P1.18

# Analysis of Operational Data from the Lightning Detection and Warning System at Los Alamos National Laboratory


***S.W. Eisenhawer*, T.F. Bott and C.R. Odom***
**Los Alamos National Laboratory**
***W.H. Beasley***
**University of Oklahoma**

*** seisenhawer@lanl.gov**



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Many outdoor experimental activities are performed at Los Alamos National Laboratory in the summer during the Southwest monsoon season. Localized convection cells develop on the up-slope of the mountains just west of the Laboratory and move eastward—producing frequent cloud-to-ground (CG) lightning. The probability of one or more lightning-producing storms in a day at one facility of interest is p = 0.75 during July and August. In 2001 a commercial Lightning Detection and Warning System (LDWS) became operational. The LDWS originally consisted of a satellite link to the National Lightning Detection Network, two electric field mills (EFMs), and a central alarm workstation. Additional EFMs have been added at five facilities, with more planned for the near future. In this paper we discuss the characteristics of thunderstorms at Los Alamos National Laboratory and experience with the LDWS and its impact on operational safety. We examine the performance of the EFM network to ascertain whether it may provide improved hazard-warning-decision support. We consider the development of EFM-based early warning algorithms and potential uses of the LDWS to provide warning information for the entire Laboratory (90 km2). Specific issues to be addressed include the potential for increased warning time for the first CG flash in a storm, improved recognition of the end of a storm, and the possibility of predicting a late CG flash after a period of time with no lightning.

# Objectives

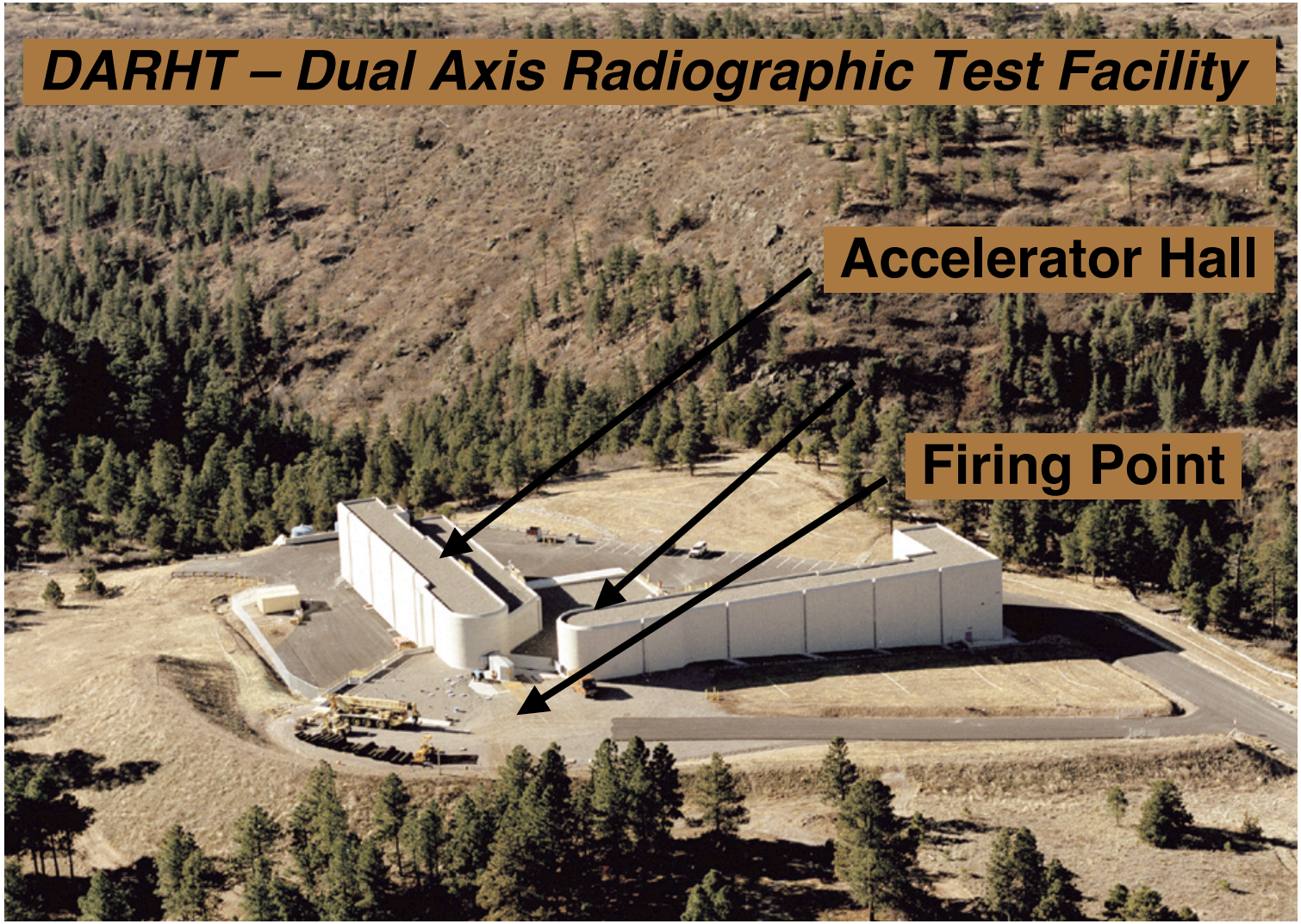
- **To evaluate current lightning risk and lightning safety practices at LANL outdoor high-explosive (HE) firing sites.**
- **To assess the use of electric field mills (EFMs) to supplement warning and alerts using lightning-flash data.**

# Approach

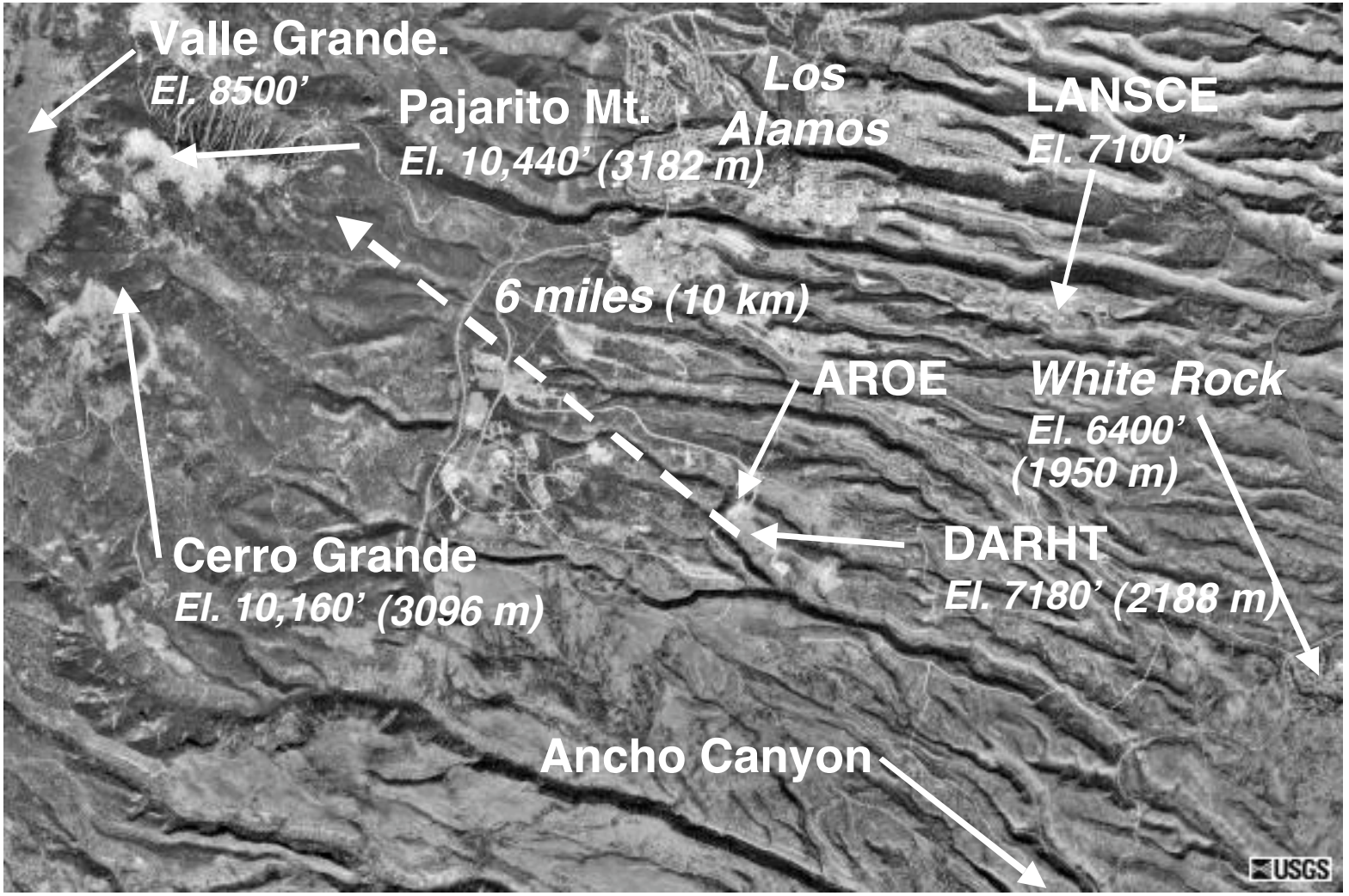
**Apply Probabilistic Risk Assessment (PRA) methodology to**

