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Title: The Space Science and Applications Group (ISR-1) at the Los Alamos National Laboratory: An Overview

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Koller, Josef
Cunningham, Gregory S.
MacDonald, Elizabeth Alice

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The Space Science and Applications Group (ISR-1) at the Los Alamos National Laboratory: An Overview

Jane M. Burward-Hoy

Co-Authors: Greg S. Cunningham, Josef Koller, Elizabeth A. MacDonald, Geoffrey D. Reeves

Outline

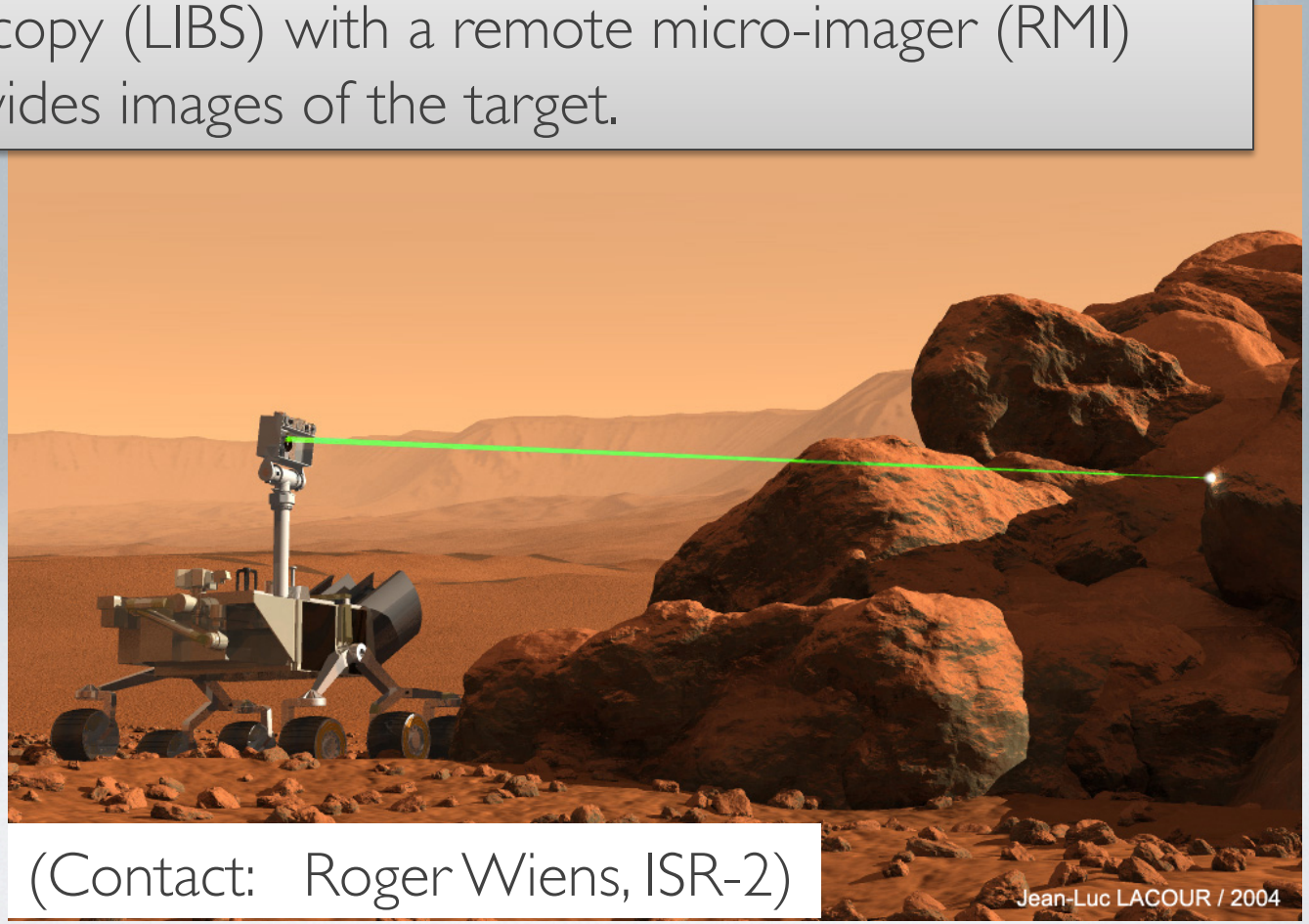
- Space Science and Applications Group in the Intelligence and Space Research Division at LANL
- NASA programs and the Van Allen Probes under NASA's Living With a Star Program
- A data assimilation model called DREAM
- Manmade radiation belts from HANE and an end-to-end model that assesses their threat to space assets (SNRTACS)
- A new orbital prediction model to avoid collisions in space (IMPACT)
- National security: our nuclear phenomenology and proliferation-detection expertise
- Space Weather Summer School

Intelligence and Space Research Divison

- ISR-1: Space Science & Applications applies world-class expertise in space and astrophysical sciences and associated technologies to detect, characterize, and respond to national security threats.
- ISR-2: Space & Remote Sensing develops and applies remote sensing capabilities to problems of global security and related sciences.
- ISR-3: Space Data Systems responds to changing national and global security challenges through the creation, delivery and support of reliable, secure and innovative detection systems in space and around the globe by applying its diverse core capabilities in remote sensing technologies, satellite command, control and mission processing and on-board and real-time signal processing and characterization.
- ISR-4: Space Electronics and Signal Processing is a science and engineering group that develops custom sensors, instruments, and systems for applications requiring advanced detection, monitoring, or assessment technologies.
- ISR-5: Space Instrument Realization provides engineering and technical expertise to support the development and deployment of space-based custom instrumentation for National Security Applications.

LANL-ISR's ChemCam onboard Mars Curiosity Rover

ChemCam combines laser-induced breakdown spectroscopy (LIBS) with a remote micro-imager (RMI) that provides images of the target.



(Contact: Roger Wiens, ISR-2)

Cubesats

In December 2010, four tiny satellites were launched into space (Perseus program)

SpaceX Falcon 9 rocket

Project's success opens door to new capability

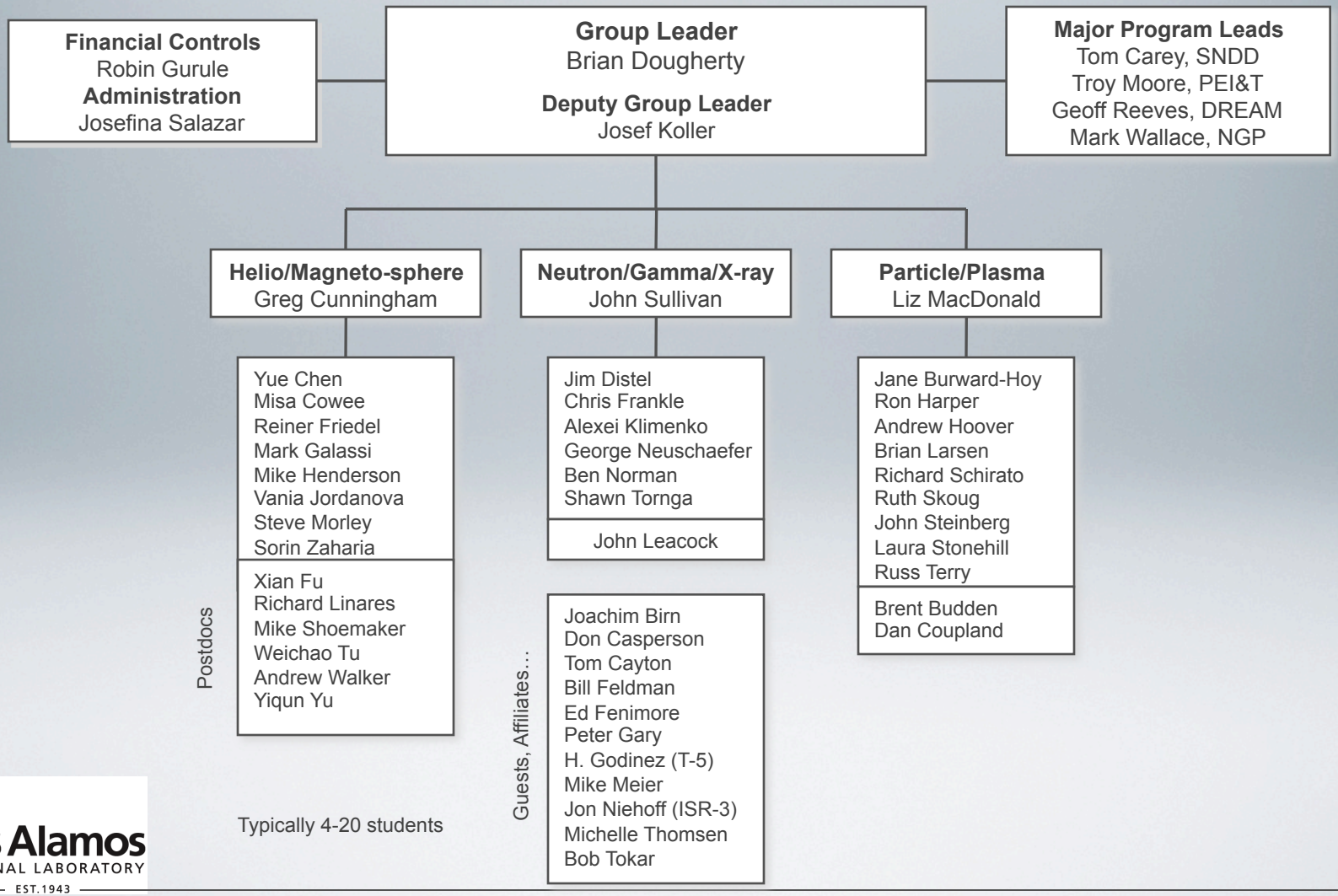
Allow development of new projects with existing and new sponsors

Contact: Nicholas Dallmann, ndallmann@lanl.gov, (505) 665-9879 (ISR-4),
Stephen L. Judd, sjudd@lanl.gov, (505) 665-3165 (IAT-2)

ISR-1: Space Science and Applications

- Broad-based capabilities from mission concept to sensor design, manufacture, calibration, spacecraft integration, mission operations, data analysis, and theory.
- A 50 year history, and this October will be the 50th anniversary of the launch of the first Vela satellites.
- Mixture of civilian and defense-related programs
  - NASA is our primary civilian customer.
  - Defense-related programs supported by DOE, DOD, and other US government agencies.
- Space Weather Summer School, established in 2011.

Who We Are


Financial Controls
Robin Gurule
Administration
Josefina Salazar
Group Leader
Brian Dougherty
Deputy Group Leader
Josef Koller
Major Program Leads
Tom Carey, SNDD
Troy Moore, PEI&T
Geoff Reeves, DREAM
Mark Wallace, NGP
Helio/Magneto-sphere
Greg Cunningham
Neutron/Gamma/X-ray
John Sullivan
Particle/Plasma
Liz MacDonald
Yue Chen
Misa Cowee
Reiner Friedel
Mark Galassi
Mike Henderson
Vania Jordanova
Steve Morley
Sorin Zaharia
Xian Fu
Richard Linares
Mike Shoemaker
Weichao Tu
Andrew Walker
Yiqun Yu
Postdocs
Typically 4-20 students
Jim Distel
Chris Frankle
Alexei Klimenko
George Neuschaefer
Ben Norman
Shawn Tornga
John Leacock
Guests, Affiliates…
Joachim Birn
Don Casperson
Tom Cayton
Bill Feldman
Ed Fenimore
Peter Gary
H. Godinez (T-5)
Mike Meier
Jon Niehoff (ISR-3)
Michelle Thomsen
Bob Tokar
Jane Burward-Hoy
Ron Harper
Andrew Hoover
Brian Larsen
Richard Schirato
Ruth Skoug
John Steinberg
Laura Stonehill
Russ Terry
Brent Budden
Dan Coupland

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NASA: Our Engagement in Pioneering Space Missions

- Enhance our underlying expertise in basic research
- Contribute to our technology base
- Programs cover a number of disciplines, including:
  - Magnetospheric physics, Planetary exploration, Astrophysics, Gamma-ray astronomy, Optical transient detection, Space situational awareness, Solar-terrestrial interactions
  - Contact: Reiner Friedel, rfriedel@lanl.gov, LANL program manager for NASA who currently leads the Science Operations Center for the ECT Instrument Suite on NASA's Van Allen Probes Mission (launched August 2012).

