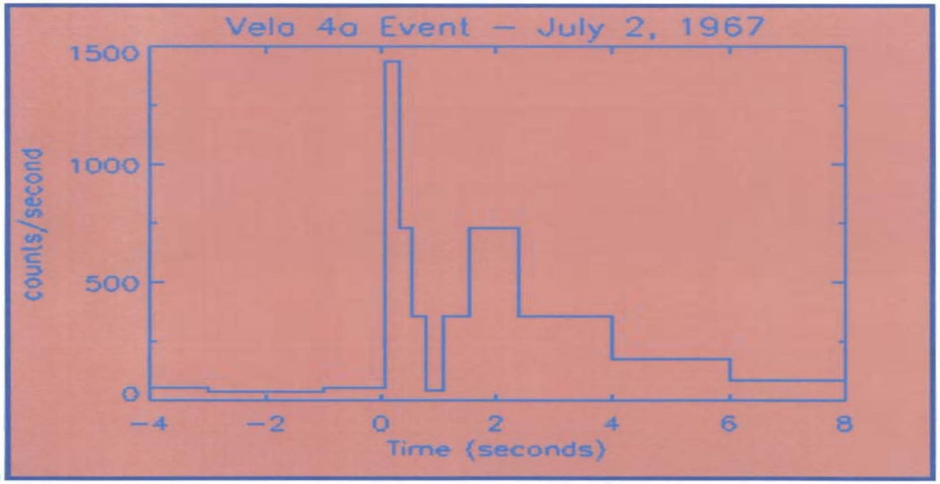
- **Discovery of Heavy Ions & High Charge States in the Solar Wind**
(Bame et al., 1968)

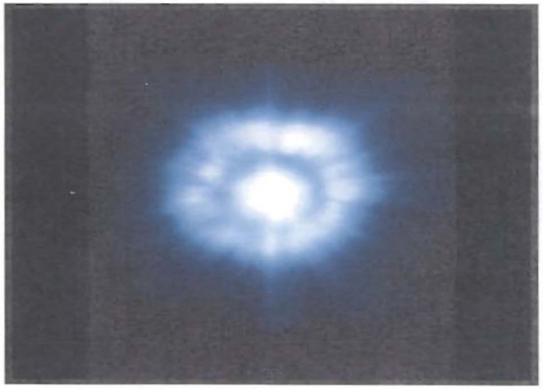


Discovery of Gamma Ray Bursts (*Klebesadel et al., 1973)*

Discovery of the Gamma-Ray Burts (GRBs)

- Each Vela satellite contained six CsI scintillation counters, which detected the arrival of the burst of gamma rays.
- The four Vela satellites (5A & B, 6A & B) recorded 73 gamma-ray bursts in the ten year interval July 1969 - April 1979





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If you're looking for gamma-ray transients…

Announcement

- In 1973, this discovery was announced in Ap.J. Letters 182, L85 by Klebesadel, Strong, and Olson. Their paper discusses 16 cosmic gamma-ray bursts observed by Vela 5a,b and Vela 6a,b between July 1969, and July 1972. γ-ray emission from supernovae predicted by Colgate (1968).
- They concluded that the gamma-ray events were of *"cosmic origin"*

THE ASTROPHYSICAL JOURNAL, 182:L85–L88, 1973 June 1

OBSERVATIONS OF GAMMA-RAY BURSTS OF COSMIC ORIGIN

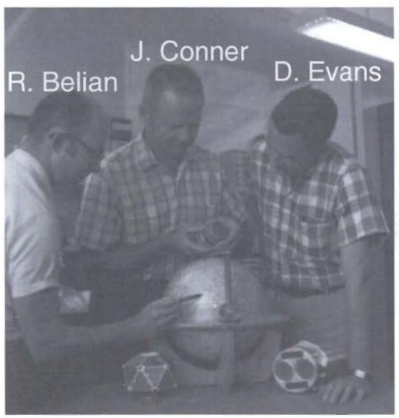
RAY W. KLEBESADEL, IAN B. STRONG, AND ROY A. OLSON

University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico
Received 1973 March 16; revised 1973 April 2

If you're looking for X-ray transients…

Discovery of X-ray Bursts or Flashes

- **First discovery from space of x-ray bursts among galactic sources: Sco X-1, Cen XR-4, sources in Norma, etc.**



The Astrophysical Journal, Vol. 157, September 1969

THE RECENT APPEARANCE OF A NEW X-RAY SOURCE IN THE SOUTHERN SKY

J. P. Conner, W. D. Evans, and R. D. Belian
University of California, Los Alamos Scientific Laboratory, Los Alamos, New Mexico
Received August 9, 1969

The Astrophysical Journal, 162:L115–L119, November 1970

X-RAY AND OPTICAL VARIATIONS OF SCORPIUS X-1

W. D. Evans, R. D. Belian, J. P. Conner, and I. B. Strong
University of California, Los Alamos Scientific Laboratory,
Los Alamos, New Mexico

The Astrophysical Journal, 206:L135–L138, 1976 June 15

THE DISCOVERY OF X-RAY BURSTS FROM A REGION IN THE CONSTELLATION NORMA

R. D. Belian, J. P. Conner, and W. D. Evans
University of California, Los Alamos Scientific Laboratory
Received 1976 February 9; revised 1976 March 19

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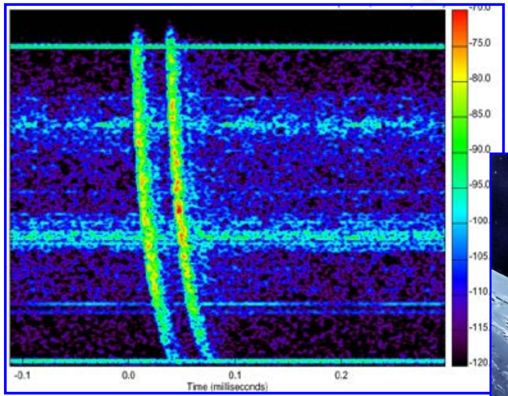
If you're looking for optical transients… Oops

Another Mission Discovery

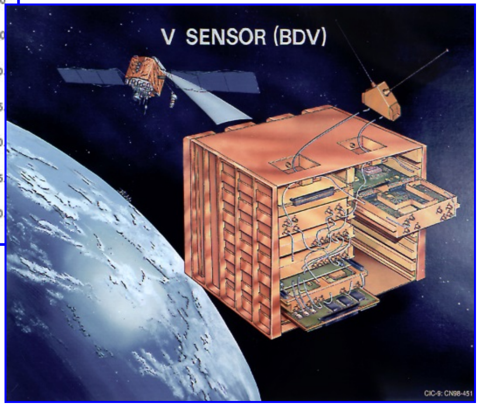
- On 22 September 1979, VELA discovered the 747 event:
  - Flash detected by bhangmeter at 0100 GMT on Vela 6911 (launched in May 1969); EMP sensor was not operational. Occurred over the Indian Ocean near South Africa's Prince Edward Island
  - Plus corroborating evidence (particles, Arecibo signal, Navy hydro acoustic signals)
- After some analysis, it was conditionally declared by LANL that *"the mystery optical flash of Sept. 22, 1979, was a nuclear explosion."*
- Was it?
  - 20 April 1997 article in the Israeli Ha'aretz Daily Newspaper: South African Dep. Foreign Minister Aziz Pahad confirmed that the incident was from a nuclear test.