- **Quantify the overall lightning risk and the contribution from high explosives.**
- **Analyze risk control strategies to determine the variation in risk and their impact on firing site operations.**
- **Analyze EFM data in the context of a possible site-wide Lightning Detection and Warning System (LDWS).**

# Outdoor HE Operations



# Aerial Photograph of the Pajarito Plateau



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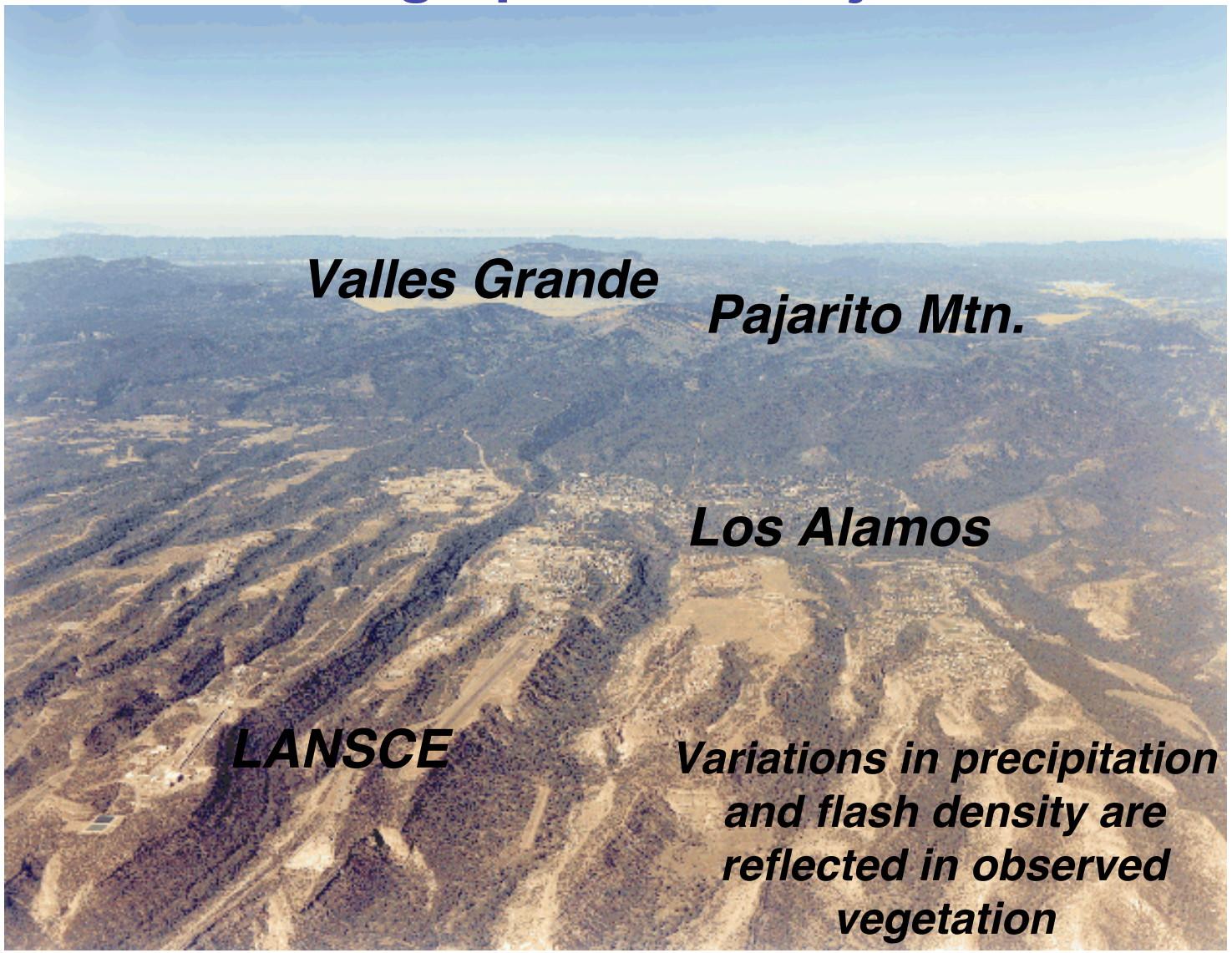
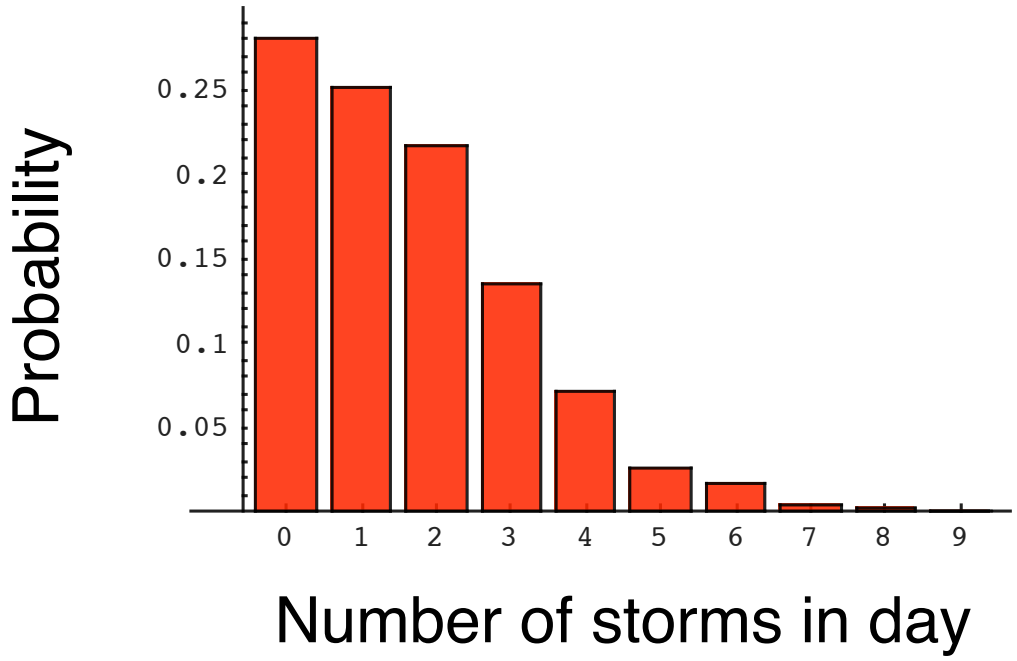


