LA-UR-24-29221

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Title:	60 years of radiation monitoring in space
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Intended for:	WRMISS, 2024-09-03/2024-09-05 (Boulder, Colorado, United States)
Issued:	2024-08-26

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NATIONAL LABORATORY

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60 years of radiation monitoring in space

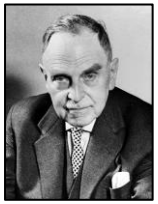
Martin Kroupa

Space Science and Application Group, Intelligence and Space Research Division

Los Alamos National Laboratory

- Established 1943
- Birthplace of Manhattan Project
- Los Alamos is located in the high desert of northern New Mexico, 35 miles from the state capital of Santa Fe
- Workforce is about 14,150
- $4B budget in FY22

LANL History: From fission to the last nuclear test



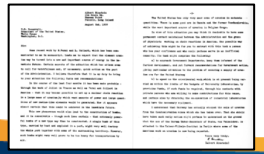
Nuclear fission discovered

1938

1939

WWII begins in Europe

Einstein-Szilard letter to FDR

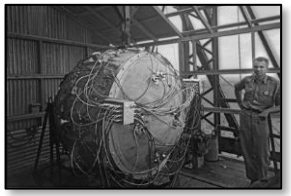


Manhattan Project begins

1942

1943

LANL begins operations



World's first nuclear test

1945

1958

Testing Moratorium

Limited Test Ban Treaty

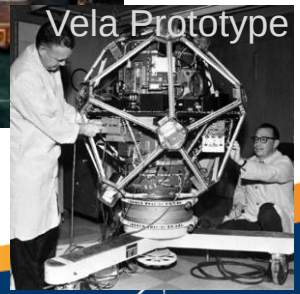
1963

1992

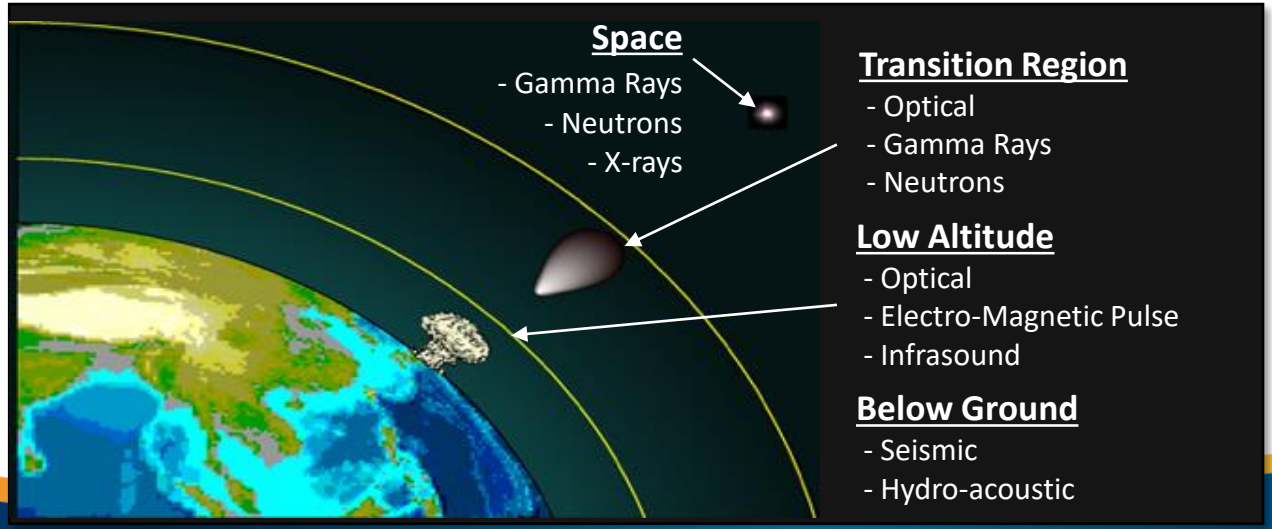
Last U.S. nuclear test

Origins of the Los Alamos National Security Space

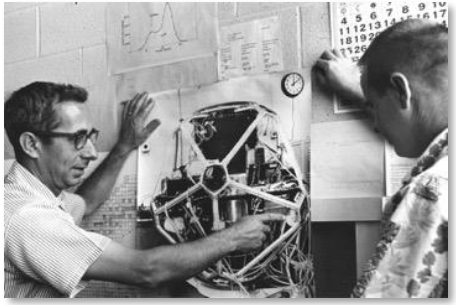
- 1952-1964 Advances in Nuclear Weapons