Supporting Today's National Security Programs

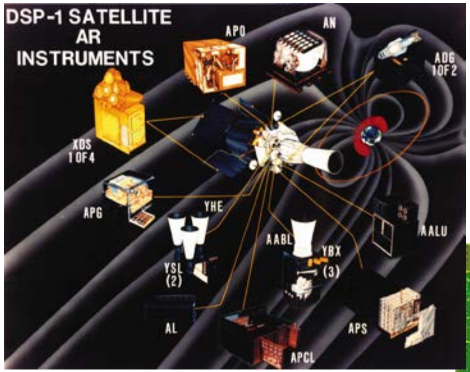
Signatures & backgrounds



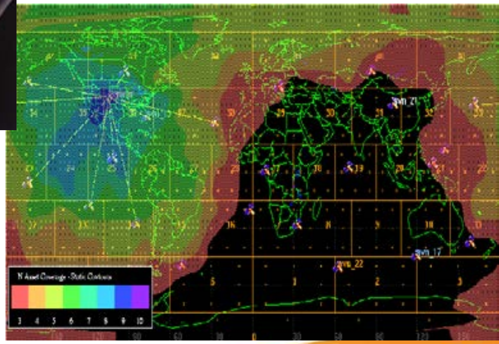
Signal propagation & instrument development



Data collection & fusion



Performance Analysis



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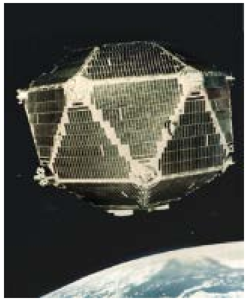
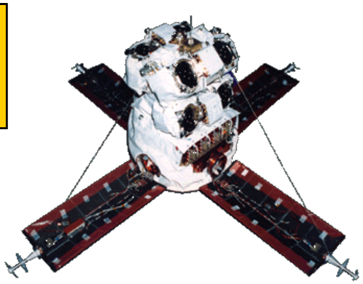
LANL has a long history of success in space!



VELA

Science => Mission Design => Instrumentation => Testing => Launch => Operations => Analysis

50+ years of experience



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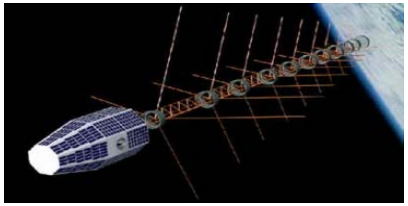
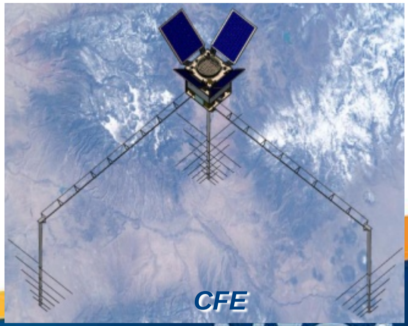


FORTE

MTI

GPS

~1400 sensors
on
~400 instruments
on
~60 satellites



CFE

Sensors and Techniques

Observational Science

- Neutron, Gamma and X-ray sensors
- Plasma sensors
- Energetic particle detectors
- Radio frequency wave detectors
- Optical and thermal imagers
- Deployed decision-making sensors
- Chem/Cam

Hypothesis Testing Science

- Electron guns
- Plasma guns
- Barium releases – thermite and shaped charge
- Ionospheric plasma depletions
- Neutral Particle Beam accelerator
- Computer models

50 Years of Technology Advancement

- Digitizers
  - Take the data and then decide whether to keep it
  - Wideband sensing
- Computers
  - Memory
  - Speed
  - Reconfigurable computers
- Communications
- Charge-coupled Device (CCD) imagers
- GPS timing
- Nuclear power in space
- Field-programmable Gate Arrays (FPGAs)

Computers

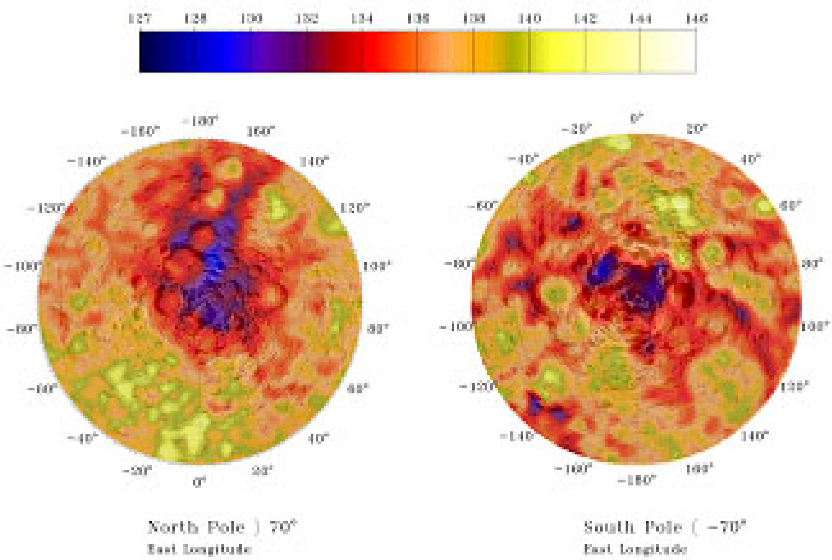
- On-orbit triggering decisions: save or overwrite?
- Memory
  - Data storage
  - Ground-based data display and analysis
- Modeling geophysical phenomena
  - Hypothesis testing – hard to isolate a single variable
  - Monte-Carlo simulations
  - Nuclear explosion phenomenology
  - Data assimilation – combining data with physics-based model to predict future
  - Systems studies – can my system meet specs?