# Lightning/Storm Characteristics

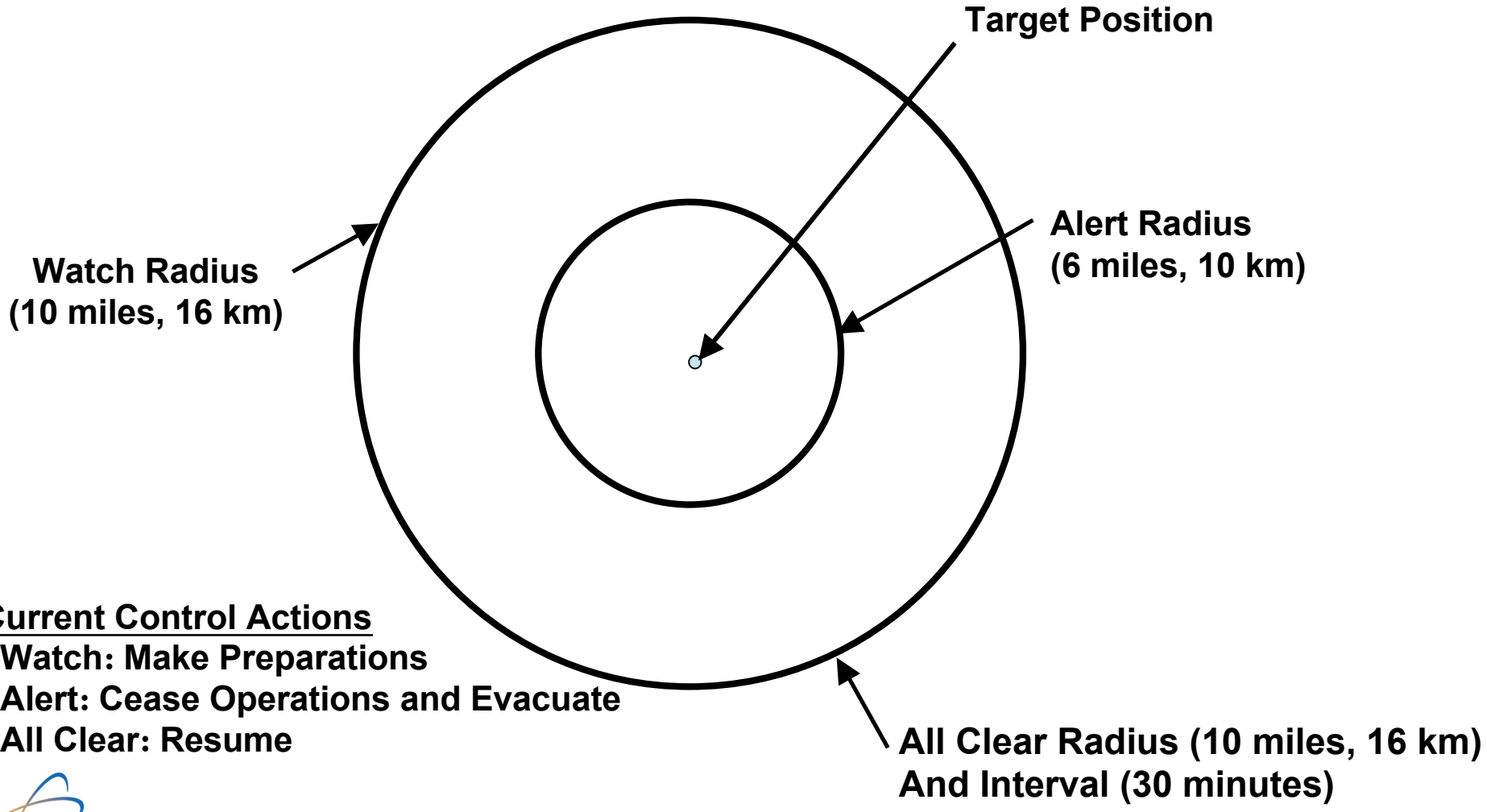
**Thunderstorms occur frequently during the summer monsoon; p(>1 storm in a day) = 0.73.**



# Lightning/Storm Characteristics

- **Storms are localized cells generated on the Eastern slopes of the Jemez Mountains**
- **July and August flash densities are approximately 1.1 flashes/km$^2$/month, in the vicinity of the Dual-Axis Radiographic Hydrodynamics Test Facility (DARHT); 3.5 flashes/km$^2$/year**
- **Individual storms vary significantly in terms of duration and intensity**