Van Allen Probes

- Van Allen Probes are 2 satellites with an extensive complement of particle and fields instruments in the Earth's radiation belts
- Goal is a better understanding of Sun's interaction on Earth and near-Earth space on various scales of space and time
  - Elliptical, near-equatorial orbit with apogee altitude ~ 30,000 km
  - Satellites are in near-identical, lapping orbits with a full range of radial separations in each LT quadrant
  - During the 2-year mission apogee will precess through all local times starting ~6 MLT
- A real-time data broadcast

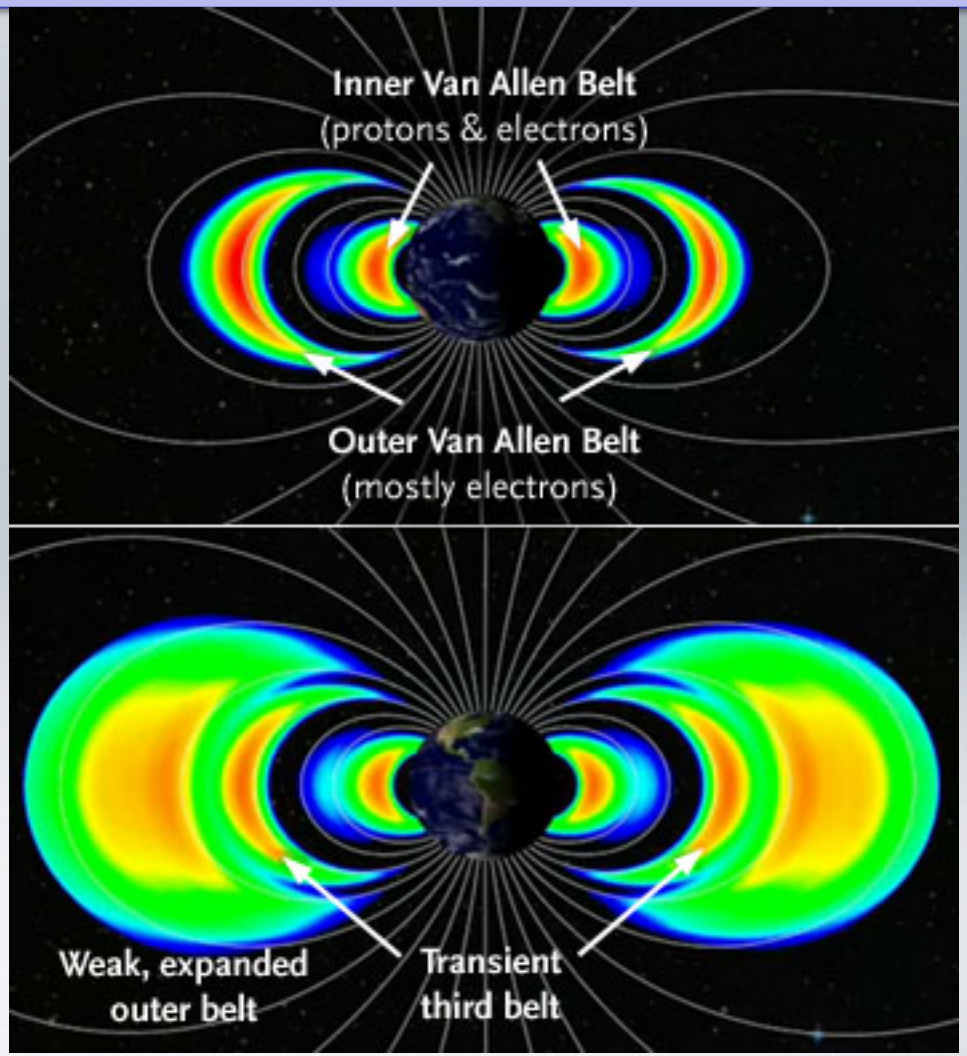
Our group was involved in defining the Van Allen Probes mission, designing a suite of instruments carried on each probe, including building one of the instruments (the HOPE mass spectrometer).

A new third belt and second slot regions…

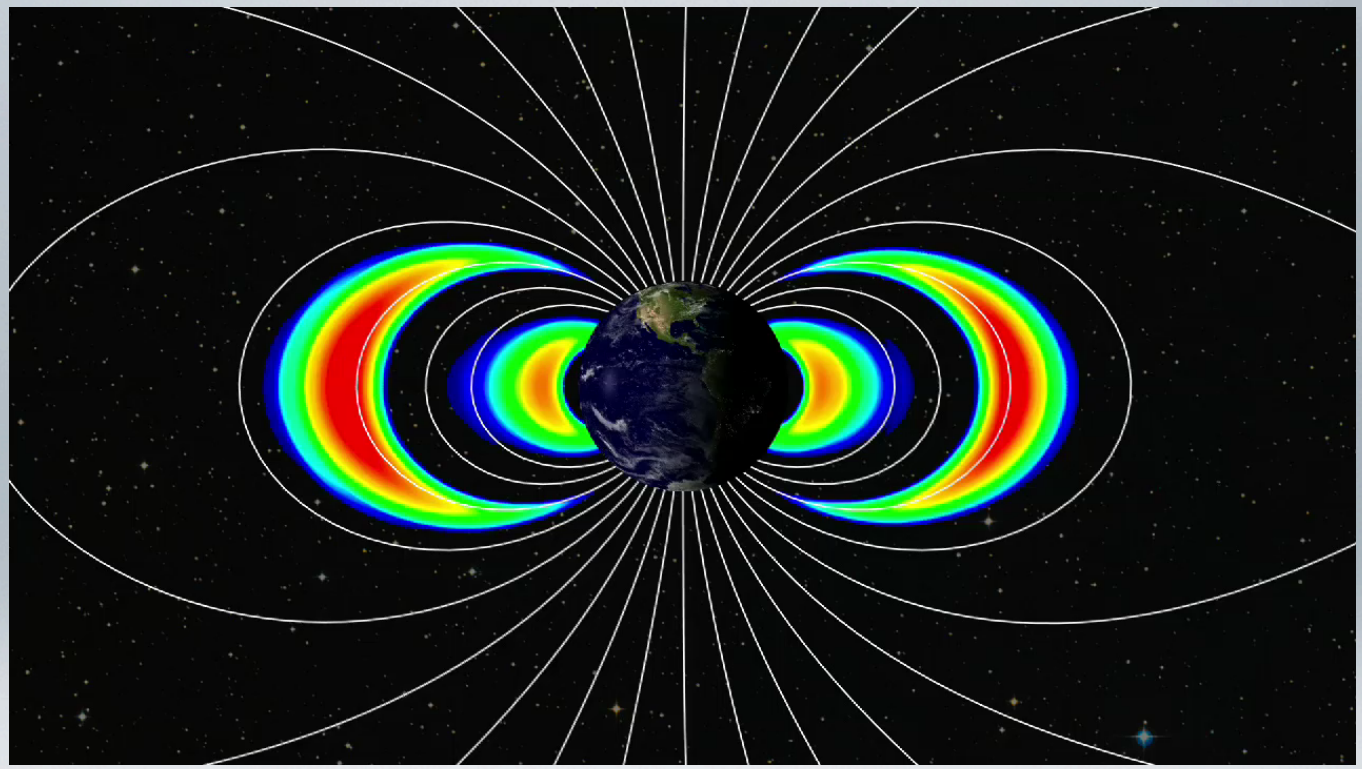
Normally only two Van Allen belts (enhancements of charged particles, seen in cross-section in the upper panel) are trapped in Earth's magnetosphere.

In September 2012, sensors aboard NASA's Van Allen Probes recorded three belts (lower panel).

NASA / JHU-APL / Univ. of Colorado



An animation of the belts' evolving appearance…



NASA / JHU-APL / Univ. of Colorado

Data from the Relativistic Electron-Proton Telescopes (REPT) on NASA's Van Allen Probes, show the emergence of new third belt and second slot regions. The new belt is seen as the middle orange and red arc of the three seen on each side of the Earth.

Van Allen Probes: Contacts

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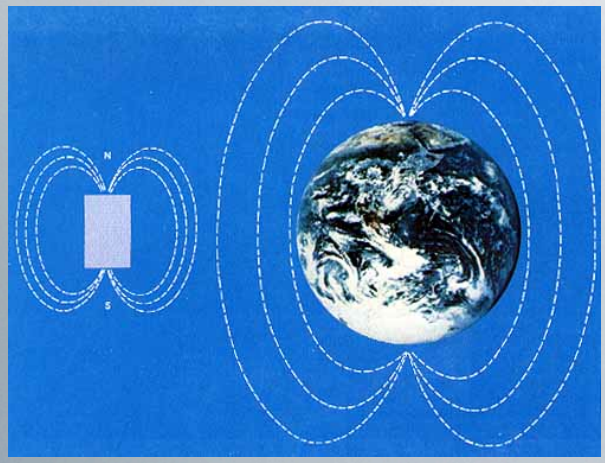
Reiner Friedel, rfriedel@lanl.gov, (505) 665-1936