  - *1st US (1952) and Soviet (1953) thermonuclear devices*
  - *Britain, France, and China join the club*
- 1958 Unilateral US & Russia moratoriums
- 1959 US DARPA & AEC starts Project Vela ("watchman") using Los Alamos, Sandia expertise
- 1961 Russia breaks self-declared moratorium: 45 tests (atmospheric and underground) in 100 days
  - *US responds in kind*
- 1963 Limited Test Ban Treaty: US, USSR & UK
  - *Prohibits nuclear detonations in the atmosphere, outer space, or under water*
  - *Vela Hotel program: space-based treaty verification*



Nuclear Detonation Detection

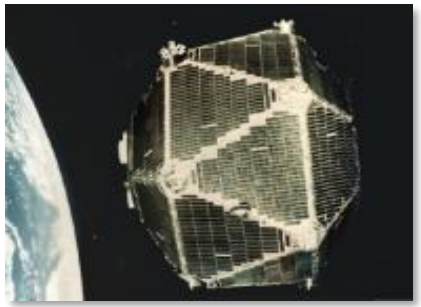


LANL Vela



Treaty Monitoring

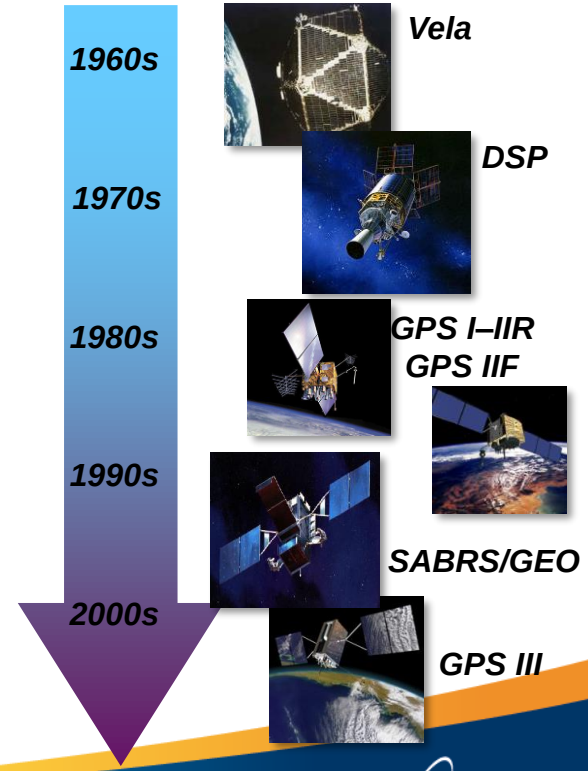
- Space-based verification
- The first pair of Vela Hotel satellites launched on Oct. 17, 1963.
- These sentinels were each equipped with sensors that could detect gamma rays, x-rays, and neutrons from enormous blasts, including rare sources.



Beyond Treaties: Today's United States Nuclear Detonation Detection System (USNDS) Mission

- The Vela heritage lives on in 60 years of continues monitoring

Provide **unambiguous, worldwide**, **highly survivable** capability to **detect, locate, and report** nuclear detonations in the earth's atmosphere or near space in **near real-time**



Today's USNDS Mission

Key questions:

- Did it happen (global high reliability)?
- Was it nuclear (high confidence)?
- Where was it?
- How big was it?