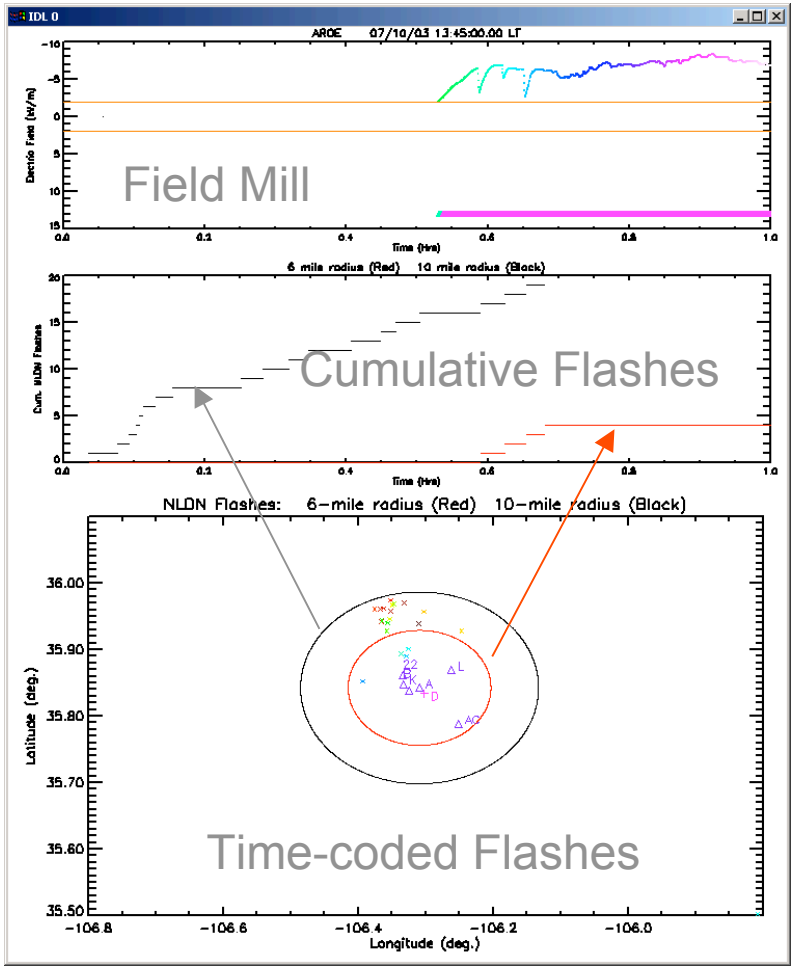
# Lightning Risk Management Controls



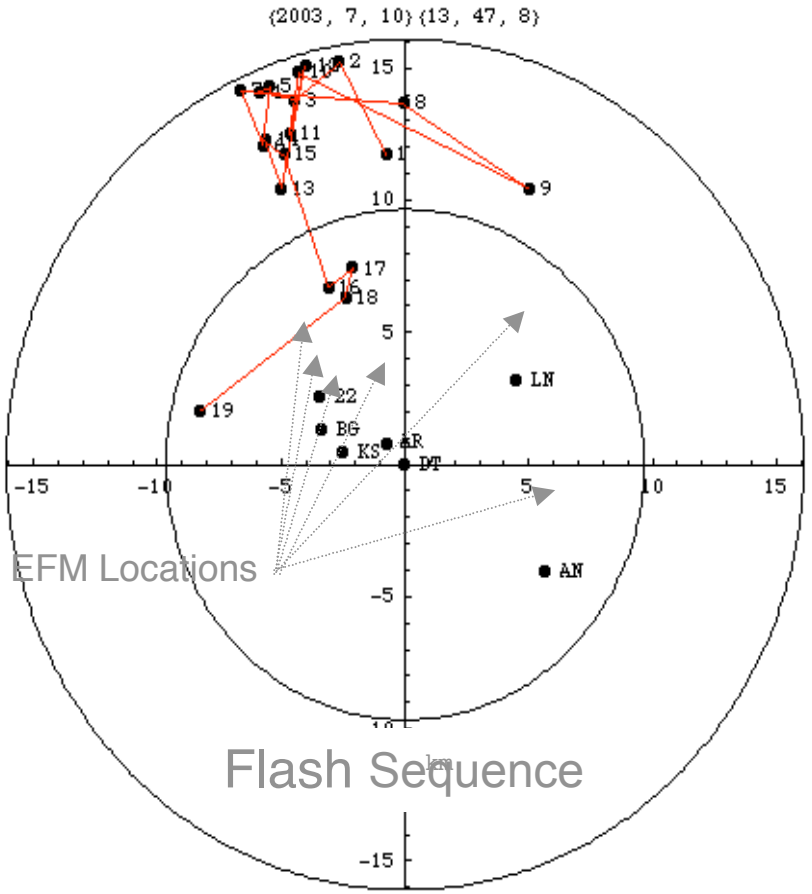

**Current Control Actions**

**Watch: Make Preparations**
**Alert: Cease Operations and Evacuate**
**All Clear: Resume**

# A Typical Storm: July 10, 2003



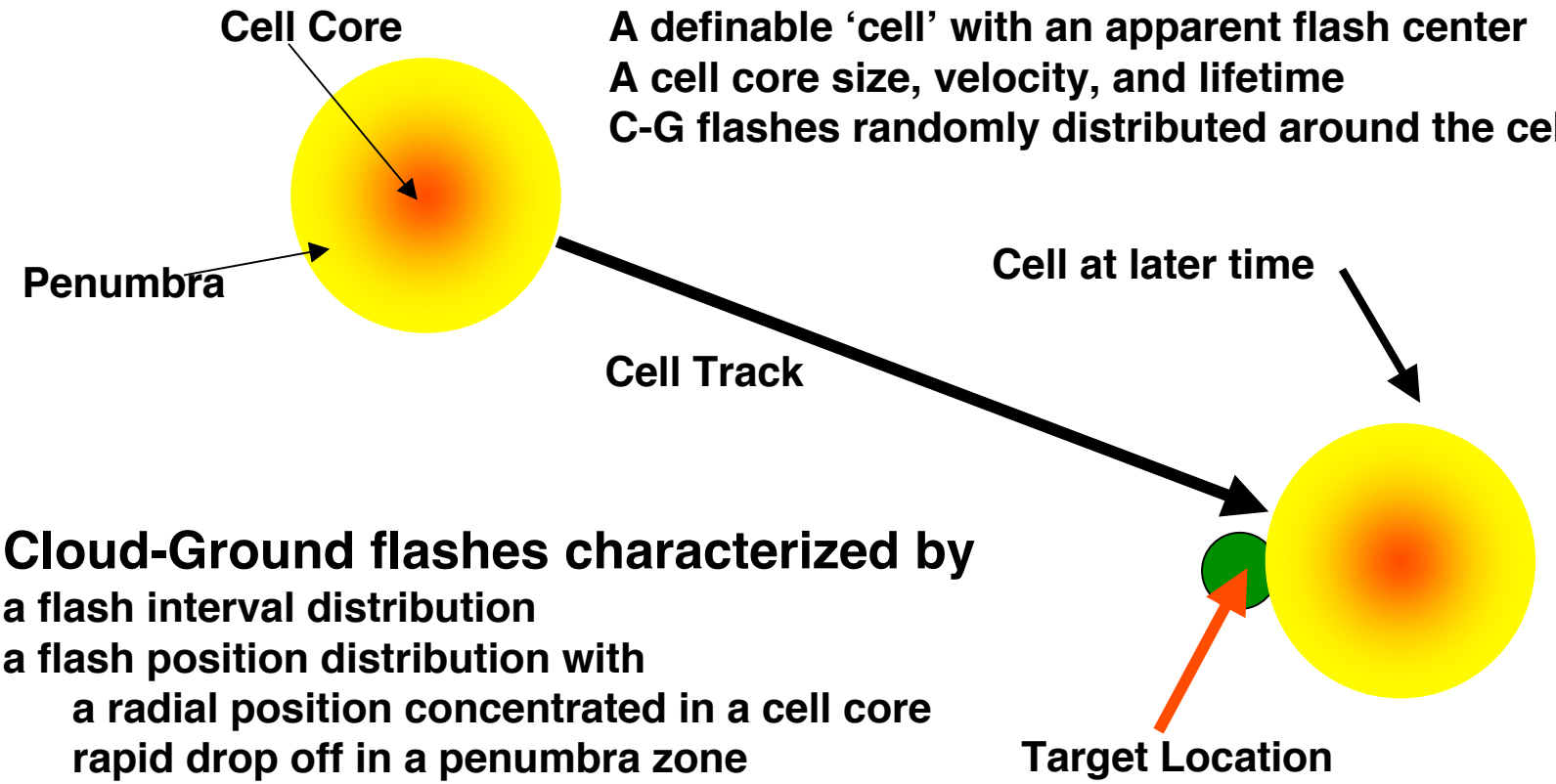

## Data for DARHT/AROE



# National Lightning Detection Network (NLDN) Data Provide the Basis for a Flash Time-Position Module (FTPM)

## Cloud-Ground (C-G) flashes characterized by

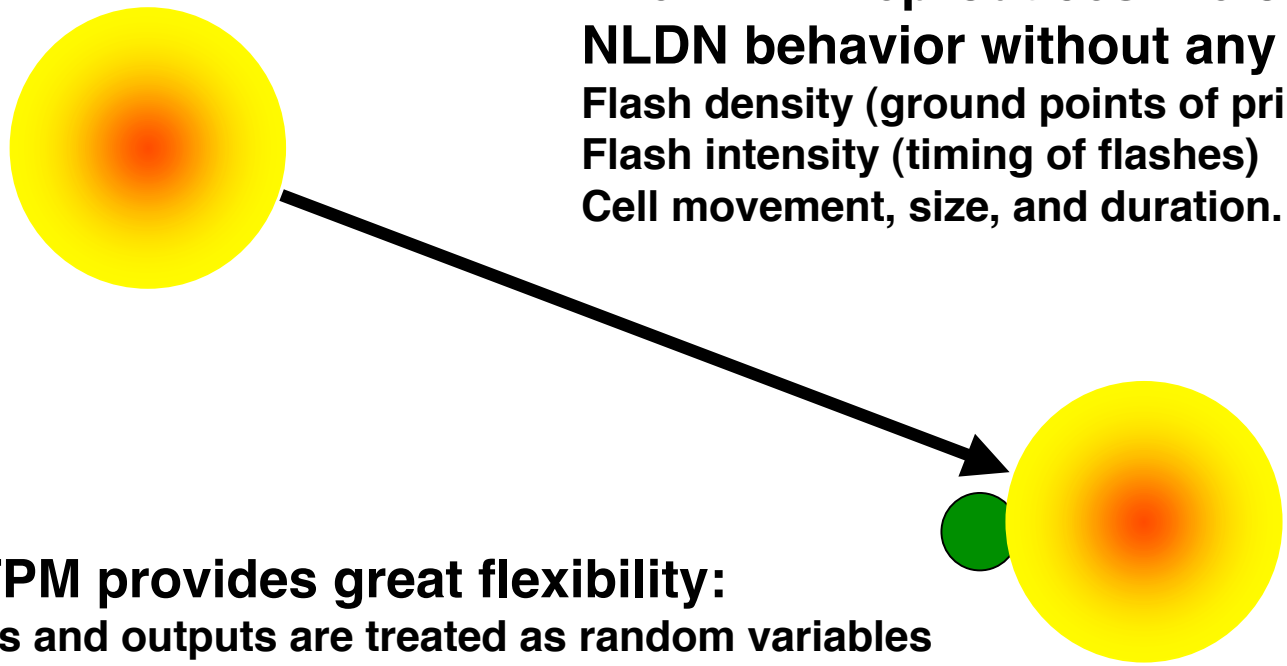
A definable 'cell' with an apparent flash center
A cell core size, velocity, and lifetime
C-G flashes randomly distributed around the cell center




## Cloud-Ground flashes characterized by

a flash interval distribution
a flash position distribution with