Elizabeth MacDonald, macdonald@lanl.gov, (505) 606-0257

Geoff Reeves, reeves@lanl.gov, (505) 665-3877

Herb Funsten, hfunsten@lanl.gov, (505) 665-4314

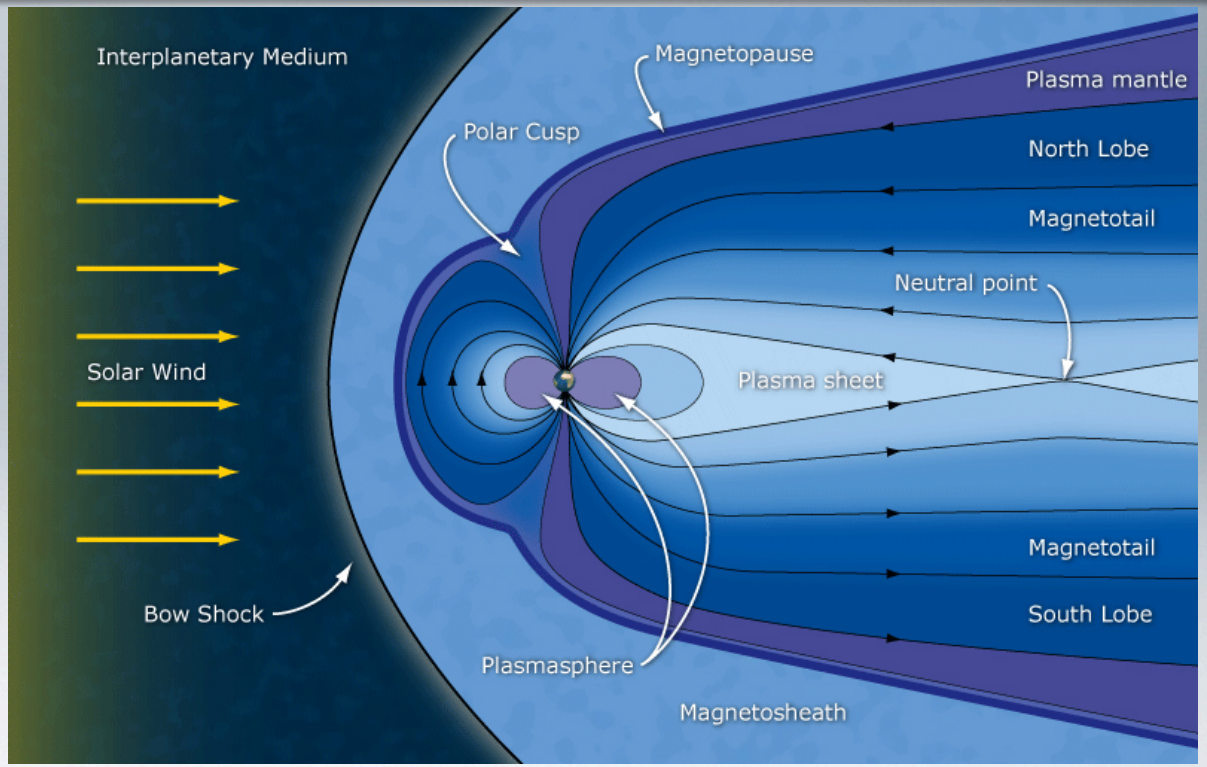


A more realistic model of the geomagnetic field…

Self-consistent ring current B-field model called RAM-SCB

Includes distortions caused by the solar wind

Includes physical processes such as the ring current



Contact: Vania Jordanova, vania@lanl.gov, (505) 667-9908,
Sorin Zaharia, szaharia@lanl.gov, (505) 667-0303

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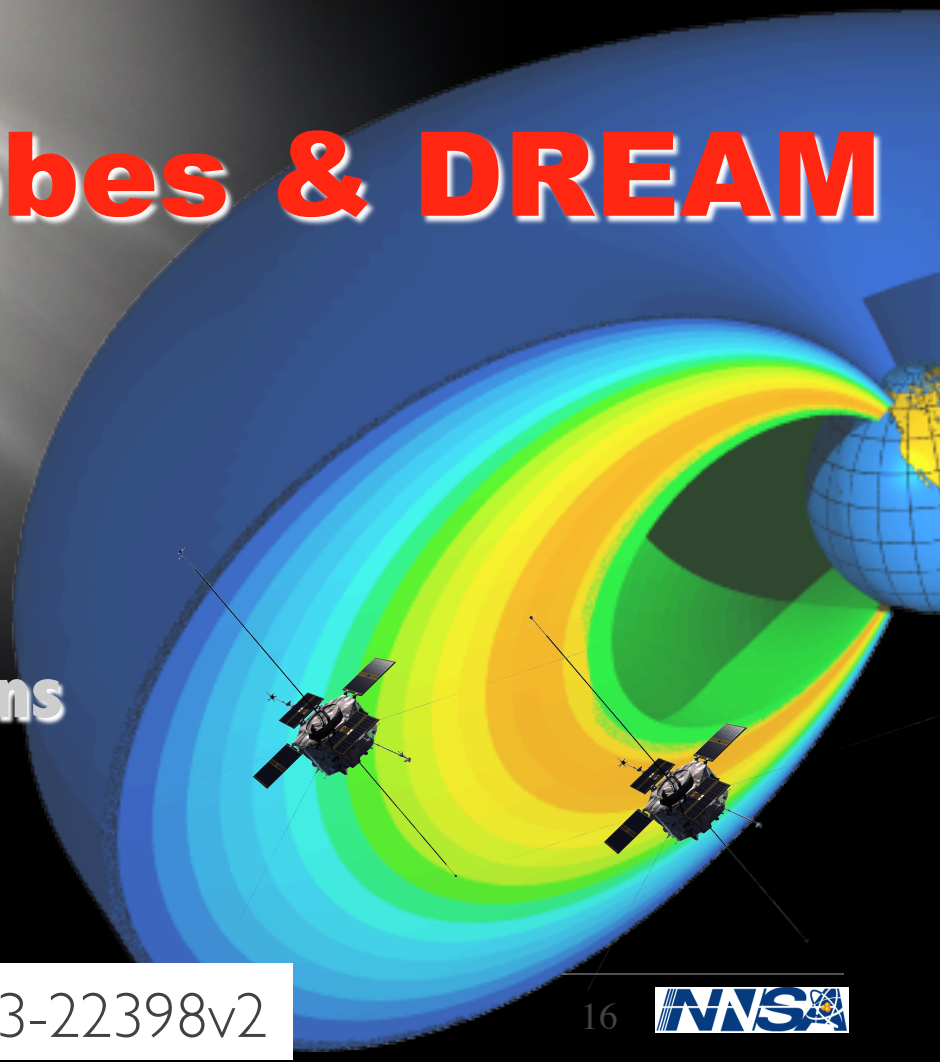
Van Allen Probes & DREAM



National Security and Space Weather Applications

Contact: Geoff Reeves
reeves@lanl.gov

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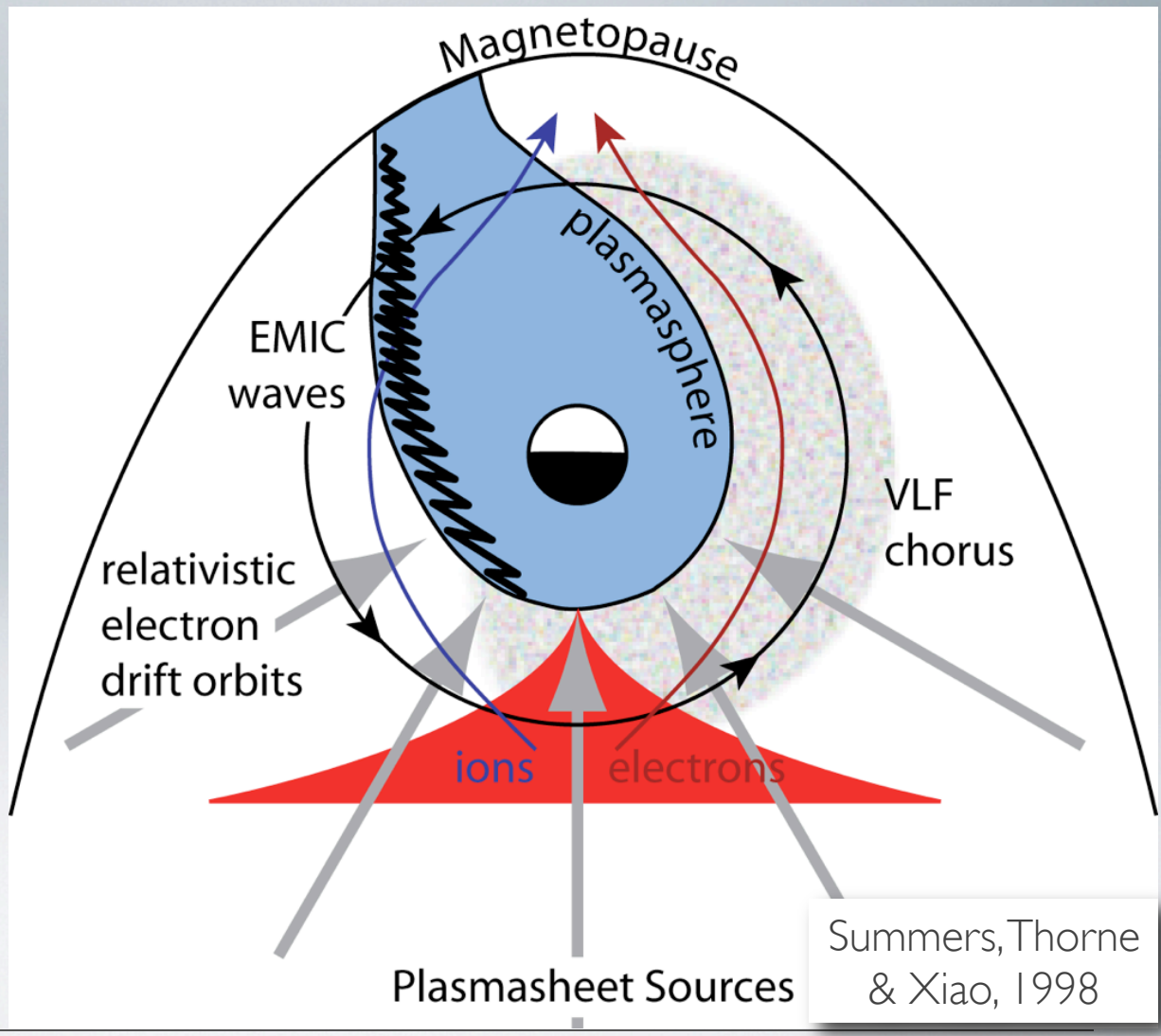
NNSA

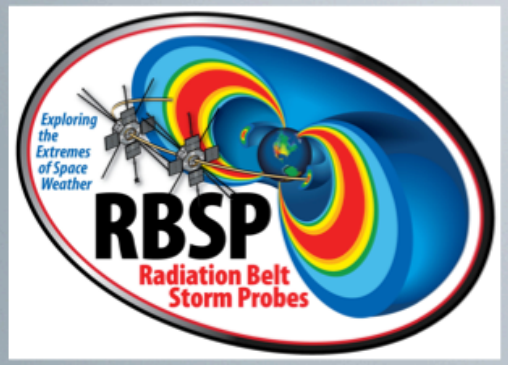
The Natural Environment is Rich but Complex, Coupled, Dynamic

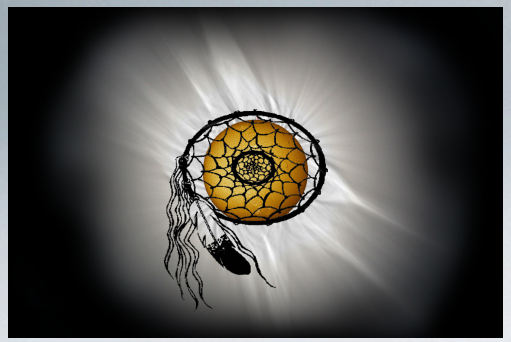
- Diffusion, Losses, & Energization, all occur in a highly-coupled system
- Individual processes are integrated, globally, by electron drift
- Many of the key phenomena are not measured
- Dynamics are not yet predictable