Neutron and γ-Ray Sensors Example - *Lunar Prospector*

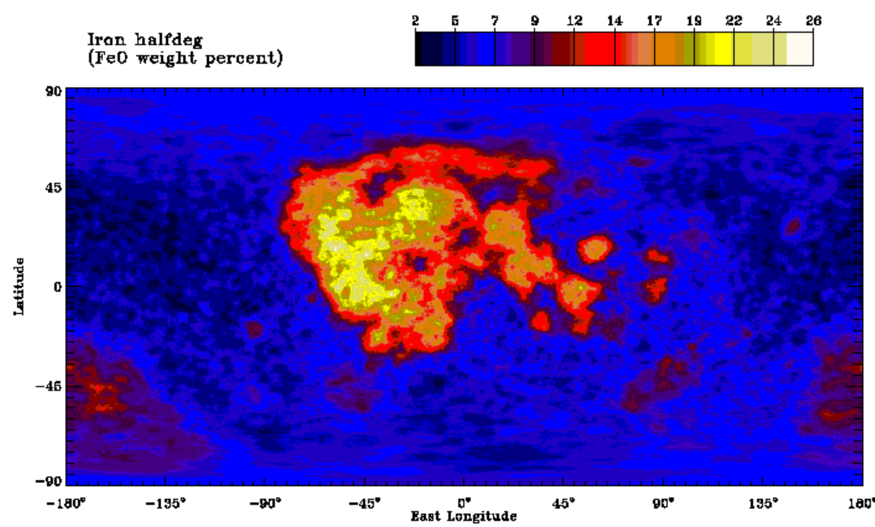
Mapping Water on the Moon: Bill Feldman, PI
• Neutrons from cosmic ray spallation are moderated by H
• Presence of H (the signature of water) is observed at the poles and bottom of craters

Mapping the Elements:
• Gamma-ray spectra enable global maps of the elements
• Major species: O, Si, Ti, Al, Fe, Mg, and Ca, and radioactive Th, K, and U

Epithermal neutrons (counts/32s)



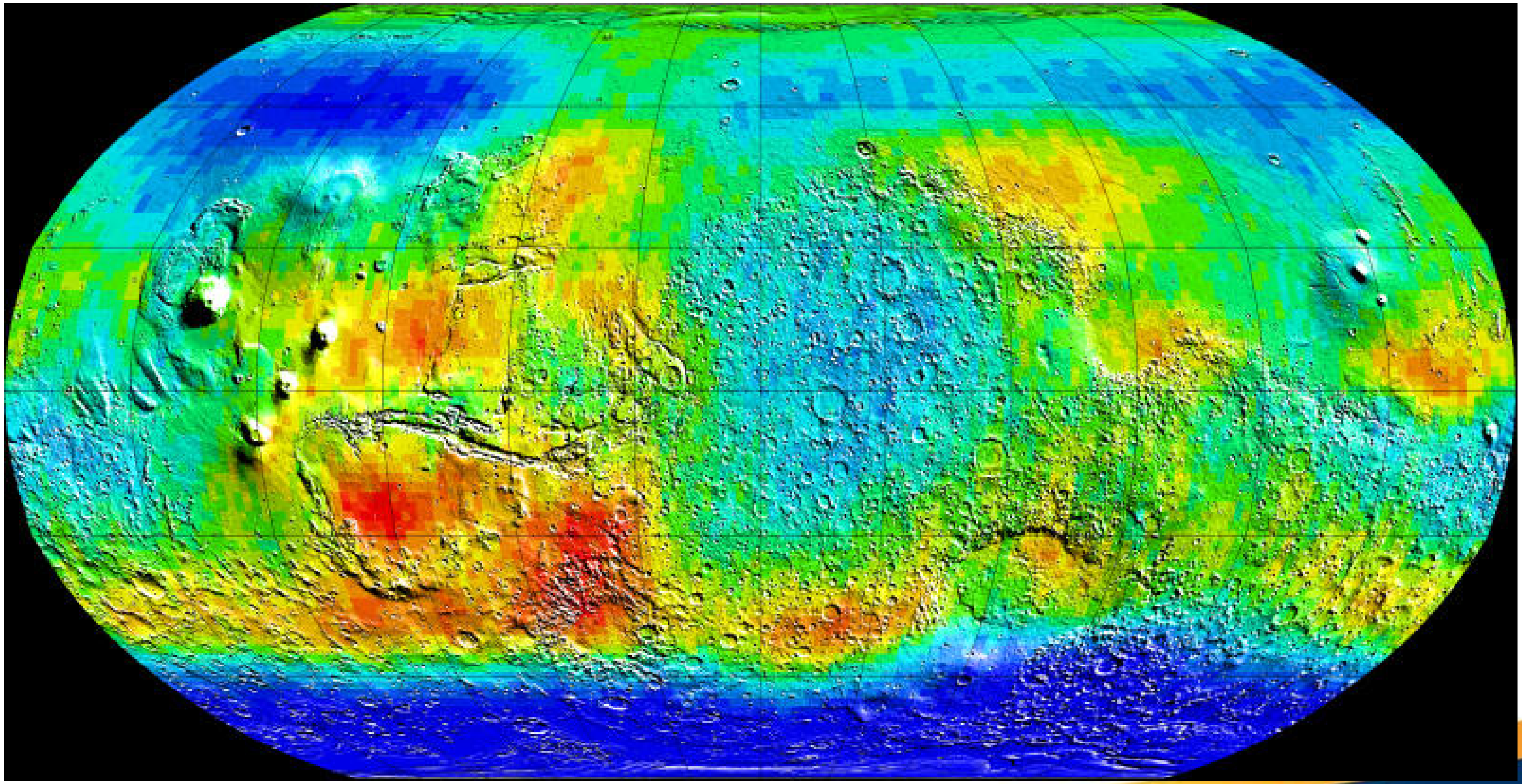
Iron gamma-rays



Planetary Neutron and γ-Ray Spectroscopy: *Mars Odyssey*

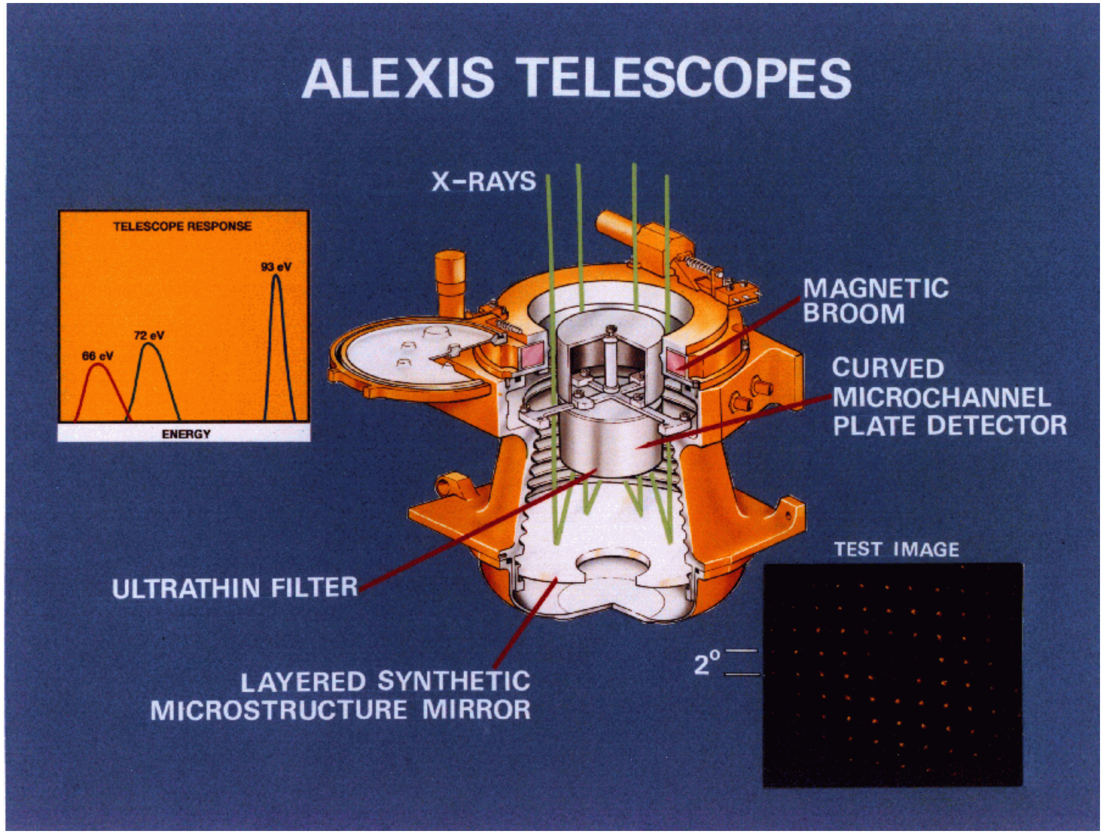
Mapping Hydrogen on Mars:

- Neutrons from cosmic ray spallation are moderated by H
- Presence of H (a signature of water) is noted as a low epithermal neutron flux
- Contours are from Mars Orbiter Laser Altimeter

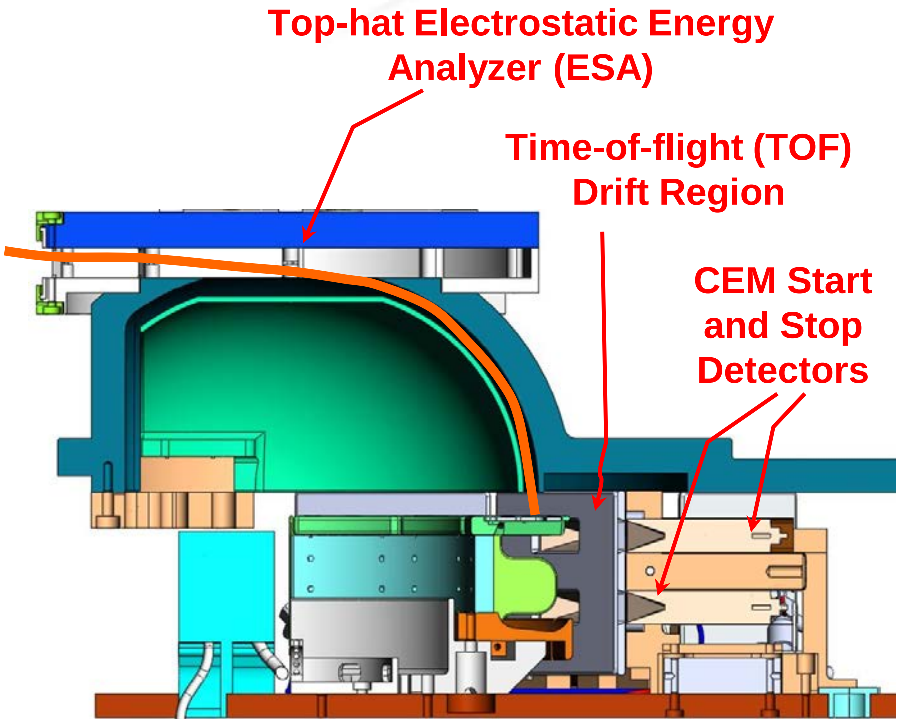


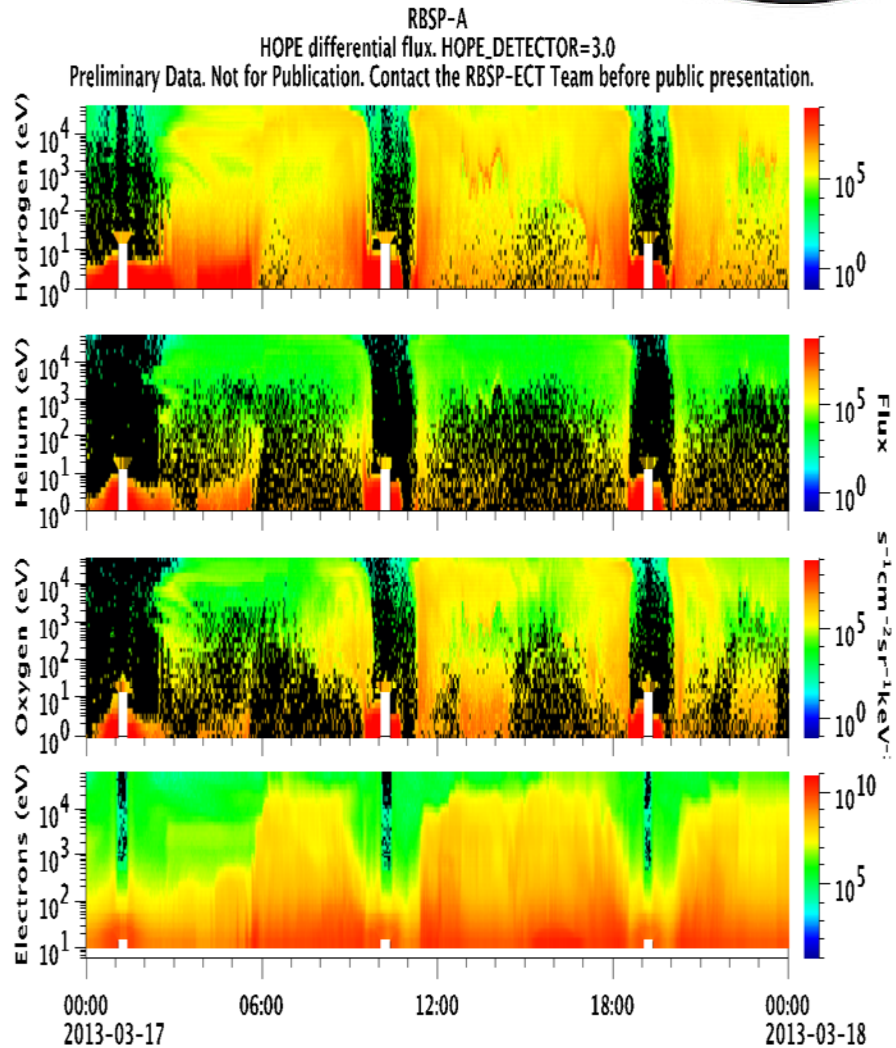
X-ray Sensor Example

- LANL's entrance into Microsat option - low cost, quick missions, experimental payloads enables program flexibility & accelerates R&D
- ALEXIS tested a novel x-ray telescope for nuclear event detection – Bill Priedhorsky and Jeff Bloch were PIs
- The mission is entirely controlled from a small ground station at LANL.
- X-ray telescopes feature curved mirrors whose multilayer coatings reflect and focus low-energy X-rays or extreme ultraviolet light the way optical telescopes focus visible light.
- Although a serious mechanical anomaly damaged a solar paddle, the ALEXIS missions was completely recovered. Cindy Little, Meg Kennison and Diane Roussel-Dupre would not give up on this bird!