- a radial position concentrated in a cell core
- rapid drop off in a penumbra zone
- uniformly distributed azimuthal position

# The FTPM is a Monte Carlo Simulation of the Space-Time Distribution of Lightning Flashes



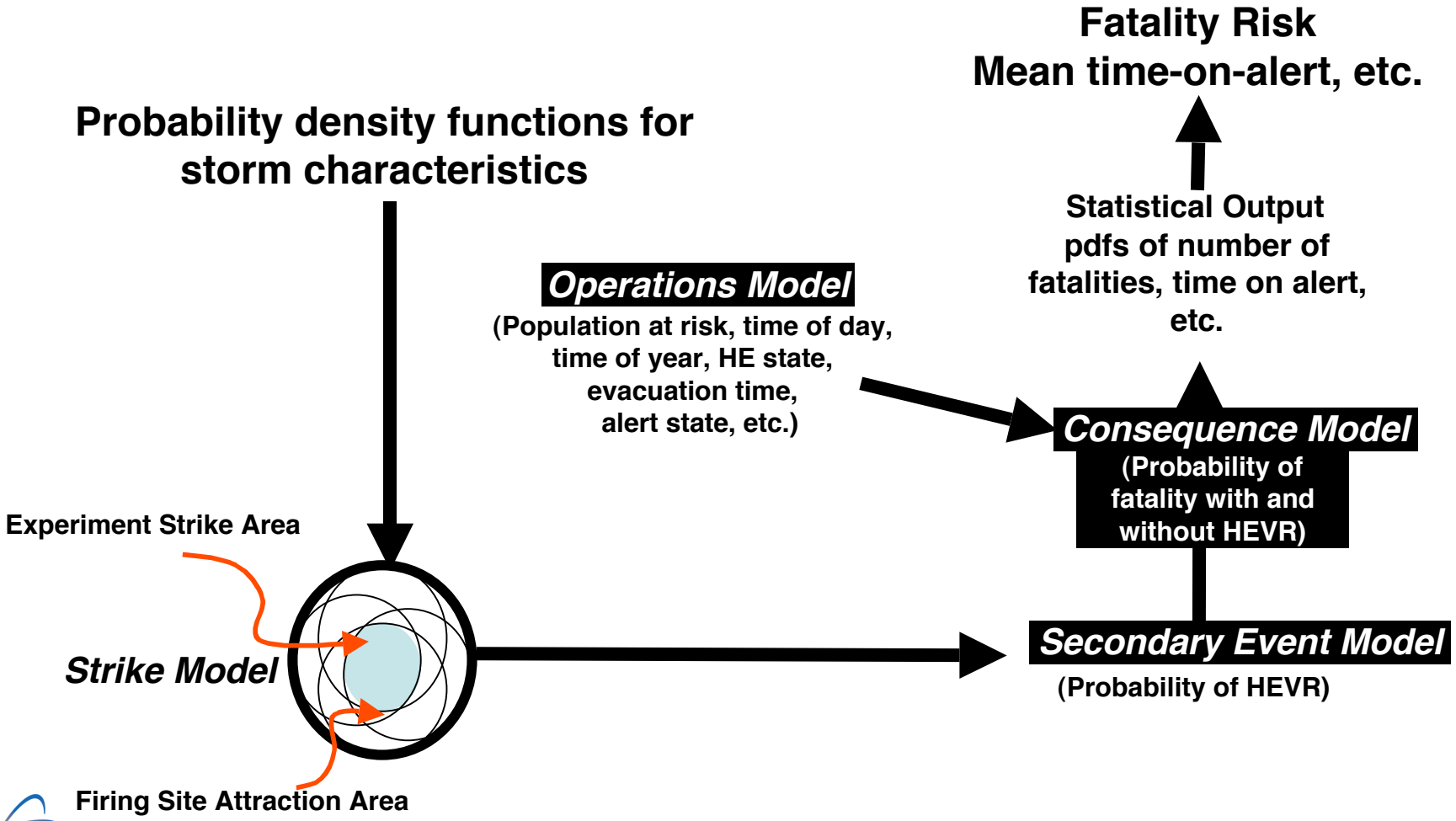
**The FTPM reproduces the observed NLDN behavior without any "knobs":**

**Flash density (ground points of primary flashes)**
**Flash intensity (timing of flashes)**
**Cell movement, size, and duration.**

**The FTPM provides great flexibility:**

**All inputs and outputs are treated as random variables**
**Flash- and cell-based controls can be treated**
**Input parameters can be generated from NLDN data for any location**
**Results can be calculated that cannot be extracted easily from available data**