Summers, Thorne & Xiao, 1998

Program Synergy

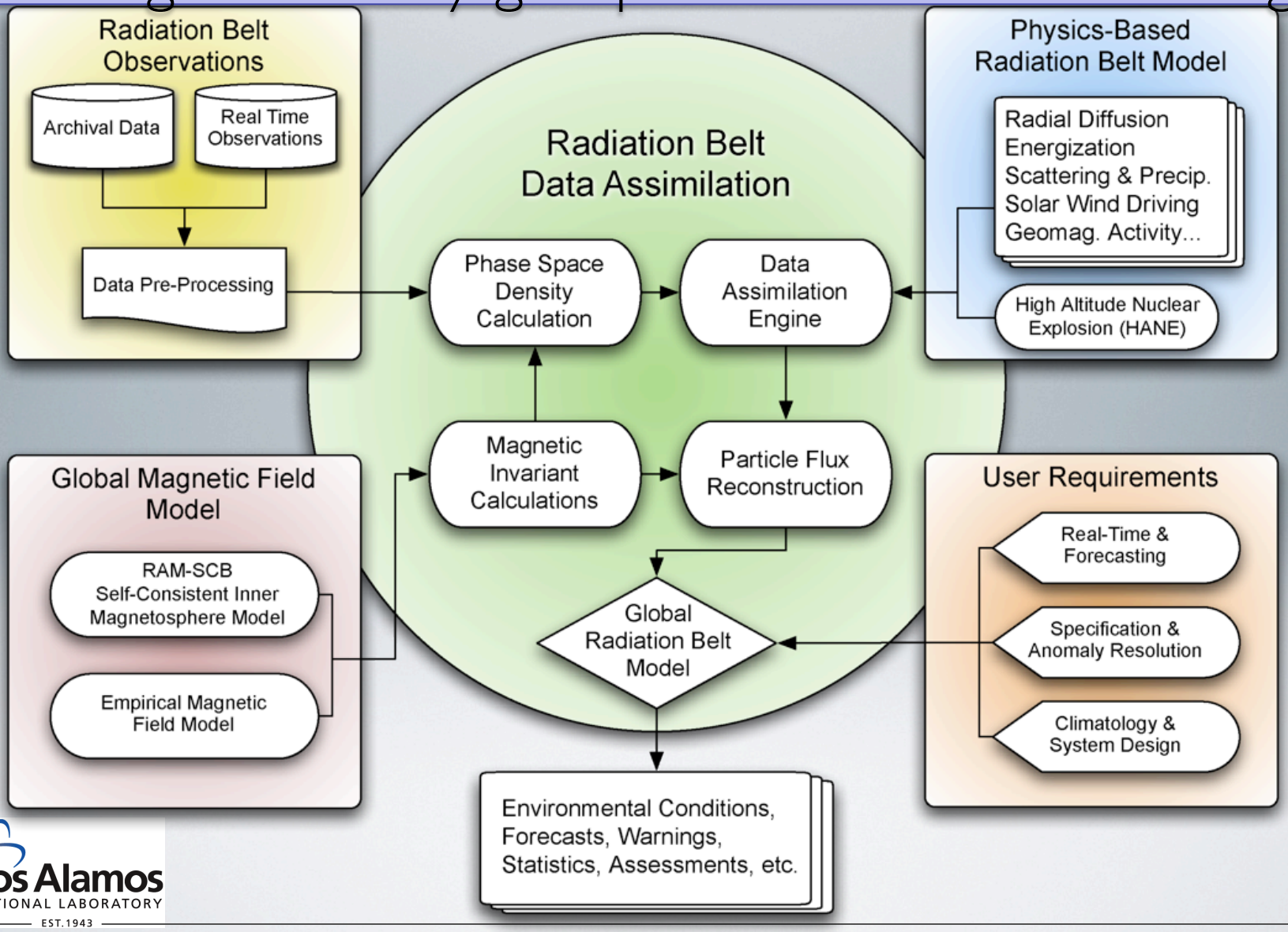




- Van Allen Probes provide the comprehensive set of particle and field measurements needed to understand fundamental radiation belt acceleration, transport, and loss processes

- **Dynamic Radiation Environment Assimilation Model (DREAM)** enables us to put Van Allen Probes observations in a global context, to test predictions based on theory and models, and to calculate the net effect of individual processes on the global distribution of radiation belt particles

DREAM is a data-assimilation modeling program that ties together many group efforts and adds leverage



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Manmade Radiation Belts

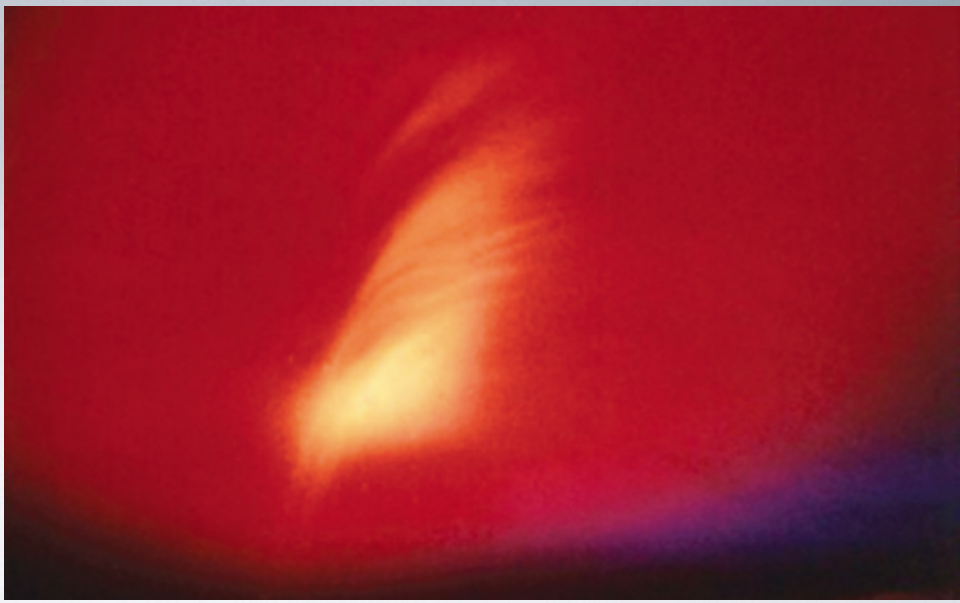
Manmade Radiation Belts can result from the injection and initial trapping of radiation from high-altitude nuclear explosions (HANE)

DREAM also contains a module, used for national security applications, for estimating the effects of the artificial belts.

Starfish, the 1.4-megaton device detonated over the Pacific Ocean at an altitude of 400 km

Seven orbiting satellites failed in the months following the test.

Failure presumably due to the addition of HANE radiation, which persisted for ~5 years.



Source: 1663 Los Alamos Science and Technology Magazine, June 2012

A Model to Assess the Long-Term HANE Threat to Space-Based Assets

Energetic (MeV) electrons produced during a High-Altitude Nuclear Explosion (HANE) by beta decay and trapped in the magnetic field surrounding earth for days to years

The model includes three main components:

1)an electron source model of the initial trapped population caused by HANE beta-decay

2)a 3D diffusion model that computes the evolution of the trapped electrons due to the effects of wave-particle interactions

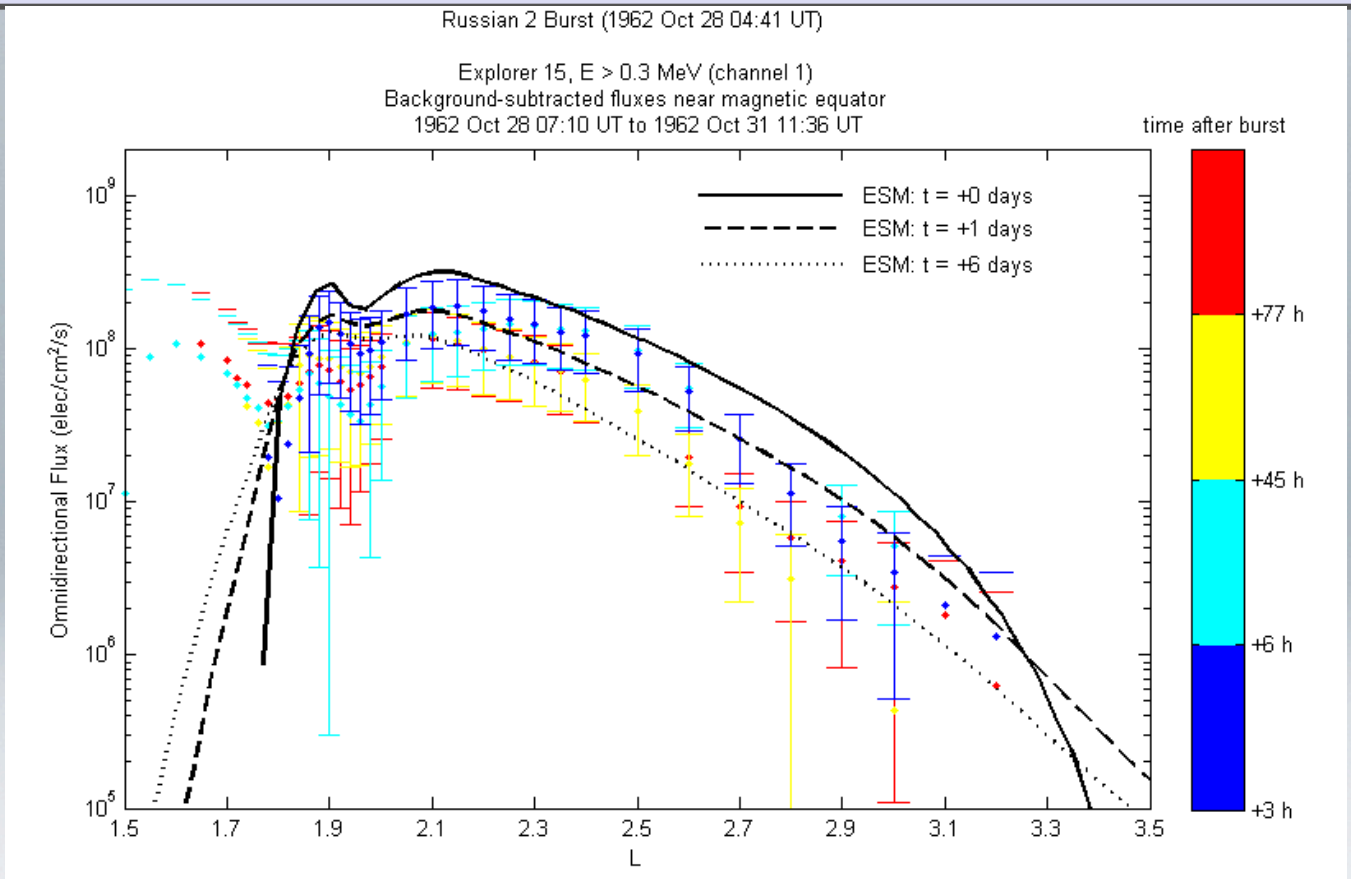
3)a dose deposition model that calculates the interaction of the evolving, trapped, electron population with satellites

For a comparison, 350 HANE scenarios defined by the Air Force Research Laboratory were simulated using the Satellite Nuclear Radiation Threat Assessment Code System (SNRTACS) and this model.

The model has also been compared to published data from high-altitude nuclear tests.

Contact: Greg Cunningham, 505-667-2562, cunning@lanl.gov

The Model has been Compared to Explorer-15 data from the 'Russian-2' HANE



The trapped fraction calculated by the ESM has been redistributed vs L-shell using 2 gaussian functions in order to fit the t=0 data; otherwise the ESM prediction would only have the narrow bump near L=1.85. The 3D diffusion code then predicts the evolution of the initial trapped population over time.