Electrostatic analyzers originally 'enabled the largest data bank of solar wind, bow shock, magnetosheath and magnetotail plasma data in existence' and this heritage of discovery continues today with LANL's HOPE (Helium, Oxygen, Proton, and Electron) spectrometers on the Van Allen Probes.





Funsten, H. O., R. M. Skoug, A. A. Guthrie, E. A. MacDonald (+30 co-authors), **Helium, Oxygen, Proton, and Electron (HOPE) Mass Spectrometer for the Radiation Belt Storm Probes Mission**, accepted to *Space Sci. Rev*., 2013, LA-UR-12-24257.

(Slides courtesy Elizabeth MacDonald, ISR-1)

HOPE data from Van Allen Probe A during a large geomagnetic storm on March 17, 2013

9 hour orbits, apogee near 6 Re, midnight at this time

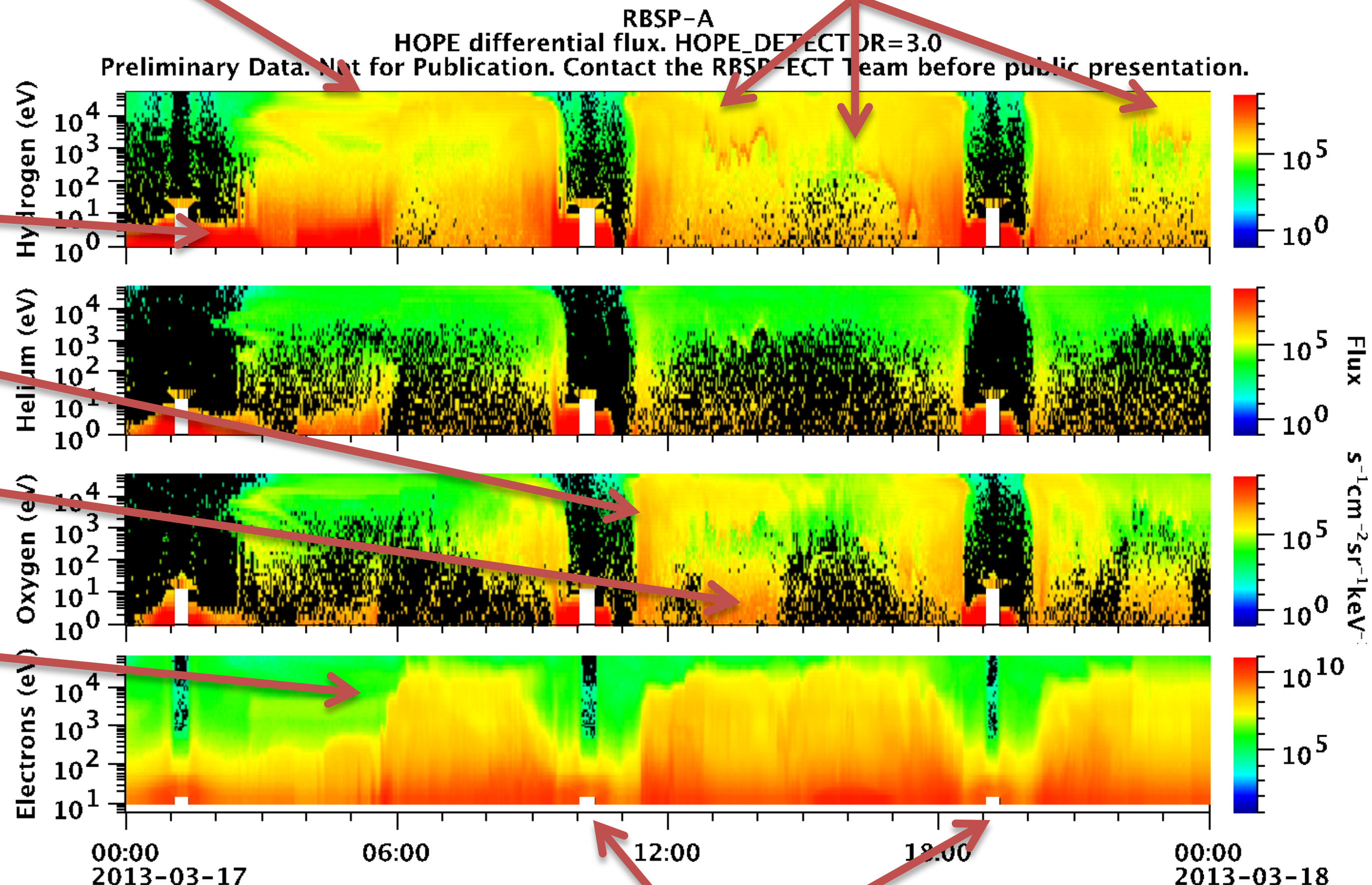
Significant spacecraft charging during eclipse and less significant during midnight apogee time (almost 10 kV!)

Low energy plasma-sphere measured

Storm-time heavy ion ouflow

Low energy diff-erential charging

Start of the storm

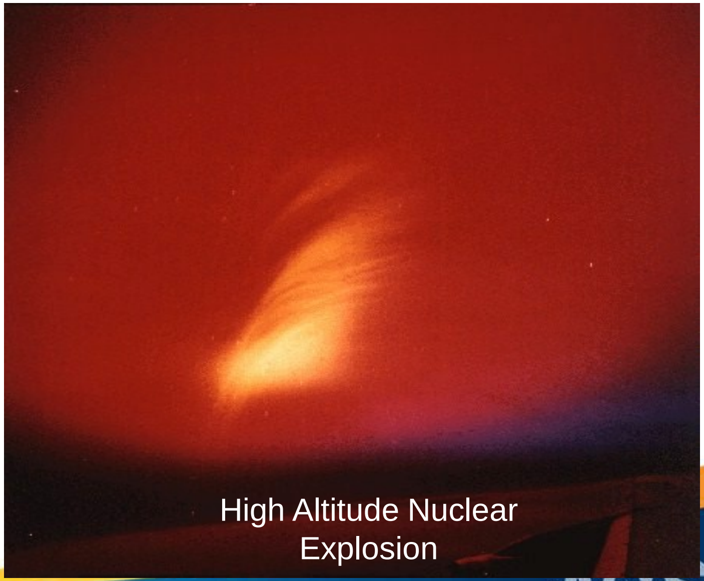


Perigee passes

Barium Release Example

- Barium is readily vaporized, photoionized and both ions and neutrals are visible.
- Photographic and *in situ* diagnostics
- Address both programmatic and scientific issues
  - Programmatic
    - Plasma Structuring – field-aligned striations affect RF propagation
    - Diamagnetic expansion
    - Artificial radiation belts
  - Scientific
    - Field line tracing – polar cusp convection
    - Mapping electric fields
    - Pick-up ion thermalization