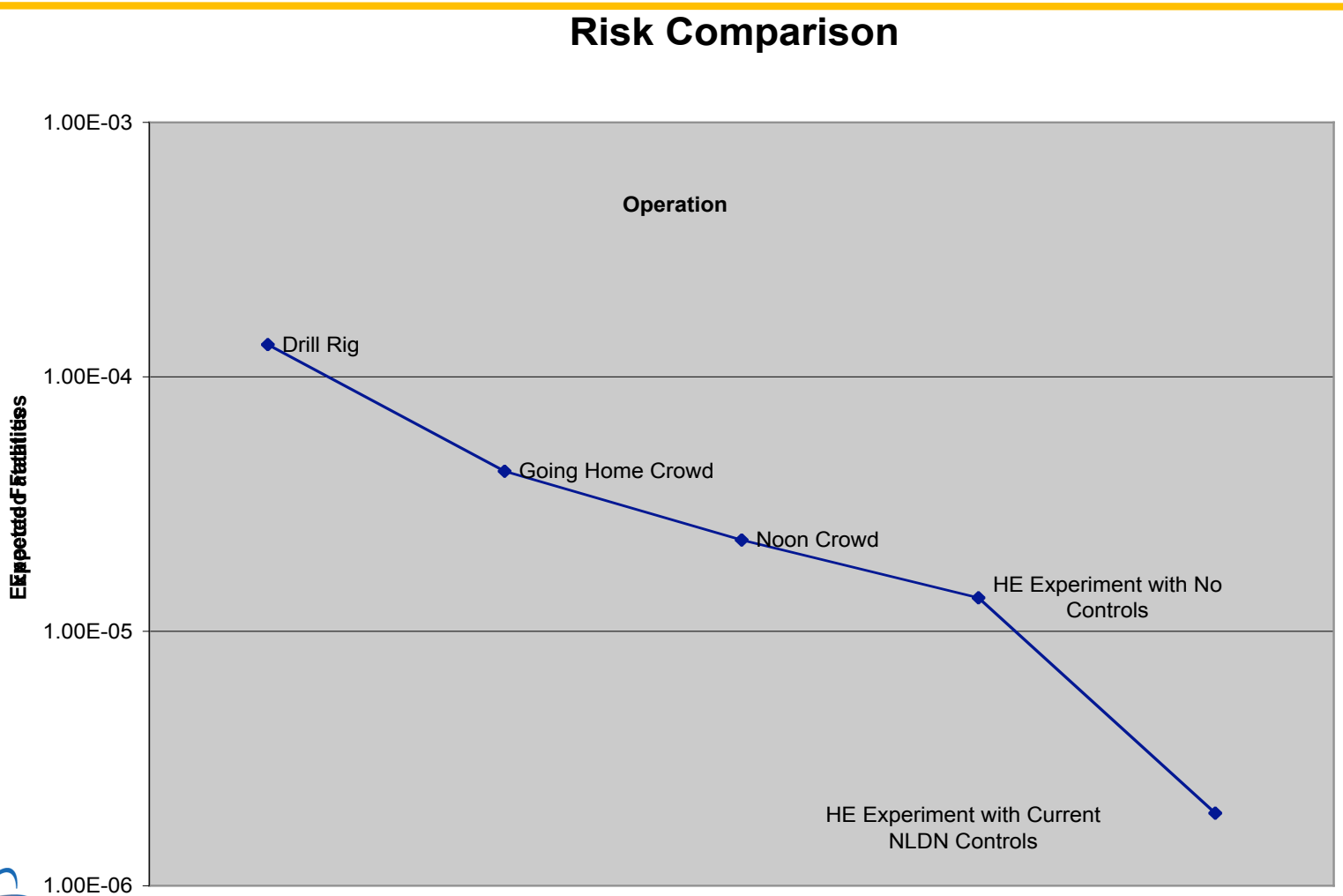
# The FTPM Module Provides Input to a Lightning Risk Module (LRM)



# Example Calculation

- **Typical single-day experiment at an HE firing site using a set of other outdoor activities for comparison.**
- July–August time frame.
- Typical lightning alert evacuation procedures.

# Comparing Sources of Lightning Risk

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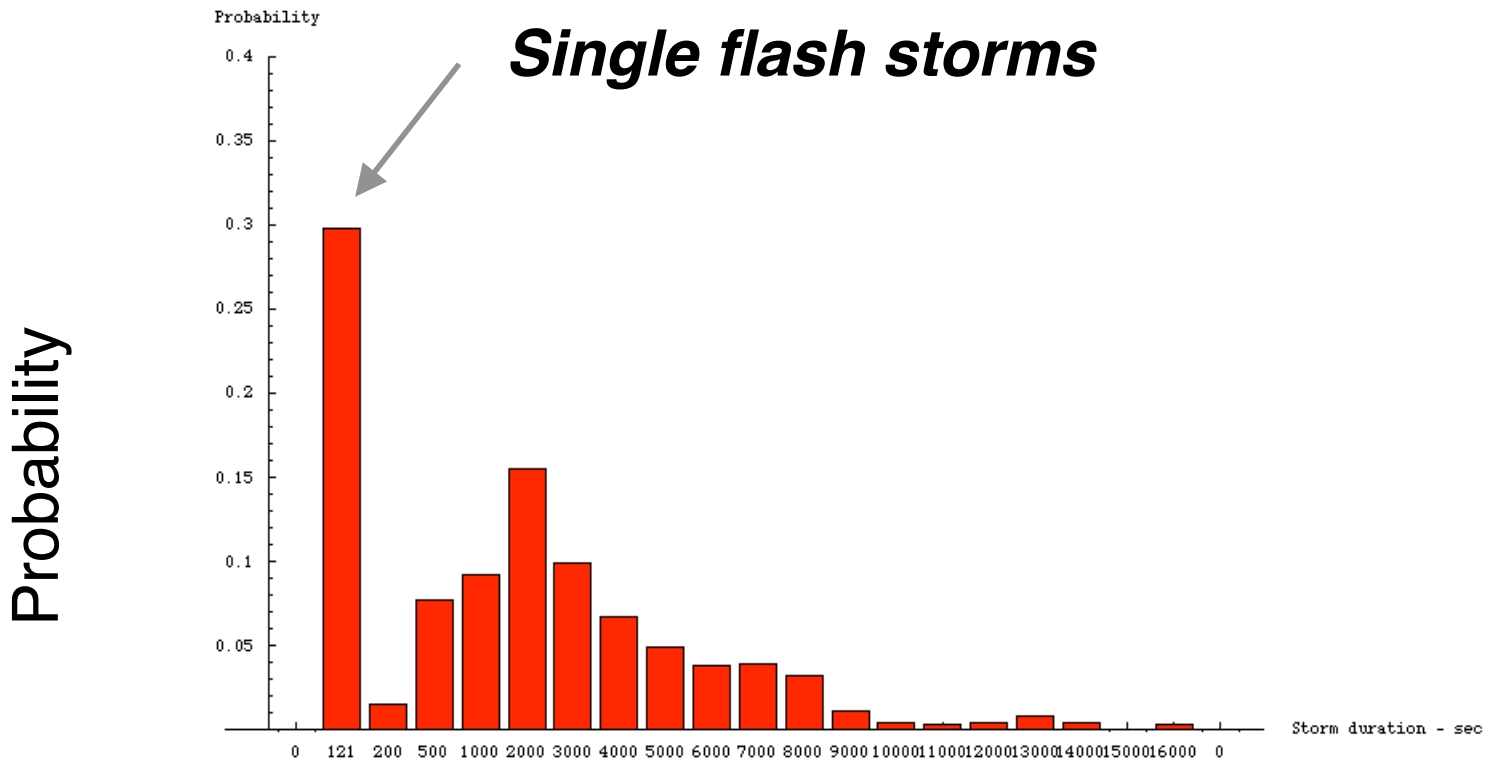
# Electric Field Mills (EFMs) As Part of an LDWS

- Potential benefits include
  - Improved warning for single-flash storms and cells that form directly overhead.
  - Reduced all-clear times relative to flash-based procedures.
  - Source of additional real time data for use in a planned site-wide LDWS.
- Potential drawbacks include
  - Generation of false alarms from non-lightning sources.
  - Increased evacuation times.
  - Increased cost and system complexity.