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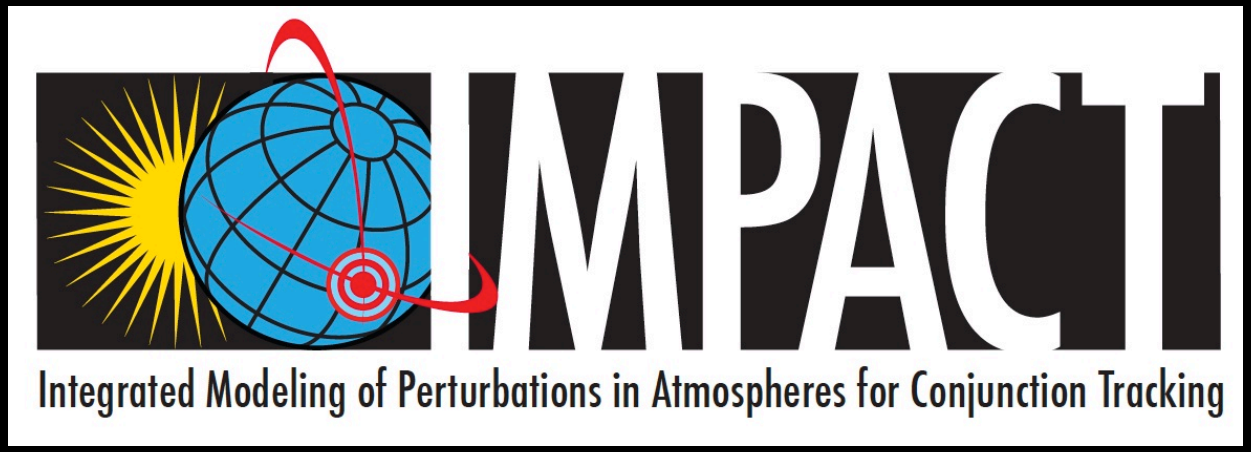
IMPACT Project

Integrated Modeling of Perturbations in Atmospheres for Conjunction Tracking

A New Orbital Prediction Model to Avoid Collisions in Space



PI: Josef Koller, ISR-1
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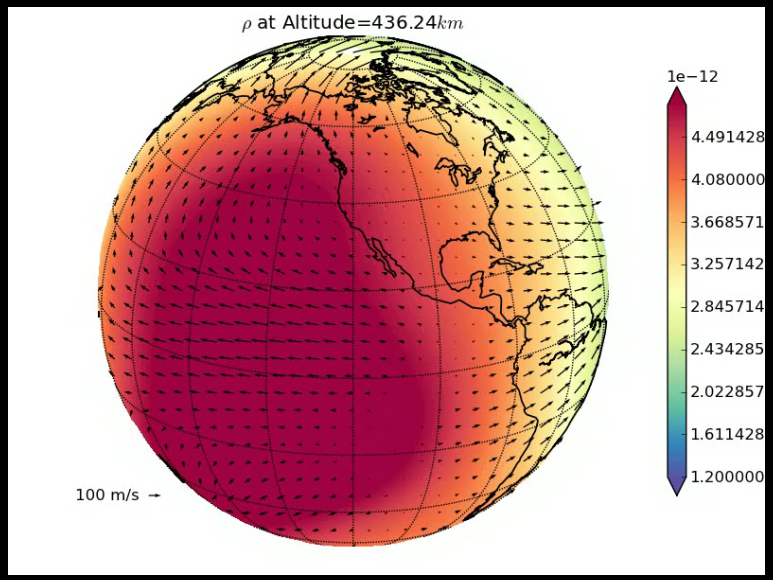
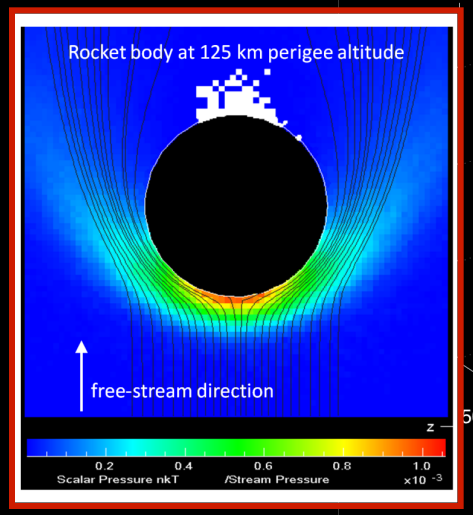
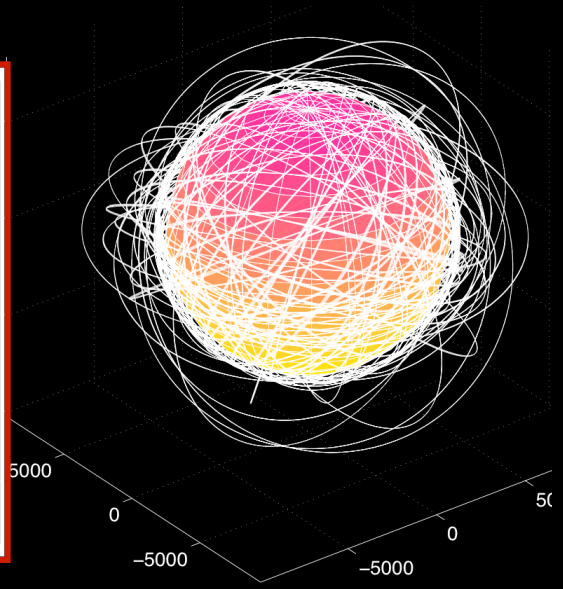
NNSA

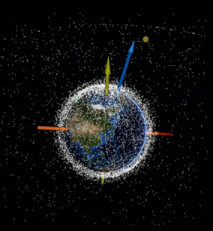
IMPACT is a new LDRD-DR project at LANL

- IMPACT stands for: *Integrated Modeling of Perturbations in Atmospheres for Conjunction Tracking*
- We are developing a new physics-based satellite drag model to accurately predict satellite paths and to prevent collisions in space.









Caption

- The movie shows the dynamic evolution of atmospheric density at high altitudes.
- We need to be able to accurately predict the atmospheric density so we can accurately predict the path of objects in space including space debris.
- The density is driven by solar UV light and space weather can change several orders of magnitudes.

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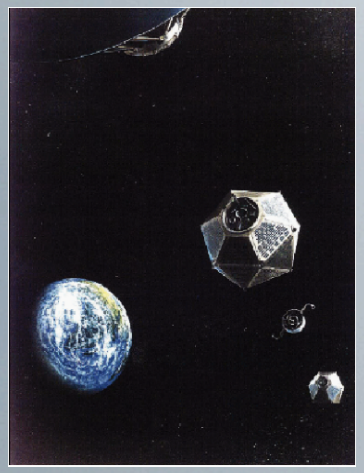
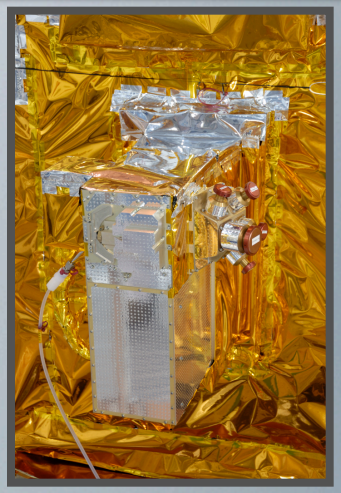
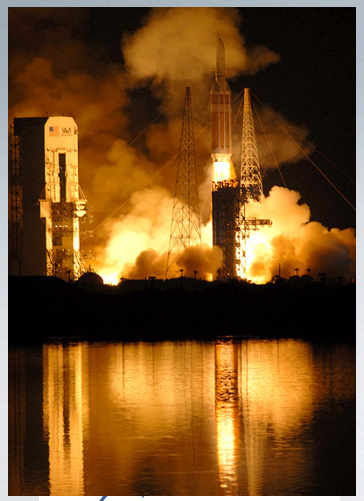
National Security
Our Nuclear Phenomenology and Proliferation-Detection Expertise





- International reputation.
- Primary DOE sponsored mission is to detect and deter clandestine nuclear weapons testing.
- Detect, characterize, and respond to national security threats.
  - Particle, gamma ray, X-ray, neutron detectors on satellites
  - Monitor atmosphere and near-Earth space for possible nuclear tests



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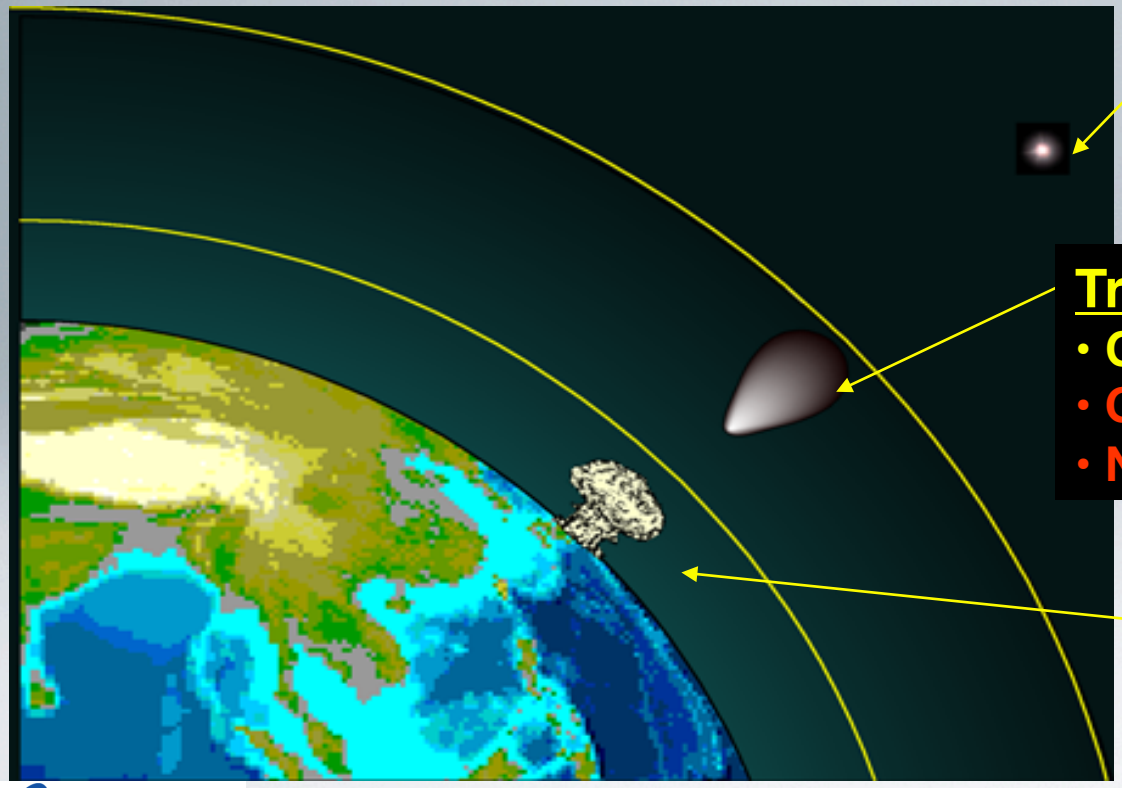
Nuclear detonations at high altitudes & in space can be detected by monitoring for radiation that results directly and indirectly from the reactions that take place in the explosion.