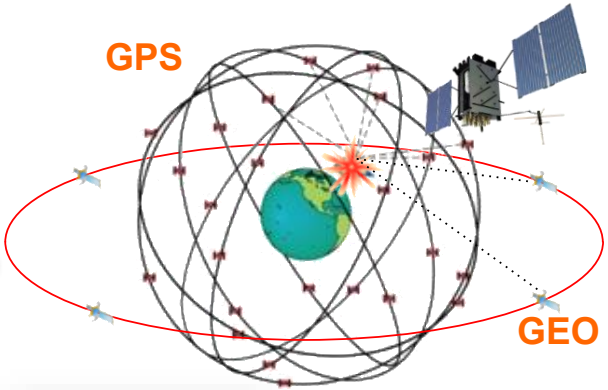
Space
- ***Gamma Rays***
- ***Neutrons***
- ***X-rays***

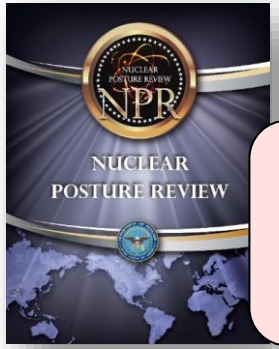
Transition Region
- ***Gamma Rays***
- ***Neutrons***
- *Optical*

Low Altitude
- *Optical*
- ***Electromagnetic Pulse***
- *Infrasound*
- *Radionuclides*

Below Ground
- *Seismic*
- *Infrasound*
- *Hydroacoustic*

Space-based sensing systems of USNDS

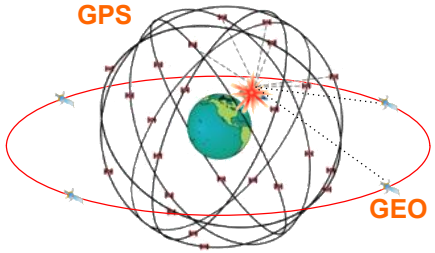




Today's Challenge
- *New threats*
- *New measurement methods*
- *More information with fewer resources*

Los Alamos USNDS Payloads

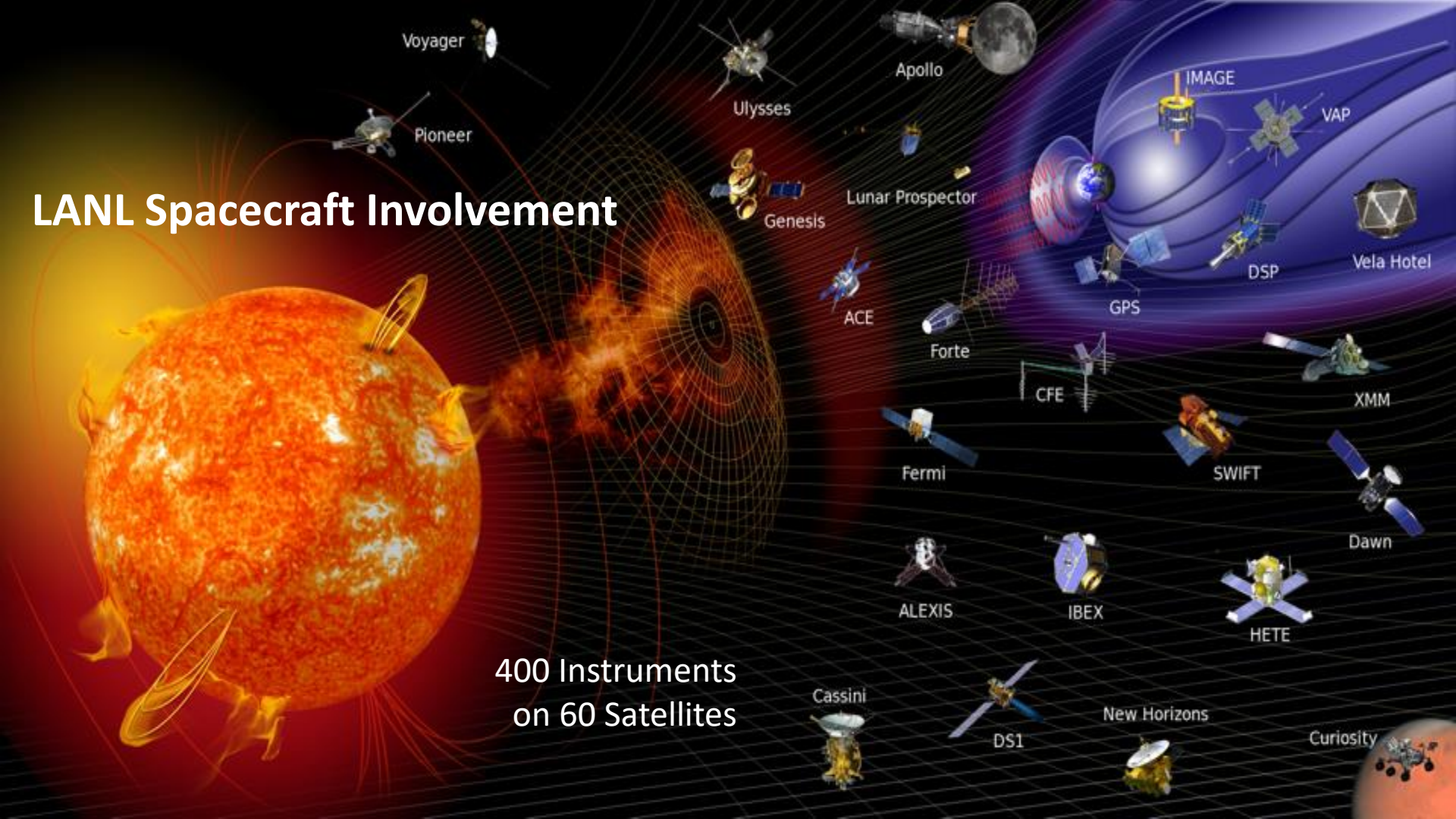
GPS
- *Electromagnetic Pulse (EMP)*
- *X-Rays*
- *Energetic Particles*