# High Incidence of One-Flash Storms at Los Alamos

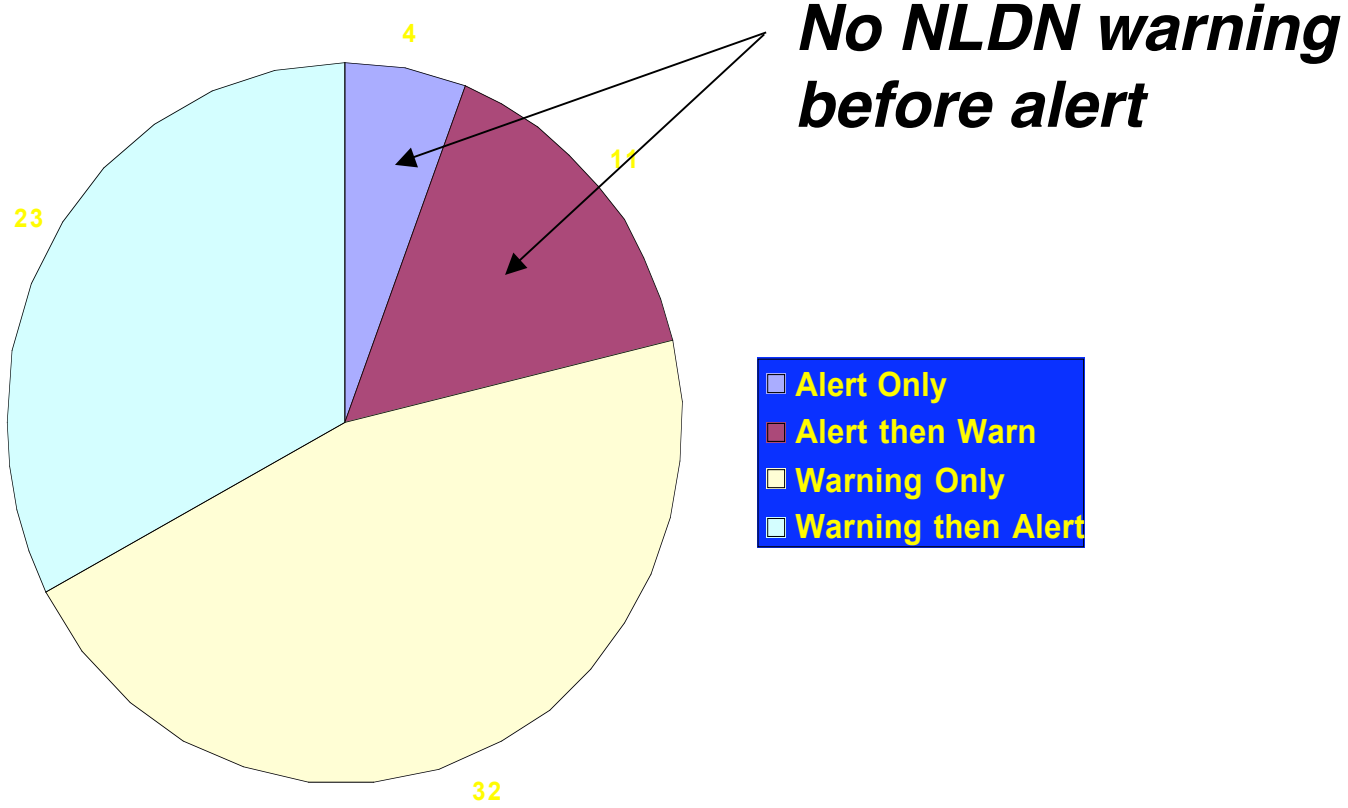



Probability

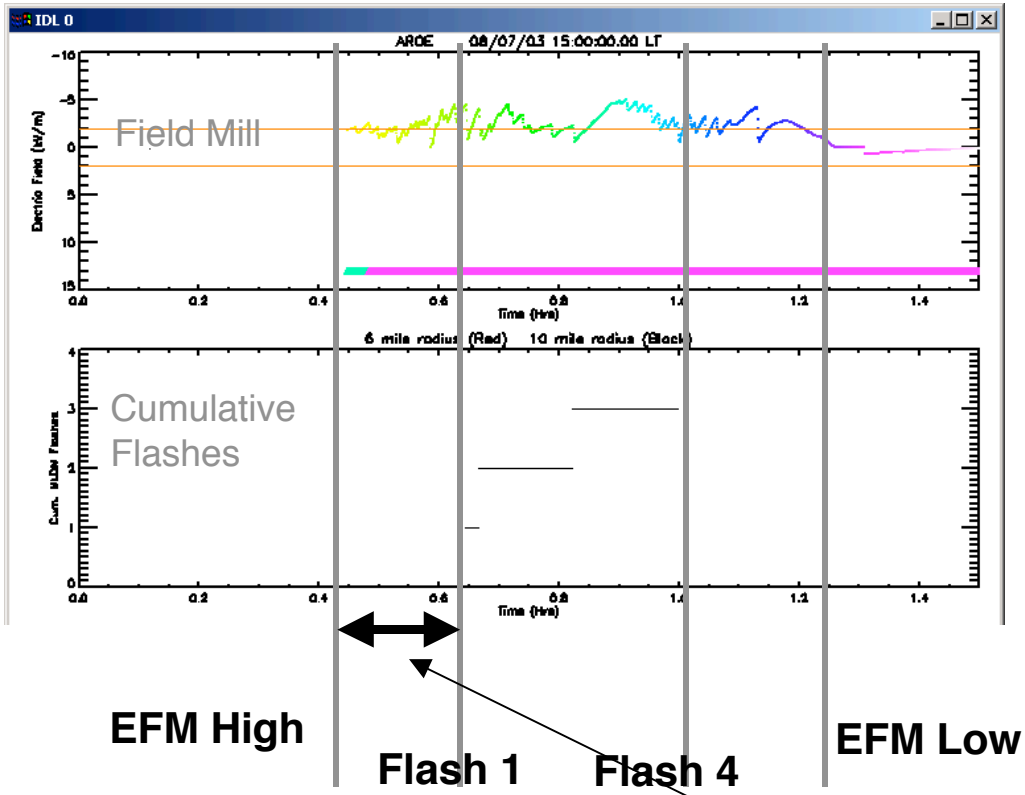
Storm duration [seconds]

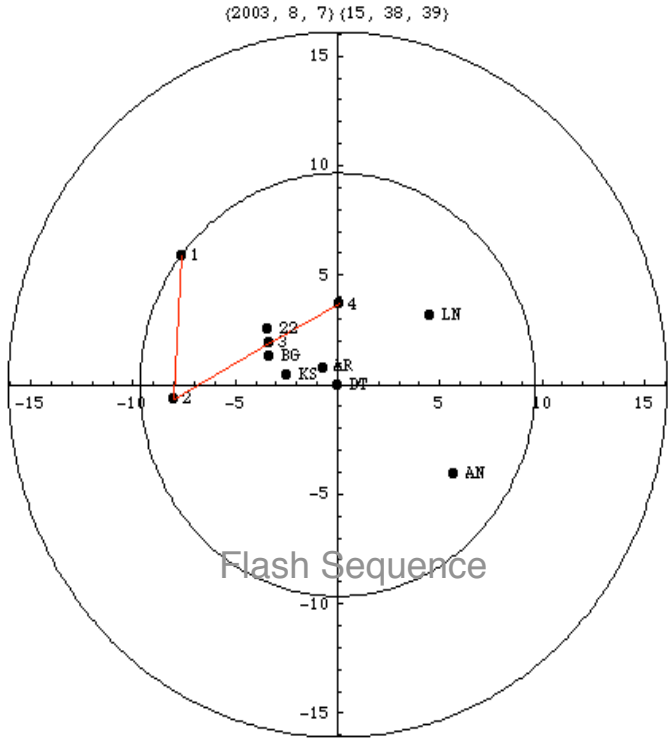
# Significant Incidence of Alert-First Storms: Cells That Develop Directly Overhead