Barium Release – ions pink, neutrals green


High Altitude Nuclear Explosion

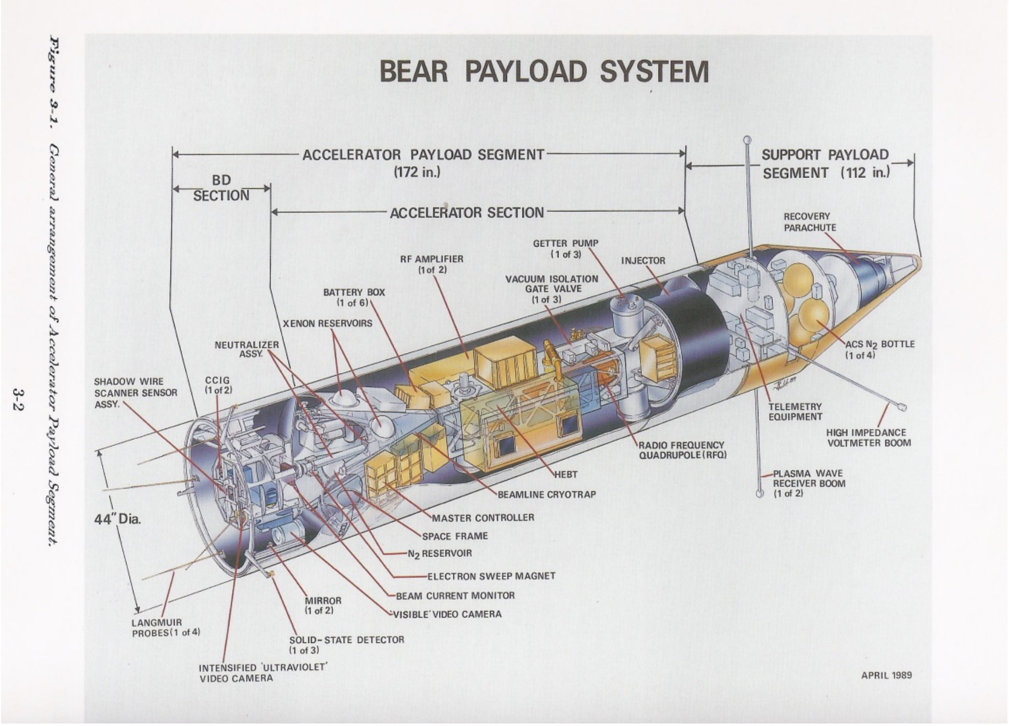
Plasma Depletion Experiments

What'd you do to the ionosphere?

- Original paper: *Mendillo, M., G. S. Hawkins, and J. A. Klobuchar, A sudden vanishing of the ionospheric F region due to the launch of Skylab, J. Geophys. Res., 80, 2217-2228, 1975.*
- The Chemistry – ionosphere is dominated by atomic ions that quickly charge exchange with a molecule followed by a three-body dissociative recombination:
  - $O^+ + H_2O \rightarrow H_2O^+ + O$
  - $H_2O^+ + e \rightarrow H + OH$
  - And poof no plasma for 50 km "hole"!
- Experiments to test the Mendillo hypothesis:
  - How to release water vapor? John Zinn – use explosives!
  - Lagopedo Uno – 1977 sunlit release from Kauai
  - Lagopedo Dos – 1977 dark release from Kauai
  - Waterhole experiments one, two and three with Canadian NRC – hypothesis – modify the aurora by removing current carriers
- Purely academic or a way to listen to HF comm from space?

B.E.A.R. Experiment
Strategic Defense Imitative Office Project

- Beam Experiment Aboard a Rocket
- Don Cobb led the first "Project Team" at LANL. Morris Pongratz was Project Scientist.
- Demonstration of neutral particle beam, RFQ accelerator in space:
    - 1 MeV hydrogen atoms
    - Most energetic accelerator ever flown in space
- The BEAR experiment successfully demonstrated operation of an NPB accelerator and propagation of the neutral beam as predicted in space, obtained first-of-a-kind NPB space physics data, and demonstrated the ability of the BEAR accelerator to survive recovery and to continue operating normally.



B.E.A.R.

Largest and heaviest object LANL put in space

BEAR PAYLOAD MOVES FROM ASSEMBLY BUILDING TO LAUNCH PAD

UNCLASSIFIED

How do you measure beam propagation without a daughter payload?

- Measure pointing and divergence in beam diagnostics section.
- Want to confirm H^o stripping cross-section at 1 MeV.
- Fly intensified UV camera to image N_2^+ airglow emissions
- Point the beam down and East and let H^+ ions mirror and reflect back up while drifting Westward (because of gradient and curvature drifts) back to payload in geomagnetic field and measure them with solid-state sensor onboard.
- Verified with Monte-Carlo model

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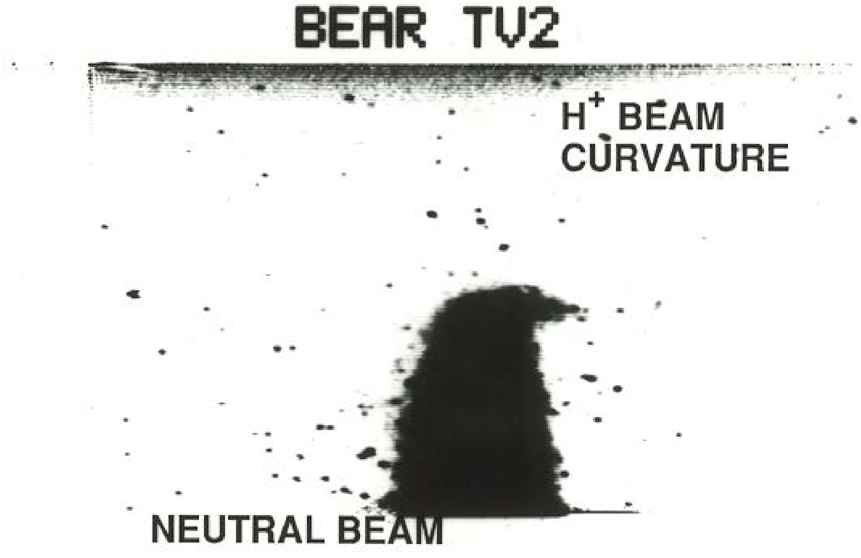
INTENSIFIED UV CAMERA SHOWS BEAM STRIPPED FROM H^0 TO H^+ WITH SUBSEQUENT BEAM CURVATURE DUE TO GEOMAGNETIC FIELD