Geosynchronous Orbit
- *Neutrons*
- *Gamma-rays*
- *Space Environment*

STPSat6 (Geo)
- *SABRS 3*
- *SENSER Technology Validation Payload*

LANL Spacecraft Involvement



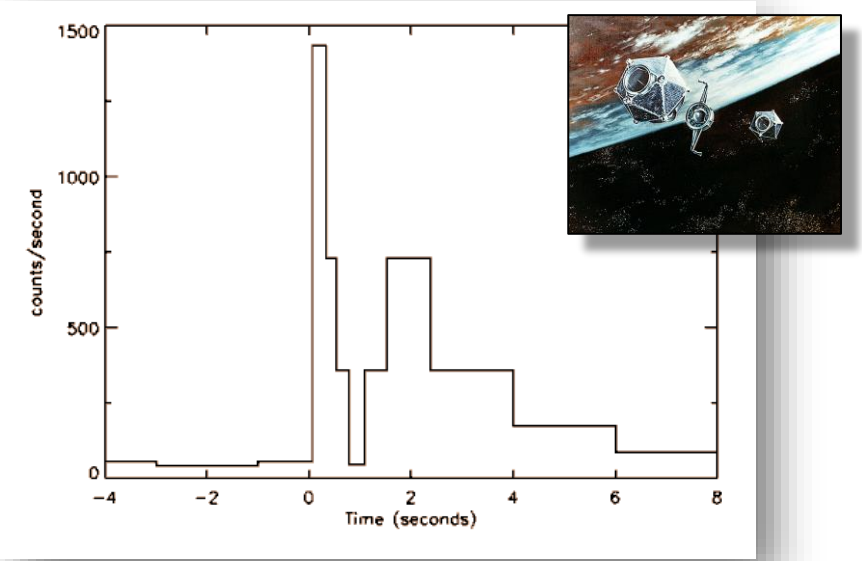
400 Instruments
on 60 Satellites

Los Alamos in Space: A Rich Fabric of National Security, Innovation and Discovery