DARHT Storms By Type: July–August 2003



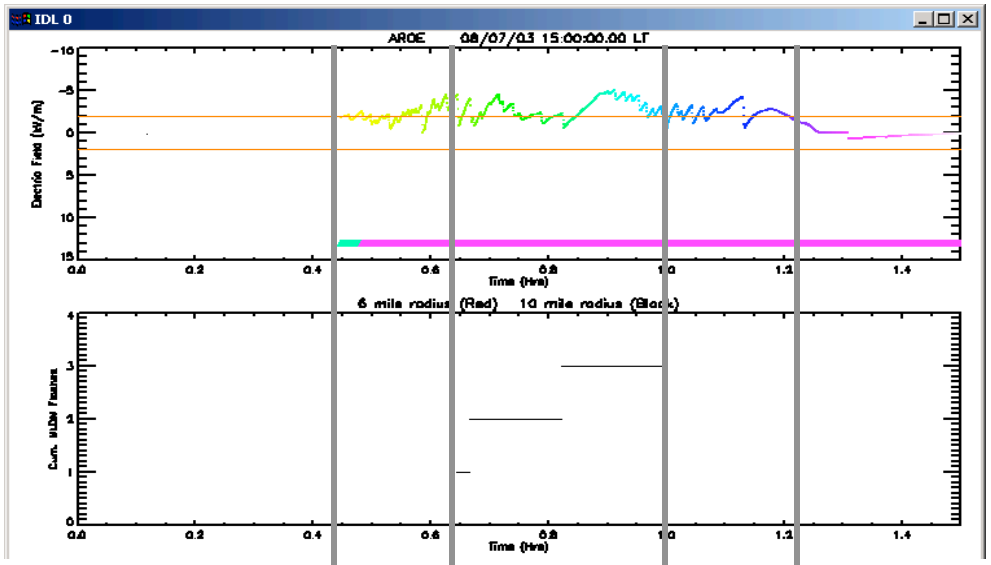
# Warning for Alert-Only Storms

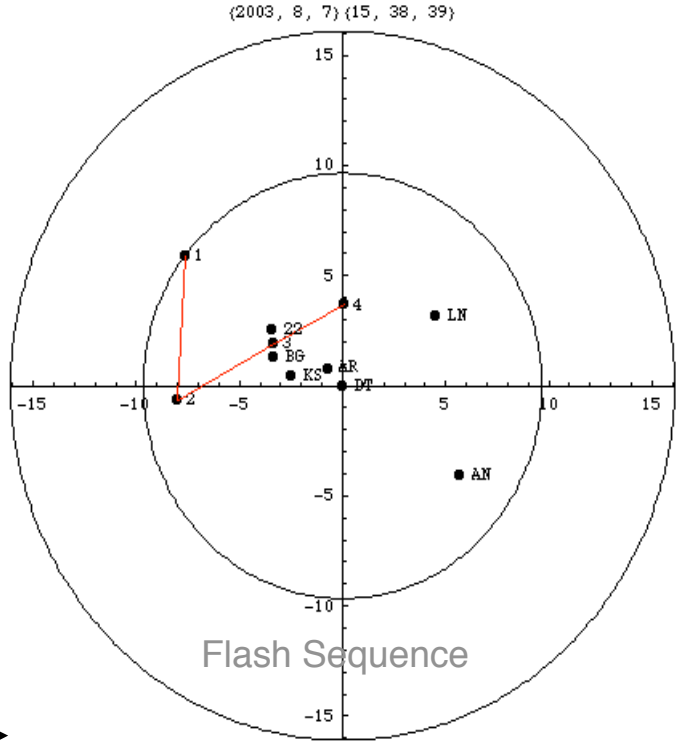



***For this storm, the EFMs provide about 12 minutes of warning***

# All Clear for Alert-Only Storms




$\Delta t_{NLDN}$

$\Delta t_{EFM}$

EFM High

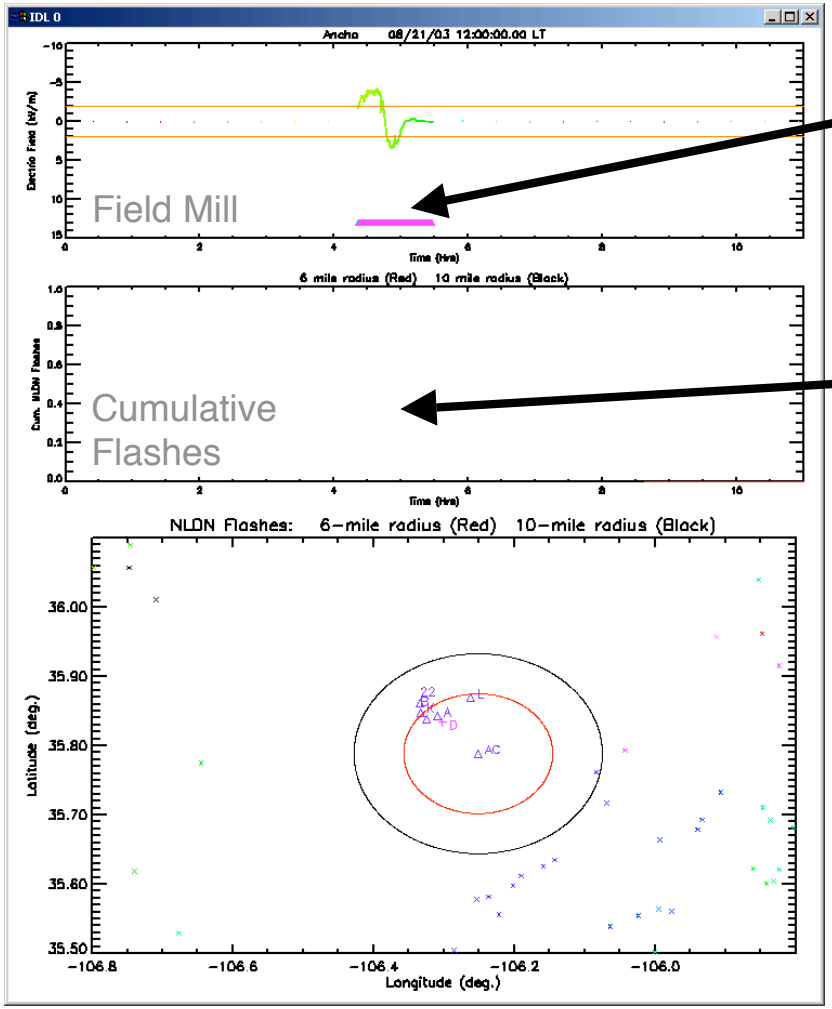
Flash 1

Flash 4

EFM Low

***All clear for NLDN at 16:00 + $\Delta t_{NLDN}$. All clear for EFM at 16:13 + $\Delta t_{EFM}$. It is unlikely that $\Delta t_{EFM} << \Delta t_{NLDN}$ so all-clear times would probably increase.***

# EFM-Based False Alarms




EFM-based alarm

No flashes

***EFM alarm may correlate with high wind . . . Many cases like this were observed.***

# Conclusions

- **We have developed a flexible computational capability for evaluating lightning risk**
  - **Based on PRA techniques.**
  - **Monte Carlo simulation of thunderstorms, consequences of a flash, and control procedures.**
- **This tool can be used to explore the impact of adjustments to lightning risk controls on risk and operations**
- **Important results**
  - **Fatality risk for HE experiments posed by lightning is low compared with accepted lightning risks.**
  - **Current all-clear rules can be relaxed considerably with no increase in risk and significant time savings from evacuation.**

# Conclusions (cont)

- **Potential cost/benefit for the use of EFMs is unclear**
  - EFMs offer improved warning for single-flash storms and for cells that develop overhead.
  - Reductions in all-clear times with EFM data may not be practical.
  - False-alarm rates for EFMs appear significant.
  - To date, significant operational issues with EFMs remain.
- **An EFM-based LDWS will be most attractive when lightning risk is high**
  - Large numbers of people and long evacuation times.
  - This is not the case for HE operations at LANL.