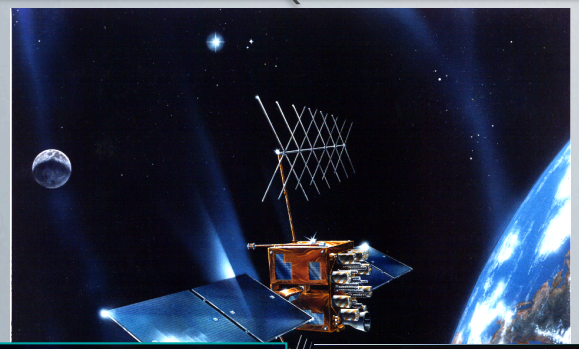


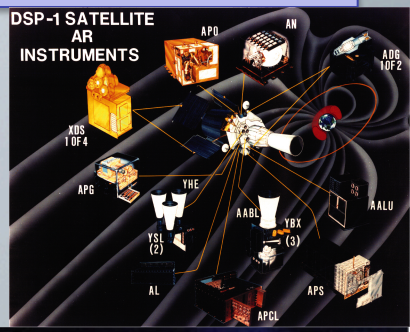
Space NUDET
- Gamma Rays
- Neutrons
- X-rays

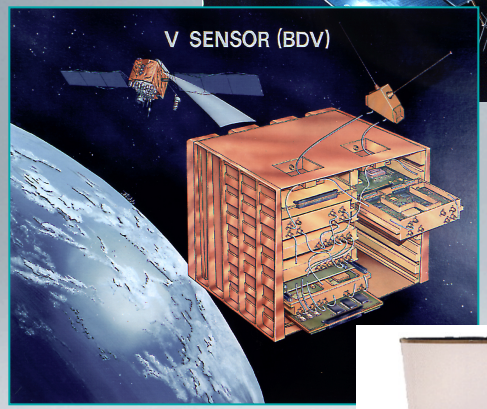
Transition Region NUDET
- Optical
- Gamma Rays
- Neutrons

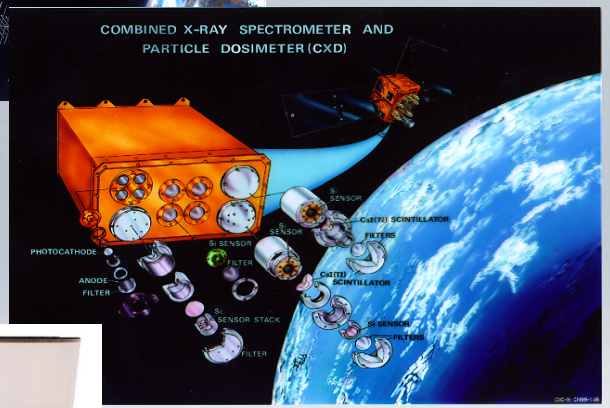
Low Altitude NUDET
- Optical
- EMP

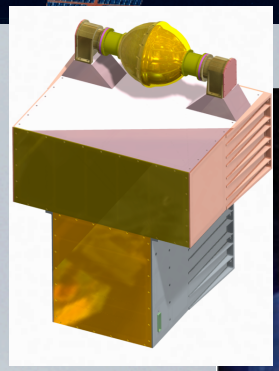
NuDet monitoring: a national program with active LANL (since 1963) and SNL involvement





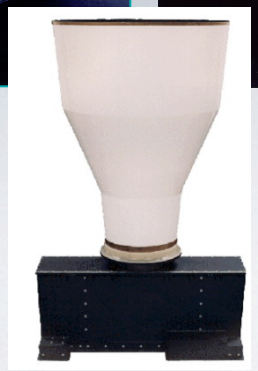






Neutron, Gamma, and X-Ray

EMP



X-Ray

Contact:
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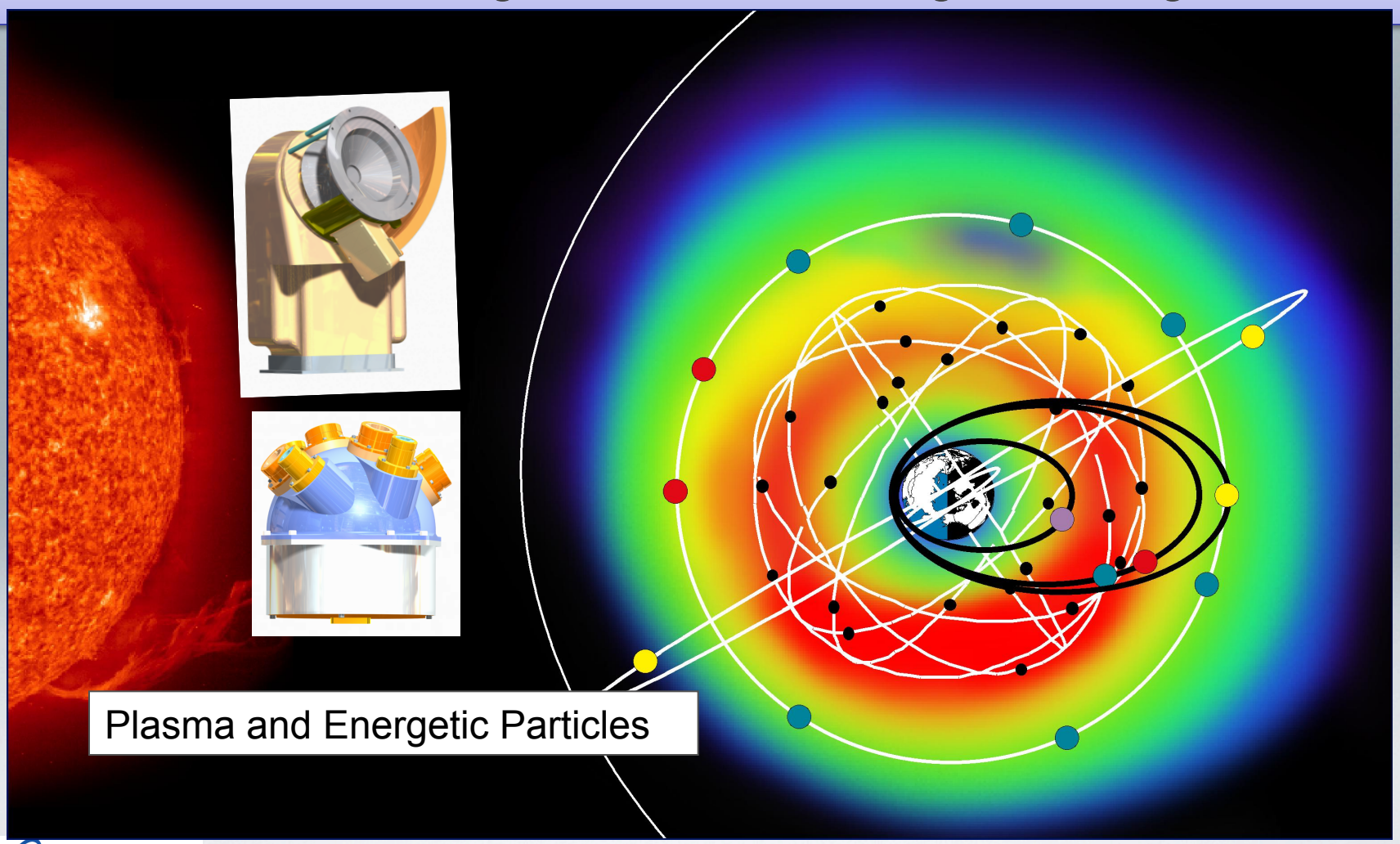
Space environment sensors on USNDS platforms contribute to the space control mission, an understanding of radiation sensor backgrounds, and global SSA



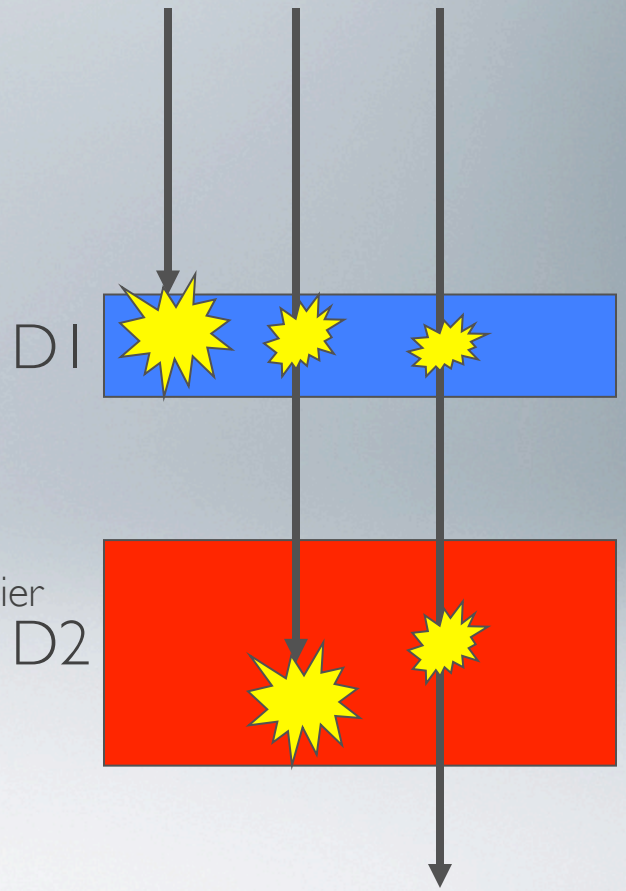
Contact: Elizabeth MacDonald, macdonald@lanl.gov, (505) 606-0257
Jane Burward-Hoy, janebh@lanl.gov, (505) 664-0485

Conceptual Overview of Novel Energetic Particle Instruments at GEO: Measurement Objectives

- Measure energetic particle fluxes of protons and electrons at geosynchronous orbit.
  - Over a wide energy range, in different energy bins for each time interval
- Provide high energy electron measurements
  - With large angular coverage.
- Contribute to the overall environmental measurement objectives with large angular coverage and angular resolution.
- Space environment effects include:
  - Deep dielectric charging
  - Total ionizing dose
  - SEU
  - Proton-induced background

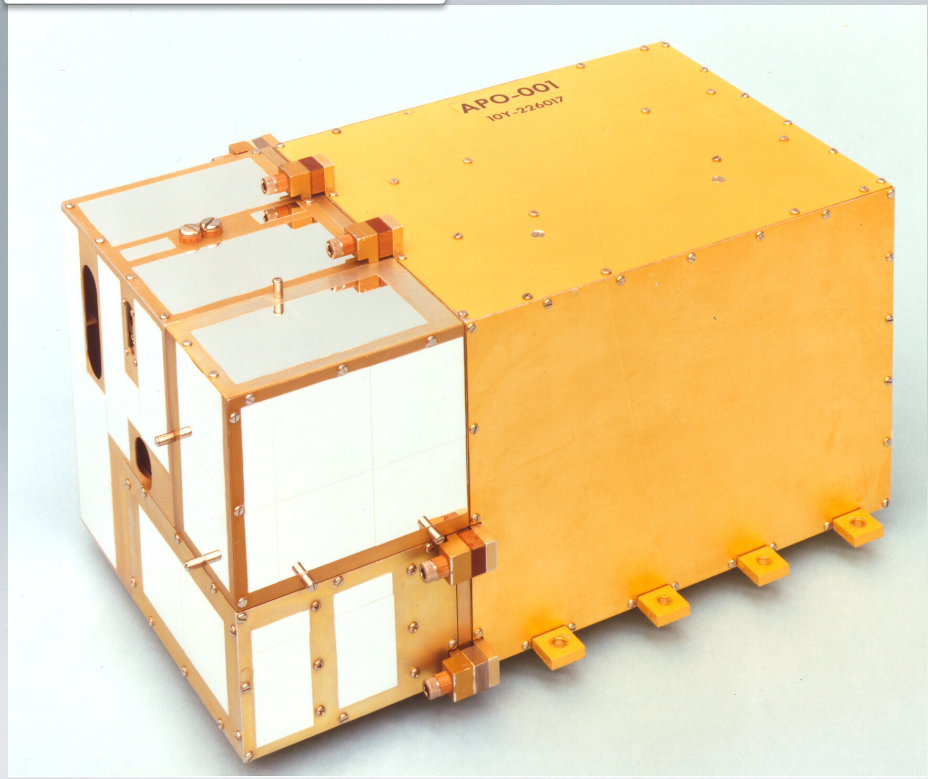
Physics Behind Energetic Particle Instruments: Energy Loss and Energy Deposition

- Energized particles interact in materials
- Energy is deposited or lost in the material (a particle's "stopping power").
  - An example: you can stop alphas with paper but you cannot "stop" neutrinos with Earth.
- Energetic charged particle telescopes
  - Two element sensors (D1 and D2)
    - Electron-hole pairs in silicon with applied bias voltage for charge collection.
    - Light in a scintillator with a photodiode or a photomultiplier tube for readout.
  - Identify particle and measure its energy
    - "Virtual" instrument (GEANT4 modeling)
    - Calibrations (sources, beamlines, charge injection,…)
    - Background calculations (Bremsstrahlung).