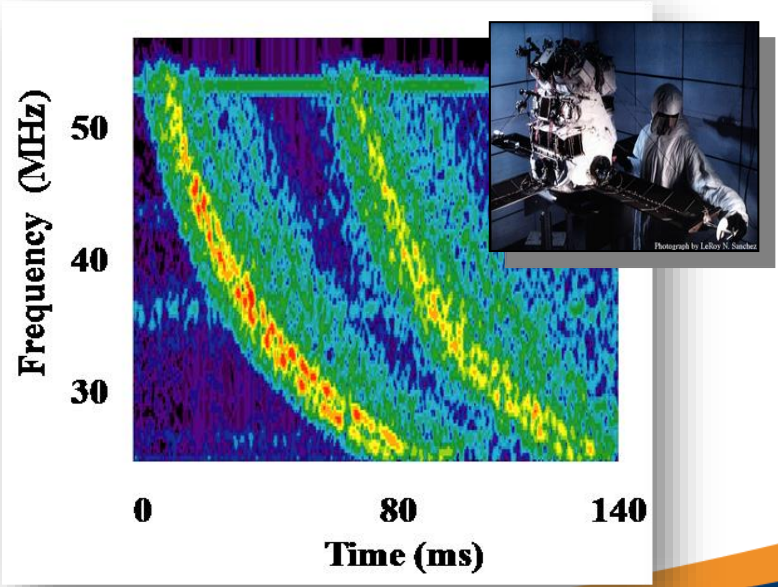
- Nuclear Detection
  - Impulsive Events
  - Dim and rare signatures
- Space Environment: *natural and artificial events*
- Space Deployment: *extreme engineering*
- Actionable Information of national security signatures

Space is a Cluttered Environment

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



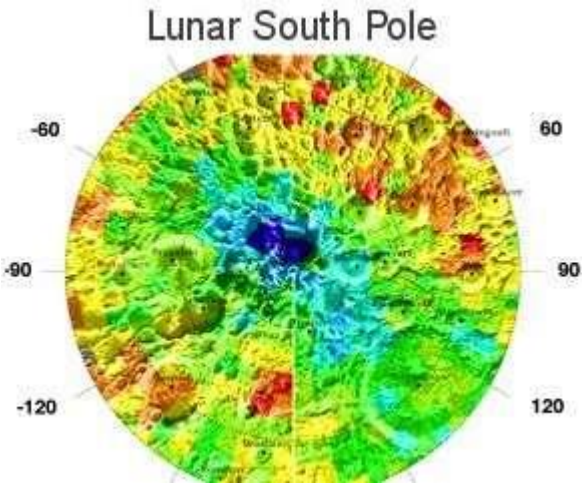
Alexis: Discovery of Trans-Ionospheric Pulse Pairs *(Holden et al., 1995)*

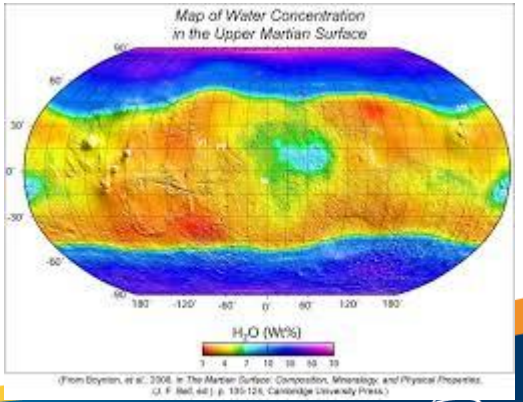


Distinguishing Natural vs Nudet is a unique, important theme!

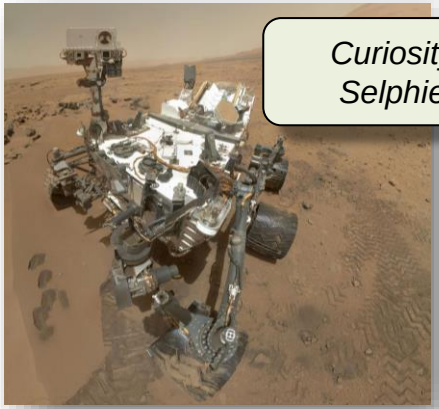
Lunar Prospector

- Measuring ratios of thermal and epithermal neutrons to estimate the water content – same technique used on Mars and Mercury later