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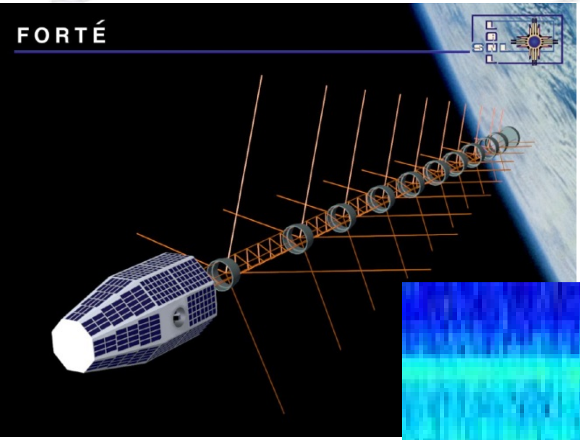
EMP Sensors

On 22 September 1979, VELA discovered the 747 event: Flash detected by bhangmeter at 0100 GMT on Vela 6911 (launched in May 1969); EMP sensor was not operational. This was motivation for adding EMP sensors to the GPS NDS suite.

- EMP Sensors flown on GPS Block IIA and following
  - Multi-frequency time-of-arrival to remove ionospheric dispersion
  - Geolocation via TDOA
  - Need GPS quality clocks
- Background is lightning
  - Provides way to determine real time Total Electron Content globally
- Ground-based lightning sensors for ground truth - EDOTX

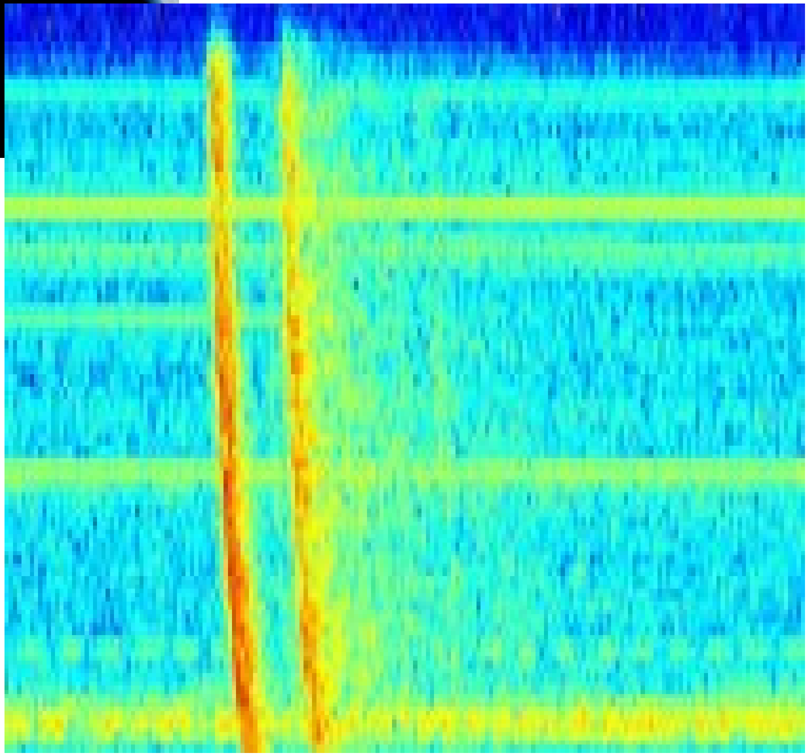
Lightning Research

One man's noise is another man's signal



FORTE: Fast On-Orbit Recording of Transient Events

Lightning Signature:
Trans-Ionospheric Pulse Pair (TIPP)



Missions
- Testbed for Next Generation Nuclear EMP Sensor Technology.
- Space-based Lightning Detection.

Platform

Altitude: ~ 825 km
Inclination: 70 degrees
Launched: August 29, 1997

Instruments:
- Broadband VHF receivers (26 – 300 MHz, 1 μs resolution)
- Photodiode (15 μS resolution)
- CCD Imager (10 km resolution)

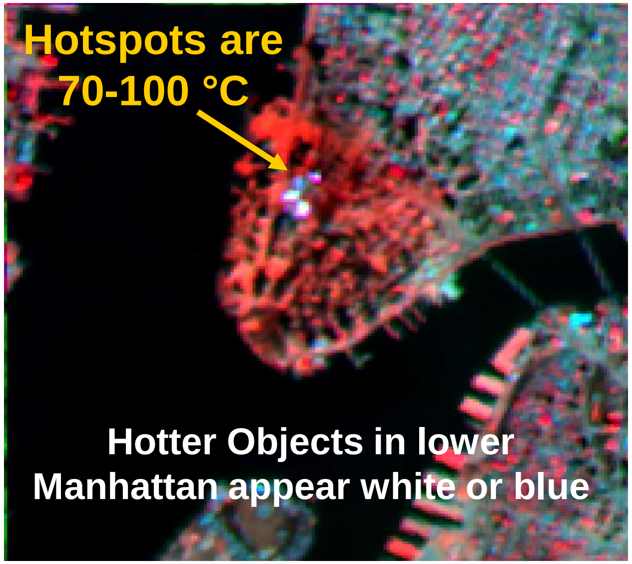
Other LANL RF Instruments: Blackbeard/ALEXIS, V-Sensor/GPS

Supporting Today's National Security Programs

Satellite-based Nonproliferation Programs

Mutispectral Thermal Imager

Launched March 12, 2000



Advanced image interpretation of MTI imagery:

GENIE: Genetic algorithm for automated feature extraction

RED: Hotspots from the WTC attack are red.

BLUE: Smoke plume is light blue

GREEN: Smoke plume's shadow

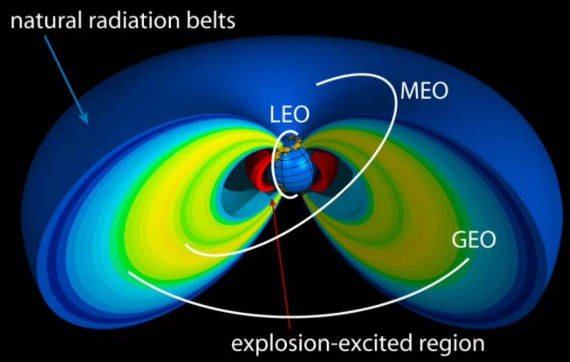
WHITE: Debris field from WTC collapse

Potential damage to ground- and space-based assets from a nuclear weapon exploded high in the atmosphere continues to raise concerns (e.g., see Scientific American, June, 2004).