Our Heritage of Energetic Particle Instruments

APO Detector



SAVE PEM on DSP

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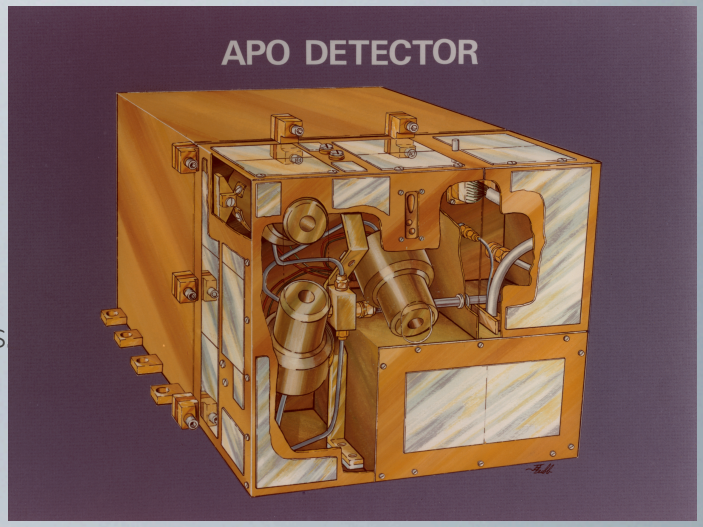
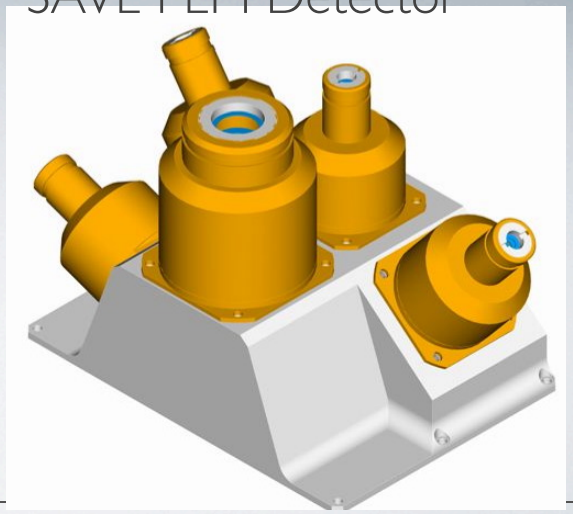
Our Heritage of Energetic Particle Instruments

- Energetic particle instruments on spinning host satellites at geosynchronous orbit.
- Instruments used solid-state Si sensors to measure both electrons and ions.
- ARII APO Detector
  - Measures electrons and various ions.
  - Extensive modeling used to understand response to backgrounds
  - Energy bins fixed on-orbit.
- SAVE PEM (Sabrs Validation Experiment Proton Electron Monitors)
  - Optimized for proton-electron separation
  - Launch early 2007 on DSP-23.
  - Two telescope design ensures good statistics over entire energy range.
  - Improved shielding to minimize backgrounds.
  - Energy bins adjustable via commanding.
  - Experimental.

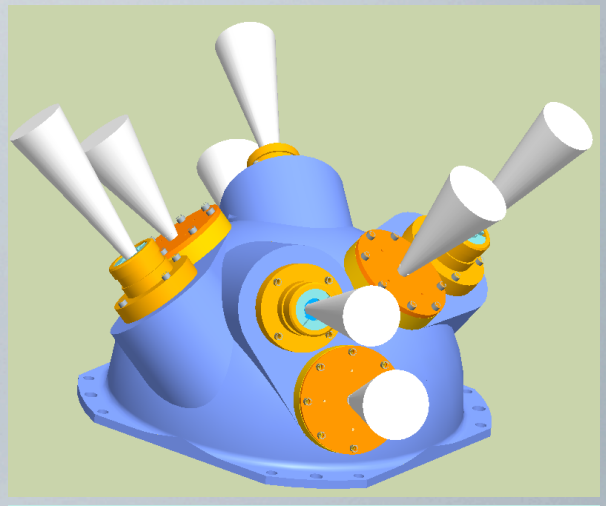


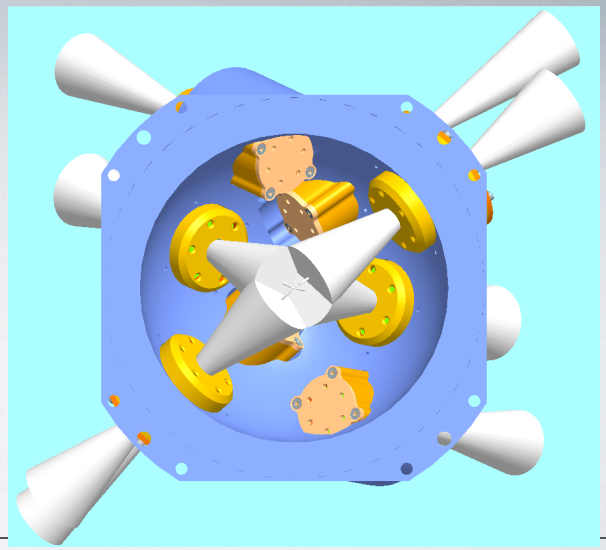
SAVE PEM Detector



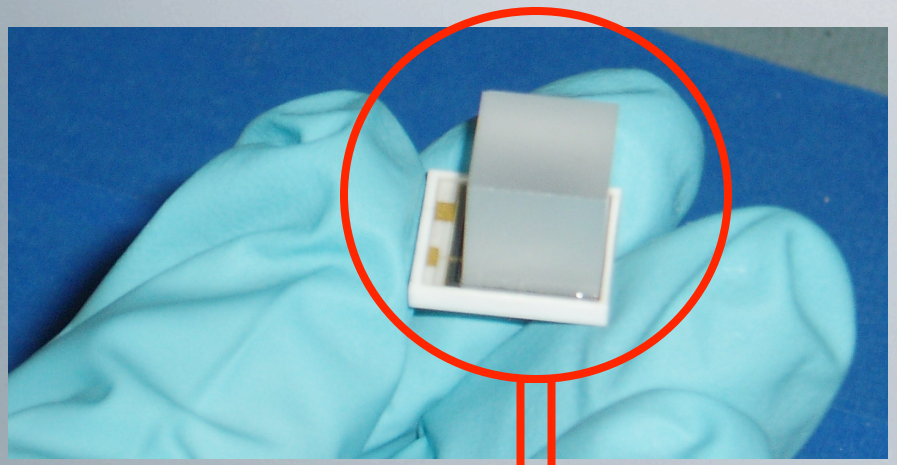
Preliminary Design Meets Required Energy Range, Angular Coverage, and Angular Resolution

- Design drivers.
  - Three-axis stabilized platform.
    - Detectors placed at specific 'look angles'
  - Minimize weight, volume, power consumption.
  - Keep electronics and data rates reasonable.
- Weight: 4.2 pounds, Power: 1.0W (sensors)
- Eight telescopes arranged on a hemisphere
  - Four low-energy telescopes (LETs), 16° opening angle.
  - Four high-energy telescopes (HETs), 26° opening angle.
    - Each radially points toward a central, fast scintillator (LYSO).
- 16 total channels over full energy range in instrument
    - 8 channels in LET, 8 channels in HET (log-spaced)
      - Electrons: 50 keV - 10 MeV
      - Protons: 200 keV - 100 MeV

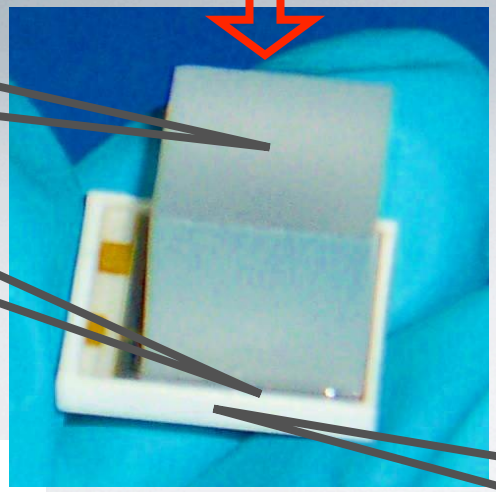




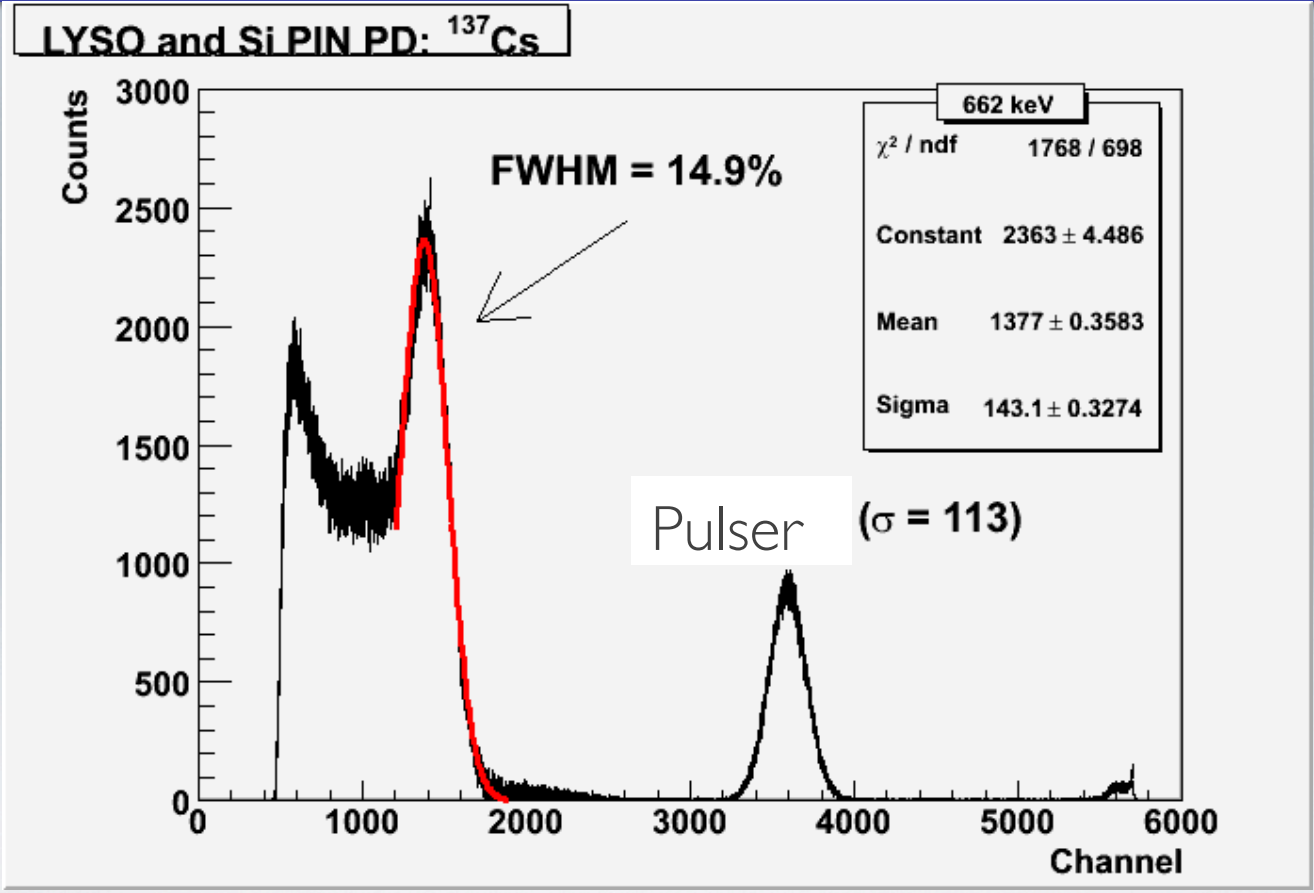
LYSO Scintillator: Energy Resolution Measurement in the Lab



- LYSO scintillator with Si Photodiode for light read-out.
- Gamma emitting source (^{137}Cs).
- Energy resolution of assembly is determined.