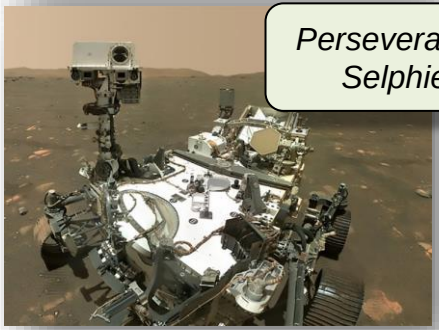




Mars Geochemistry: ChemCam on Curiosity, SuperCam on Perseverance



Curiosity Selphie



Perseverance Selphie

Highlights

- *Discovery of Mn oxides…from a wet, O_2-rich era?*
- *Discovery of Boron…wet, pre-biotic chemistry?*

Balancing Basic R&D and National Security

Space Research
NASA, LDRD

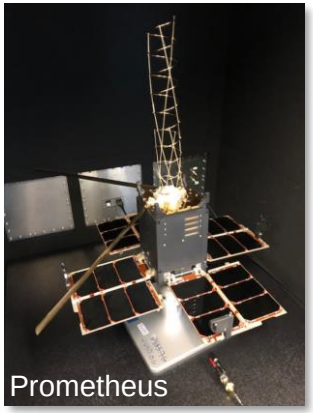
Invention, first time	Key Trait	*High reliability*
Few	Starting Requirements	*Most*
Trans-formational	Product Evolution	*Incremental*
Many	Latent Errors	*Few*
High	Risk Tolerance	*Low*
Expert-based	Workflow Basis	*Process-based*

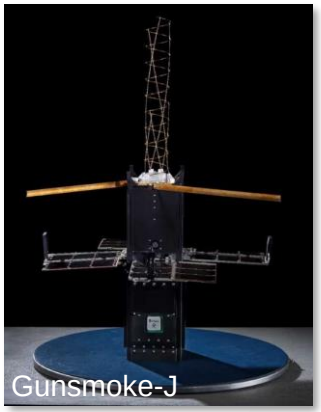
National Security
Operational Systems

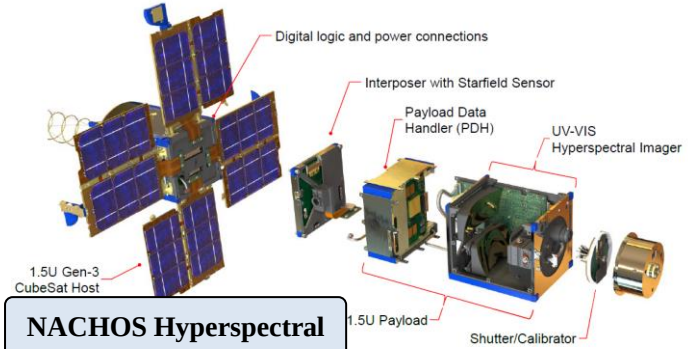
Two fundamentally different risk landscapes and risk management approaches

Agile Space Portfolio

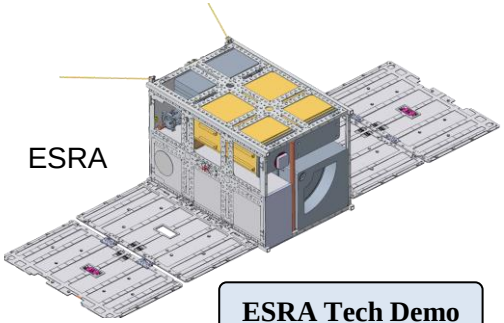
26 CubeSats launched in the past 12 years


Prometheus

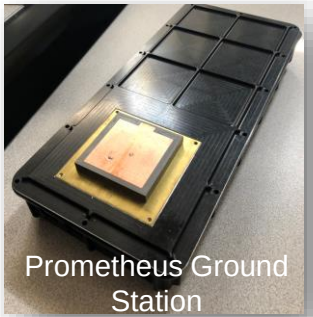

Gunsmoke-J

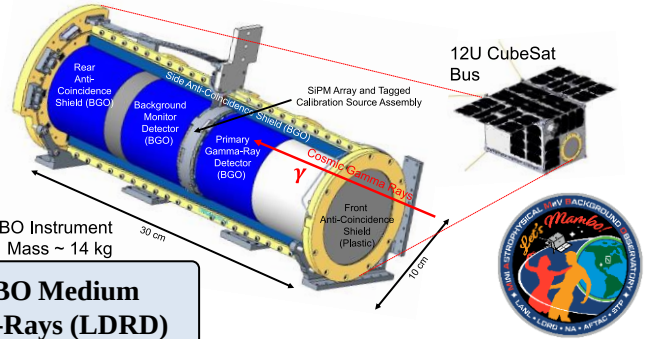


NACHOS Hyperspectral Imager (NASA)