DREAM

The Dynamic Radiation Environment Assimilation Model

Natural Sources



Nuclear Sources

Los Alamos
NATIONAL LABORATORY
EST.1943

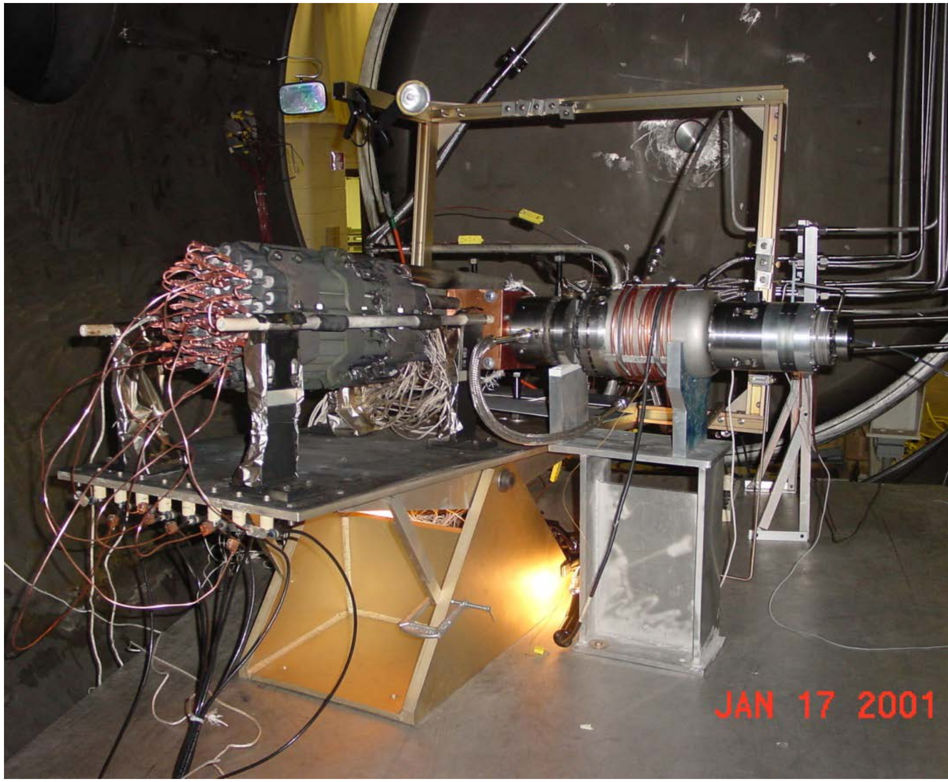
LOS ALAMOS HAS A LONG HISTORY IN SPACE NUCLEAR POWER AND PROPULSION

- The ROVER program (1955-1972) built and tested high power/propulsion reactors with up to 4100MW of power and 930kN of thrust.
- Plutonium-fueled radioisotope thermoelectric generators have provided electrical power for several space missions, from SNAP-3B (2.7W) in 1961 to Cassini (630W) in 1998.
- SNAP-10A, the only reactor flown in space by the US, provided 300We to a satellite.
- The SP-100 reactor program, promoted during the Strategic Defense Initiative, was to provide 100-300 kWe power to joint DOE/NASA/DoD missions.
- Los Alamos was also heavily involved in the testing and evaluation of the Russian TOPAZ II reactor (1989-1997), a 6kWe reactor utilizing thermionic fuel elements.

Advanced Space Nuclear Power

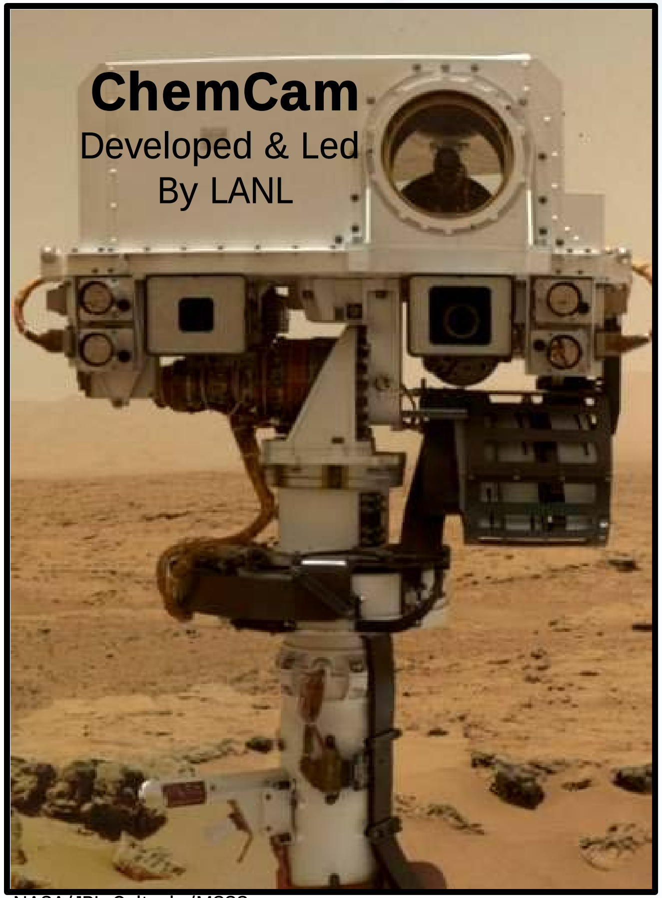
Heat Pipe System (HPS):

- Missions to the outer planets and heliosphere; Manned missions to Mars
- HPS successfully demonstrated at MSFC with a 25 kWt electric heaters and a 350 We Sterling engine
- "end-to-end" testing with DS-1-type ion thruster at JPL; 250 kWt heaters at MSFC
- Critical role in reactor development for NASA's Jupiter Icy Moons Orbiter (JIMO) mission



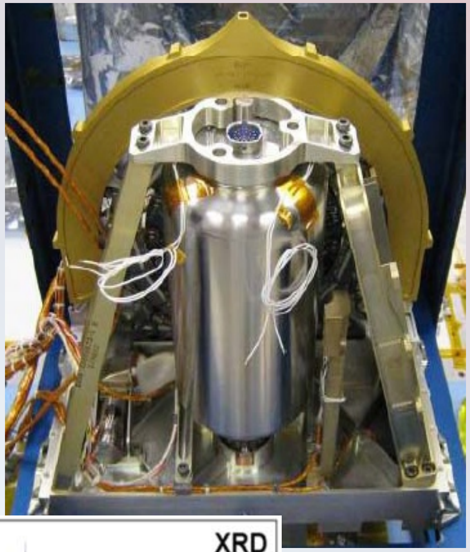
Also, RTG fuel fabrication, reactor design, particle transport codes.

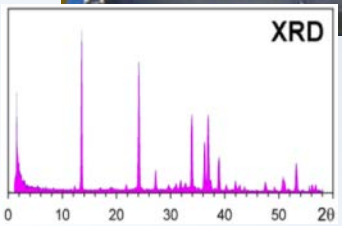
Los Alamos Involvement in Curiosity



NASA/JPL-Caltech /MSSS


NASA/Cory Huston


NASA/JPL-Caltech



CheMin

Science Co-lead is from LANL

The Future
…to infinity and beyond!