Measured Energy Resolution of LYSO and Si PIN Photodiode Meets Measurement Objective



Contact: Jane Burward-Hoy, janebh@lanl.gov, (505) 664-0485

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Outline

- Space Science and Applications Group in the Intelligence and Space Research Division at LANL
- NASA programs and the Van Allen Probes under NASA's Living With a Star Program
- A data assimilation model called DREAM
- Manmade radiation belts from HANE and an end-to-end model that assesses their threat to space assets (SNRTACS)
- A new orbital prediction model to avoid collisions in space (IMPACT)
- National security: our nuclear phenomenology and proliferation-detection expertise
- Space Weather Summer School

- Established in 2011
- Projects related to space weather, space science and applications
- Applications solicited annually and competitive space science graduate students (both U.S. and foreign) in space physics, planetary sciences, aerospace engineering or related fields are selected to work with internationally recognized researchers (deadline to apply is mid-February, http://www.swx-school.lanl.gov)
- Educational and collaborative atmosphere with lectures
- Students receive a fellowship to cover relocation and living expenses (housing is at the discretion of the student).
- Sponsored and supported by a number of organizations, including: Los Alamos Institute of Geophysics and Planetary Physics (IGPP), Laboratory Directed Research and Development Office (LDRD), Center for Information Science and Technology

Contact: Josef Koller, jkoller@lanl.gov, (505) 665-3399

LOS ALAMOS SPACE WEATHER SUMMER SCHOOL

Seminars

- Students attend a variety of lectures given by distinguished researchers at Los Alamos.
- Topics are related to current space weather research including plasma physics, radiation belts, numerical modeling, solar wind physics, spacecraft charging, orbital drag modeling, and others.
- We also provide opportunities to develop the students' written and oral communication skills, including resume writing.

Faculty of the Space Weather Summer School

Director: Josef Koller, ISR-1, contact

Dep. Director: Russ Terry, ISR-1, contact

LANL Adjunct Faculty:

Name	Group	Mentor	Lecturer	Contact
Brian Larsen	ISR-1	x	x	contact
David Palmer	ISR-1	x		contact
Eberhard Moebius	ISR-1		x	contact
Geoff Reeves	ISR-1		x	contact
Greg Cunningham	ISR-1		x	contact
Jane Burward-Hoy	ISR-1	x		contact
John Sullivan	ISR-1		x	contact
Mike Henderson	ISR-1		x	contact
Mike Shoemaker	ISR-1	x	x	contact
Peter Gary	ISR-1		x	contact
Reiner Friedel	ISR-1	x	x	contact
Sorin Zaharia	ISR-1	x	x	contact
Steve Morley	ISR-1		x	contact
Vania Jordanova	ISR-1		x	contact
Weichao Tu	ISR-1		x	contact
Jon Niehof	ISR-3		x	contact
Herb Funsten	ISR-DO		x	contact
Gian Luca Delzanno	T-5	x		contact
Humberto Godinez	T-5	x	x	contact
Balu Nadiga	CCS-2	x		contact

Non-LANL Adjunct Faculty:

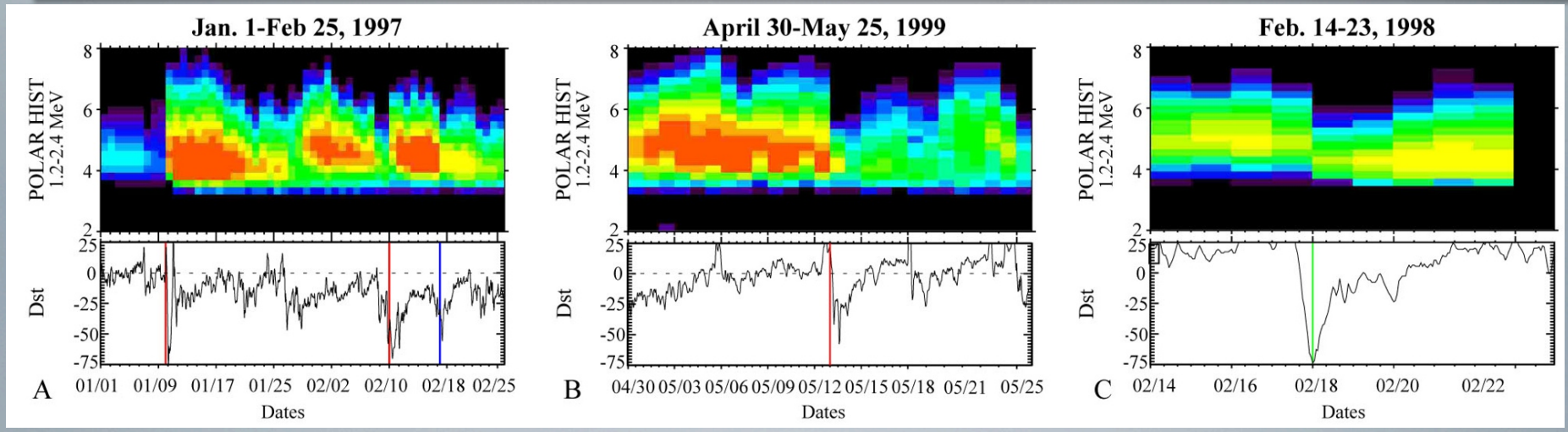
Name	Group	Mentor	Lecturer	Contact
Alan Lovell	AFRL Kirtland		x	contact

Summary

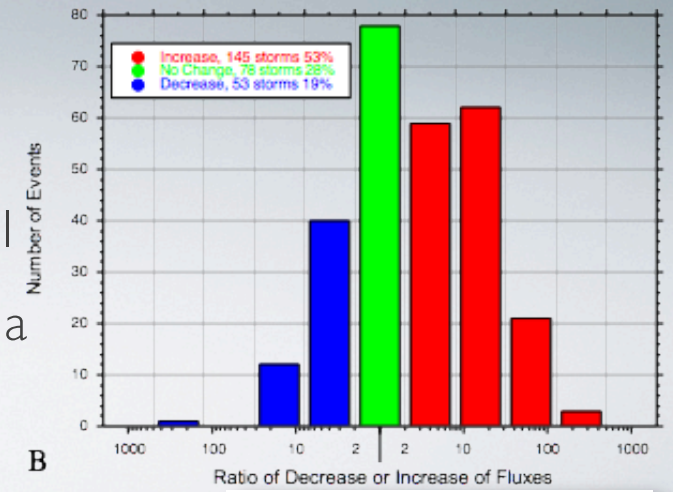
- Broad-based capabilities from mission concept to sensor design, manufacture, calibration, spacecraft integration, mission operations, data analysis, and theory.
- A 50 year history, and this October will be the 50th anniversary of the launch of the first Vela satellites.
- Mixture of civilian and defense-related programs. NASA is our primary civilian customer. Defense-related programs supported by DOE, DOD, and other US government agencies.
- Space Weather Summer School, established in 2011.

Additional Slides

Dynamics are not yet predictable

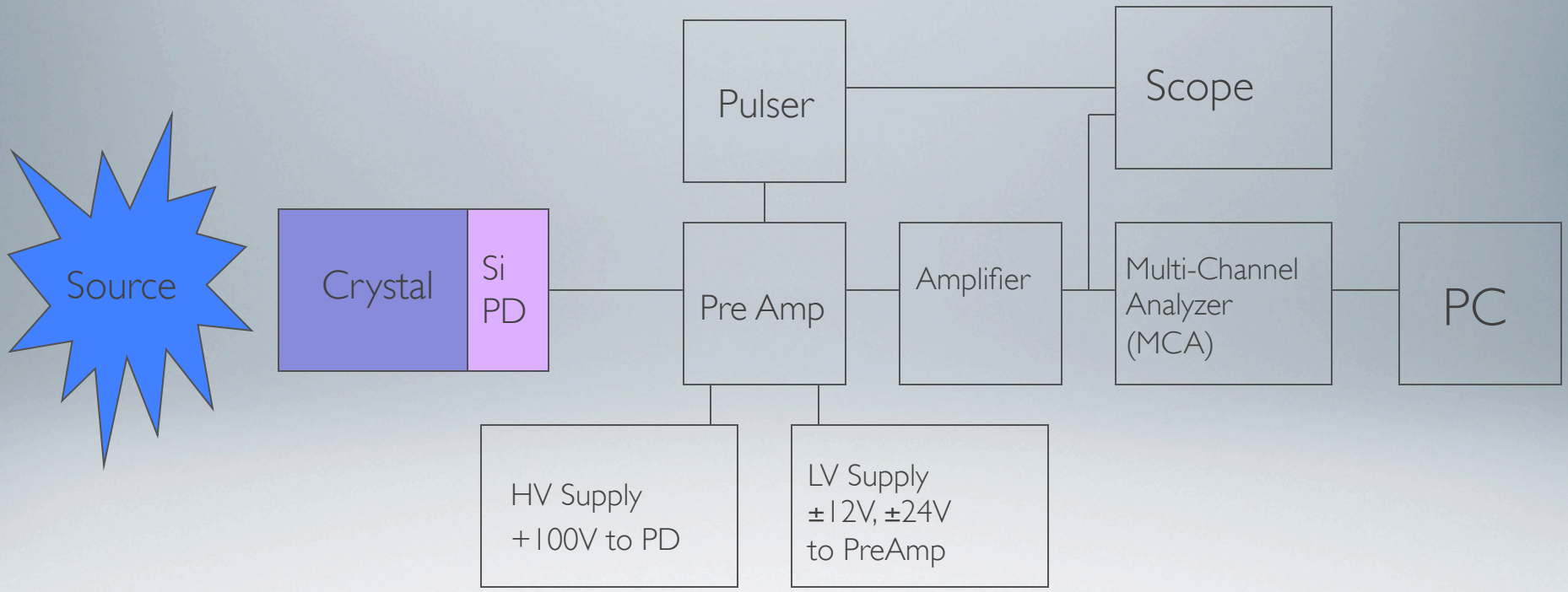


- The radiation belts respond to geomagnetic storms
- Strong storms do not imply strong radiation belt intensity
- Storms don't always produce intensifications at all
- Radiation belt structure and dynamics result from a delicate balance of processes



Reeves et al., GRL 2003

Lab Setup for Scintillator-Si PD Measurements



The Measurement Objectives are Met

Instrument	Time Reso.	Energy Reso.	Angular Reso. (deg)	Flux $(cm^2\text{-}sr\ s)^{-1}$	Pitch Angle (deg)	Energy Range
Objective	2-30 min.	40-100%	30-45	$100 - 10^6$	~30 - 90	e: <300 keV - 10 MeV p: 200 keV - 100 MeV
Design	2-30 min.	20-100% (varies with energy bin choice)	16 -26	$100 - 10^6$	Optimized telescope positions based on data	e: 50 keV - 10 MeV (both LET and HET) p: 200 keV - 100 MeV (both LET and HET)