ESRA

ESRA Tech Demo (NNSA/NA-22)


Prometheus Ground Station



MAMBO Medium Energy γ-Rays (LDRD)

ReDX-1,2,3 Stockpile Responsiveness (NNSA)

Rec…s: Extreme Engineering

Instrum…

- SuperCam o… Mars 2020 Rover
- 2019: Van Allen …obes ends (radiation belt scie…
- 2022 launch: BeamPie Rocket Experimen…
- 2025 launch: IMAP

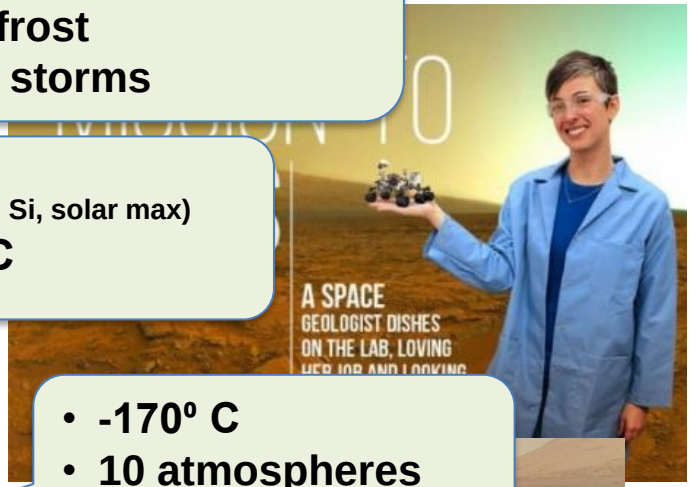
Medium Class Exp… …posals:

- …asphere
- …sphere coupling
- …udy the solar wind

Planetary Mission Proposals:

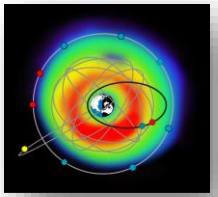
- OrganiCam: Laser-induced flourescence & imaging at Europa
- VEMCam: Raman-LIBS (i.e., SuperCam) at V…

- **First active experiment in space in > 20 years**
- **Atomic hydrogen from the interstellar medium, 1 count every 5 sec**
- **-55º C**
- **0.01 atmospheres bar**
- **CO_2 frost**
- **Dust storms**
- **76 rads/hr** (2 mm Si, solar max)
- **-40º C to +50º C**
- **-170º C**
- **10 atmospheres**
- **Frozen ocean**
- **450º C**
- **90 atmospheres**
- **Sulfuric acid rain**
- **Supercritical CO_2**

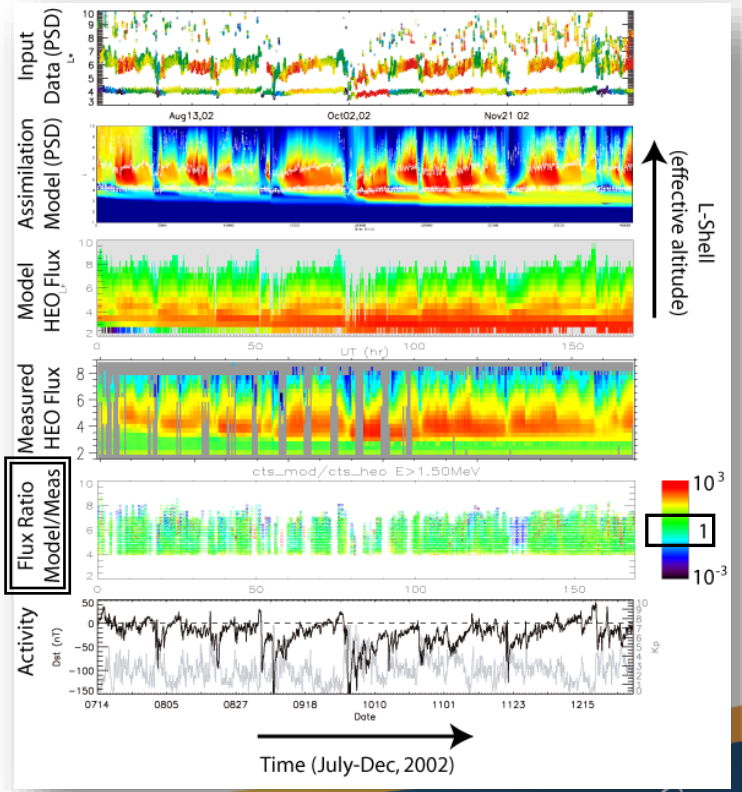


DREAM: Nowcasting the Space Environment

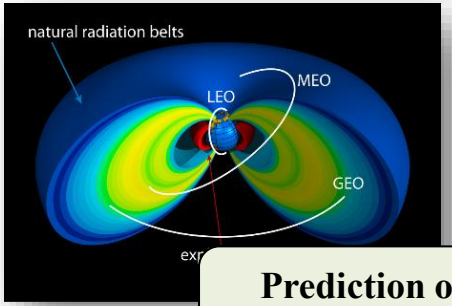
Dynamic Radiation Environment Assimilation Model (DREAM)



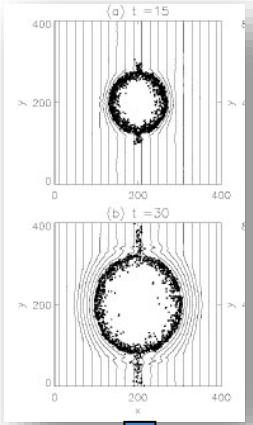
- Input:
  - Los Alamos USNDS instruments in geosynchronous & GPS orbits
  - NASA data (some Los Alamos instruments)
- State-of-the-art physics models and data assimilation methods
- Provides global knowledge of radiation fluxes, dose rate, or cumulative dose in any arbitrary satellite orbit (Geo, HEO, MEO, LEO, etc.)



Modeling Artificial Radiation Belts
From a High Altitude Nuclear Explosion (HANE)

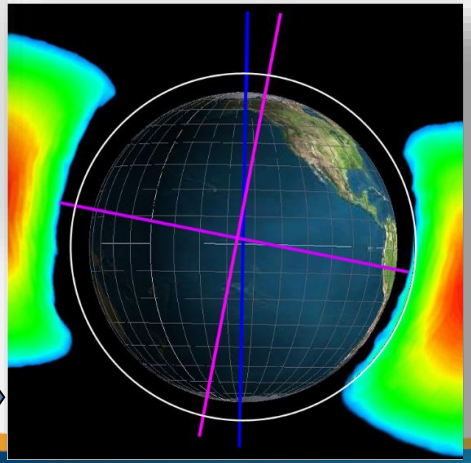


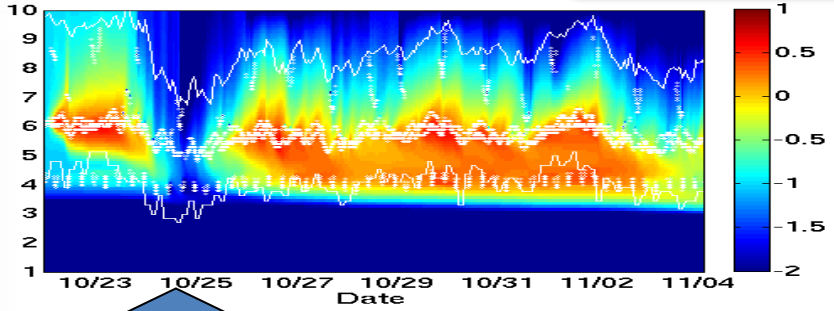
Prediction of HANE Effects on Spacecraft



Geomagnetic Coupling

Radiation Belt Dynamics





Prediction of HANE Radiation Belt Environment